University of North Carolina at Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2013

The Effects of Aging on Creativity, Cognition, and Event Related Potentials in a Visual Working Memory Task

Abigail Ruffle and Madison Savage
Department of Psychology
The University of North Carolina at Asheville
One University Heights
Asheville, NC 28804 USA

Faculty Advisor: Dr. Michael Neelon

Abstract

There are currently two leading hypotheses that attempt to explain the cognitive decline associated with old age. The first is the "processing speed hypothesis," which attributes cognitive impairment to slower processing speeds. The second is the "inhibitory deficit hypothesis," which suggests that the inability to suppress irrelevant stimuli leads to poorer performance on tests of cognitive function. These models further suggest different impacts of age on diverse cognitive functions such as executive attention, convergent thinking, and divergent (i.e., creative) thinking. The present study investigates these questions using a paradigm from Gazzeley et al. (2008) in which EEG is used to compare the performance of younger and older adults in a visual working memory task. The task consists of three conditions in which subjects are asked to: (1) remember faces and ignore scenes, (2) remember scenes and ignore faces, and (3) passively view scenes and faces without trying to remember them. Following previous results, EEG responses of older adults were expected to show 1) delayed suppression of irrelevant information due to a decline in processing speed; and 2) reduced suppression to distracting stimuli due to failed attentional control. EEG results were also compared with performance on a series of neuropsychological tests to assess the relationship between creativity and executive functioning.

1. Introduction

Aging is known to be associated with a decline in executive function, including attention and working memory.[1] There are currently two leading hypotheses that attempt to explain the cognitive impairment that accompanies old age. The first is the "processing speed hypothesis," which attributes cognitive impairment to slower processing speeds. The second is the "inhibitory deficit hypothesis," which suggests that the inability to suppress irrelevant stimuli leads to poorer performance on tests of cognitive function.[1] The inability to suppress irrelevant information may be due to age-related declines in top-down modulation. Top-down modulation is the neural process that underlies our ability to suppress irrelevant stimuli and pay attention to important information via the suppression and enhancement of sensory cortical activity. This process can be measured behaviorally using working memory tasks. Engle (2002) describes working memory as a cognitive ability that allows us to use attention to maintain or suppress information in an ongoing situation. Deficits in top down modulation result in an inability to ignore distractions and focus attention on relevant stimuli, which is associated with poorer working memory performance.[2]

Gazzaley et al. (2008) found a relationship between the two cognitive aging hypotheses using an EEG study in which they compared the performance of younger and older adults in a visual working memory task. Their results found that top-down suppression was delayed in older adults in the early stages of visual processing, such that there was sufficient interference from irrelevant stimuli to impair working memory performance. This is because working memory is limited in capacity, so that the inability to suppress distractions overwhelms it and leads to a loss in retention.[3]

The present study will attempt to replicate the findings of Gazzaley et al. using electroencephalography (EEG) recordings and a visual working memory task. The working memory task will consist of three conditions during which participants will be presented with a series of images displaying neutral faces and scenes. In each of the conditions the participants will be asked to either: (1) remember scenes and ignore faces, (2) remember faces and ignore scenes, or (3) passively view faces and scenes without trying to remember them. The first two conditions will be compared to the passive condition to distinguish top-down enhancement and suppression in the data.

EEG is particularly effective to determine the precise timing of top-down modulation changes, because of the high temporal resolution of EEG relative to other neuroimaging techniques. EEG can also be used to detect changes in magnitude of particular wave components. The P1 component, which occurs around 100ms post stimulus, is thought to be the first event related potential (ERP) component that is influenced by attention and it may reflect a mechanism that enhances perceptual processing of stimuli.[4] The N1 component occurs around 200 ms post stimulus and may reflect response inhibition.[5] Changes in magnitude of the P1 component will reflect either suppression or enhancement of stimuli while the latency of the N1 component will reflect delays in processing.

