

AGE RELATED DIFFERENCES IN FEEDBACK-BASED
ASSOCIATIVE LEARNING

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By

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LIST OF ABBREVIATIONS

| | |
|----------------|--|
| ACC | Accuracy |
| ANOVA | Analysis of Variance |
| Consec Correct | Consecutive Correct Responses |
| CRUNCH | Compensation-Related Utilization of Neural Circuits Hypothesis |
| DT | Decision Time |
| fMRI | functional Magnetic Resonance Imaging |
| HAROLD | Hemispheric Asymmetry Reduction in Older Adults |
| Mastery8 | Identification of first 8 consecutive correct responses |
| MMSE | Mini Mental Status Examination |
| MoCA | Montreal Cognitive Assessment |
| MRI | Magnetic Resonance Imaging |
| PALPA | Psycholinguistic Assessment of Language Processing in Aphasia |
| PET | Positron Emission Tomography |
| SD | Standard Deviation |
| SPSS | Statistical Package for the Social Sciences |

ABSTRACT

AGE-RELATED DIFFERENCES IN FEEDBACK-BASED ASSOCIATIVE LEARNING

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Laine and Salmelin (2010) described language as dynamic, constantly changing as new words, expressions, and meanings appear and fade away. As a result, all speakers of a language, regardless of years of language use, must be able to update their lexicons to reflect these changes. Recently, there has been a growing literature exploring processes involved in new word learning across the lifespan suggesting that there are age-related differences on behavioral (Simon & Gluck, 2013) and neurofunctional (Cornelissen et al., 2003) levels. The present investigation explored these changes across decades of life, which, to the researcher's knowledge, had not yet been done. In a picture-word verification task, the participants learned eight pairings of novel pictures and nonsense words using feedback provided throughout the task. Results revealed significant changes relating several dynamics of the study, including mastery decision time (DT), cumulative accuracy (ACC), and cumulative DT. In addition, the number of consecutive correct answers, as well as the total number of trials completed, revealed meaningful changes across the lifespan. With the following data, researchers were able to determine that there was a difference in decision time and accuracy in feedback-based associative learning across the lifespan. These data may influence programs designed to facilitate healthy cognitive aging in older adults, which would likely have an impact on overall

quality of life. It might also benefit researchers developing future treatments of anomia to lessen signs of aphasia in those with the disorder.

CHAPTER ONE: INTRODUCTION

The way in which people of different ages learn new words is the driving force of this research. The literature to be discussed show that there are changes in areas of the brain associated with the learning of new words; however, this study investigates the behavioral/functional changes in the associative memory processes involved in learning new words across the adult lifespan.

Physical aging of the brain occurs consistently throughout our lifetime; however, the effects often go unnoticed until older age when independent daily living becomes more difficult. As part of the aging process, humans experience natural changes that have an impact on working memory, attention, and problem solving with regard to brain function (National Institution on Aging, 2015). Samson and Barnes (2013) referred to these changes in the human brain as a “fundamental dichotomy” of cognition either progressing toward dementia or a relatively intact cognitive capacity over their lifespan (p. 1903). Normal aging of the brain consists of shrinking due to the loss of various brain cells. Miller and colleagues (1980) analyzed the white and grey matter volumes while performing a post mortem study, which found a 2% decrease per decade in these matter volumes after the age of 50 years. Research has shown that the reason for brain shrinkage is white matter deterioration, or neuron degeneration, which causes these affected neurons to be less effective messengers (Kemper, 1994, as cited in Ganzer & Zauder, 2011), the possible disfigurement of myelin sheaths (Peters & Sethares, 2002), and possibly a loss of myelinated fibers (Marner et al., 2003; Bartzokis et al., 2004). Multiple studies have been performed over the last decade to determine the brain’s neural plasticity and brain aging effects of neurodegeneration on cognition in an effort to determine the relationship between aging and

cognitive performance for memory. There is speculation that with increased age comes decreased ability to accurately recall information in addition to advancing memory loss. However, Cabeza, Nyberg, and Park (2004) suggested that cognitive neuroscience studies only take into consideration the performance of episodic and working memory as being affected by normal aging.

In addition to these structural changes, there are functional aging patterns. For example, basic perceptual and cognitive abilities change, including declines in long and short-term memory, task abilities, processing abilities, and reasoning abilities (Hartman-Stein & Rue, 2011, p. 25). Usually, these kinds of changes are associated with difficulties in performing everyday activities important for functional independence. Myriad explanations have surfaced to explain why episodic memory declines with age. One is that the decline is an illustration of a more general decline in efficiently processing information (Birren, 1965; Cerella, 1985; Craik & Byrd, 1982; Salthouse, 1996). Another is that there is a decline in mnemonic processes, the ability to devise a technique to facilitate encoding and later recall (Jennings & Jacoby, 1993; Naveh-Benjamin 2000; Howard et al., 2006; Prull et al., 2006). Duverne, Motamedinia, and Rugg (2008) agreed that there are differing findings across studies, but when compared to younger adults, “older adults tend to demonstrate a pattern of over recruitment, exemplified in several studies by a more bilateral pattern of memory-related activity than that evident in the young” (p. 733). This suggests that older adults initiate a compensatory strategy of activating other areas of their brain, primarily the right hemisphere, to facilitate accurate recall of pertinent testing information. In a testing of this theory, Nielson et al. (2013) discovered that a certain degree of lateralization takes place when recalling memories, thus providing support to the networks that have a common connection of interest. The researchers went on to report that the broader left and

right dominant connectivity networks have specific roles, stating the “left-dominant connections are associated with language and perception of internal stimuli” and the “right-dominant connections being associated with attention to external stimuli” (p. 8), therefore facilitating the idea that the older population needs to utilize more memory recruiters and connections in order to recall something that a typically developing person from a younger generation would be able to recall without additional neuronal connections.

Positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) can be used to determine the neural activity in specific areas of the brain, thereby identifying potential patterns of activation patterns for younger and older adults. Studies using magnetic resonance imaging (MRI) have demonstrated that structural changes, such as brain atrophy, may occur at different rates (Draganski, Lutti, & Kherif, 2013). For example, brain volume reductions associated with aging have been shown to be more pronounced in the frontal lobe compared to other brain regions (Cowell et al., 1994; Jernigan et al., 2001), while age-associated frontal and temporal lobe volumes were found to decrease with age at similar rates (Bartzokis et al., 2001). Imaging studies have also revealed age-related under- and over-activation patterns for older adults compared to younger adults. The Compensation-Related Utilization of Neural Circuits Hypothesis (CRUNCH; Reuter-Lorenz & Cappell, 2008) proposes that an increased number of neuron properties require activation in older adults to complete similar tasks of those younger adults, suggesting that older adults demonstrate over-activation for smaller memory loads when compared to younger adults (Cappell, Gmeindl, & Reuter-Lorenz, 2010). Using the CRUNCH hypothesis, subjects were tested using event-related fMRI to determine if memory load was affected by age-related variations for the activation patterns of the brain. Interestingly, it was determined that smaller memory loads triggered over-activation despite similar performance

accuracy when comparing younger and older adults, meaning performance was similar to that of the younger participants, but that activation of memory recruiters and neuronal support was increased for smaller memory loads. However, older adults were less accurate and demonstrated an under-activation pattern for larger memory loads when compared to younger adults.

Due to these typical changes in brain structure and function, it is hypothesized that age differences in decision time, accuracy of the learning process, and overall mastery can be expected across the lifespan. That is, younger adults should demonstrate faster and more complete learning of targets, than older adults. During the language learning, associations between a phonological sequence and its referent are established, and these associations are strengthened with subsequent experience. Adolescents and adults often learn language explicitly, as is the case in acquiring a foreign language. According to the associative word-learning model proposed by Regier and colleagues (2001), the phonological sequence of a novel word is associated with the semantic features of the referent; however, this association is initially vulnerable to interference from words similar in sound or meaning. As learning continues, the unique phonological and semantic features of the word allow the strengthening of the association between sound sequences and meaning. These features become a part of the target word's association network, lessening the likelihood of interference from similar, but different words. Eventually, automaticity of phonological form and meaning occur and interference with similar targets is no longer a threat.

Children are known to learn new words quickly, adding approximately six to eight new words to their receptive vocabulary each day (Beck & McKeown, 1991; Nagy & Herman, 1987 as cited in McGregor, Sheng, & Ball, 2007) between the ages of 2 and 6. Further, they have approximately 60,000 total words by the time they have graduated from high school (Aitchison,

1994; Bloom, 2000 as cited in McGregor, Sheng, & Ball, 2007). As previously mentioned, word learning is a process that involves an understanding of a word's lexical form, its meaning, and finally the association between the two. Logically, the learner's ability to recall the target's semantics and proper use depends on frequency of exposure and understand of the concept.

Davis and colleagues (2008) used fMRI to identify cortical structures involved in learning and consolidation of novel words. Over two days, participants completed a series of tasks including lexical competition, repetition, forced-choice recognition, and word meaning ratings. The researchers determined that initial encoding of novel words involved recruitment of the left hippocampus, the primary structure used for memory. After the initial encoding and before consolidation into long-term memory, the superior and middle temporal gyri were bilaterally recruited, as well as the left supplementary motor area (in the case of unconsolidated novel words) and the left cerebellum (in the case of untrained novel words). Following consolidation, similar patterns of activation in the areas mentioned above were observed between novel words consolidated overnight and pre-existing words; greater activation was only seen in the right anterior superior temporal gyrus and the left posterior middle temporal gyrus for consolidated novel words. Therefore, when these novel word forms become consolidated into memory, they take on a form similar to that of other words in the lexicon.

In a study by Breitenstein and colleagues (2005), participants underwent fMRI scanning while completing a learning task to investigate brain activity associated with implicit learning of familiar picture and pseudoword pairs in a single scanning session. Data were collected across five consecutive training blocks, which, when pooled together for fMRI analyses, revealed primary clusters of activation in the middle and superior temporal gyri bilaterally and the left inferior and middle frontal gyri, along with other areas to a lesser extent. Comparisons of fMRI

data across the five training blocks revealed that a gradual signal decrease in the left hippocampus was significantly correlated with successful learning. These results are consistent with the findings of Davis et al. (2008), and provide a vision of widespread functional recruitment associated with novel word learning, suggesting that success on novel-word learning tasks can be predicted by changes in left hippocampal activation.

These studies together provide a rather consistent picture of brain activity patterns associated with the initial encoding and eventual consolidation of novel words. The initial, successful encoding of a novel stimulus appears to be mediated by recruitment of the left hippocampus. As the word is learned and no longer novel, hippocampal activation decreases, and this gradual decrease in the recruitment of the hippocampus is correlated with learning success. Between initial encoding and eventual consolidation, neural activity in the bilateral temporal and frontal cortices, cerebellum, and subcortical structures is observed. Over time, as the novel word is consolidated into memory, brain activation becomes more similar to that of existing lexical items.

These previous studies have all utilized young adult participants, and it remains to be seen if similar learning behaviors would be observed in the older adult population. There is reason to believe that different outcomes would be observed across the lifespan as the literature documents cognitive changes associated with normal aging (Baddeley, 1996; Park et al., 2002). Structural imaging has also revealed morphological changes in the aged brain (Raz et al., 2005). The hemispheric asymmetry reduction in older adults (HAROLD) model (Cabeza, 2002) supports the presence of functional changes in brain behavior in response to complex cognitive tasks. As explained by this model, bilateral recruitment may be due to a compensatory response to difficult tasks.

