SACCADIC EYE MOVEMENT RATE DURING NON-VISUAL COGNITIVE TASKS IN THE AGED

by

Amber Sousa

City University of New York, Graduate Center

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dissertation requirement for the degree of Doctor of Philosophy

	Howard Ehrlichman
_____	_____
Date	Chair of Examining Committee
	Maureen O'Connor
_____	_____
Date	Executive Officer
	Laura Rabin, Ph.D.
	Alan Kluger, Ph.D.
	Joan Borod, Ph.D.
	Anil Chacko, Ph.D.
	Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

Saccadic Eye Movement Rate During Non-Visual Cognitive Tasks in the Aged

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Amber Sousa

Advisor: Howard Ehrlichman

This study examined saccadic eye movement rate during non-visual cognitive tasks in individuals over age 70. Research in the area of saccadic eye movement rate (EMR) has traditionally been carried out in young adult populations and has shows that people have higher EMR during tasks requiring retrieval from long term memory and lower EMR during tasks requiring the use of working memory. The current research examined EMR during long-term memory retrieval tasks and working memory tasks. We found that saccadic EMR patterns were preserved in older individuals, with significantly higher EMR during tasks requiring long-term memory retrieval and lower EMR during working memory tasks. However, EMRs were lower in general for older individuals and showed a decline over age groups such that by ages 90 to 101, EMR during fluency tasks was half that of EMR for young adults. We also found that elders with significant self-report of depressive symptoms exhibited significantly lower EMR on non-visual cognitive tasks. There was no relationship found between EMR and general cognitive ability or subjective memory decline as measured by the Dementia Rating Scale-II and the Metamemory in Adulthood-Abridged Change Scale respectively. There were no relationships found between performance on cognitive tasks (verbal fluency and episodic memory) and EMR during the same task. Our results suggest that EMR during non-visual tasks changes in older adulthood. This change does not appear to be related to general cognitive ability or specific task performance.

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Specific Aims

The current study was designed to examine saccadic eye movement rates (EMRs) during non-visually based cognitive tasks in individuals over 70 years of age. Research from our laboratory has consistently found that there is a relationship between EMR and non-visual cognitive tasks such that higher rates of eye movements are associated with tasks requiring retrieval of information from long-term memory (LTM) storage and lower rates of saccadic eye movements are associated with tasks that require the use of working memory (WM) or rote memory retrieval of highly-accessible information (e.g. the days of the week). This work has historically and exclusively been carried out in young adult populations (undergraduate students). Recent research from our laboratory (Micic, Ehrlichman, & Chen, 2010) also indicates that voluntary suppression of saccadic eye movements seen during episodic or semantic retrieval tasks does not negatively impact performance on such memory tasks. This suggests that these saccades are epiphenomenal in nature and not necessary for search through LTM. Our laboratory's research has found no relationship between performance on memory tasks and eye movement rates. However, there remains the possibility that changes in cognitive task performance due to the neurophysiological changes associated with aging may impact saccadic EMR during retrieval from LTM or working memory tasks. It is known that there are both normal age-related changes in memory as well as pathological etiologies of memory deficits in older adults. Moreover, it has been found that encoding and recall strategies used by older people with and without pathological processes differ. Given the neurocognitive changes found in aging people, it is possible that saccadic eye movement rates may be differentially affected either by normal aging or neurodegenerative processes.

The present study is designed to answer the following questions:

1. Do older individuals exhibit the same patterns and rates of saccadic eye movements during non-visual cognitive tasks as compared to younger individuals?
2. Is there any relationship between general cognitive abilities, memory abilities, or other clinical variables and saccadic eye movement rates during non-visual cognitive tasks in elders?
3. After dividing older individuals into three cognitive performing groups (intact/above average, below average/mild impairment, and moderate to severe impairment) are there significant differences between EMR during long-term memory or attention tasks across these groups?

Introduction

As the population of the United States ages and millions of baby boomers reach older adulthood, there is an increasing need for improved diagnosis and intervention for people with both normal age-related memory problems and neurodegenerative memory disorders. In the United States in 2010, there were approximately 50 million individuals over the age of 62 (United States Census Bureau, 2010). Approximately eight million of these individuals met diagnostic criteria for mild cognitive impairment (MCI), a condition highly associated with preclinical forms of dementia, and another 5.3 million of these individuals had diagnosable Alzheimer's disease (AD) (Alzheimer's Association, 2009). While AD and MCI are only two forms of pathological cognitive aging, we focus here on these illnesses because they are the most prevalent. The cognitive difficulties associated with pathological aging result in loss of productivity and reduced quality of life for affected individuals (Lopez-Bastida, Serraon-Aguilar,

Perestelo-Perez & Oliva-Moreno, 2006). Therefore, the reduction or amelioration of such difficulties is an important public health initiative.

Cognitive abilities change over the life span (Gunstad et al., 2006). The nature and causes of these changes have been researched and elucidated in the last few decades. However, given that our measurement of cognitive abilities and of physiological brain changes is imperfect, there remains the need for the ability to diagnose more accurately and to develop treatments for the diseases of the brain prevalent in aging. As our techniques to measure cognitive abilities and to image the brain's anatomy and physiology improve, many of these questions will be answered. However, in the interim, there remains a clinical need for earlier indicators and diagnosis of MCI and dementia in order to provide better care to people affected by these disorders.

There is a strong association between saccadic EMR and non-visual cognitive tasks (Ehrlichman, Micic, Sousa, & Zhu, 2007). People exhibit high rates of saccadic eye movements when engaged in tasks requiring search through long term semantic or episodic memory and low rates of saccadic eye movements during tasks requiring the use of working memory (Ehrlichman et al., 2007). Although the phenomenon is readily visible in everyday activity, it remains an area of inquiry that has largely been overlooked by the scientific community.

This saccadic EMR phenomenon has yet to be measured in older adults or children. It is unknown whether the phenomenon changes over the course of the lifespan. The current study will address whether saccadic eye movement rate during nonvisual cognitive tasks in people over age 70 is comparable to patterns of these eye movements in young adults (undergraduate students). As older people experience changes in the cognitive functions that correlate with saccadic eye movement rate, it is possible that the EMR during these tasks also changes.

The current paper will outline the history of research on saccadic eye movements during nonvisual cognitive tasks. It will also outline relevant cognitive changes in healthy aging and pathological aging processes including MCI and AD.

Saccadic Eye Movements

Saccadic eye movements— the rapid and highly stereotyped conjugate eye movements that allow humans to change fixation from one object in the environment to the next— have been extensively studied regarding their functions as part of the visual system. Yarbus (1967) pioneered the study of saccadic eye movements in visual cognitive processing. While there are four types of eye movements, saccadic eye movements are the only types that enable people to bring new visual stimuli onto the fovea. Saccadic eye movements can be divided into smaller micro saccades, which require specialized technology to measure, and larger macro saccades, which are readily visible (Robinson, 1964).

Saccadic eye movements during non-visual cognitive activity

There is a smaller literature examining saccadic eye movements that are associated with factors other than visual stimulation. Saccades related to non-visual cognitive processes were initially studied in the 1960s and 1970s. Antrobus and Singer (1964) found increased rates of ocular motility in people who were engaged in internal cognitive processes as compared to people in a resting state. Day (1964) found that people were more likely to make either leftward or rightward eye movements in response to questions designed to elicit reflection but not after questions that asked for simple factual information. Eye movements were then further examined in the context of laterality, focusing on the relationship between the horizontal direction of the saccade and the cognitive demands of the task. It was hypothesized that shifts in eye movements represented secondary motor activity, which was contralateral to the asymmetrically activated

cerebral hemisphere. Specifically, saccades to the left were said to occur in response to activation of the right cerebral hemisphere when people were cognitively involved in visual imagery tasks (e.g., describing one's living room) and saccades to the right were said to be elicited by activation of the left hemisphere when people were engaged in verbal processing (e.g., defining words) (Kinsbourne, 1972). There were also findings suggesting that lateral eye movements to either direction were associated with the emotionality of the cognitive stimuli (Borod, Vingiano, & Cyrtryn, 1988).

Studies following these findings revealed that left (verbal) and right (visuospatial) tasks did not consistently show the predicted directional patterns hypothesized by the laterality theory (Ehrlichman & Weinberger, 1978). However, it was consistently found that tasks differed in the frequency with which saccadic eye movements were elicited. Specifically, visuospatial tasks elicited fewer saccades than verbal tasks (Ehrlichman & Weinberger, 1978).

The study of saccadic eye movements branched out from two main theoretical frameworks: that saccades are related to the interplay between cognitive activity and visual processing, and that there are saccades that are related solely to internal cognitive processes independent of visual processing (Bergstrom and Hiscock, 1988; Ehrlichman & Barrett, 1983). In parallel, these two main frameworks developed into multiple lines of inquiry. Gaze aversion research examines saccadic activity that is thought to be the result of a need to move eyes from a distracting stimulus (e.g., a person's face) in order to minimize distraction while thinking. The quasi-visual approach examined saccades thought to result from internal processes dealing with visual imagery (Spivey & Geng, 2001). The activation approach examined saccades thought to result from general motoric activation or asymmetry in cerebral hemisphere activation (Meskin and Singer, 1974). The cognitive processes approach, as used in the current study, examines

saccadic eye movement generation as it relates to the different cognitive processing requirements involved in completing various cognitive tasks. The latter three of these lines of research all rest on the premise that internally mediated cognitive processing affects saccadic eye movement activity (Ehrlichman, Weiner, & Baker, 1974).

Further research not only examined initial saccades but also the saccadic eye movement rate (EMR) per second during answer periods for questions. Hiscock and Bergstrom (1981), for example, found that average EMR was 1.00 for verbal questions and 0.31 for spatial questions. This difference in EMR between verbal and spatial questions remained consistent when EMR was measured by visual observation, by electrooculography (Hiscock & Bergstrom, 1981), when subjects viewed a face or a gray oval, when subjects were in a visually complex environment, or when subjects were in total darkness (Ehrlichman & Barrett, 1983).

In order to understand why verbal and visuospatial questions would produce different rates of eye movements, Ehrlichman and Barrett (1983) examined the questions utilized in these studies more closely and found that the questions also varied in their memory demands. The verbal questions required an extensive memory search and the visuospatial questions more often required the use of working memory. This finding was followed by an examination of EMR during questions that varied in what was termed "constraint." Bergstrom and Hiscock (1988) found that unconstrained verbal questions, or questions that required an extensive memory search, produced higher EMR than constrained verbal questions that required little search through memory.

While research in the area of "non-visual" saccadic eye movements (Ehrlichman & Micic, 2012) has branched out in a few directions, findings converge to demonstrate that people make eye movements during cognitive processing. Further, these changes in eye movement rates

are associated with the processing demands of the cognitive tasks in which people are engaged (Antrobus, & Singer, 1964; Bergstrom & Hiscock, 1988; Ehrlichman & Barret, 1983). Research examining saccadic eye movements during non-visual cognitive tasks indicates that the average eye movement rate (EMR) per second is significantly associated with the type of cognitive task. Retrieval from long-term memory (LTM) is associated with higher EMR than working memory tasks, which are associated with lower EMR (Ehrlichman, Micic, Sousa & Zhu, 2007). These EMRs are each compared to EMR from a baseline in which no cognitive task is imposed upon the subject. During a continuous performance ("N-back") task in which subjects pressed a clicker when they heard a specific pattern of letters within a stream of auditory presented letters, EMR was recorded at rates from 0.14 to 0.40 per second. During a semantic word retrieval task (i.e., naming vegetables), EMR was recorded at rates from 1.01 to 1.41 per second (Ehrlichman et al., 2007). Higher rates of EMR have been found for retrieval of semantic information, episodic memory, and recently-learned episodic memory as compared to working memory or baseline EMR (Experiment 2; Micic et al., 2010). Saccades may occur continuously as people retrieve and report material from LTM or in bursts, separated by periods of ocular quiescence.

While LTM retrieval and WM are associated with EMR in opposite directions, these higher and lower EMRs are relative to EMR at baseline (Ehrlichman et al., 2007). Baselines have been measured when no cognitive task is imposed on subjects, and while subjects are seated in minimally visually demanding environments. EMRs during baseline are found to be intermediate between EMR during LTM retrieval and WM tasks. Specifically, Ehrlichman et al. (2007) found rates of EMR during relatively high-retrieval LTM of (1.08 per - EMR during low retrieval tasks of (0.52 per second), and EMR during a "no task" baseline as intermediate between these two conditions. This is consistent with the hypothesis that LTM retrieval leads to an activation of

saccadic eye movement activity and that WM maintenance of information leads to a suppression or inhibition of saccadic eye movement activity. However, because the baseline that has been employed in most research does not impose a cognitive task upon the subject, it is unknown to what extent visual processing or non-visual cognitive processing contribute to EMR during baseline.

How is EMR measured?

Studies from our laboratory have generally employed methods in which participants are tested in a small room with minimal visual and social stimulation. Specifically, white sheets are draped on the walls of a small room and the examiner is heard over an intercom from a separate room. EMR is most often quantified by observers counting eye movements from a video recording of the participant's behavior. Using this method, the video image is slowed to half speed and increased in size to 1.5 times its original. The program allows the rater to delineate answer periods of tasks and to score observable saccadic eye movements with a key press. The program forms a data file and generates statistics including length of answer period, total number of eye movements scored, and rate of eye movements (EMR in seconds). Inter-scorer reliability is quite high, mostly over 0.9, and accurate for eye movements as small as 2 to 3 degrees in size (Micic, Ehrlichman, & Chen, 2010). Electrooculogram has also been used (Micic, 2011).

How are we sure that LTM and WM are the salient differences between tasks that elicit higher and lower EMR?