We expect to find that older adults still display significant enhancement of the P1 wave of the ERP in the EEG data, but that suppression of the N1 wave in the time course of visual processing will be delayed. We also expect older adults to show a deficit in suppression of irrelevant stimuli. As a consequence, older adults should perform worse than younger adults in behavioral measures of a visual working memory task because the impaired ability to suppress distractions should reduce retention of task relevant information.

1.1 Creativity and Executive Function

As well as analyzing working memory deficits we compared creativity measures and executive function. Creativity is defined as the ability to generate novel and useful ideas.[6] However, there are controversies about the workings of creativity and working memory that suggest that they could correlate positively or negatively depending on what aspect of creativity is being measured, as well as the influence of age.[6] On the one hand, creative ideas may be preceded by a period of unconscious incubation or mind wandering during which there is mental relaxation (i.e. a relaxation of executive functions), which may correspond to poorer performance on a working memory task.[7] On the other hand, some neuroimaging studies have found that highly creative people use bilateral prefrontal regions of the cortex during an Alternate Uses task (generating alternate uses for common objects).[7] Similarly, there is evidence that the prefrontal region of the right hemisphere supports processing of distant associations and divergent thinking.[5,7] In some cases then, executive function may be a necessary component of creativity if the particular task requires planning, working memory, response selection and the suppression of stereotypical responses.[5]

Overall, it seems that creativity experiments have been inconclusive and creativity has not necessarily been linked with working memory or any particular region of the brain.[5,7] We compared creative measures and performance on the EEG working memory task to see if a correlation exists regardless of direction. We did expect to find a positive correlation between the neuropsychological tests and the EEG working memory task because they are all measures of executive function.

2. Methods

2.1 Participants

Fifty-nine participants were recruited from the UNC-Asheville campus to participate in the experiment. 47 of the participants were healthy older adults (60 years and older) and 12 were healthy younger adults (age 18-30 years old). Of the older subjects, 16 returned to participate in the present EEG study. The older adults were recruited from a pool that had participated in an initial testing session establishing baseline measures of neuropsychological functioning and creativity in divergent thinking tasks. These subjects were originally recruited from the Osher Lifelong Learning Institute (OLLI) on the UNC-Asheville campus. Recruited participants provided informed consent to participate in multiple behavioral, neuropsychological, and EEG measures assessing cognitive ability and creativity. Three older adults and five younger adults had to be excluded from the analysis due to unreliable or incomplete data.

All subjects completed the MMAS to screen for cognitive impairment (all passed) and completed further surveys on mindfulness (not analyzed here), demographic, education and mental health information.

2.2 Neuropsychological Tests

The Stroop task is a test of executive attention that measures one’s ability to monitor and control behavior via response inhibition. This task is administered in 3 different increments: one sheet of paper with color words printed in black and white ink; one sheet of paper with “XXXX” printed in a limited number of colors, in which participants are supposed to name the ink color; and one sheet of paper with the color words printed in colored ink, all of which conflict with the word (e.g., the word “RED” may be printed in blue) and the participants are asked to name the color of the ink. The task is timed to measure the participants’ ability to inhibit distracting stimuli. An interference score was obtained by subtracting the time of the second subset from the third subset.

Symbol Digit Modalities Test (SDMT) evaluates attention and visual processing. The test involves filling in boxes to pair numbers with specific symbols using a key. An individual’s score is the number of items completed correctly in 90 seconds.

2.3 Creativity Tests

To study creative potential, participants completed the Remote Associates Test and the Alternate Uses Test. The Remote Associates Test contains 15 items. Each item includes three words (e.g., heart, sugar, tart) that can be linked through a fourth associated word (i.e., sweet). Participants are given 15 minutes to solve as many items as possible.

The Alternate Uses Test involves producing as many uses as possible for two common objects (brick and newspaper). Participants are urged to be as creative as possible and are given three minutes for each object. The final score is calculated by adding the total number of uses generated across the two objects.