Statement of Purpose

Physical aging of the brain occurs consistently throughout our lifetimes, yet behavioral effects are often not revealed until individuals advance in age. In addition to structural changes, there are functional aging patterns occurring that result in differences in learning. Recently, there has been a growing literature base exploring processes involved in new word learning across the lifespan suggesting that there are age-related differences on behavioral (Simon & Gluck, 2013) and neurofunctional (Cornelissen et al., 2003) levels. Although much is already understood about the aging brain, it is important to understand when and in what ways these changes begin. Older adult learners may acquire new words using different or fewer strategies than their younger counterparts, and this may affect the effectiveness and efficiency of their learning. Persons with acquired communication disorders, such as aphasia, are often treated by helping them relearn or re-access words. Therefore, knowing more about how older people learn or relearn words can be clinically useful.

The present investigation sought to explore changes in novel word learning across decades of life. The data obtained in this study will shed light on the effects of aging on feedback-based associative learning and will better delineate when age-related changes in this particular aspect of cognition begin, as the feedback provided after each response will be the method in which each participant will learn the task. It will also serve as pilot data to confirm the adequacy of the paradigm to elicit these differences for the purpose of neuroimaging research and in extramural funding submissions to develop protocols to support healthy brain aging across the lifespan. Questions and hypotheses are as follows:

Question 1: Is there a relationship between age and successful learning of novel words during a feedback-based word-learning task?

Hypotheses

H₀: There is no relationship in learning of novel words during a feedback-based word-learning task for participants of increased age.

H₁: There is a relationship in learning of novel words during a feedback-based word-learning task for participants of increased age.

Question 2: Is there a relationship between performance on cognitive screening measures and with successful learning of novel words during a feedback-based word-learning task?

Hypotheses

H₀: There is no relationship between performance on cognitive screening measures and successful learning of novel words during a feedback-based word-learning task.

H₁: There is a relationship between performance on cognitive screening measures and successful learning of novel words during a feedback-based word-learning task.

Question 3: Can successful learning of novel words during a feedback-based word-learning task be predicted by age?

Hypotheses

H₀: Successful learning of novel words during a feedback-based word-learning task cannot be predicted by age.

H₁: Successful learning of novel words during a feedback-based word-learning task can be predicted by age.

CHAPTER TWO: METHODS

Participants

Participants included 65 persons between the ages of 20 and 85. Of these participants, 45 were female and 20 were male. Participants consisted of a sample of convenience, as they were recruited from a number of sites, including Western Carolina University and communities in western North Carolina, northern South Carolina, and central Florida. Recruitment strategies included word-of-mouth and flyers provided by the research investigators. All potential participants completed a short medical history form related to history or presence of managed hypertension (or absence of hypertension), corrected vision/hearing impairment (or absence of impairment), ability to read single words, and absence of neurological impairment. Neurological impairment was assessed using the Mini Mental Status Examination (MMSE; Folstein et al., 1975) and the Montreal Cognitive Assessment (MoCA; Nasreddine, 1996). Persons with a history of unmanaged hypertension; uncorrected visual or hearing impairments; inability to read at the single word level; and cognitive impairment as measured by the MMSE and MoCA were excluded from the study. After confirming eligibility, participants were asked to provide information related to gender, age, and highest level of education completed. These demographic and cognitive assessment data are provided in Table 1 as summary data.

Cognitive Measures

The MoCA and MMSE are standardized cognitive assessments commonly used in hospital, psychiatric, and clinical research settings to determine the onset of early dementia. Specifically, the MoCA assesses short term memory recall, visiospatial abilities, executive

Table 1

Number of Participants (N), Mean, and Standard Deviation (SD) for Age, MoCA, MMSE, and Years of Education Completed (EduLevel)

| | N | Mean | SD |
|----------|----|-------|-------|
| Age | 65 | 51.25 | 19.30 |
| MoCA | 65 | 27.71 | 2.02 |
| MMSE | 65 | 29.39 | .87 |
| EduLevel | 65 | 16.80 | 2.40 |

function, attention, and working memory. The MMSE assesses similar aspects of cognition, including attention, calculation, ability to follow simple commands, and orientation. The MoCA and MMSE served two purposes in the present study. First, these measures were used to determine if neurological impairment was present; a minimum passing score of 26/30 was required in order for individuals to participate in the computer paradigm. Instituting this requirement provided reliability that participants did not present with cognitive decline, and therefore were reliable participants for determining normal aging of the brain. The cognitive measures were also used as measures of individual differences in participants. Because the study seeks to determine age-related differences across the lifespan, it is important to use the MoCA and MMSE as sources for determining these differences in cognition with age.

Experimental Paradigm

Each participant completed a novel-word learning task developed using E-Prime 1.1 computer software (Psychology Software Tools, Inc., 2002). Prior to beginning the task, target). These pairings are shown in Table 2.

Participants were instructed to indicate whether the stimulus pair was a match or non-match by using red and green response buttons. To indicate a novel picture-pseudoword match

participants were informed of the goal of the task: to learn which pseudoword was paired with which novel picture using the response-feedback provided. During this task, participants were presented simultaneously with phonologically plausible pseudowords (e.g., “sprawn”, “drange”, “acutty”) visually as the written word paired with photographs of unfamiliar abstract drawings. The onsets of the graphemic and pictorial visual stimuli were synchronized. The first trial for each participant was a guess, as there was no preliminary learning period. Each stimulus pair was shown for three seconds. During this three-second window, the participant would indicate whether he or she judged the pair to be a match or non-match (i.e., that the written word shown named the picture). After the three seconds, the stimuli were removed and feedback was provided indicating whether the participant’s response was correct, incorrect, or not recorded (e.g., no response provided or delayed response which was not given within the three second timeframe), facilitating learning of the abstract picture pseudoword pair based on the feedback. Participants’ decision time (DT) and accuracy (ACC) were recorded. For trials in which the novel picture-pseudoword pair did not match, the pseudoword was either a match to another novel picture in the paradigm (i.e., incorrect match but familiar target) or an unmatched pseudoword word not presented elsewhere in the paradigm (i.e., incorrect match and unfamiliar the participant was instructed to press the green button. For a non-match, the participant pressed the red button. After this response period, visual feedback was presented for one second following each response. Feedback was given related to response accuracy in the form of a green box reading “Correct Response”, red box reading “Incorrect Response”, or a blue box reading “No response recorded” cueing the participant to respond more quickly on subsequent presentations. Participants were told of the response time requirements prior to starting the experiment.