The finding that saccadic EMR is higher during LTM retrieval than during WM task is robust even when the visual environment is altered (Ehrlichman & Barrett, 1983). This is important because it is necessary to rule out visual perception's influence on EMR if we are to claim that saccades can be induced by factors unrelated to visual stimulation. There are two lines

of evidence to support this conclusion. First, changes in the complexity of the visual environment have had no effect on task-related EMR. Comparable results are found whether people are in a visually reduced environment or a visually enriched environment, including a lab with artwork on the walls and being face-to-face with the interviewer (Micic, 2010). Second, the difference between EMR in LTM and WM tasks have been found using EOG recordings when participants were in total darkness (Ehrlichman, 1981) and when their eyes were closed (Micic, 2010).

The differences found in EMR also do not seem to be a result of differential response requirements of tasks. Specifically, verbal output requirements have been found not to affect EMR during LTM retrieval or WM tasks. When verbal demands were altered to make LTM tasks and WM tasks equivalent for verbal output, there was no significant change in the pattern of EMR across tasks (Ehrlichman et al., 2007).

The saccadic EMR differentiation between LTM retrieval tasks and WM and attention tasks has thus far been studied only in undergraduate student age groups. It is not known whether the same pattern would be found in older individuals. LTM ability declines in healthy aging (Craik & Grady, 1992) and declines to a greater degree in people with the most common form of dementia, AD (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991). Therefore, it is also of interest whether differences in saccadic EMRs would accompany these changes.

An anatomical model of the circuitry responsible for EMR patterns has been posited (Micic et al., 2010). The superior colliculus is one of the main areas responsible for saccadic eye movements. The basal ganglia projections to the superior colliculus provide both saccadic activation and suppression. The striatum, the major region within the basal ganglia that accepts afferent input, receives projections from brain areas implicated in both long-term memory and working-memory tasks. Specifically, LTM brain areas, including the medial temporal lobe, lead

to inhibition of the striatum, which causes disinhibition of saccadic production. WM tasks, which would demand less processing by the medial temporal lobe, lead to activation of the striatum, and therefore inhibition of saccadic-producing neurons (Figure 1, Micic et. al., 2010). This anatomical model allows us to make predictions about EMR changes because areas of the brain implicated in eye movements are also areas of the brain that change with age.

Given the above anatomical model in combination with the current understanding of specific brain areas implicated in memory functioning, we can predict that EMRs may decrease during LTM tasks in older individuals or in individuals with dementias as the medial temporal areas become less proficient at developing memories. EMR during WM tasks may remain unchanged as working memory abilities decline, as the areas responsible for these cognitive abilities do not form direct connections with the brain areas in the above-described anatomical model.

Cognitive Changes in Aging

Cognition, along with many other physical and social variables, changes in the latter part of the lifespan (MacDonald, Dixon, Cohen, & Hazlitt, 2004). Research in this area is complicated by increasing variability in people's experiences over time. Specifically, diseases, environmental influences, and genetic changes over the lifespan have the capacity to impact brain and cognitive functions. While in infancy and youth, normal developmental markers are relatively stable and predictable, in older individuals changes in cognition are more variable, likely attributable to an increase in the amount of time that genetics and the environment have had a chance to interact (Demetriou, Doise, & van Lieshout, 1998). Interestingly, individuals with pathological aging or dementia begin to look like a more cognitively homogenous group as

the illness progresses, likely due to the effects of the disease process overshadowing the effects of other variables (Backman et al., 2004).

Changes in cognition over the life span are difficult to measure because neither cross-sectional nor longitudinal study designs assess cognition perfectly. Cross-sectional studies can underestimate abilities of older individuals because of cohort effects (i.e., differential access to education). Older U.S. cohorts statistically have lower levels of education, a variable that can affect performance on neuropsychological tests. Conversely, longitudinal studies can skew estimates of cognitive abilities due to practice effects and familiarity with neuropsychological tests inflating scores, and causing individuals to perform better on tests than is reflective of their underlying abilities. There are also selective attrition factors (e.g., the tendency for lower scoring or more impaired participants to drop out of studies at a higher rate). In general, longitudinal studies are thought to be a more accurate method of assessing changes in cognition over time (Hultsch, 2004). Hultsch argues that longitudinal studies with longer periods between re-administration of neuropsychological tests are more accurate because they avoid the problem of cohort confounds and minimize practice effects when follow-up assessments are sufficiently spaced in time.

The literature supports subtle but broad cognitive changes in healthy aging. Episodic memory changes are among the most prominent cognitive declines observed in aging (Craik & Grady, 1992). However, it is clear that both normal and pathological aging produce declines in other cognitive areas, including attention and executive functions (Backman, 2008; Buckner, 2004). Processing speed declines in normal aging beginning in adulthood (Finkel & Pedersen, 2004). Executive functions including the ability to divide attention and inhibit responses decline after age 60 (Treitz, Heder, & Daum, 2007). Overall, studies have consistently found gradual

decline in reasoning abilities, working memory, free recall of long-term memory, and source memory (Cansino, 2009).

Despite the similarities among normal aging, MCI, and AD, MCI and AD are marked by changes not typically observed in normal aging. For example, Broder, Herwig, Teipel, and Fast (2008) found that older individuals diagnosed with MCI have a memory retrieval deficit not seen in normally aging individuals, exhibiting qualitatively different deficits in acquisition and recall strategies. Therefore, the differences between normal and pathological cognitive aging are not only quantitative, but also qualitative.

Although much research focuses on cognitive declines in aging, there is also evidence for aspects of cognition that remain stable and improve in older age. Short-term memory, autobiographical memory, implicit memory, procedural learning, and semantic knowledge generally do not show significant decline in healthy aging (Fleishman & Gabrieli, 1998; Carlesimo et al., 1998). Some abilities including general semantic knowledge and vocabulary appear to increase until around age 60. In addition, there is evidence for compensatory mechanisms including differential brain area recruitment during specific tasks in the absence of cognitive deficits (Glisky & Riddle, 2007).

The Structure of Memory Systems

Memory was initially believed to be a unitary cognitive process whereby any type of information that was learned, including facts, personal events, or skill was encoded, stored, and retrieved by the same system. However, in the last couple of decades, the idea of a unitary memory system has become unable to explain the dissociations found between the acquisition and retrieval of information in different domains. Decades of research and observation of memory functions have found that the different types of memory are encoded, stored, and

retrieved by multiple systems. This is evidenced by the observation that memory impairment is often limited to specific functions. Schacter and Tulving (1994) divided memory into two subsystems: declarative (explicit) memory and non-declarative (implicit) memory. Declarative memory includes memory for events or information that can be explicitly expressed by the individual for whom the memory exists. Implicit memory is memory that the individual is not explicitly aware of (e.g., how to ride a bicycle). Following this work, researchers have further divided memory into five systems including semantic memory, episodic memory, working memory, procedural memory, and perceptual representation memory (Schacter, Wagner, Buckner, Tulving & Craik, 2000). This model is supported by results of linear equation modeling analysis (Nyberg et al., 2003). This classification is also useful for making distinctions between aspects of memory functions that are affected by various disease processes.

Semantic memory is the long-term knowledge of facts and information, with examples including vocabulary and general knowledge. Semantic memory is not necessarily bound to a specific context or experience. Source memory is the memory of the context in which one learned facts and information. It may be described as the memory of the context in which semantic memory was learned. Episodic memory is the long-term knowledge of specific autobiographical events and is made up of memories of places, emotional experience, and contextual information. Procedural memory is the long-term memory of skills and motor sequences of behavior. Working memory, sometimes called short-term memory is a system of memory that temporarily stores information and allows manipulation of information in the short-term store. Working memory can be divided into short-term storage and executive components. Perceptual representational memory, also known as repetition priming, is the memory system that improves one's ability to process a stimulus after an individual has been exposed to the

stimulus previously, even in the absence of conscious awareness of its familiarity (Schacter, 1990).

Much research has led to the adoption of a multiple system framework of memory. A multiple system framework explains the functions of memory as executed by multiple brain areas that are differentially affected by aging and disease processes. A multiple system framework is consistent with a greater range of psychological and imaging data than a single system framework (Poldrack & Foerde, 2008). The discovery of the dissociation between procedural and episodic memory in patients with amnesia (Brooks & Baddeley, 1976) first provided evidence for a multiple system mechanism for memory formation. Following that work, the field of cognitive psychology discovered dissociations in memory abilities that provided further support for a multiple systems framework.

One of the first of these dissociations in the field of cognitive psychology was found by use of the Probabilistic Classification Task (PCT), a task that requires test subjects to classify a set of stimuli into one of two groups. Knowlton, Squire, and Gluck (1994) first illustrated the neuropsychological dissociation between performance on the PCT and declarative memory for the learning context. Amnesic patients were found to perform similarly to non-amnesic age-matched controls on tasks requiring learning classification of stimuli, while declarative memory for the learning situation was significantly reduced for the amnesic group.

Neuroimaging data during the PCT also suggested a multiple system framework for memory. Different brain areas were recruited dependent upon whether the PCT was learned under single- or dual-task conditions. Dual task conditions included a simultaneous tone-counting task. Specifically, accuracy of classification for information learned during single-task conditions was associated with activity of the medial temporal lobe while accuracy of

classification for information learned during the dual-task condition was associated with activation of the striatum.

Brain injuries and diseases are not the only illustrations of the relative independence of various memory systems. Changes in memory abilities in older age also lend evidence to the multiple system framework of memory. Different types of memory change in unique directions and at varying rates across the life span and into old age. Below, what has been elucidated about the age-associated changes for each of the types of memory described above will be described as well as cognitive changes in executive functions.

Semantic Memory

It is widely established that semantic memory, the recall and recognition of facts and general information, is relatively stable well into later adulthood and that education accounts for more of the variance in semantic ability than age (Backman & Nilsson, 1996). However, there is some late decline seen in semantic memory. Nyberg et al. (2003) divided semantic memory into verbal fluency and general knowledge by factor analysis. These authors found that semantic memory increases into middle age and remains relatively stable until around age 75, at which point it begins to decline. Within the semantic memory domain, verbal fluency shows more decline than general knowledge. This may be due, in part, to a decline in processing speed as verbal fluency measures are timed tasks. However, because category fluency declines more than phonemic fluency, speed is not thought to be the only cause of the age-related semantic memory decline (Brickman et al., 2005).

There is also evidence for impaired lexical access, or access to phonological representation of word forms in adults over age 50, with additional semantic object naming failures in individuals over age 70 on tests of confrontation naming (Barresi, Nicholas, Tabor,

Obler & Albert, 2000). Barresi et al. (2000) found that individuals over age 70 began to lose the ability to name pictured items that they previously were able to name, and phonemic cues were not helpful to them. Zoccolli (2008) examined an indirect and a direct measure of semantic memory. Results indicated that the direct measure, the ability to access and retrieve feature knowledge about everyday objects, showed no change over adults age 17 to 86. However, confrontation naming or the ability to name the same objects did show decline in older age. Kave, Knafo, & Gilboa (2010) also found confrontation naming to increase until around age 50 and to decline thereafter.

These findings shed light on the semantic deficits seen in older age. In general, results suggest that semantic declines in older adulthood are the product of earlier declines in lexical access resulting in naming failures and later semantic degradation in older adults. In general, these semantic declines are smaller in magnitude than the episodic memory declines in normal aging.

Source Memory

Source memory, the explicit recall of the context of episodes or origin of facts, declines with age and is consistently found to begin declining earlier and to a greater degree than episodic or semantic memory in normal aging (Cansino, 2009; McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). Cansino et al. (2012) found that source memory declines gradually and linearly over each decade across the adult life span. Schacter et al. (1991) found that older adults who were read statements by multiple individuals were able to recall the statements more accurately than information about which individual read the statement. McIntyre and Craik (1987) found that older adults were less accurate at recalling the source of trivia facts than younger adults. Because source memory relies upon the ability to associate

information with its contextual counterparts, this is further evidence of the poorer integration of information in old age. In support of this assertion, researchers have found that semantic clustering is significantly related to source memory performance (Wegesin, Jacobs, Zubin, Ventura & Stern, 2000). These findings suggest that the age-related difficulty with associating units of information to bind and retain memories contributes to deficits in source memory.

Episodic Memory

Episodic memory changes in cross-sectional and longitudinal studies

Episodic memory, or memory for personal events and experiences, shows decline in both healthy and some forms of pathological aging. People often consider this type of memory to be the primary difficulty that people experience as they age and it may be the change that people find the most upsetting. Changes in episodic memory over the lifespan are evidenced by studies employing both cross-sectional and longitudinal designs.

Cross sectional studies have indicated that episodic memory declines linearly from young adulthood (Ronnlund, Nyberg, Backman & Nillson, 2005). These cross-sectional studies indicate that by age 60 individuals exhibit episodic memory performance one standard deviation below their peak and by age 80, this decline increases to two standard deviations (Nilsson et al., 1997). However, cohort effects have been argued to play a role in these figures.

Longitudinal studies have found that episodic memory abilities are stable in young and middle adulthood, but begin to decline past middle age, around age 60, with positive acceleration in older adulthood (Rabbit et al., 2004; Ronnlund et al., 2005). A meta-analysis of both cross-sectional and longitudinal studies indicated that episodic memory is only moderately associated with age until age 50, when this association increases (Verhaeghen & Salthouse, 1997).

Encoding and retrieval of episodic memories in aging

Changes in encoding of episodic memories accounts for most of the declines in episodic memory in aging. Retention of information over time and recognition of episodic memories is found to be preserved in healthy aging. Preserved retrieval and storage functions are reflected by relatively spared retention on memory measures. Haaland, Price, and LaRue (2003) examined memory changes with the Wechsler Memory Scale-Third Edition (Wechsler, 1997b). They examined verbal and visuospatial learning in normal aging in a sample of healthy individuals aged 16 to 89. They found that while there was an age-related decline in immediate and delayed retrieval of episodic memory, these were largely explained by declines in immediate memory. Therefore, the change in rate of forgetting in normal aging is minimal, and immediate memory difficulties are present. This initial encoding could be reduced by factors including reduced attention or ability to organize information for encoding.