2.4 Procedure

Grayscale, neutral images of faces and scenes provided by Gazzaley et al (2208) were used as stimuli for the EEG working memory task. Participants were presented with four images of two faces and two scenes in pseudo-random order (image order was initially randomized across trials and conditions, but all subjects viewed the same ordering). Each image was presented for 800 ms with a 200 ms inter-stimulus interval (ISI). Each set was followed by a 9 second delay during which the participants could mentally rehearse the images. After the delay a fifth image appeared (probe). In the active conditions, participants were asked to respond whether or not the probe matched one of the previous images. In the passive condition participants had to indicate the direction of an arrow presented on the screen after the 9 second delay.

The visual working memory task consisted of three conditions in which the participants had to: (1) remember faces and ignore the scenes, (2) remember scenes and ignore the faces, and passively view the images without trying to remember them. The task was presented in three separate conditions in randomized order (i.e face, scene, and passive) with 20 trials in each condition for a total of 60 image presentations. The task took approximately one hour to complete.

2.5 Behavioral Analysis

Statistical analysis compared the Remote Associates Test, the Alternate Uses Test, the Stroop task, the SDMT, and the EEG working memory task. The Remote Associates task and the Alternate uses task were especially important because they measure creative ability and divergent thinking. Scores from the neuropsychological and creativity tasks were compared to performance on the EEG working memory task in individual regression analyses to see if there were correlations between creative ability and working memory performance. The Stroop task was compared to the EEG working memory task because it measures functions of cognitive inhibition. Recognition accuracy (hits + correct rejections/total possible items) in the EEG working memory task was compared in the face condition across older adults to determine working memory performance.

2.6 EEG Analysis

A 64-channel EEG system (Biosemi / Cortech Solutions) was used to record cortical neural activity during the visual working memory task. Raw EEG recordings from each condition for each subject were first re-referenced to common average reference, FIR filtered between 1-30 Hz, and ocular-artifact corrected. Event-related potentials (ERPs) were then formed for each condition by averaging relevant epochs extracted from the processed EEG waveform in 1s windows time-locked to relevant picture onset, depending on condition (-200ms pre-stimulus baseline – 800ms post-stimulus). Epochs +/- 50μV were removed before averaging to form ERPs and ERPs were baseline corrected. Subjects with 60 or more acceptable epochs across the three conditions were used to create grand-average ERP's. (13 / 17 older; 7 / 9 younger)

The grand average ERP for the older subjects was formed by averaging all subject ERPs from electrode P10. This electrode was chosen for analysis because it generally had the highest peak P1 once the ERPs were averaged across all subjects. The locality of the grand average ERP for younger subjects was much more variable, but electrode P10 was ultimately chosen for analysis to keep comparisons consistent. A P1 attention effect was calculated by subtracting the mean peak P1 component (+/- 5 ms window centered on peak)[1] in the ERP in response to faces when attending to scenes from the same measure when attending to faces.