Table 2

Picture-Pseudoword Match and Nonmatch Pairs

| Stimulus # | Word Match | Word Nonmatch |
|------------|------------|--------------------------|
| 1 | ality | drange, polid, cleast |
| 2 | drange | polid, cleast, larden |
| 3 | polid | cleast, larden, truggle |
| 4 | cleast | larden, truggle, slurch |
| 5 | larden | truggle, slurch, prenoch |
| 6 | truggle | slurch, prenoch, ality |
| 7 | slurch | prenoch, ality, drange |
| 8 | prenoch | ality, drange, polid |

The picture stimuli were abstract pictures of varying shapes and colors judged by the investigator to be unfamiliar to the participant and not resembling images that would be familiar. These items were judged by the authors to be novel and unfamiliar to participants. The pseudoword stimuli were phonologically plausible nonsense words found in Subtest 8 of the *Psycholinguistic Assessment of Language Processing in Aphasia* (PALPA; Kay, Lesser, & Coltheart, 1992). Words were presented in black, bolded Courier font size 36, and placed directly under the picture during presentation.

Each item to be learned was presented 19 times. Correct nonsense word-novel picture pairs were presented between 9 and 10 times each; incorrect pairs were presented between 9 and 10 times each. The total number of items presented was 152. As a result, the experimental paradigm was a continual task, lasting approximately 13 minutes.

Data Analyses

Decision time to response from stimulus onset (DT) and response accuracy (ACC) were analyzed. Overall means were calculated for each participant to compare overall performance

across age. Degree of Mastery, defined as eight consecutive correct responses, was also analyzed. The number value used to represent mastery was the trial number of the eighth consecutive item (Mastery8). The mastery DT was calculated as the average DT for the eight responses that led to mastery being reached (Mastery8 DT). Data used in the analyses included: Mastery8 and Mastery8 DT; overall ACC and DT for all completed trials; number of persons attaining the Mastery8 criterion (Mastery Achieved); number of items with a recorded response (Items Completed); scores on cognitive measures (i.e., MoCA, MMSE); and maximum number of consecutive responses (Consec Correct). All non-responses were removed for the purpose of the statistical analyses where those null scores would have skewed data. These are further defined in Table 3.

In order to compare the results of individual participant performance and assess learning over time, statistical analyses were completed using the Statistical Package for the Social Sciences (SPSS; IBM Corp., 2013). Correlation analyses were run to determine the relationship between age, MoCA score, and MMSE score compared with successful learning of novel words. A regression analysis was then run to determine the ability of the independent variables of age, MoCA score, and MMSE score to predict the dependent variables of Mastery8, Mastery8DT, OverallACC, OverallDT, and ConsecCorrect. All statistical tests were based on a .05 level of significance.

Table 3

Dependent Variables, their definition, and indication of what was being assessed (Measurement)

| Dependent Variable | Operational Definition | Measurement |
|--------------------|--|---|
| Mastery8 | Trial number of the eighth consecutive item represent mastery | At what point in the paradigm mastery was met. |
| Mastery8 DT | Average DT for the eight responses that led to mastery being reached | Speed of Mastery8 responses |
| ConsecCorrect | Number of consecutive correct responses | Number of consecutive correct responses |
| Overall ACC | Mean accuracy of all recorded responses | Percentage of learning of paradigm |
| Overall DT | Mean decision time for all recorded responses | Speed of all responses |
| Mastery Achieved | Number of persons attaining the Mastery8 criterion | Number of people that did and did not reach mastery criteria. |

CHAPTER THREE: RESULTS

Relationships Between Novel-Word Learning And Age

To examine the relationship between age and mastery, the dependent variables of Mastery8, Mastery8 DT, Consec Correct, Overall ACC, Overall DT, and Mastery Achieved were compared to the independent variable of age. Descriptive statistics in Table 4 provide mean, standard deviation, and the number of participants for each dependent variable. According to the literature, mean MoCA and MMSE scores were higher than typically seen; however this is due to the exclusion of those individuals that did not meet the minimum requirements of a 26/30 for both exams due to the MoCA and MMSE definition of clinical cognitive decline. Participants were compared to evaluate significant changes across the lifespan.

A Pearson product-moment correlation was run to determine the relationship between age and performance on the novel-word learning task. Specifically, age was compared to the following dependent variables: MoCA, MMSE, EduLevel, Mastery8, Mastery8DT, OverallACC, OverallDT, ConsecCorrect, and Trials Completed. These data are presented in Table 5. As hypothesized, significant correlations were observed between age and several of these dependent variables. It was determined that as age increases, the following variables also increase: Mastery8 ($r = 0.253, N = 54, p < .032$), Mastery8DT ($r = 0.448, N = 54, p < .000$), and OverallDT ($r = 0.513, N = 65, p < .000$). Conversely, it was suggested that as age increased, values of the following variables decreased: MoCA scores ($r = -0.465, N = 65, p < .000$), MMSE scores ($r = -0.260, N = 65, p < .018$), OverallACC ($r = -0.653, N = 65, p < .000$), ConsecCorrect ($r = -0.614, N = 65, p < .000$), and Trails Completed ($r = -0.586, N = 65, p < .000$). No significant correlations were observed between age and EduLevel ($r = 0.097, N = 65, p < .222$).