Further support for this conclusion comes from Rybarczyk, Hart, & Harkins (1987) who reported that when older individuals were able to practice information and immediately recall the same amount of information as younger individuals, their percent retention over time was still at the enhanced level, suggestive of a relatively un-accelerated rate of forgetting. Similarly, Haaland et al. (2003) found that the amount of information retained after a delay does not decrease with age. Therefore, the evidence supports significant declines in immediate memory that largely explain declines in delayed memory with no evidence for rapid forgetting or an accelerated loss of information over time.

A number of theories delineate possible causes of episodic memory deficits in aging, with the most support found for the associative deficit hypothesis (described below). Other researchers have found that the declines can be accounted for by other neurological and cognitive factors, including declines in hippocampal and prefrontal volume, working memory, inhibitory

processing, and temporal processing (Head, Rodrigue, Kennedy & Raz, 2008). Possible explanations for episodic memory decline in aging are reviewed below.

The causes of episodic memory decline in aging

A great deal of research has examined the possible contributing variables to episodic memory declines in aging. Correlations have been found between performance on measures of executive functioning and measures of episodic memory and some authors have suggested that declining function of the frontal lobes contributes to episodic memory decline (Craik, Morris, Morris & Lowen, 1990). Older individuals exhibit liberal response biases on delayed recognition tasks. For example, older individuals are more likely to incorrectly endorse having been exposed to stimuli as opposed to incorrectly denying such exposure. Because patients with frontal lobe dysfunction also tend to exhibit a liberal response bias, it is thought that recognition memory may be partly reduced in older age due to executive functioning deficits (Huh, Kramer, Gazzaley & Delis, 2006). Furthermore, Crawford, Bryan, Luszcz, Obansawin, and Stewart (2000) found that one measure of executive function, the Modified Card Sorting Task, was reduced in older age and that performance on this measure mediated performance on memory tasks above and beyond general cognitive functioning.

Some researchers have also found that the ability to minimize the distraction of task-irrelevant stimuli is deficient in older age, and contributes to episodic memory decline. Healey, Cambell, and Hasher (2008) found that older individuals are less efficient at inhibiting attention to irrelevant information and inappropriate responses, which leads to impairment on episodic memory tasks. Conversely, most other researchers have found that attentional capacity is less predictive of age-related episodic memory declines than other cognitive functions including processing speed abilities (Ewert & Martin, 1993) and associative deficits (Kilb & Naveh

Benjamin, 2007). Nyberg, Nilsson, Olofsson, and Backman (1997) found that divided attention requirements did not result in greater episodic memory deficits in older individuals, as compared to tasks with lower attentional demands. Although executive functioning does contribute to some aspects of memory in aging it has not been found to account fully for episodic memory ability declines (West, 1996).

The associative deficit hypothesis of memory decline in aging posits that older individuals' difficulty recalling long-term memories results from a failure to create or retrieve associations between memories and the context in which they should be associated. The theory explains episodic memory declines in aging as a product of difficulty forming associations between single units or parts of an episode. This hypothesis was first described by Naveh-Benjamin (2000). Naveh-Benjamin found that older individuals' deficit in the ability to recall associations between items was disproportionately larger than their ability to recall the items. Specifically, on a word-face pair learning task, older individuals do not improve in performance with repetition of pairs while younger adults do improve. Further support for this hypothesis comes from data indicating that older individuals have difficulty recalling associated information that is disproportionate to difficulty with recalling specific single item recall. Subjects were shown a video of people performing everyday actions and asked to recall individual people, individual actions, and person-action combination. Older individuals displayed a significantly higher false alarm rate of associations than of specific item errors, indicative of a deficit in associating units of information (Old & Naveh-Benjamin, 2008).

Bastin and Van der Linden (2006) also found support for the associative deficit hypothesis by use of a forced-choice face recognition task, in which participants were tested on their memory of individuals' faces as well as face-face and face-spatial location association

pairs. Their results indicated that older adults exhibited deficits in associative information while individual item recognition was intact.

The above findings support the associative deficit hypothesis of episodic memory declines. However, this associative deficit may stem from a decline in the spontaneous use of organization and association as opposed to the ability to use such strategies if instructed. In fact, research has found that enhancement in performance can be achieved through cognitive assistance such as increased study time, organizability of stimuli, and retrieval cues, that were unaffected by age (Backman & Wahlin, 1995). This suggests that the spontaneous initiation of an associative strategy, which is useful for the enhancement of long-term memory, is deficient in older age, but that the ability to use such strategies when instructed is intact. Additionally the associative deficit hypothesis does not exclude other contributions to impaired episodic memory with age (Overman & Becker, 2009).

In summary, there is evidence for multiple factors contributing to episodic memory decline. Head et al. (2008) used path analysis to examine the mediating effects of brain changes and cognitive function changes on episodic memory in aging. They found that episodic memory declines were instantiated by hippocampal shrinkage and prefrontal volume declines via deficits in inhibitory control and working memory. Backman, Lindenberger, and Nyberg (2010) discussed research findings indicating that neurotransmitter levels, including dopamine levels are related to aging as well as cognitive ability. These finding suggests that there are both primary memory area disturbances as well as changes in other executive functioning areas that contribute to episodic memory decline. Because many systems of cognition require proper functioning for memory to be efficient (i.e., attention, association, and consolidation), it follows that memory is one of the more fragile aspects of cognition and declines even in healthy aging.

Executive Functioning Changes in Normal Aging

Executive functions are the frontally-mediated, higher-order cognitive abilities that allow human beings to carry out goal-directed behavior. There is evidence for declines in executive functioning in normal and pathological aging. There is no consensus for a taxonomy of executive functions and they are often difficult to measure in isolation. Executive functions include such processes as reasoning, problem-solving, planning, resistance to interference, and divided attention. Executive control has been described by Smith and Jonides (1999) as five related components of executive functioning, most of which are found to decline with aging. They include attention to relevant information and suppression of irrelevant information (e.g., the Stroop Task in which an examinee is presented with a list of color names printed in different colors and instructed to name the print colors), set-shifting (e.g., Wisconsin Card Sorting Test in which subjects must categorize cards by three criteria and shift set when the rules change), planning (e.g., construction tasks that require individuals to draw a complex figure or a clock), updating working memory for sequential tasks or 'task management' (dual tasks), and encoding the context of situations into working memory (Smith & Jonides, 1999). The subcomponents of executive functioning are found to be differentially affected by normal aging.

Treitz et al. (2007) examined these subcomponents of executive control functions longitudinally in individuals aged 20 to 75. They found that inhibition of irrelevant information and divided attention both significantly declined by age 60, while verbal fluency and reasoning were relatively unaffected. The pattern of change suggested by this study was minimal decline before age 60 and accelerated decline after age 60. Other authors have found declines in planning but not inhibition (Zhang, Han, Verhaeghen & Nilsson, 2007). Other specific executive functions that decline in older adulthood include organization and integrating information for encoding.

Set shifting or mental flexibility has been shown to be only minimally affected by aging, once general cognitive slowing has been accounted for (Verhaeghen & Cerella, 2002). Research on age-related change in areas of executive functioning relevant to the current study are reviewed below. The areas of executive functioning reviewed reflect the areas that correspond to EMR patterns.

Working memory declines in aging

Working memory, the ability to hold and manipulate information, has been found to decline in older adulthood. Longitudinal studies indicate that there is a linear lifelong decline in WM, with equal decline in verbal and visuo-spatial working memory, and no acceleration in older adulthood (Borella, Carretti, & De Beni, 2008).

Different components of WM have been found to be differentially affected by aging. Gazzaley, Sheridan, Cooney, and D'Esposito (2007) found that older adults have impaired delayed recognition of span items when distractors (e.g. words on a screen presented in delay) were used and memory load was high (working memory span capacity determined encoding information length). These findings suggest that recall of information held in working memory is not impaired by aging, but that maintenance of information is more difficult when this system is taxed by high memory load and distractors. Similarly, work by Hull, Martin, Beier, Lane, and Hamilton (2008) suggests that the updating or monitoring of executive function is responsible for the declines seen in working memory over the life span. However, this effect seems to be at least partially due to age-related slowing of processing speed, and many researchers have found that processing speed declines are partially responsible for the decreases in working memory abilities (Salthouse, 1994). Lange and Verhaeghen (2009) found that differences in memory scanning rates in older individuals can be accounted for by age-related changes in attention, processing

speed, and decision processes. Using a Self-Ordered Pointing task in which participants must choose novel designs from a grid of designs re-arranged on each trial, Chaytor and Smitter-Edgecombe (2004) found no evidence for an inhibitory deficit responsible for the non-verbal working memory declines seen. They also found little evidence for strategy-use deficits. They did find that processing speed significantly contributed to the WM decline, but there were still age-related declines, and monitoring was found to be a contributor. Furthermore, Emery, Hale, & Myerson (2008) found that while older adults were more susceptible to proactive interference, these susceptibilities did not contribute to working memory performance.

Inhibitory theory of working memory declines in aging.

There are data to suggest that inhibitory deficits emerge in older adulthood. Dulaney and Rogers (1994) found larger Stroop effects for older individuals, indicative of difficulties inhibiting prepotent responses. Treitz et al. (2007) also found inhibitory declines in people over age 60. Olk and Kingstone (2009) employed an antisaccade task, in which examinees needed to inhibit pre-potent saccadic responses in order to perform well on the task. Older adults performed worse on this task due to deficits in inhibition.

The inhibitory theory of aging posits that WM deficits in older individuals are caused by declines in inhibitory efficiency. Evidence for this theory comes from research by Witthoft, Sander, Suss, and Wittmann (2009), who found significant associations between inhibitory deficits and higher-order cognitive functions, independent of decreases in processing speed. However, some studies have found that the influence of inhibitory deficits on WM abilities were small compared to the influence of age on WM (Borella et al., 2008). Colette, Schmidt, Scherrer, Salmon, and Adam (2009) found that intentional inhibitory control of memory processes declines in normally aging individuals and declines to a greater degree in AD patients. Still

others have found that WM deficits in older age are better explained by encoding deficits. Using a delayed matching to sample task, Dumas and Hartman (2008) found that distractors had equivalent impact upon younger and older individuals, and that the working memory deficits were better accounted for by encoding deficits rather than aspects of inhibition. These findings illustrate the ongoing debate as to the nature of working memory declines in normal aging.

Overall, the research on WM and executive functions in aging presents a complicated picture, whereby working memory deficits can be broken down and attributed to more than one neuropsychological change. Specific deficits that have been found to negatively impact WM include intentional inhibition, encoding, processing speed, and self-monitoring.

Fluency abilities in aging

Verbal fluency tasks measure the speeded ability to generate words based on a defining feature such as semantic category (e.g. fruits, animals) or phonemic category (e.g. starting with the letter F). Verbal output on such tasks are often used to examine language fluency, executive functions including initiation, monitoring and set-shifting, cognitive flexibility, and semantic clustering.

In normal aging, both category fluency and phonemic fluency are found to have small decline. Bolla, Gray, Resnick, Galante, and Kawas (1998) found that semantic and phonemic fluency both show small declines in normal aging. Backman et al. (2004) found moderate declines in both semantic and phonemic fluency over adulthood and older age. Brickman et al. (2005) examined verbal fluency in a large sample of healthy 21 to 82 year olds. Results of this cross sectional study revealed that both phonemic and semantic fluency decline linearly with age, but semantic fluency declines to a greater degree. Henry and Phillips (2006) found that neither phonemic nor semantic fluency were significantly influenced by age after controlling for

crystallized intelligence, and processing speed. Other researchers have found that phonemic fluency is influenced by education level and that semantic fluency is influenced both by education level and age (Mathuranath et al., 2003; Tomer & Levin, 1993). However, Tombaugh, Kozac, and Rees (1999) found that phonemic fluency was better predicted by age while semantic fluency was better predicted by education. The inconsistency of degree of decline for semantic and phonemic fluency inspired further exploration of the underlying processes involved in semantic and phonemic fluency.

Imaging work has aided in understanding brain areas implicated in fluency tasks. There is evidence that temporal lobe activity is associated with semantic fluency tasks (Pihlajamaki et al., 2000) and frontal lobe activity is associated with phonemic fluency tasks (Abrahms et al., 2003). Meizner et al. (2009) employed functional MRI to determine brain areas recruited during fluency tasks for younger and older individuals. Younger people recruited left frontal areas for both semantic and phonemic fluency tasks. Older individuals performed worse on semantic fluency tasks than younger individuals, and this poorer performance was positively correlated with increasing recruitment of right inferior and middle frontal regions.

In sum, the current knowledge on fluency in older adulthood suggests that both semantic and phonemic fluency decline in aging, and that semantic fluency declines to a greater degree, with an associated change in brain area recruitment. There is also evidence that phonemic fluency performance has more implication for frontal-executive influence while semantic fluency is more influenced by left anterior temporal regions.

Neuropsychological Constructs Differentiate Between Normal and Pathological Aging

Research indicates that there are both quantitative and qualitative differences between normal cognitive aging and dementia-related cognitive decline, with many of the same cognitive

functions, including episodic memory, being both quantitatively and qualitatively affected (Carlesimo et al., 1998). These types of differences prove useful in diagnosis of dementia because deficits in areas of functioning that are qualitatively impaired in dementia would be easier to identify.