3. Results

3.1 Neuropsychological and Working Memory Performance

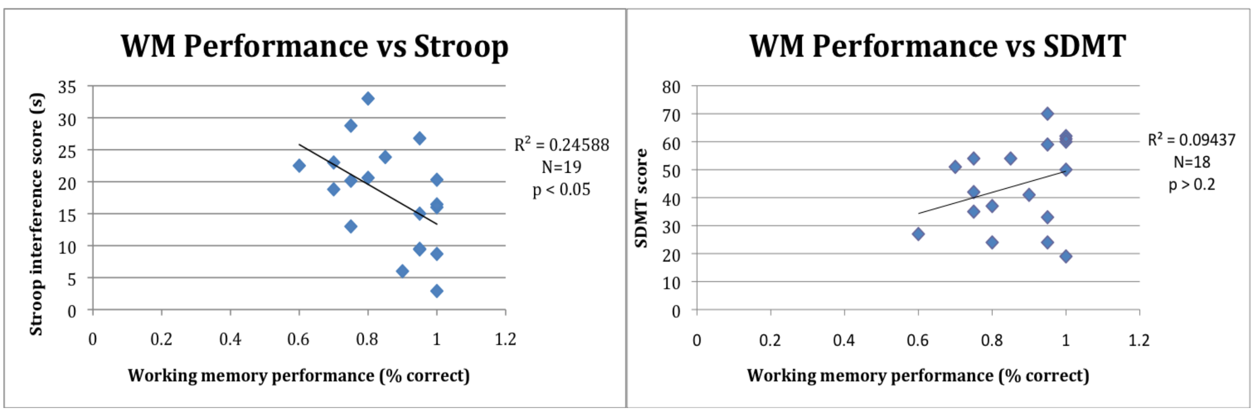

Figure 1 – Older and younger subjects' combined performance on the Stroop task and the SDMT versus working memory performance during the EEG task. There is a significant negative correlation between working memory and Stroop interference scores. The Stroop task measures reactions times, so the negative correlation indicates an expected positive relationship between working memory and inhibition (two components of executive function). This trend is reflected in the positive relationship between working memory performance and SDMT scores, although the correlation is not significant.

Due to a lack of younger subjects, the data from younger and older adults were combined to obtain the correlations in Figures 1 and 2. Analyses contrasting the two groups will wait until futher data are collected. Figure 1 shows the results of regression analyses between working memory performance and: (1) Stroop interference scores and (2) SDMT scores. There was a significant negative correlation between working memory performance and Stroop interference ($t(15) = 2.36$; $p < 0.05$) The Stroop task measures reactions times, so the negative correlation indicates an expected positive relationship between working memory and inhibition (two components of executive function). There was a positive correlation between the SDMT scores and working memory performance, although the relationship was not significant ($t(16) = 1.29$; $p > 0.2$). Differnet N values represent the number of complete data sets available for each test.

3.2 Creativity and Working Memory Performance

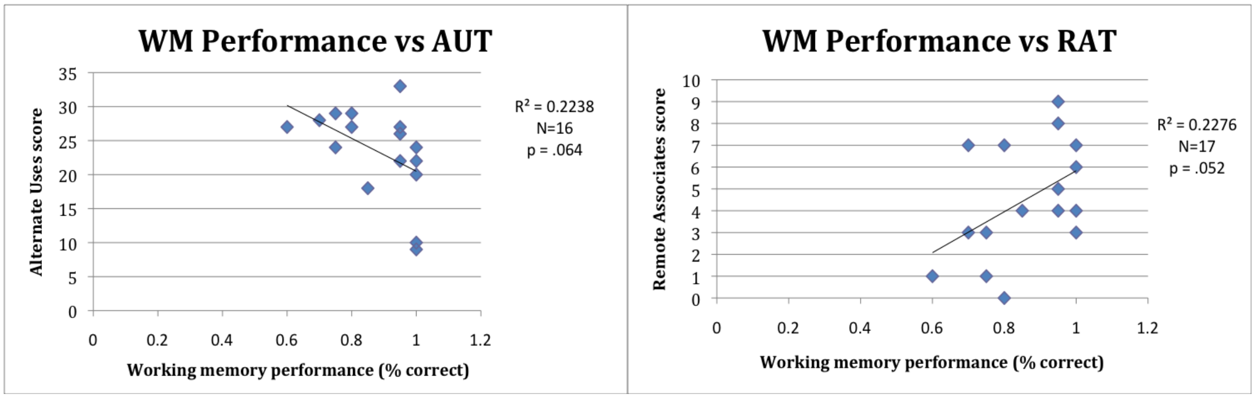

Figure 2 – Older and younger subjects' combined performance on the Remote Assoicates Test and the Alternate Uses Test against working memory performance during the EEG task. There is marginally non-significant, positive correlation between working memory performance and Remote Associates scores There a non-significant negative correlation between working memory performance and scores on the Alternate Uses Test.