Table 4

Descriptive statistics including mean, standard deviation, and number of participants for experimental variables.

| | <i>N</i> | Mean | Std. Deviation |
|------------------|----------|---------|----------------|
| Age | 65 | 51.25 | 19.30 |
| MoCA | 65 | 27.71 | 2.02 |
| MMSE | 65 | 29.39 | .87 |
| EduLevel | 65 | 16.80 | 2.40 |
| Mastery8 | 54 | 71.35 | 30.07 |
| Mastery8DT | 54 | 1429.38 | 275.64 |
| OverallACC | 65 | 78.17% | 13.82% |
| OverallDT | 65 | 1309.14 | 305.20 |
| ConsecCorrect | 65 | 19.23 | 13.21 |
| Trials Completed | 65 | 146.20 | 4.60 |

Table 5

Correlations between independent variable of age and dependent variables

| | Pearson Correlation (Age) | Sig (1-tailed) | Pearson Correlation (MoCA) | Sig (1-tailed) |
|------------------|---------------------------------|----------------|----------------------------------|----------------|
| Age | 1 | | -.465** | .000 |
| MoCA | -0.465** | .000 | 1 | |
| MMSE | -0.260* | .018 | .380** | .001 |
| EduLevel | -0.097 | .222 | .123 | .164 |
| Mastery8 | 0.253* | .032 | -.304* | .013 |
| Mastery8DT | 0.448** | .000 | -.136 | .164 |
| OverallACC | -0.653** | .000 | .478** | .000 |
| OverallDT | 0.513** | .000 | -.210* | .046 |
| ConsecCorrect | -0.614** | .000 | .499** | .000 |
| Trials Completed | -0.586** | .000 | .364** | .001 |

** . Correlation is significant at the 0.01 level (1-tailed).

* . Correlation is significant at the 0.05 level (1-tailed).

Relationships Between Cognitive Screening Performance and Age

A Pearson product-moment correlation was run to determine the relationship between age and performance on the MoCA and MMSE cognitive screenings. These data are presented in Table 5. As hypothesized, significant correlations were observed between age and performance on the MoCA ($r = -0.465, N = 65, p < .000$) and MMSE ($r = -0.260, N = 65, p < .018$), suggesting that as age increased, performance decreased on these cognitive measures.

Predicting Novel-Word Learning Success

A multiple regression was run to predict performance on the novel-word learning task given age, MoCA score, and MMSE score. Pertaining to the mastery criteria, it was determined that Mastery8 was statistically significantly predicted by the variables, $F(3, 50) = 4.699, p < .006$, adjusted $R^2 = .173$. More specifically, performance on the MoCA was significantly predictive of Mastery8 when the other variables were statistically controlled: $t(50) = -2.522, p = .015$. In addition, performance on the MMSE was significantly predictive of Mastery8 when the other variables were statistically controlled: $t(50) = 2.631, p = .011$. However, age was not significantly predictive of Mastery8 when the other variables were statistically controlled: $t(50) = 1.019, p = .313$. Interestingly, Mastery8DT was statistically significantly predicted by the variables, $F(3, 50) = 5.290, p = .003$, adjusted $R^2 = .195$, and it was determined that age was responsible for this significance: $t(50) = 3.342, p = .001$. Performance on the MoCA and MMSE was not significantly predictive of Mastery8DT when the other variables were statistically controlled ($t(50) = -0.092, p = .927$ and $t(50) = 1.569, p = .123$, respectively).

Similar analyses were run using overall performance on the task as the dependent variable. OverallACC was statistically significantly predicted by the variables, $F(3, 61) = 18.508, p = .003$, adjusted $R^2 = .451$. Again, it was age predicted OverallACC when the other

variables were statistically controlled: $t(61) = -5.103, p < .001$. However, performance on the MoCA and MMSE was not significantly predictive of OverallACC when the other variables were statistically controlled: $t(61) = 1.669, p = .100$ and $t(61) = 1.169, p = .247$, respectively. Similarly, OverallIDT was statistically significantly predicted by the variables, $F(3, 61) = 7.914, p < .001$, adjusted $R^2 = .245$. This significance was represented by age ($t(61) = 4.412, p < .001$). Performance on the MoCA was not significantly predictive of OverallIDT, $t(61) = -.074, p = .942$, nor was performance on the MMSE: $t(61) = 1.170, p = .247$.

The final analysis suggested that ConsecCorrect was statistically significantly predicted by the variables, $F(3, 61) = 15.656, p < .001$, , adjusted $R^2 = .407$. Age was significantly predictive of ConsecCorrect when the other variables were statistically controlled: $t(61) = -4.439, p < .001$. Performance on the MoCA and MMSE were not significantly predictive of ConsecCorrect: $t(61) = 2.351, p = .022$ and $t(61) = .136, p = .893$, respectively.

As hypothesized, when determining the R^2 change associated with the addition of the age variable in the regression model (Model 2), age was determined to account for a statistically significant amount of the variability in the data ($p < .001$) for most dependent variables. However, it did not account for the variability in the Mastery8 regression line. These data are presented in Table 6.