Although episodic memory declines are present in both normal and pathological aging, specific measures of episodic memory are useful in differentiating between normal aging and dementia. Preserved retention of learned information over time is an example of an ability that qualitatively differentiates normal aging from AD. Specifically, individuals with age-related episodic memory declines may initially encode less information but they exhibit intact retention. Conversely, those with dementia and encephalopathy do not retain the information over time and exhibit an increased rate of forgetting (Schoenberg et al., 2008).

Broder, Herwig, Teipel, and Fast (2008) found that people with MCI could be distinguished by their acquisition and recall strategy deficits on verbal memory measures, while both young and older control participants showed no such deficit. Carlesimo et al. (1998) also found that young, old, and very old healthy individuals showed no decrement in the ability to utilize semantic relatedness of words in order to improve retention, but individuals with AD did show a decline in this ability. There are also qualitative differences between the deficits seen in MCI and normal aging. Broder et al. (2008) used a multinomial modeling analysis to examine storage and retrieval changes and found that MCI individuals exhibited global declines in word learning as well as retrieval deficits that were not seen in normally aging individuals. These results are examples of qualitative differences between normal and pathological aging.

Quantitative differences between normal and pathological aging are also common. Individuals with dementia exhibit more severe episodic memory deficits than healthy older

individuals. Carlesimo et al (1998) found there to be a continual decline across a number of cognitive variables. The groups examined were healthy young (average age 29), healthy old (average age 66.7), healthy very old (average age 82.5), and AD (average age 67.1). They found that episodic memory learning rate declined quantitatively both with age and AD.

Episodic memory is an important cognitive function in terms of its implications for trajectory of decline over adulthood and ability to aid in the diagnosis of pathological aging processes. The differences between normal aging and dementia are seen in both quantitative and qualitative differences on measures of episodic memory functioning.

Structural Brain Changes in Aging, MCI, and Alzheimer's Disease

There is a great deal of evidence for brain changes over the lifespan. Walhovd et al. (2005) found that brain volume decreases after age 30. This decrease in volume has been found to be a result of a decrease in the length of the small collateral myelinated fibers, while the density of neurons remains relatively unchanged and the main axons are not affected (Pakkenberg et al. 2003). Specific brain regions have been implicated in age-related changes. Both the hippocampus (Jack et al., 2008) and frontal cortex (DeCarli et al., 2005) decrease in size. In general, studies have found that the orbitofrontal cortex is more affected than lateral and temporal regions (Bartzokis, Beckson, Neuechterlein, Edwards & Mintz, 2001).

A multi-component model of memory-related brain change is the current reigning view explaining memory decline with aging. There is evidence for both a frontal lobe executive component and a temporal lobe associative component (Moscovitch, Nadel, Winocur, Gilboa & Rosenbaum, 2006). These two regions work together to allow for encoding and retrieval of long-term episodic memories (Schacter, Curran, Reiman, Chen, Bandy & Frost, 1999). These two regions also change with age (Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998). Over the

past decade, the physiological changes responsible for age-related memory variations have been widely studied, but the relationship between structural changes and cognitive decline remains unclear. What is known is that structural change is seen in both healthy and pathological aging. Specific structures, including the prefrontal cortex and medial temporal lobe are particularly susceptible, while other areas including the occipital cortex are seemingly unaffected. Kramer et al. (2007) completed a four-year longitudinal study of older individuals with average age 73 at study onset. They found that decreased hippocampal volume was associated with declines in episodic memory. Golomb, de Leon, Kluger, and George (1993) also found that hippocampal atrophy in healthy older adults was associated with impaired delayed episodic memory.

Brain changes characteristic of pathological aging have also been found. MCI patients exhibit decreased volume compared to control participants in medial temporal areas, retrosplenial cortex, and cingulate, based on MRI data (Bigler et al., 2002). Furthermore, some brain changes can be used to predict who will go on to develop dementia. For example, atrophy rate is predictive of who will go on to develop AD (Sluimer et al., 2009). Tondelli et al. (2012) found that brains of people who will go on to develop MCI and early AD change as much as 10 years before measurable cognitive changes are measurable; specifically these individuals exhibit reduced brain volume in the medial temporal lobes, posterior cingulate/precuneus, and orbitofrontal cortex.

Functional Brain Changes and Cognitive Change in Aging

Many researchers have examined changes in function of brain areas as they related to cognitive changes in older individuals. Multiple researchers, employing PET or fMRI have found that older individuals tend to exhibit a pattern of widespread prefrontal cortex over-recruitment during verbal recall tasks as compared to younger individuals (Cabeza et al. 2004; Grady,

McIntosh, & Craik, 2005). Specifically, more bilateral recruitment of prefrontal cortex during various tasks appears in older individuals as compared to young. Additionally, in a number of studies, this change is accompanied by a reduction in activity during memory tasks in areas that are active in younger subjects. Some researchers have argued that changes in asymmetry reflects a compensatory mechanism in older subjects' brains in response to age-related decline in the function and integrity of the typical brain areas utilized. Others have argued that these changes reflect psychogenic strategical changes in cognitive methods of performing tasks (Cabeza et al. 2004; Grady, McIntosh, & Craik, 2005).

PET and fMRI studies have discovered frontal under-recruitment in older individuals. Findings of such under-recruitment has been replicated and found to be present for both verbal and nonverbal tasks. (Logan, Sanders, Snyder, Morris, & Buckner 2002) Buckner, Wheeler, & Sheridan (2001) found, using fMRI, that older individuals exhibited under-recruitment as compared to younger individuals in the anterior ventral region during intentional memory encoding. However, this under-recruitment was reversed when the tasks required semantic elaboration. This provides evidence that frontal under-recruitment is context-dependent. Many authors have also found changes that suggest that differential recruitment and increased recruitment is an aspect of compensation (Reuter-Lorenz & Cappell, 2008). Logan et al. (2002) also found that older individuals exhibited nonselective frontal recruitment during both verbal and nonverbal tasks, and this persisted even when under-recruitment was diminished with mnemonic strategies.

A meta-analysis by Spreng, Wojtowicz, and Grady (2010) found that in general over-recruitment of frontal regions in older adults is observed during all tasks but to a greater extent for executive functioning tasks, and that the laterality of frontal recruitment was associated with

performance on tasks, whereby left frontal area recruitment was associated with better performance than right frontal recruitment.

In sum, there is evidence for changes in neural recruitment during neurocognitive tasks, and these changes are sometimes associated with changes in performance on tasks. The underlying reasons for these changes in recruitment remains an area of debate.

Mild Cognitive Impairment; Definition, Characteristics, and Risk of Conversion to Alzheimer's Disease

Individuals with memory impairment beyond that expected in normal aging have been studied in order to understand the risk factors and causes of dementia. These individuals have been found to exhibit not only memory deficits, but also greater than expected deficits in executive functions, processing speed, and global cognition (Albert, Moss, Blacker, Tanzi & McArdle, 2007; Petersen, Smith, Waring, Ivnik, Tangalos & Kokmen, 1999). Individuals with such declines at greater than age- and education-expected levels have been categorized by different criteria and classification systems, but MCI has been used most frequently due to its clinical usefulness and predictive validity for subsequent dementia (Cargin, Maruff, Collie, & Masters, 2006). MCI, conceptualized as the presence of memory complaints and deficits without accompanying general cognitive decline or significant impairment in daily functioning, has been found to be a risk factor for AD. Data indicate that 10-15% of people with MCI convert to AD within one year compared to 1-2% annual conversion rate for individuals who do not have MCI (Petersen et al., 1999).

In clinical practice, MCI is often divided into two subtypes: amnestic and non-amnestic. Within the amnestic subtype, individuals may exhibit memory deficits in isolation or alongside deficits in other areas of cognition. Therefore diagnoses include amnestic MCI with impairment

in single domain or amnestic MCI with impairment in multiple domains. In the non-amnestic subtype, memory problems are not predominant, and impairment can occur in one or multiple areas such as language, visuospatial ability, and executive function. The diagnoses include non-amnestic MCI single domain and multiple domain (Petersen & Negash, 2008).

Individuals with amnestic MCI exhibit global cognition functioning scores similar to healthy older individuals but storage and retrieval memory deficits similar to people with dementia (Ribeiro, Guerreiro, & De Mendonça, 2007). In general, individuals diagnosed with MCI were found to exhibit verbal episodic memory deficits akin to those seen in AD, while executive functions remain at the level of healthy older adults (Petersen et al., 1999). However, other researchers have found that patients with MCI also exhibit reduced clustering and retrieval abilities on fluency tasks (Broder et al., 2008). There is also evidence that individuals with MCI exhibit changes in complex and fine motor abilities (Kluger et al., 2008). Longitudinal studies of MCI illustrate that verbal memory deficits appear earlier than visual learning and memory difficulties (Collie & Maruff, 2000).

There is evidence that individuals with MCI who have both memory deficits and declines in other cognitive domains, including the combination of verbal memory, psychomotor speed, and executive functioning deficits having the highest rate of conversion to AD (Tabert et al., 2006). These results suggest that the criteria for MCI need to be further elaborated in order to increase the predictive value of the diagnosis.

Individuals with the amnestic subtype of MCI have a higher conversion rate to AD, suggesting that amnestic MCI may be closer to an earlier presentation of AD than non-amnestic subtype. Researchers have found that individuals with amnestic MCI who experience deficits in

episodic memory are the most at risk for converting to AD. Specifically, delayed verbal recall was the most predictive of conversion to AD (Perri, Serra, Carlesimo, & Caltagirone 2007).

Amnestic MCI is a better predictor of AD than non-amnestic. Some researchers have suggested that amnestic MCI is the earliest presentation of AD (Morris, 2006). However, not all individuals with amnestic MCI go on to develop AD. Alternatively, individuals may develop other forms of dementia, remain cognitively stable, or improve. The debate over the best method of predicting conversion from MCI to AD remains an area of inquiry.

Alzheimer's Disease; Definition, Prevalence, Physiology, and Cognitive Changes

AD is the most common form of dementia with a prevalence rate of 3 percent in individuals aged 65 to 74 and 50 percent in individuals age 85 and older. The largest risk factor for AD is age. Other risk factors include genetic influences, Apolipoprotein E4 allele status, gender, history of head trauma, toxins, and vascular disease (Bilbul & Schipper, 2011). The neuropathological correlates of AD have been found to be neurofibrillary tangles, neuropil threads, and senile plaques that first selectively affect the transrhinal and entorhinal cortices, and later, hippocampal areas (Braak et al., 1999). The brain changes associated with AD have been found to begin decades before the onset of symptoms meeting criteria for dementia (Reiman et al., 2004). Episodic memory deficits have been found to be the first measurable difficulties in AD, and imaging data are consistent with this finding, revealing that hippocampal volume reduction is an early structural brain change. There is an imperfect relationship between cognitive decline and physiological markers of AD pathology (Katzman et al., 1988). The individual variability of brain pathology has made it difficult to find physical markers unique to AD.

Cognitive changes seen in AD begin with episodic memory declines and become more generalized as the disease progresses. Herlitz, Hill, Fratiglioni, and Backman (1995) examined differences between normally aging individuals and those with mild and moderate AD. They found that mild AD patients exhibited more severe episodic memory and executive deficits than healthy aging individuals. They found that short-term memory and visuospatial declines emerge later and were more severe for moderate AD patients than for mild AD patients. These results indicate that the early changes associated with AD are episodic memory changes, and later changes include other cognitive declines, including short-term memory and visuospatial abilities.

A loss of recently-learned information or poor encoding of information over time is one of the first memory changes to occur. Individuals with AD perform worse on verbal word-list recall tasks than normally aging individuals (Baddeley, 1988). They also perform worse on verbal recognition tasks. This is evidence that the decline is in encoding information rather than retrieval alone (Greene, Baddeley, & Hodges, 1996).

Research has indicated that executive function declines emerge early in AD. These include psychomotor speed, mental flexibility, working memory, and attention. Chen, Ratcliff, Bell, Cauley, DeKosky and Ganguli (2001) examined a group of older individuals and found that executive measures of pychomotor speed and mental flexibility, including Trails A and B showed the greatest decline in people who would go on to be diagnosed with AD 1.5 years later.

Verbal short term memory deficits have been found in AD. Peters and Majerus (2007) found that verbal short term memory deficits exhibited by people with AD resulted from executive control processes including coordination and integration, while phonological loop efficiency and lexical and sublexical language knowledge were preserved in both AD and normal

aging. This suggests that the short-term memory deficits seen in AD result at least in part from executive dysfunction.

Deficits in the executive function of inhibition have been found to be larger in AD patients than in healthy aging individuals (Amieva et al., 2005). Evidence comes from the Stroop task, in which slowing in AD is greater than for healthy elderly, even when processing speed differences were taken into account. These authors also found that intrusion and perseveration errors were more common in AD individuals during list recall tasks, possibly indicative of difficulties with inhibition during episodic memory tasks.

Belleville, Chertkow, and Gauthier (2007) examined three attentional processes in MCI and AD individuals: divided attention, manipulation capacities, and inhibition. They found evidence for attentional control deficits in all three domains in people with AD. However, in MCI, only divided attention was found to be deficient. For MCI patients who experienced further decline, both divided attention and manipulation processes were impaired. These findings indicate that as MCI progresses into AD, there are parallel declines in components of complex attention.

The work done in the area of executive function and working memory in AD has illustrated that there is a decline in executive functioning early in the course of the disease. It is now clear that executive deficits are related to memory difficulties, but also stand alone as deficits with unique predictive value.

In AD semantic fluency declines are found to be greater than phonemic declines. Semantic fluency is often impaired, while phonemic fluency remains parallel to normal aging decline (Monsch, Bondi, Butters, & Salmon, 1992).