Figure 2 shows the results of a regression analysis between working memory performance during the EEG task and: (1) Alternate Uses scores and (2) Remote Associates scores. There was an non-signifcant (t(14) = 2.01; p = .064) negative correlation between working memory performance and the number of alternate uses and a borderline significant (t(15) = 2.10; p = .052) positive relationship between working memory performance and the number of items correct on the Remote Associates test. Again, differnet N values represent the number of complete data sets available for each test.

3.3 EEG Data

Figure 3 shows an increased amplitude of the P1 wave for relevant stimuli relative to the passive condition and a decreased P1 amplitude for irrelevant stimuli relative to the passive for the older adults. Enhancement of relevant stimuli and suppression of the irrelevant stimuli (i.e., actively ignored stimuli) suggests that older subjects in general are successfully ignoring distractions in the working memory task. This result is somewhat inconclusive because a t-test comparing the difference between the active and passive conditions is only marginally significant (t(24) = 1.97; p = 0.06). Younger subjects seemed to show a more anterior peak to their ERP at electrode PO8 (Figure 4). Data was also analyzed at electrode P10 for comparison with older adults. At electrode PO8 the P1 amplitude of the relevant stimuli has the highest magnitude suggesting a slight attention effect, but otherwise there is little discrimination between the relevant and irrelevant stimuli at electrodes PO8 and P10 (Figures 4 and 5).

Gazzaley et al. found an N1 latency around 170ms post stimulus for older adults.[1] In the present study, the N1 latency for older adults was around 200ms post stimulus across all three conditions (Figure 3). The N1 latency at electrode P10 for younger adults ranged from around 175-188 ms post stimulus, depending on the condition. T-tests revealed significant differences in N1 latencies for younger and older adults when they were attending to scenes or viewing images passively, but not when they were attending to faces.

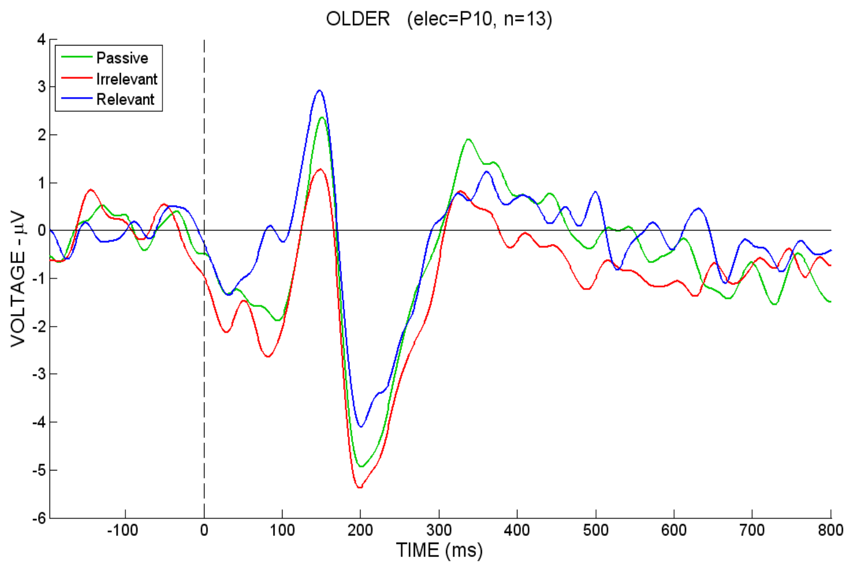

Figure 3 – Grand average ERP results (baseline corrected) when attending to, ignoring and passively viewing faces for older subjects at electrode P10. Older subjects showed the highest P1 amplitude for the relevant stimuli (face), followed by the passive and irrelevant (scene) stimuli.