Table 6

Regression analysis used to determine the significance of age as a predictor of change for dependent variables listed

| Dependent Variable | Model 1 R^2 | Model 2 R^2 | R^2 change | Significance |
|--------------------|---------------|---------------|--------------|--------------|
| Mastery8 | 0.204 (.003) | 0.22 | 0.016 | NS |
| Mastery DT | 0.062 (NS) | 0.241 | 0.179 | .001 |
| OverallACC | 0.253 (.000) | 0.477 | 0.224 | .001 |
| OverallDT | 0.050 (.000) | 0.28 | 0.23 | .001 |
| ConsecCorrect | 0.253 (.000) | 0.435 | 0.183 | .001 |
| Trials Completed | 0.142 (.009) | 0.376 | 0.233 | .001 |

Note. Model 1 = MoCA and MMSE; Model 2 = MoCA, MMSE and Age

CHAPTER FOUR: DISCUSSION

Conclusions

The purpose of this study was to determine the effectiveness of an experimental learning paradigm in detecting differences in novel-word learning across the lifespan. Data included decision time and accuracy obtained during task completion, as well as data recorded following administration of two cognitive screening tools: MoCA and MMSE. Data analyses revealed several statistically significant relationships between age, MoCA scores, and MMSE scores and performance on the task. Further, age was found to be a significant predictor of several learning variables.

The current data support previous studies suggesting declines in information processing speed, memory, visuospatial abilities, and executive function in the typically aging population, especially in those 65 years of age and older (Harada, Love, & Triebel, 2013). The task used in the current study likely required the participation of all of these process for learning to occur. Given that age, rather than MoCA and MMSE scores, was found to predict performance on almost all mastery measurements, there is reason to believe that these changes in cognitive performance are happening across the lifespan, and not just later in life. It is possible that inefficiencies in selecting and implementing compensatory strategies could be to blame (Plett, 1990). Learning tasks such as this would inherently require creative use of strategies, and perhaps the aging brain attempts to compensate for these challenges using less efficient and less effective strategies.

The differences become more representative of the steady decline with age as decision time is considered. One of the reasons these age associations occurred may be due to the speed-

accuracy tradeoff. It has been suggested that with increased age there is a greater concern for accuracy rather than speed of response. Forstmann et al. (2011) described older adults as being more hesitant and cautious in responding incorrectly. This was reported decades earlier by Rabbitt (1979) who suggested the accumulation of additional information prior to making a decision is what causes the cautious and slowed responses even when asked to emphasize the speed of a response rather than the accuracy. This is evident in the data demonstrated by the mean number of trials completed decreasing as age increased. Due to the time constraint of three seconds per picture-word pair exposure, many older participants may have felt this pressure of speedy responses rather than answering with accuracy

Implications

Rowe and Kahn (1998) defined successful aging as consisting of physical health and well-being; maintenance of cognitive function; and sustaining of quality of life. Given that cognitive function can positively or negatively affect these other variables, it stands to reason that maintaining this ability should be the focus of preventative programs for seniors. In fact, evidence suggests that older adults can be trained to select and use specific strategies in functional ways (Gross & Rebok, 2011). However, in order to develop programs that are both effective and efficient in this endeavor, research must continue to explore the changing strengths and needs of this aging population. Understanding the process of learning and how that process changes across the lifespan has implications in typical and atypical aging. From the perspective of the typically aging adult, it is important to recognize the unique processing needs of the population. Learning occurs throughout life, and people are regularly bombarded with new terminology to be learned and recalled in meaningful and functional ways. An example of this is an unfamiliar illness that may occur towards the end of life or technological advances such as

computers and cellular phones. By learning more about how learning happens across the lifespan, it may be possible to personalize presentation of new information in a way that will increase the likelihood of effective and efficient learning.

Of additional importance, and certainly relevance to the field of speech-language pathology, is the implication of learning patterns and strategies for persons with stroke-induced aphasia, a language disorder resulting from brain injury. Persons with aphasia inherently have difficulty with retrieving the names of objects, an impairment referred to as anomia, and this impairment may be addressed by direct training of words lost or inaccessible. It is important to understand learning of words across the lifespan as aphasia can occur to anyone at any age. Given the limited time for intervention with this population despite the chronic nature of the disorder, predicting appropriate treatments would likely save time, reduce frustration, and improve ultimate functional outcome.

Limitations

Recruitment consisted of a sample of convenience, primarily those individuals within a 60-mile radius of Cullowhee, NC and central Florida area. This recruitment strategy limited the randomization of the study, therefore increasing biases. Recruitment of older adults (persons between the ages of 80-89) presented to be quite difficult for many reasons, some of which include onset of dementia, an unwillingness to participate due to fear of judgment, and inclement weather. The small sample size of each population could also be a consequence of recruitment strategies. There was a 4-month window in which participants were recruited from areas surrounding western North Carolina. Due to limited resources in providing availability for testing, several potential participants were unable to complete the task. It is also a concern that

several potential participants cancelled testing sessions for personal reasons or did not attend to sessions without cancellation.

Another limitation is related to the cognitive measures used in the study with the purpose of ruling out persons with cognitive declines not attributable to typical aging. The MoCA is designed to specifically assess different cognitive domains including attention and concentration, executive functions, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. The MMSE is designed to specifically look at number of different mental abilities as well, including a person's memory, attention and language. It is also possible that the MoCA and MMSE were not the most reliable measures to use for ruling out atypical cognition. As a result, there is a chance that older participants may have had early stages of cognitive decline that went undetected by the cognitive screens. This would certainly skew results as the study was designed to assess learning in healthy aging. Further research on reliability of these measures revealed that MoCA scores were consistently lower than MMSE scores (Cumming et al., 2013), and Spencer et al. (2013) concluded that the MMSE had poor test-retest reliability and reduced sensitivity to brain abnormalities that may be subtle, illustrating the severe limitations of the MMSE in detecting differences in cognitive functions, primarily in healthy older adults. When directly compared to the MMSE, researchers agreed that the MoCA was a sensitive screening test for identification of early cognitive involvement, as it detected cognitive impairment that was not detected by the MMSE in a large number of participants (Markwick, Zamboni & de Jagar, 2012; Olson et al., 2011).