The changes seen in AD include neuropathological brain structural and functional changes, cognitive declines in memory, language, visuospatial and executive functioning. Some of the declines are quantitatively greater than the changes seen in normal aging and some are qualitatively different (not seen in normal aging). Research in this area continues to elucidate the characteristics of AD with the improvement of measurement techniques (e.g., imaging, cognitive measurement). Treatment strategies will likely improve as our understanding of the disease improves.

Subjective Memory Impairment

The objective aspects of cognitive aging have been discussed. Individuals with both healthy aging and early stage dementia often recognize cognitive changes in themselves. A large body of literature surrounds the subjective aspects of cognitive changes during aging. The area of subjective cognition, specifically memory, is complicated by the great number of measures and definitions of the construct. The finding that subjective memory complaints are related to actual memory deficits is inconsistent, and this is likely at least partially resultant from researchers using various construct definitions and measures of subjective cognition (Abdulrab & Huen, 2008).

Some researchers have found that subjective memory complaints predict future decline in memory abilities (Jorm, Christensen, Korten, Jacomb, & Henderson, 2001). There is evidence that people with subjective cognitive impairment progress to MCI or dementia at a rate of 7-8% per year (Reisberg & Gauthier, 2008). There is also neuroimaging data indicating that subjective cognitive complaints, even in the absence of measurable objective neurocognitive deficits are related to reduced medial temporal lobe gray matter volume changes. Saykin et al. (2006) found that older individuals with cognitive complaints exhibited similar medial temporal gray matter

atrophy as individuals with MCI, and both groups differed significantly from healthy older individuals with no complaints. These results suggest that the physiological changes and awareness of difficulties that accompany cognitive impairment likely emerge before objective neuropsychological tests are sensitive enough to measure the declines.

Others have indicated that subjective cognitive disturbance is more closely associated with depressive symptoms and various personality and emotional variables. For example, Cook and Marsiske (2006) found that subjective memory complaints were indicative of depression or MCI, but once individuals progressed to AD, insight into their memory difficulties decreased. Jorm et al. (2001) also found that memory complaints were most indicative of depression and anxiety, but also reflected early memory impairments.

When combined with objective neuropsychological deficits, subjective cognitive disturbance becomes a useful predictor. Guarch, Marcos, Salamero, Gasto, and Blesa (2008) found that people with subjective cognitive complaints who progress to AD within two years exhibit episodic memory and visual memory deficits. In this study, delayed verbal memory 1.5 standard deviations below the mean in people expressing cognitive complaints was found to be a significant prognostic indicator.

Jessen et al. (2010) found that subjective memory impairment with and without worry about this subjective impairment, followed by a diagnosis of MCI one year later was predictive of subsequent diagnosis of AD with a sensitivity of 66.7 percent and a specificity of 98.3 percent. This finding highlights the usefulness of both subjective complaints and a subsequent diagnosis of MCI as a dual-step predictor of conversion to AD.

Bartley et al. (2012) found that subjective memory complaints in cognitively normal individuals age 55-90 were significantly associated with a history of anxiety or depression while

white matter disease or APOE allele types were not significantly different between individuals with and without subjective memory impairment. This finding highlights the remaining controversy as to the correlates of subjective cognitive appraisal.

Subjective cognitive complaints have also been associated with brain changes that are present in both MCI and AD. Wang et al. (2006) found that corpus callosum atrophy was present in people with cognitive complaints and no neuropsychological test deficits. This finding illustrates the potential usefulness of subjective cognition as an early indicator of brain changes associated with MCI and AD.

Calley et al. (2010) examined subjective ratings of both memory and language/word finding difficulties and their relationship to objective neuropsychological performance. They found that memory ratings by both patients and their neurologists correlated significantly with objective memory performance while language and word finding complaints did not correlate with objective language performance.

From this review of the literature describing subjective cognition, it is apparent that much inconsistency surrounds the construct and its correlates. Some researchers have found subjective cognition to be related to mood and psychological factors, while others find relationships to objective cognitive performance. The variety in measurement instruments likely contributes to the variation in findings. Examination of the instruments and their differences may shed light on the specific aspects of the construct that are more closely associated with mood versus objective cognition.

General Summary

The field of neurocognition in normal and pathological aging is rapidly advancing. However, it remains an area requiring better elucidation of the causes of cognitive change in

healthy aging and in pathological processes including AD dementia, as well as the relationship between the two. The cognitive and brain changes in normal aging, MCI, and AD have been reviewed. The suspected pathology of AD is found to begin years before the illness produces the cognitive and functional deficits that create the disability in affected individuals' lives. The period between healthy aging and the onset of pathological aging is a potential target for intervention if individuals who are at risk were reliably identified. In order to develop targeted treatments for MCI and AD, earlier indicators for the disease are necessary objectives for research.

The current research attempts to bridge two areas of inquiry that have not historically overlapped. EMR research has predominately been carried out in college student samples as basic science research, examining EMR during various non-visual cognitive processes. EMR rates are higher (than baseline) during long term memory retrieval and lower (than baseline) during working memory tasks. Because long term memory and working memory are neuropsychological constructs that change in the course of the lifespan, we were interested whether EMR would accompany these changes. We believe this work has possible clinical implications as EMR is a readily visible phenomenon that seems to reflect endogenous processes during cognitive tasks and is possibly an indicator of the integrity of neural systems carrying out memory and working memory tasks.

Rationale for the Current Study

In the current study, EMR during cognitive tasks was examined in individuals over age 70. These individuals included those experiencing healthy aging and those who exhibited deficits in one or more domains of cognitive functioning. We did not have any data on EMR during non-visual cognitive tasks in older individuals. The current study examined whether the phenomenon

of EMR variation across tasks was consistent at different points in the life span, specifically young adults versus older adults. The age group of individuals over 70 years was chosen because by this age both normal age-related changes in memory are prevalent and neurodegenerative disorders of aging, including Alzheimer's Disease are increased in occurrence.

Additionally, the current study's procedures were carried out in an environment that is different from previous studies. It was not feasible to have older individuals travel to the lab at Queens College and therefore it was necessary to carry out the procedures in environments that were not as visually controlled. The use of our control group of undergraduate students in the same setting allowed us to examine whether EMR was altered when the procedures were carried out in a different setting. Because we have previously found no differences when experimenter is present or not present or whether eyes were open or closed, we predicted that this would not affect EMR across tasks.

Finally, it was of interest whether EMR during tasks would be altered by the effects of cognitive declines in normal aging or in pathological aging such as AD. It was possible that EMR would increase or decrease compared to younger subjects. We examined whether general cognitive performance was related to EMR. Although in younger participants, performance on tasks has not been found to correlate with EMR, it was possible that the reason for differential performance between subjects related to EMR differentially. Whereby normal variation in healthy young people has not shown differential EMR, changes associated with aging or with early AD symptoms may show different patterns than those found in previous studies with undergraduate participants.

The tasks that were administered during EMR recording included episodic memory, verbal fluency (semantic and phonemic), working memory (auditory N-back, backward digit span), and attention (digit span).

Subjective cognitive functioning was also measured. As researchers have found that cognitive complaints are associated with brain changes and incipient objective cognitive decline, we examined whether there is a change in EMR during cognitive tasks in individuals who differentially exhibit self-perceived cognitive decline.

Semantic and phonemic fluency were assessed in the current study. As these measures are typically found to decline in normal aging and differentially in AD, we examined whether there are associated changes in EMR during these tasks. Working memory declines have been found in aging. It was of interest whether EMR during WM tasks in elders would be different than EMR during WM in younger people.

Methods

General procedures

The current research protocol was reviewed and approved by the Queens College Institutional Review Board (IRB). Older adults and undergraduate students participated in the current study individually, and the study required approximately two hours of time for older individuals and one hour for undergraduate students. The flier used for older individuals' recruitment described the study procedures briefly and inclusion criteria (see Appendix A). One experimenter completed all of the data collection and scoring. Participants were explained the procedures of the study by the experimenter, including that their face would be videotaped during part of the procedures. Their participation was explained to be voluntary and that they were able to terminate participation at any time. Prospective participants were explained the

procedures and given the opportunity to ask questions. Written informed consent was obtained. During the recruitment and consenting processes, the study was explained as an examination of facial expressions during non-visual cognitive tasks. As in past research in our lab, participants were not explicitly told that we were examining eye movements. This was done to prevent participants from being aware of or altering their eye movements during the study. Because eye movements are considered one aspect of facial expressions, this was not considered explicit deception by the IRB.

Participants and recruitment

Recruitment was carried out at local senior citizen centers, where fliers were posted and handed out to members. Recruitment also occurred at local senior residences, where fliers were posted and handed out to residents. Older participants called the researcher in order to ask questions and set up appointments. Participants were explained the exclusion criteria of neurological disorders, epilepsy, and mental retardation. These were made exclusionary in order to ensure that informed consent could be obtained with proper understanding by subjects and because it is unknown whether neurological disorders affect EMR. For undergraduate students, participants signed up on the Queens College Psychology 101 subject pool website and schedule appointments with the researcher.

The experiment was carried out in various locations that were quiet and convenient to the participant, including a quiet conference room in a senior residence and in a quiet room in participants' homes. For undergraduate students, the experiment was carried out in an office in the Psychology Department at Queens College. The camera was positioned approximately three feet from the participant, who was seated in a chair. The camera was secured on a tripod. The examiner was present and seated behind the camera to ensure that the participant's face remained

in range of the camera. The experimenter sat off to the side and informed participants that they neither had to look at the camera nor the experimenter, but that they should keep their heads as steady as possible in order to stay in range of the camera. Reminders to remain still were given as needed.

Practice examples of tasks were given for videotaped measures before the testing session commenced. This was done in order to familiarize participants with procedures. Clinical measures and questionnaires were administered after video-recorded measures. The examiner was seated across from the participant in a fashion that is standard for neuropsychological evaluation procedures.

Forty people over age 70 were recruited from the community and local senior centers and residences. Twelve undergraduate students from the Queens College undergraduate psychology subject pool were recruited as a control group. The students carried out the study in a quiet office at Queens College and the older participants carried out the study in offices at senior centers or senior residences. Procedures were consistent between control participants and older participants. Older individuals were recruited with fliers (shown in Appendix B) and paid $15 dollars each for their participation. The 12 undergraduate students were recruited by the Queens College subject pool and received 1 hour of research credit for their participation.

Tasks and measures

Video-recorded measures were carried out with the undergraduate students. They did not complete the subsequent clinical and symptom measures because these data are not necessary for the analysis and because no dementia or cognitive declines seen in aging would be present in the sample of young individuals.

The examiner first explained the procedures and purpose of the study and then gave participants the consent form to review and sign. Consents were tailored for the procedures of the study. Undergraduates completed only videorecorded EMR tasks so their consent form explained these procedures. Older individuals also completed neuropsychological measures, self-report mood measures, and a demographic form, and their consent form described these procedures.

These tasks were chosen in order to examine pertinent neuropsychological constructs that are related to aging, MCI, and Alzheimer's Disease. We designed the battery to allow us to measure global cognitive functioning as well as specific areas of memory, verbal fluency, and psychological functioning. We also matched tasks across EMR and non-videorecorded tasks in order to assess whether performance on the task related to EMR during the same type of task.

The videotaped tasks were completed first for all subjects. These tasks were included in order to compare EMR data to previous research. It was important to use the same tasks in order to keep this variable consistent while the visual testing environment was altered in the current study.

The tasks were carried out in the following order:

1. Episodic Memory: Hopkins Verbal Learning Test-R (HVLT-R) (Benedict et al., 1998) form 1- this is an episodic list-learning task in which a list of 12 words from three semantic categories is read to the participant at a rate of one word per 1.5 seconds. After each reading of the list, the participant repeats all of the words he or she can recall. The list is read three times, with an immediate recall trial following each presentation. Delayed recall is assessed after a 25-minute delay followed by a yes/no recognition trial that includes both semantically-related and unrelated stimuli in addition to target items. Immediate recall memory is scored by adding correct responses over the three immediate

trials. Delayed recall is scored by adding number of correct freely recalled words at a 25-minute delay. Recognition memory is scored by subtracting incorrectly recognized (false positive) words from correctly recognized (true positive) words. Age-corrected norms are provided in the manual. This measure was included in order to assess EMR during a long-term episodic memory tasks for which standardized and normative data was also collected.

2. Working Memory: (a) A continuous performance N-back task (Owen, McMillan, Laird, & Bullmore, 2005) in which participants listen to a string of letters and then press a small clicker based on characteristics of what they hear. For the one-back condition, they click when they hear 2 of the same letters in a row. For the two-back condition, they click when they hear the same letter separated by exactly one letter. This task was used only as an EMR task and only EMR was scored during performance of this task. (b) A word list in which participants were given four words and asked to silently hold them in their memory for 7 seconds. When 7 seconds had elapsed, they were asked to repeat the words they had been read. This was done with a set of semantically-related and semantically-unrelated words. (Micic et al., 2010) No scoring was completed for this task's performance, but EMR was scored during the delay period (while subjects were holding words in their memory). This measure was included as one of the standard measures used in EMR research in order to assess for age or environment effects.
3. Verbal Fluency: The semantic verbal fluency task required participants to name vegetables for one minute. Phonemic fluency tasks included naming words beginning with the letters C, P, and W, each for one minute. Participants were instructed to name as many exemplars as they could think of in one minute. For phonemic fluency, participants

could give any word beginning with the letter excluding proper names and derivatives of the same word (Spreen & Strauss, 1998). Only EMR was scored during performance of these tasks. These tasks were included in order to assess EMR during a task for which standardized measure was also collected and normed. It is also a standard EMR task which has been used in previous EMR research.

4. Rote Memory/Overlearned Sequences: Participants were asked to recite the days of the week and months of the year (Micic et al., 2010). Only EMR was scored during performance of this task. This task was included as a previously used EMR task and it was also included to assess whether changes in cognition during aging might elicit a change in EMR during this task.