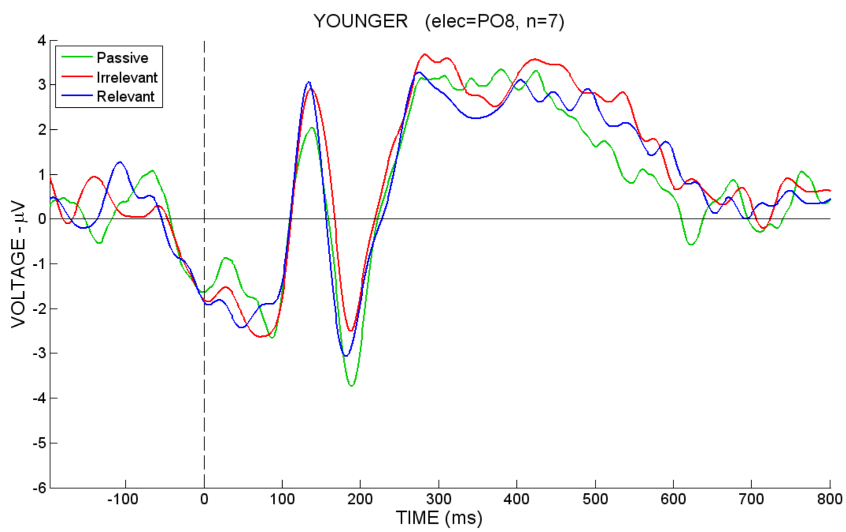

Figure 4 – Grand average ERP (baseline corrected) when attending to, ignoring and passively viewing faces for younger subjects at electrode PO8. Younger subjects showed the highest P1 amplitude for the relevant (face) stimuli, followed by the irrelevant (scene) stimuli and the passive stimuli.

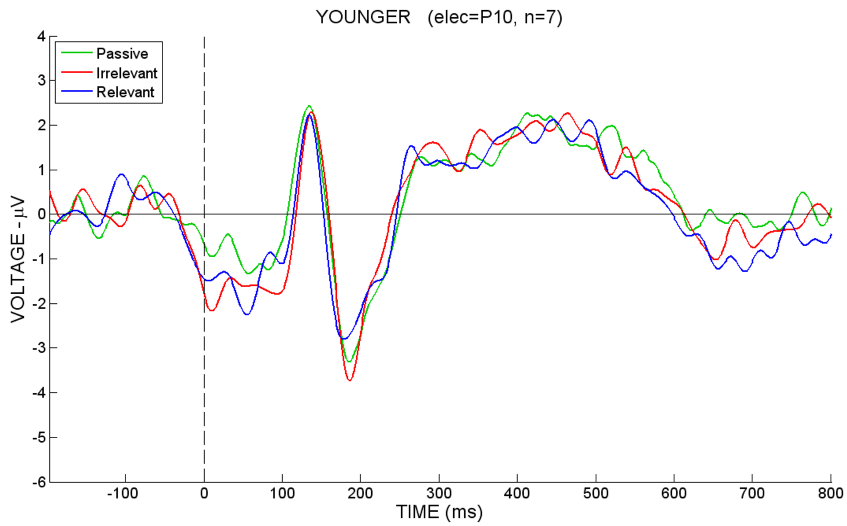

Figure 5 – Grand average ERP results (baseline corrected) when attending to, ignoring and passively viewing faces for younger subjects at electrode P10. Younger subjects showed the highest P1 amplitude for the passive stimuli, followed by the irrelevant (scene) stimuli and the relevant (face) stimuli.

3.3.1 attention and working memory performance

Younger adults performed significantly higher on the working memory task than older adults ($t(18) = 2.10$; $p < .05$), but there was no significant correlation between working memory performance and the P1 attention effect. There was also no significant difference between the magnitudes of the P1 effect for younger and older adults at electrode P10, although these results should be viewed with caution given the unequal number of observations between the two groups.