The prevalence at which the MMSE is administered regardless of its reliability is also a concern, as it is a common screening measure utilized by geriatricians, neuropsychologists, and other clinicians and researchers (Spencer et al., 2013). Due to its wide usage in several medical

and health care professions, the frequency of exposure and commonality of the MMSE could have put some participants at an advantage, as they may be more familiar with this screening tool from previously being administered the test or administering the test themselves.

Additionally, it has been hypothesized that the word-learning environment can play a vital role in the ability to learn and retain the meaning of a referent (Huttenlocher, Levine, & Veva, 1998; Plomin & Dale, 2000 as cited in McGregor, Sheng, & Ball, 2007). The abstract pictures and pseudoword stimuli in the present study were not meaningful and presented as single words rather than in a syntactically significant environment, and therefore presented the task in a decontextualized learning environment that provided very little support from the word-learning environment. It is possible that the older population has demonstrated more difficulty learning from decontextualized learning tasks. Include

Finally, the response buttons used in the study may need to be replaced with another response system. Throughout the study, some participants complained of submitting a response that was not recorded; therefore, a “no response” would be documented. Despite the 152 stimulus presentations, there was the potential for the nonresponses to affect data as the nonresponses ranged from 0 to 25 per participant. Simple adjustments to the paradigm would allow participants as much time as desired to respond to items. This would inherently shorten or lengthen the paradigm, but may be worth the increased likelihood of gathering all data points for each participant.

Future Directions

Although there was sufficient data to complete statistical analyses, a larger sample size would likely provide more robust data with which to answer questions. During this selection process, greater attention should be devoted to recruiting participants with greater homogeneity.

Specifically, steps should be taken to match participants according to variables such as gender, education, cognitive screening performance, and age.

Although the current paradigm did detect relationships between learning and age, the paradigm could be improved. For example, unlimited time to respond to each picture-word pair presented would allow the participant additional time to rehearse correct pairs presented and recall correct pairs through whatever strategy worked for the individual. Increasing the number of attempts at picture-word pairs may increase exposure and opportunities for learning. Different types of feedback, as well as opportunities to use more explicit learning and compensatory strategies, may facilitate faster and more accurate learning, as the abstract picture-word pairs may have posed difficulty for some participants. It would also be of benefit to include the independent measure of motor ability to determine the effectiveness of reaction time when submitting each decision or match or nonmatch. In doing so, a pre test to the actual paradigm would facilitate understanding of the task instructions, as well as provide additional information as to whether or not reaction time is a significant dependent variable when compared to age.

Finally, based on the data it was determined that age correlated with general cognitive abilities; however, it is of increasing interest whether or not the declines seen across most dependent variables were due to general cognitive decline or if it was due to some other factor not previously considered. Even after accounting for differences in general cognitive abilities, there could be additional relationships of age to learning new words that is unaccounted for by cognitive abilities as measured by MoCA and MMSE. The next step in research would be to determine what other correlates, in addition to cognitive decline, account for cognitive decline.

CHAPTER FIVE: REFERENCES

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APPENDIX A

Informed Consent Form

Age-Related Differences in Feedback-Based Associative Learning

PURPOSE

Recently, there has been research on how we learn new words as we get older. This study will explore how the brain learns in each decade of life, which has yet to be done. The results of this study will help us understand how the brain changes as we get older so we can better design programs to help slow normal brain aging.

PROCEDURES

If you agree to be in this study, the following will happen:

1. You will complete a personal information form to provide age, gender, and education, and a medical history form related to hypertension, vision, hearing, reading abilities, and general brain health.
2. You will complete two short cognitive screenings to check your memory, language, and other functions. Each test will take approximately 10 minutes. During these, you will be asked to perform a series of tasks and answer questions.
3. You will complete a computer task to test your ability to learn new picture-words pairs that you have never seen or read before. While sitting in front of a computer screen, you will be instructed to press a button to indicate if you think the picture and word you see match or do not match, and you will be told if your answers are right or wrong to help you learn these new picture-word pairs. Completion of this computer task will take approximately 15 minutes.

POSSIBLE RISKS

Any experiment has possible side effects. The procedures used in this study may cause all, some, or none of the side effects listed.

You will be required to complete two short cognitive screenings and a learning task on the computer. These may be difficult and cause some frustration. However, any frustration related to these tasks is expected to be minimal, and similar to what you might experience visiting your doctor for an annual check-up. Also, research will be conducted in a quiet, accessible, and private environment. Breaks will be offered at several points throughout the session.

EXCLUSIONS

People under the age of 20 years and over the age of 90 will not be allowed to participate in the study. This research is only interested in persons that fall from the age of 20 to 89. Also, persons experiencing signs of cognitive decline as measured by the Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination (MMSE), untreated hypertension, uncorrected vision/hearing, illiteracy, or history of neurological involvement (e.g., Parkinson's disease, stroke, and traumatic brain injury) will be excluded from the study.

POSSIBLE BENEFITS

In order to facilitate the healthy aging process, it is necessary to understand how and when changes in the brain occur. This can lead toward the development of intervention programs and community supports that foster independence, health, and wellness of our aging population. This

knowledge allows practitioners to take steps towards *preventing* cognitive decline associated with age, thereby *preventing* strains (e.g., financial, emotional, physical, occupational) on individuals, families, communities, and beyond.

COST TO YOU FOR PARTICIPATING IN THIS STUDY

There will be no cost to you for participating in this study.

PAYMENT FOR PARTICPATION

To You:

You will not be paid for participating in this study.

To Investigators:

The investigators on this study are not being paid to conduct this research beyond their usual salary. None of the investigators on this project stand to gain financially from the results of this study.

To Institution:

Western Carolina University will not be paid for this study.