Clinical Measures were administered in standard format in order to assess cognitive functioning in the older individuals. These measures were not video-recorded and include the following in this order:

1. Dementia Rating Scale-2. This is a brief assessment of overall cognitive functioning with five subscales-- Attention, Initiation/Perseveration, Memory, Construction, and Conceptualization (Jurica, Leitten, & Mattis, 2001). The test was administered by standard procedure according to the administration and scoring manual. Scores are created for the five domains listed above and a total score is generated. Normative data were provided in the administration and scoring manual. Cutoff scores are often used for the total score in order to diagnose global cognitive impairments and as a diagnostic too for MCI and AD. This measure was included in order to categorize subjects into diagnostic groups.

2. HVLT form 2. This is the same as described above but with a different set of words (Benedict et al., 1998). This measure was included in order to assess memory performance of subjects for comparison to EMR performance during the same task.
3. Wechsler Memory Scale-Third Edition, Digit Span subtest. This task assesses simple auditory attention by having participants recite back strings of numbers increasing in length (forward digit span). The task provides two items for each string length and is discontinued when the participant fails two items of the same length. Working memory was assessed by having participants recite back strings of numbers in the reverse order to what was read (backward digit span). The discontinue rule is the same as in digits forward. (WMS-III; Wechsler, 1997). Total scores of correct items were computed and norms from the administration and scoring manual for WMS-III were used to compute standard scores. This was added in order to assess working memory performance for subjects for comparison to EMR performance during the same task.
4. Demographic information questionnaire- information including participant's age, educational background, health history, psychiatric history and race. See appendix A.
5. Geriatric Depression Scale-Short Form (Sheikh & Yesavage, 1986). This is a 15-item self-report instrument that measures the severity of depressive symptoms in older adults. The items were read aloud to participants who had difficulty seeing the print. A cutoff score of 5 was used to separate subjects into those reporting as significant level of depressive symptoms and those who did not. (Marc, Raue, & Bruce, 1998) This measure was used to form groups of higher and lower depressive symptom reporters in order to carry out comparisons of EMR across groups.

6. Adult Manifest Anxiety Scale-Elderly (AMAS-E; Reynolds, Richmond, & Lowe, 2003). This is a self-report measure of anxiety symptoms for older individuals. Items were read aloud for participants who had difficulty seeing the print. The AMAS-E is a 44 item self-report questionnaire. We used the Total Anxiety scale which included 37 items. The questions are in a yes or no format and a higher score indicates higher anxiety.
7. Metamemory in Adulthood Questionnaire- Abridged version, change subscale (Ponds et al., 1996). This questionnaire is 10-item measure of subjective change in memory for the past ten years. Items are rated on a 7-point likert scale with and scores were added to produce the total score (0-70). This measure was used to quantify subjects own perception of memory changes in order to examine EMR as it related to this variable.
8. Wechsler Test of Adult Reading (WTAR; The Psychological Corporation, 2001).

This is a measure of estimated premorbid verbal intelligence. The participant is given a card with 50 words and asked to read them aloud; they are scored on ability to pronounce the words. Total number of items correct is used to determine normative standard score and estimated premorbid verbal intellectual functioning.

Videorecorded measure administration lasted for approximately 30 minutes. Neuropsychological measure administration and self-report measures lasted approximately another one hour.

Data collection and scoring

Data were collected for 40 people over age 70 and 12 undergraduate students. Video-recorded tasks were classified into 12 categories based on type of task: 1. Immediate list-learning free recall; 2. N-back tasks, including both 1-back and 2-back; 3. Category/semantic (vegetable) fluency; 4. Phonemic (C, P) fluency; 5. Phonemic fluency for W; 6. Digit span forward for

shorter spans (4, 5 digits); 7. Digit span forward for longer spans (6, 7, 8 digits); 8. Digit spaN-backwards for shorter spans (2, 3 digits); 9. Digit spaN-backwards for longer span (4, 5, 6 digits); 10. Rote memory tasks (reciting the days of the week and months of the year); 11. Delayed list-learning recall; and 12. Working memory for a list of words (7-second retention).

Tasks were separated based upon previous EMR research and task properties. Because W is a lower frequency letter and results in lower fluency production, C and P were grouped separately from W. Digit span tasks were also separated into shorter and longer spans in order to control for the level of difficulty of the task.

Eye movements were scored for tasks answer periods for memory measures, fluency measures, and digit span measures. For the 7-second working memory task, EMR was scored during the subject's 7 seconds of holding the words in memory. EMR results are presented as a rate, number of saccades per second.

Some of the tasks we employed allowed for variable response times. N-back tasks and fluency tasks were designed to be standardized for time. However, variability in answer periods occurred when subjects asked questions during the task or made many head movements placing their head out of range of the camera. For episodic list-learning tasks, answer periods varied because subjects took varying amounts of time to recall and state the words they were able to recall. Therefore, in order to equalize answer periods, the data for these tasks were analyzed again with 30-second answer periods. Two variables were created by combining the shortened EMR task times. Semantic and phonemic fluency tasks were combined into one verbal fluency variable and the first 30 seconds of the 1-back and 2-back tasks were combined into one WM (N-back) task.

Neuropsychological measures were scored according to standard instructions provided in the instructional published manual and normative or raw data were used dependent upon the analyses, described below. For analyses that examined relationship between performance on a given cognitive measure and EMR during the same measure, raw scores were used. For analyses that examined differences between elders grouped by cognitive performance, normative scores were used.

EMR was collected using a JVC Camcorder on an adjustable tripod. Video recordings were transferred to a laptop for scoring. A program specifically designed for scoring eye movements was used, as in previous research (Ehrlichman et al., 2007; Micic et al., 2010). EMR is presented in a rate of eye movements per second such that an EMR value of 1.0 would represent an average rate one eye movement per second during a given cognitive task.

Inter-rater reliability was performed for 12 randomly selected subjects. The average Pearson correlation for EMR calculated by the primary experimenter and a separate experienced scorer was r=0.88. Scoring for neuropsychological measures were scored and re-checked by the primary experimenter.

Analyses

ANOVA analyses were used to compare independent groups (elders and undergraduates). Correlations were used to assess relationships between performance on cognitive tasks and EMR during cognitive tasks.

Because the environment in which eye movement data are collected was altered for the current study, it was important to run a sample of undergraduate students in order to examine whether the change of environment would have any effect on EMR during nonvisual tasks. Specifically, we asked the following: Will completing tasks in a room with more visual stimuli

than the lab's white walls, and having the experimenter present instead of heard through an intercom, change EMR in any way? We expected that there would be no change based upon a previous study examining EMR during eyes closed conditions and experimenter present conditions. In order to examine for changes across, a one-way ANOVA for the twelve tasks was run for the 12 undergraduate student sample and compared to previous studies.

We examined whether elders produced the same pattern of EMR observed across tasks in previous research. This analysis was exploratory and we had no scientifically-guided reason to expect a difference in either direction. However, because elders exhibit changes in cognition that are implicated in EMR research, we found this to be an interesting inquiry. In order to examine whether the sample of individuals over 70 years of age exhibited a similar pattern of EMR during nonvisual cognitive tasks, a one-way ANOVA for the twelve tasks was carried out. The General Lineal Model for repeated measures was employed (IBM SPSS 20).

We next examined whether EMR during verbal fluency and WM tasks would differ between age groups. In order to examine whether EMR during verbal fluency tasks and WM tasks, in general, were different between younger and older participants, a two-way ANOVA was carried out for EMR during these two types of tasks (verbal fluency and working memory) comparing older with younger participant groups. General Linear Model for repeated measures (IBM SPSS 20) was used for this procedure.

Our next analysis examined whether there were changes in EMR over age groups in elders. In order to examine EMR across age groups, elders were separated into three age groups. For this step, undergraduate students were compared to the individuals over 70 separated into three groups (age 73-85, 86-89, 90-101). In order to examine whether there were any significant differences between EMR for the verbal fluency and working memory tasks across the age

groups represented, a two-way ANOVA of group by task was completed for the two combined EMR tasks.

For the next set of analyses, the older sample was examined in order to form three groups based on global cognitive performance on the DRS-2. We had no scientifically-guided reason to expect a difference between EMR for these groups in a specific direction. However, because the changes in EMR across tasks in general involve tasks that are susceptible to the effects of aging and dementia, this was a question of interest. The DRS-2 normative total scaled scores were used to determine these individual groupings. Consistent with DRS scale standardized classification, the groups were defined as normal/above average (DRS standard score=10-17), below average (DRS standard score= 8-9), and mild to moderately impaired cognitive performers (DRS standard score=2-7). In order to examine whether there were differences in EMR for each task between the levels of cognitive performers a two-way ANOVA was run for cognitive performers' group by EMR task.

Subjective cognitive decline has been found to be related to objective cognitive decline, even before it is measured by neuropsychological tests; others have found it to be more closely related to psychological factors. We were interested in examining whether EMR would be related to subjective cognitions as assessed by the MIA-abridged 10-item memory change scale. In order to examine whether EMR was related to subjective cognitive decline correlations were computed between subjective cognitive performance and EMR tasks (fluency and N-back).

Depressive symptoms have been correlated with poorer performance on neurocognitive measures (e.g., verbal learning and memory and motor speed) (Thomas et al., 2009). We were interested in whether EMR would be related to depressive symptoms as rated on the Geriatric Depression Scale. Elder subjects were separated into groups based on self-reported level of

depressive symptoms on the Geriatric Depression Scale (15-item). A two-way ANOVA was performed for elders with more than five reported depressive symptoms and individuals with fewer than five reported depressive symptoms by EMR tasks (fluency and N-back).

Results

Twelve undergraduate students from the Queens College Psychology Subject Pool participated in the study. In addition, 37 elders over age 70 participated in the study. Three elders were excluded due to inability to maintain head position in range of the camera. The mean age of the 12 undergraduate participants was 19.9 years old (*SD*=1.6) The undergraduate group was 9% male and 91% female. The mean age of 34 participants for the older group was 88 years old (*SD*=6.17) They were 27% male and 73% f emale.

Table 1 includes descriptive statistics for demographic information for both young and older subjects. Table 2 includes descriptive statistics for EMR data for both groups (over 70 and undergraduates. Table 3 includes descriptive statistics for neuropsychological measure data for older individuals.

Table 1

Descriptive Statistics for Demographic information

	n	*M*	*SD*
Undergraduate Subjects			
Age	12	19.9	1.6
Elders			
Age	34	88.3	6.2
Years of Education	34	14.3	2.5

Table 2

Descriptive Statistics (Standard Score) for Neuropsychological Measures

	n	*SS*	*SD*
WTAR	34	111	14
DRS Total Score	34	88	15
Semantic Fluency (animal naming)	32	87	18
Digit Span	34	102	15
Episodic Memory Immediate (HVLT)	34	66	10
Episodic Delayed Recall (HVLT)	32	61	9
Recognition Memory (HVLT)	23	60	13

Table 3

Descriptive Statistics for Raw Scores of Self-Report Measures in Elders

	n	*M*	*SD*
Geriatric Depression Scale	34	3.3	2.9
Metamemory in Adulthood Abridged	34	33.4	7.7
	n	*t* score	*SD*
Adult Manifest Anxiety Scale	34	45	10.7

First, we established that EMR patterns during non-visual cognitive tasks were not significantly altered by changing the testing environment. For the undergraduate sample, mean EMRs for tasks were comparable to past studies, with the exception that the rote memory tasks had higher EMRs than previous studies. This is addressed in the discussion section. The pattern across EMR during tasks was consistent. EMRs for verbal fluency tasks were highest, EMRs for rote memory and attention tasks were lower than for fluency, and EMRs for working memory N-back tasks were lowest. These means were compared to previous research. Table 4 illustrates that the means for the undergraduate sample are similar to previous studies.

Table 4

Mean EMR for the current study and for previous research

Group	EMR verbal fluency	EMR N-back	EMR rote memory
Previous Research-Young	1.10 (7)*	0.36 (4)*	0.58 (5)*
Current Study-Young	1.01	0.28	0.82
Current Study-Elders	0.46	0.03	0.36

*number of studies used to determine composite score

Table 4 also shows that the pattern of EMR during tasks in older adult subjects was similar to that found in previous studies, with long-term memory tasks having the highest EMR, rote memory task EMR lower than fluency task EMR, and WM tasks having the lowest EMR.

There was a significant effect for tasks on EMR for both the undergraduate group and elderly group. For the 12 undergraduates, EMR was significantly greater for the fluency tasks (EMR M = 1.01, SD=0.44) than for N-back tasks (EMR M=0.28, SD=0.25) F (1,11)=38.62, p=0.000, η^2 =0.78. For the elderly group, EMR was also significantly greater for the fluency tasks (EMR M=0.46, SD=0.28) than for N-back tasks (EMR M=0.03, SD=0.05).

Next, a comparison between EMR across tasks for younger (undergraduate) and older (over age 70) participants was completed. We wanted to determine if older subjects had significantly lower EMR than younger subjects during each task. Elders as a group had lower EMR during fluency tasks than younger subjects F(1,44)=23.54, p=0.000, η^2=0.36. Elders had significantly lower EMR during rote memory tasks than young subjects F(1,43)=16.33, p=0.000, η^2=0.28. Elders also had significantly lower EMR during N-back tasks as compared to younger subjects F (1,44)=30.81, p=0.000, η^2=0.41. See Table 5.