4. Discussion

One of the goals of the present study was to examine the relationship between working memory performance and creative ability. The correlations between the creative measures and working memory performance were borderline significant. Our results showed a positive correlation between the Remote Associates Test and working memory performance, which suggests that there may be some evidence that people who perform better on working memory tasks will also perform well on creativity tasks. On the other hand, the negative correlation between working memory performance and the Alternate Uses Test suggests the opposite. This is possible because the Remote Associates Test is a more semantic task, which may have connections to traditional intelligence measures, while the Alternate Uses Test is a purely divergent task. These conflicting results support the notion that the relationship between creativity and executive function may be task dependent.[5]

The results of the regression analysis of the Stroop task and the EEG working memory task revealed the expected significant negative correlation. Low interference scores on the Stroop task represent increased reaction times and fewer errors, so a negative correlation between working memory and Stroop interference actually corresponds to a positive relationship between working memory and inhibition. There was a positive correlation between working memory performance and scores on the SDMT, although the relationship was not significant. As expected, different measures of executive function (working memory, inhibition, and attention) correlated with one another. Greater analysis of outliers present in the data and increased subject recruitment may provide more reliable results (especially between younger and older adults).

4.2 Attention and Working Memory Performance

Older adults were expected to show significant enhancement of the P1 wave for relevant stimuli and a deficit in suppression of irrelevant stimuli. As a result, older adults were also expected to perform worse on the working memory task.Data from the older subjects suggest successful enhancement of relevant stimuli and suppression of irrelevant stimuli as revealed in the visual ERP. However, these results are not significant and do not correspond with increased performance on the working memory task. The EEG data from the younger subjects revealed little discrimination between the P1 magnitudes across the three conditions, yet the younger adults performed significantly better on the working memory task. One possible explanation for these results is that older adults may have found the task more challenging, resulting in increased attention, while younger subjects did not need to work as hard to get the right answers. In the future, analysis of theta power[5] or other power bands (alpha or beta)[5,7] could reveal a relationship between attention, mental effort, and working memory performance.

Younger subjects had earlier N1 latencies across all conditions compared to the older adults, although the differences were only significant when subjects were attending to scenes or passively viewing images. The reason for this is unclear. Although this trend supports the processing speed hypothesis, it will be necessary to collect more subjects to obtain more meaningful results.

A few factors, such as the unique sample population and limited data set, affected our results. The older population of subjects came from the Osher Lifelong Learning Institute (OLLI) at UNC Asheville and therefore consists of older adults who are still enrolled in academically and physically stimulating coursework. As a result, these participants were anticipated to do better than expected on working memory tasks and to show results that differed from Gazzaley et al. A larger sample size is needed to increase statistical power for a greater probability for significant effects. Future research might recruit more subjects and recruit subjects from the surrounding community to reduce the effects of the study's unique, older sample population. It is expected that improvements in data analysis and the continued collection of both younger and older subjects will support the original hypotheses, namely that (1) younger adults will perform better on the working memory task and 2) older adults and younger adults will display significant enhancement of the P1 wave of the ERP and suppression of the N1 wave in older adults will be delayed.

5. Acknowledgements

The authors would like to thank Dr. Michael Neelon for his help with data analysis and Bryan Hough and JJ Morrow for their assistance in data collection and support.

6. References

1. Adam Gazzaley et al., "Age-related Top-down Suppression Deficit in the Early Stages of Cortical Visual Memory Processing," *PNAS* 105, 35 (2008): 13122-13126.

2. Randall Engle, "Working Memory Capacity as Executive Attention," *Current Directions in Psychological Science* 11, 1 (2002): 19-23.

3. George Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," *Psychological Review* 101, 2 (1994): 343-352.

4. Yan Wang et al., "Perceptual Load, Attention, and Aging: An Event Related Potential Study," *International Journal of Psychophysiology* 84 (2012): 17-25.

5. Arne Dietrich and Riam Kanso, "A Review of EEG, ERP, and Neuroimaging Studies of Creativity and Insight," *American Psychological Association* 136, 5 (2010): 822-848,

6. Arne Dietrich, "The Cognitive Neuroscience of Creativity," *Psychon Bull Rev.* 11, 6 (2004): 1011-1026.

7. Keith Sawyer, "The Cognitive Neuroscience of Creativity: A Critical Review," *Creativity Research Journal* 23, 2 (2011): 137-154.