COMPENSATION FOR INJURY AS A RESULT OF STUDY PARTICIPATION

Although it is not anticipated, if you get hurt or sick because of participating in this study, emergency medical treatment is available but will be provided at the usual charge. The study

sponsor will not pay for this treatment. You will be responsible for any charges accrued. No financial compensation (payment) will be available to you from the study sponsor. You or your insurance company will be charged for continuing medical care and/or hospitalization. You understand that you have not given up any of your legal rights by signing this consent form.

VOLUNTARY PARTICIPATION

Your participation in this study is voluntary (your choice). You may refuse to take part in or stop taking part in this study at any time. You should call the investigator in charge of this study if you decide to do this. Your decision not to take part in the study will not affect any current or future services provided by us.

The investigators and/or the sponsor may stop your participation in this study at any time if they decide it is in your best interest. They may also do this if you do not follow the investigator's instructions.

NEW INFORMATION

During this study, you will be told of any important new information that may affect your willingness to participate in this study.

AUTHORIZATION TO USE MEDICAL INFORMATION

As part of this research study, only the principal investigator and her research team will have access to the medical information you provide while you are participating in this study. Medical information will not be requested from your physicians or any hospital from which you have

received medical care. These study records may be kept on a computer or in a locked filed cabinet and will include all information collected during the research study, and any health information you provide that is related to the research study. The principal investigators will use this health information as they conduct this study. To evaluate the results of the study, and with compliance with federal and state law, your information may be examined by the Institutional Review Board of Western Carolina University. This study may result in scientific presentations and publications, but steps will be taken to make sure you are not identified, such as the assignment of an identification number to take the place of your name on all study related materials. All study related information will be kept for five years following the completion of the study. After that time, all information will be destroyed.

If you have any questions about the privacy of your health information, please discuss this with the principal investigators.

CONTACT FOR QUESTIONS OR TO REQUEST SUMMARY OF RESULTS

For more information concerning this study and research-related risks or injuries, or to request a summary of the results for this study, you may contact the primary investigators Melissa J. Blackstone at (828) 227-3381 or Dr. Leigh Morrow-Odom at (828) 227-3834. You may also contact a representative of the Institutional Review Board of Western Carolina University for information regarding your rights as a participant involved in a research study at (828) 227-7212.

CONSENT TO PARTICIPATE

The investigators have explained the nature and purpose of this study to me. I have been given the time and place to read and review this consent form, or it has been read to me, and I choose to participate in this study. I have been given the opportunity to ask questions about this study and my questions have been answered to my satisfaction. I agree that my health information may be used and disclosed (released) as described in this consent form. After I sign this consent form, I understand I will receive a copy of it for my own records. I do not give up any of my legal rights by signing this consent form.

Instructions:

The screen will reveal an abstract picture-novel word pair in three-second intervals. Use the green button to answer “match” and red buttons to answer “nonmatch” when indicating if the abstract picture is represented by the novel word.

Feedback will be given based on your response. Feedback includes “correct response”, “incorrect response” and “no response”.

You will have 152 exposures to abstract picture-novel word pairs; therefore, it takes approximately 13 minutes to complete the paradigm.

QUALIFYING INFORMATION

Age: _____ Gender: M F

Highest level of education

completed: _____

Please indicate if you have any of the following:

Y N Hearing Impairment

 If yes, has it been corrected? Y N

Y N Hypertension

 If yes, do you take medication? Y N

Y N Visual Impairment

 If yes, has it been corrected? Y N

Y N Neurological Impairment (e.g. Parkinson's, dementia, TBI)

 If yes, please

explain: _____

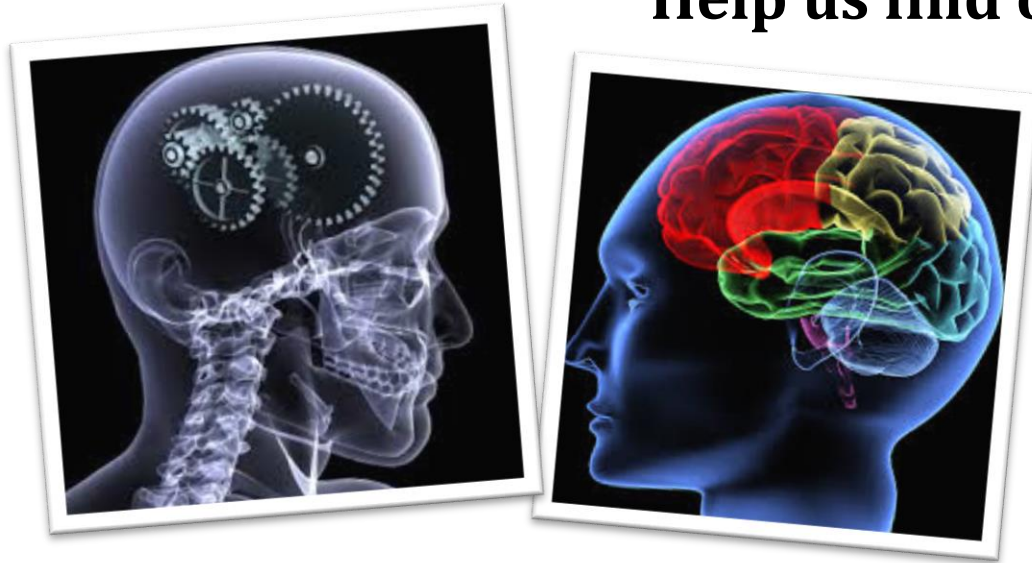
APPENDIX B

Recruitment Flyer

Age-Related Learning

HOW DO WE LEARN NEW WORDS AS WE GET OLDER?

Help us find out!



This study will explore how the brain learns new words in each decade of life, which has yet to be done! The results of this study will help us understand how the brain changes as we get older so we can better design programs to help slow normal brain aging.

We're seeking:

- * Males and Females
- * Between the ages of 20 and 89 years

Please contact Melissa Blackstone at the WCU Speech and Hearing Clinic

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(828) 227-3381

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