Table 5

EMR during Fluency, Rote Memory, and N-back tasks differences between groups

EMR Task	*Undergraduate Group (n=12)*	*Elder Group (n=34)*	*Significance*	*Partial Eta Sq*
Fluency EMR	1.00 (*SD*=0.44)	0.46 (*SD*=0.29)	*p*=0.000	0.36
Rote Memory EMR	0.82 (*SD*=0.45)	0.36 (*SD*=0.28)	*p*=0.000	0.28
N-back EMR	0.28 (*SD*=0.25)	0.03 (*SD*=0.05)	*p*=0.000	0.41

Older subjects were separated into thirds by age, forming three age groups (age 73-85, *n*=11; 86-89, *n*=11; 90-101, *n*=12). Three groups were made in order to compare groups of about 10 people as effect sizes have been found to be large in this group size. For the youngest (age 73-85) of the elder group, EMR during fluency tasks was significantly higher than during N-back tasks $F(1,10)= 71.20$, $p=0.000$, $\eta^2=0.89$. For the next oldest group (age 86-89), EMR during fluency tasks was significantly higher than during N-back tasks $F(1,10)=19.12$, $p=0.001$, $\eta^2=0.66$. For the oldest group (age 90-101), EMR during fluency tasks was significantly higher than EMR during N-back tasks $F(1,11)=44.93$, $p=0.000$, $\eta^2=0.80$. These differences are shown in Table 6.

Table 6

EMR for N-back and Fluency tasks for each age group

Age Group	*Fluency EMR*	*N-back EMR*	*Significance*	*Partial Eta Sq*
Undergraduates	1.01 (*SD*=0.44)	0.28 (*SD*=0.25)	*p*=0.000	0.848
Elders (73-85)	0.59 (*SD*=0.23)	0.05 (*SD*=0.07)	*p*=0.000	0.880
Elders (86-89)	0.50 (*SD*=0.38)	0.03 (*SD*=0.05)	*p*=0.001	0.666
Elders (90-101)	0.29 (*SD*=0.15)	0.02 (*SD*=0.02)	*p*=0.000	0.826

In order to further examine the relationship between age and EMR during fluency tasks a correlation was run between age of participant and EMR. This was done only for individuals

over 70 in order to assess this relationship only in older individuals and because of the gap between the two age groups. This correlation was significant. Pearson r= -0.45, p= 0.007. EMR during fluency tasks was significantly lower as age increased in the group of elders.

We next examined whether general cognitive performance in the elder group was related to EMR during tasks. We separated the older adults into cognitive performance groups based on the Dementia Rating Scale-2 (DRS-2) normative standard score. Descriptive statistics for total and age-corrected standard scores for the three groupings are shown in Table 7. The highest-performing group had 7 individuals with an average DRS-2 score of 12.1 (*SD*=2.1) with a range from 11 to 17. These scores fall within the intact to above average range. The middle group had 9 individuals with a mean DRS-2 score of 9.4 (*SD*=0.5) with a range from 9 to 10. These scores fall within the below average range. The lowest-performing group had 18 individuals with a mean DRS-2 score of 5.4 (*SD*=2) with a range from 2 to 8. Table 8 shows the mean EMR for the three cognitive performance groups. There were no significant differences for EMR during fluency tasks between the three DRS-2 performance groups, F=0.04, p=0.996. There were no significant differences for EMR during rote memory tasks between the three DRS-2 performance groups, F=0.49, p=0.617. There were no significant differences for EMR during N-back tasks between the three DRS-2 performance groups, F=2.13, p=0.136.

Table 7

DRS-2 Score Descriptives for Elder Groups

Group	N	Age	DRS-2 total raw score	DRS-2 Standard Score
Intact Elders	7	88.8	136 (*SD*=1.6)	12.4 (*SD*=0.78)
Below Average Elders	9	86.9	132 (*SD*=2.5)	9.4 (*SD*=0.5)
Impaired Elders	18	88.9	117 (*SD*=10.5)	5.4 (*SD*=1.8)

Table 8

EMR during Fluency, Rote Memory, and N-back tasks across Cognitive Performance Groups

Group	EMR Fluency	EMR Rote Memory	EMR N-back
Intact Elders	0.46 (*SD*=0.26)	0.46 (*SD*=0.16)	0.06 (*SD*=0.08)
Below Avg Elders	0.46 (*SD*=0.25)	0.33 (*SD*=0.21)	0.04 (*SD*=0.06)
Impaired Elders	0.45 (*SD*=0.32)	0.34 (*SD*=0.35)	0.02 (*SD*=0.02)
Significance	p=0.996	p=0.617	p=0.136
Partial Eta Sq	0.001	0.126	0.028

Within the group over 70, 11 people reported a clinically significant level of depressive symptoms (GDS cutoff score = 5) (Sheikh & Yesavage, 1986). They were compared to the 11 people who reported one or no depressive symptoms. The low depression group had a mean Geriatric Depression Scale score of 0.36 (*SD* = 0.51, *n*=11). The high depression group had a mean Geriatric Depression Scale score of 6.64 (*SD* = 2.29, *n*=11). People who had clinically significant higher levels of depressive symptoms had significantly lower EMR during fluency tasks than people with lower levels of depressive symptoms (See Table 9).

Table 9

EMR during tasks for depressed and non-depressed elders

Group	EMR Fluency	EMR Rote Memory	EMR N-back
Depressed Elders (n=11)	0.32 (*SD*=0.21)	0.39 (*SD*=0.30)	0.03 (*SD*=0.05)
Non-depressed Elders (n=11)	0.54 (*SD*=0.22)	0.27 (*SD*=0.25)	0.04 (*SD*=0.05)
Significance	*p*=0.027	*p*=0.30	*p*=0.56
Partial Eta Sq	0.221	0.053	0.017

A correlation was run to examine the relationship between subjective cognitive complaints and EMR during fluency, N-back, and rote memory tasks. No significant correlations were found (See Table 10).

Table 10

Correlations between subjective cognitive decline and EMR during fluency, N-back, and rote memory tasks

Correlations	EMR Fluency	EMR Rote Memory	EMR N-back
Elders (n=34) subjective decline	-0.103	0.053	0.087
Significance	p=0.56	p=0.77	p=0.63

Discussion

The current study was designed to examine saccadic EMR during non-visual cognitive tasks in people over 70 years of age. EMR research in non-visual cognitive tasks has been carried out exclusively in undergraduate student populations with young adult samples and in a laboratory setting with minimal visual stimulation. The central finding from this area of research is that EMR among tasks that require search through long-term memory are associated with higher EMR as compared to working memory or attention tasks. The current research extended the examination of EMR in non-visual cognition to an older age group and more natural setting. It also examined the relationship of EMR in elders to performance on neurocognitive tasks, subjective assessment of cognition, and self-reported level of depression.

The sample of individuals over age 70 included both relatively healthy individuals with cognition representative of normal aging as well as individuals who exhibited significant deficits in one or more cognitive domains suggestive of pathological processes that are prevalent in aging, including AD and other neurodegenerative disorders. A control group of 12 Queens

College undergraduate students also participated in the study. The control group was included for two reasons: The first reason was to examine whether the change in setting would affect EMR. The second reason was to serve as a comparison group to the sample of elder individuals.

Various procedures have been used to examine EMR during non-visual cognitive tasks. The most common procedure has been to have the subject seated in a small white room while hearing the examiner through an intercom while EMR was recorded with a video-camera. Other procedures include having the subject complete the tasks with eyes closed, in front of a gray oval or a face on a monitor, and using an EOG to record EMR. All of these procedures have resulted in similar patterns of EMR across tasks in undergraduate student samples. Therefore, we did not expect the change in testing environment to have a significant impact upon EMR. This is likely due to EMR during cognitive tasks being driven by internal cognitive processes, since this is the only difference between our trials that produce higher vs. lower EMR (relative to a baseline).

It was necessary to assess the elder participants in a non-laboratory setting because it was not feasible for them to travel to the lab at Queens College due to transportation and physical challenges. Additionally, if EMR is ever to be used as a marker for a clinical diagnosis, its measurement in non-laboratory settings would be useful. In the current study, the experimental setting was a quiet conference room or quiet room in the subject's home. The video camera was placed three feet from the subjects on a tripod and level with their face. The examiner was seated in the room across from the subject next to the video camera. These procedural changes were found to have no significant effect on the pattern of EMR during non-visual long term memory retrieval and working memory tasks. This was evidenced by results in the undergraduate control group sample. EMR during LTM tasks and N-back tasks in our undergraduate sample was similar to that observed in young adults studied in laboratory settings. However, EMR was found

to be significantly higher during rote memory tasks in undergraduates tested in our current study. It is possible that because these rote memory tasks are low in cognitive demand, other aspects of the environment drove EMR to some extent, while EMR during more demanding tasks did not allow for the environment to alter EMR. The lack of difference in EMR across fluency and N-back tasks in this new environment that was very different in visual aspects supports the idea that although eye movements are typically thought of as being visually initiated and guided, EMR during non-visual cognitive tasks is internally-driven and seems to be primarily responsible for saccadic eye movement activity during our tasks. Even as the environment is altered, saccadic EMR is consistent during the tasks we employ.

The main goal of this study was to examine possible changes in EMR of older individuals and individuals who often have difficulty with the memory and attention tasks that are associated with higher and lower EMR. The current study extended EMR research into a group of elders, age 70 and over. The average age of the group was 88 years old and cognitive abilities of the group were representative of this age group albeit likely somewhat more impaired reflecting the large number of individuals that were residing in assisted living residences.

The most central finding from the current study was a significantly lower EMR as age increased for all of the tasks employed. However, there was a preservation of the pattern in EMR across tasks from earlier studies. That is, the highest EMR was found for fluency, mid-range EMR for rote memory tasks, and lowest EMR for N-back tasks. Increasing age was associated with lower EMR. This effect was quite large; the elder individuals exhibited an EMR during fluency tasks half that of undergraduate-age individuals (see Figure 2). During the fluency task older adult subjects exhibited an average EMR of 0.46 while undergraduate students exhibited an

average EMR of 1.01. The possible mechanisms by which this decline in EMR emerges are discussed below.

EMR during non-visual fluency tasks in the elder group was also related to depressive symptoms. People with clinically significant self-reported levels of depressive symptoms exhibited lower EMR during fluency tasks (EMR=0.32) than individuals without significant self-report of depressive symptoms (EMR=0.52). Self-reported depression was neither significantly correlated with age nor with performance on semantic or phonemic fluency tasks.

We do not yet know the precise origin of saccades during non-visual cognitive tasks. However, we do have a hypothesized anatomical model of saccade generation during non-visual tasks (Figure 1, Micic et al, 2007). It is worthwhile to make inferences regarding the origin of changes with age and in older individuals with as it may shed light on areas implicated in these saccades' origin.

It is possible that the motor slowing evident in aging is contributory to the EMR decline. General motor slowing is evident in aging (Salthouse, 2000). Rossini et al. (1999) found that the excitability of motor neurons in older individuals was reduced. Presuming that our anatomical model of non-visual saccadic EMR is correct, it is possible that the connections between basal ganglia and motor neurons are such that the reduced excitability leads to a reduction in EMR. Evidence for the lack of fatigue in the human oculomotor muscle system also is consistent with a central neurophysiological origin of changes in saccadic EMR in aging and depression (Prsa, Dicke & Thier, 2010) as opposed to peripheral muscular fatigue.

The current study is not the first to find changes in saccades that occur in aging and in individuals with depressive symptoms. Shafiq-Antonacci et al. (1999) examined the effects of aging and mood on saccadic function in older individuals. They found that in healthy adults

(mean age of 62) saccade latency increased with age and antisaccade error rate increased with increasing age. Increasing levels of depressive symptoms was associated with decreased saccadic latency. Saccade velocity and accuracy were not related to age in the study.

Research in the area of neuropathological changes in depression may also shed light on the EMR decreases we observed in depressed subjects. Murray et al. (2013) found that late life depression was associated with hyperintensities in the basal ganglia and brainstem. These neuropathological changes may similarly impact upon the circuits responsible for EMR during non-visual cognitive tasks. In people with Major Depression, Sweeney, Strojwas, Mann and Thase (1998) found evidence for neurophysiological changes in pre-frontal cortex and cerebellum that contribute to oculomotor changes including delayed initiation of voluntary saccades to a stimulus. Winograd-Gurvich, Georgiou-Karistianis, Fitzgerald, Millist, and White (2006) found that individuals with melancholic depression exhibited saccades with increased latencies and reduced peak velocities and they attribute this finding to possible functional changes in the fronto–striatal–collicular networks. Crevits, Van den Abbeele, Audenaert, Goethals, and Dierick (2005) found that therapeutic repetitive transcranial magnetic stimulation in depressed patients' prefrontal cortex was associated with significantly shortened latencies on antisaccades tasks after 10 treatment session. Given our hypothesized EMR neuroanatomical model (Figure 1), the dorso-lateral and ventro-lateral prefrontal cortices may be implicated in this change. However, these studies all involve saccades during visual cognitive tasks, and these saccades may be generated and moderated at least in part by different brain areas.

In the present study we also measured general cognitive performance. There are many factors that contribute to cognitive performance variability and change over time. Some changes are part of normal aging and some changes are indicative of pathological processes such as AD.

We conjectured that changes in EMR might be related to performance on neurocognitive measures even though there has been no evidence found for any relationship between EMR and task performance in undergraduate aged samples. This is because the neurological underpinnings of these cognitive performance variations are known to be different. That is, the neurological reasons that most young people may have difficulty with fluency tasks are different than the neurological variability that a pathological process like AD presents. We found no significant relationship between general cognitive performance and EMR during our tasks. There was no significant correlation between DRS-2 standard scores and either EMR during fluency nor N-back tasks (r=0.10, p=0.6; r=0.26, p=0.13). Additionally, when older individuals were separated into three groups based on clinical Dementia Rating Scale-2 scores (intact, below average, impaired) no differences in EMR were found between groups. Taken together, these findings suggest that age alone, and not the cognitive change often seen in aging, is related to EMR during non-visual cognitive tasks. Therefore, the neural changes associated with change in EMR during our tasks is likely neural change that is evident in individuals as they age, regardless of cognitive ability.

Consistent with previous research, we found no relationship between EMR and performance on parallel cognitive tasks. After we examined the relationship of general cognitive performance with EMRs during tasks, we looked specifically at the correlations between performance on fluency tasks and EMR during fluency tasks. We considered the possibility that the increase in different underlying mechanisms by which fluency and working memory tasks change in older age may be related to changes in EMR. However, we found no evidence for this idea. Specifically performance on fluency tasks (animal naming) was not significantly correlated with EMR during fluency tasks (r=0.03, p=0.88) and performance on working memory tasks

(DRS-attention subscale score) was not significantly correlated with EMR during N-back tasks (r=0.21, p=0.22).

We also found no significant relationship between EMR and self-perceived cognitive decline as measured by the Metamemory in Adulthood scale (abridged version, change scale). There were no significant relationships between EMR during either fluency or N-back tasks and subjective cognitive decline. There is some work indicating that subjective memory abilities indicate incipient cognitive decline and elevated levels of brain amyloid deposits even before declines are measurable by objective neuropsychological tests (Amariglio et al., 2012). In our sample there was no significant correlation between the Metamemory in Adulthood total score (subjective cognition) and objective cognitive performance on the DRS-2 (r^2=-0.09, p=0.6). It is possible that in our sample, as individuals were more impaired, insight was reduced as compared to those with mild or no impairment. There is evidence to support the loss of insight as AD progresses (Mangone et al., 1991). This attribute of the subject sample might mask a possible effect in very mildly impaired or prodromal individuals. In order to explore this possibility, we examined the differences between subjective cognition scores among the three general performance groups (Intact, below average, and impaired individuals). There were no significant differences between the three groups (F=0.348, p=0.708). Therefore it is unlikely that there are relationships between EMR and subjective cognitive decline that were masked.

Subjective memory decline has also been associated with mood disturbances (Tournier et al., 2011). In our sample there was no significant correlation between Geriatric Depression Scale score and Metamemory in Adulthood scale score (r=0.21, p=0.2). There was also no significant correlation between subjective cognitive decline and anxiety as measured by the Adult Manifest Anxiety Scale (r=0.271, p=0.10).

There are several limitations to this study that warrant discussion. First, we cannot determine from these data at what age EMR begins to decline. It is possible that EMR during non-visual cognitive tasks is stable across most of the life span and begins to decrease in older adulthood. It is also possible that there is a steady decrease across the adult lifespan. Future work is needed to elucidate this change.

We also cannot determine whether undergraduate-age individuals' EMR would be related to level of depressive symptoms, as this measure was not used in the undergraduate sample. This would be an interesting question for future research in the area of EMR.

We did not examine a 'baseline' EMR in the current study. Other studies have shown the baseline EMR (that is, EMR in the absence of any instructed task) to be intermediate between EMR during long-term memory retrieval tasks and working memory tasks. It is possible that the change in visual environment would have elicited a different baseline EMR pattern.

We were unable to detect significant age differences for EMR during N-back tasks. This was possibly due to the floor effect observed for EMR during these tasks. It is possible that cognitive tasks that we have not yet examined, may provide more information about the reduced EMR in aged individuals. Future research on EMR should include new cognitive domain measures during recording of EMR.

We cannot determine whether measures of general motor speed would be related to the EMR patterns we saw in older individuals. A measure of motor speed in our battery of clinical neurocognitive tests would have given more information about this issue. It will be important to include a motor speed measure in future research in this area of EMR.

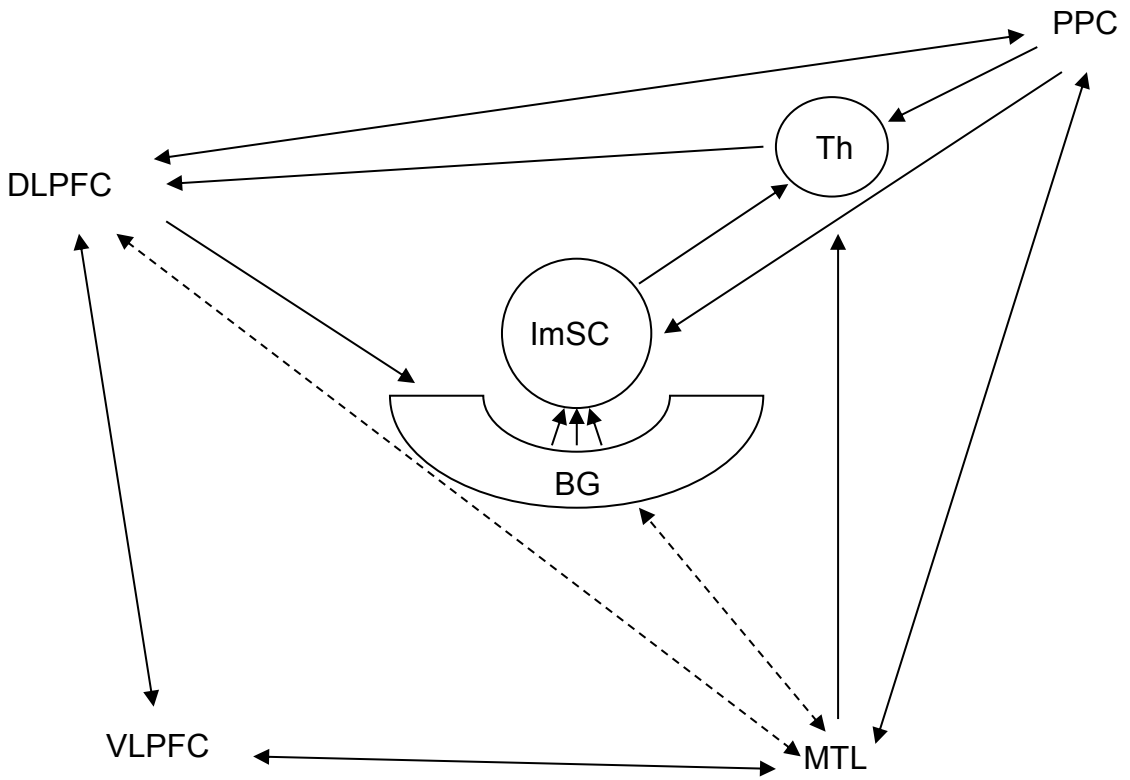
Although we have extended the examination of EMR during non-visual cognition into a sample of older adults, the development and changes in EMR over the life span remains an area

of inquiry. Because LTM and working memory change over the life span, it is of interest whether EMR also change. We have found that EMR during non-visual cognitive tasks does change in older adulthood, with a global decrease in the rate of saccadic eye movements across our fluency and working memory tasks.

Future work may focus on EMR across a greater age range, specifically over adulthood and childhood. It is of interest whether there is a change in EMR gradually over these lifespan periods. This could also shed light on whether EMR would be expected to change in a number of neuropathological conditions. Because of the possible implications on the basal ganglia on EMR, it is of interest whether individuals with disorders that affect basal ganglia functioning would exhibit altered EMRs. For example, Parkinson's Disease affects saccadic eye movement latency to a greater degree than in healthy individuals (Litvinova et al., 2011). These researchers found that the latency of saccades increased with older age and also increased with Parkinson's Disease. Because of these changes, it is reasonable to speculate that EMR during non-visual cognitive tasks may be further reduced in patients with Parkinson's Disease.

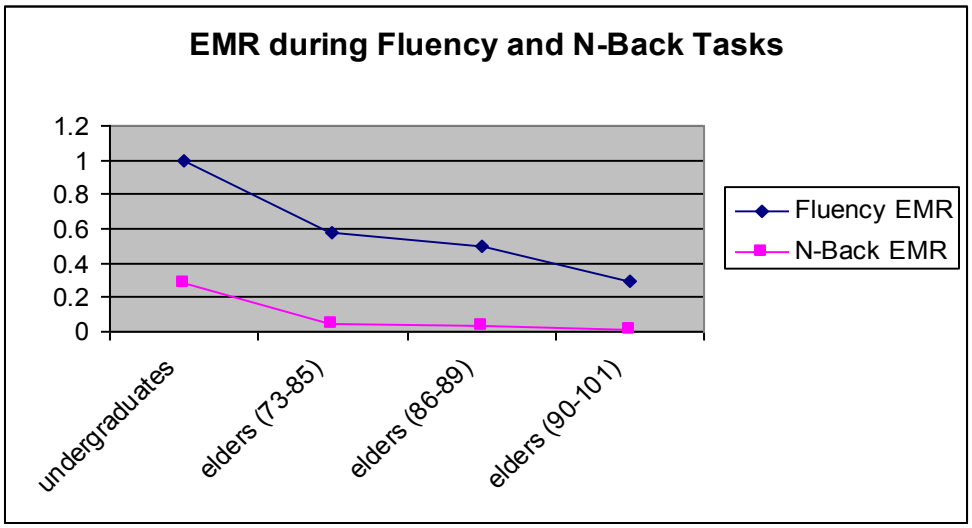
In conclusion, this research has uncovered significant findings of reduced EMR during semantic memory and fluency tasks in elder individuals and reduced EMR during semantic memory and fluency tasks in elder individuals with clinically elevated depressive symptoms. Future work would benefit from expanding upon age groups to examine EMR over different parts of the lifespan and examining EMR in individuals with other neurological conditions.

Figure 1.



Note: ImSC – intermediate layer of the superior colliculus; BG – basal ganglia; Th – thalamus; MTL – medial temporal lobe; VLPFC – ventrolateral prefrontal cortex; DLPFC – dorsolateral prefrontal cortex; PPC – posterior parietal cortex; full line – noncompetitive connection; broken line – competitive connection (Micic et al. 2007)

Figure 2.


EMR during Fluency and N-Back Tasks
1.2
1
0.8
0.6
0.4
0.2
0
undergraduates
elders (73-85)
elders (86-89)
elders (90-101)
Fluency EMR
N-Back EMR

Appendix A.

Demographic Information

Study ID#:_____
Date of Birth: ___/___/____ Age:_____ Gender: M F
Handedness: R L B Education: _____ years
Mother's Ed _____ years Father's Ed_____ years
What was your profession or occupation? _____
English as a first language? Y N If "no," at what age did you learn English?
____ What is the primary language spoken at home? _____
Are you color blind? Y N
Height: _____ Weight: _____
How did you hear about our study?_____
How is your health? _____
Have you had any major medical problems or surgeries? Y N
_____

How is your hearing? _____ Do you wear a hearing aid? Y N
Have you seen your regular doctor recently? Y N
Do you have hypertension? Y N Is it well-controlled? Y N
Are you on medication to control hypertension? Y N _____
Do you know your blood pressure? _____
Do you have high cholesterol? Y N
Do you take medication to control your cholesterol? Y N _____
Have you ever had an MRI? Y N If so, what part of the body and why?
_____
What was the result (e.g. normal/problems)? _____
Are you taking any medications? What are they for?

MEDICATION	PROBLEM	DOSAGE
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Do you take any vitamins or nutritional supplements?
(ask about Vitamins E, C and ginkgo -- and any others)

_____ _____
_____ _____
How is your vision? _____
Do you have double vision or problems reading print? Y N _____

Have you ever had cancer? Y N If so, what type?

_____

Have you ever undergone chemotherapy or radiation treatment? Y N

_____

Have you ever had heart surgery? Y N _____

Have you ever been diagnosed with a neurological disease such as a stroke, epilepsy, head injury? Y N

_____

Have you ever lost consciousness? Y N _____

Have you ever had severe headaches or migraines? Y N _____

Have you had heart or kidney problems? Y N _____

Do you have problems regulating your blood sugar? Y N _____

Do you have arthritis? Y N Type? Treatment? _____

How is your sleep? _____ Do you awaken in the middle of the night? Y N

How much do you sleep on average? _____

Any changes or chronic problems with your sleep? Y N _____

How is your appetite? _____ Has it recently increased or decreased? Y N

Do you have problems with your lungs? Y N _____

How much alcohol do you drink per week? _____

Have you ever had an alcohol problem? Y N _____

Have you ever had a problem with anxiety or depression? Y N

_____

Have you ever been diagnosed with a psychiatric disorder? Y N

_____

Were you ever diagnosed with a learning disorder? Y N

_____

Are you a smoker? Y N Do you wear a nicotine patch? Y N

_____

Is there a family history of Alzheimer's disease or other memory problems ? Y N _____ Is there a family history of psychiatric problems? Y N _____, Parkinson's disease, epilepsy, or other medical problems? Y N

_____

Do you have any problems with walking or balance? Y N

_____

If yes, how severe? And for how long?_____

Do you have any problems with incontinence? Y N _____

If yes, for how long?_____

Appendix B.

WE ARE CURRENTLY LOOKING FOR **HEALTHY INDIVIDUALS OVER AGE 70** TO PARTICIPATE IN A RESEARCH STUDY LOOKING AT THE EFFECTS OF COGNITIVE TASKS ON FACIAL EXPRESSIONS. Those interested should be free of neurological disorders including epilepsy, learning disabilities, and mental retardation.

THIS STUDY IS BEING CONDUCTED BY A DOCTORAL STUDENT FROM THE

CITY UNIVERSITY OF NEW YORK Queens College, supervised by Queens College psychology department faculty.

WE CAN TRAVEL TO YOU IN ORDER TO COMPLETE THE 1 & 1/2 HOUR STUDY AND YOU WILL BE COMPENSATED FOR YOUR TIME.

IF YOU ARE INTERESTED PLEASE CALL:

Amber Sousa

Phone: 631-680-5646

Department of Psychology
Queens College, CUNY
65-30 Kissena Blvd
Flushing, NY 11367

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