Use of explicit memory cues in patients with amnestic mild cognitive impairment

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USE OF EXPLICIT MEMORY CUES IN PATIENTS WITH AMNESTIC MILD COGNITIVE IMPAIRMENT

by

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USE OF EXPLICIT MEMORY CUES IN PATIENTS WITH AMNESTIC MILD COGNITIVE IMPAIRMENT

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ABSTRACT

Along with impaired memory, Alzheimer’s disease (AD) patients having amnestic mild cognitive impairment (aMCI) show a high rate of false memory distortions. The impact of these events on the lives of AD patients warrants further research into their neurobiological mechanisms. One type of distortion, known as false recognition, results in a greater tendency to endorse unstudied items as “old” on recognition memory tests. This tendency means patients often response “old” more than 50% of the time and is known as liberal response bias. Originally thought to be a byproduct of poor discrimination, evidence now demonstrates it to be part of a distinct neurological process (Budson et al. 2006). Further understanding of the processes responsible for determining individuals’ responses will help researchers understand the origin of false recognition and have the potential to direct effective behavioral interventions for patients and caregivers. Studies aiming to attribute these finding to abnormalities in the frontal lobes have been inconclusive. Parietal lobe activity has been associated with recognition memory in many studies over a variety of paradigms, including work examining shifting the decision
criteria, responsible for altering response bias. Differences in how AD patients with aMCI set criteria for recognition could be important in understanding their high rate of false recognitions. Recently, patients with parietal lesions have been shown to use explicit memory cues differently than healthy controls, suggesting that the parietal lobes may function in integrating external information when setting decision criteria. Our objective was to determine whether patients with aMCI would show results similar to those seen in parietal patients, due to the early AD-related pathophysiologic involvement of the parietal lobes in aMCI patients. Ten aMCI patients and 10 healthy controls were administered a recognition memory test that incorporated a mix of correct (valid) and incorrect (invalid) cues presented before the stimuli in the test phase. Participants were instructed that the test would include some trials preceded with hints of 80% accuracy. Patients and controls completed two recognition memory tests, one utilizing a shallow encoding at study and one using a deep encoding. We compared the baseline performance (performance with no cue) to cued performance in order to determine if the two groups used the cued condition in different ways. If AD damages processes within the parietal lobe required for utilizing information to set decision criteria, then patients with AD would not be affected negatively by invalid “Likely New” cues, and their performance would not improve on validly cued new item trials. Significant differences were seen between groups for the use of “Likely Old” cues in one condition (shallow). While statistically significant interaction effects were not observed for other conditions, graphical representations of data suggest future study is needed to reject or accept our hypothesis.
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<tr>
<td>AD</td>
<td>Alzheimer’s disease</td>
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<tr>
<td>AG</td>
<td>angular gyrus</td>
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<tr>
<td>aMCI</td>
<td>amnestic mild cognitive impairment</td>
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<tr>
<td>DRM</td>
<td>Deese, Roediger, McDermott paradigm</td>
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<tr>
<td>ERP</td>
<td>event-related potentials</td>
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<tr>
<td>fMRI</td>
<td>functional magnetic resonance imaging</td>
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<tr>
<td>IPL</td>
<td>inferior parietal lobule</td>
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<td>MTL</td>
<td>medial temporal lobe</td>
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<tr>
<td>PFC</td>
<td>pre frontal cortex</td>
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<td>SMG</td>
<td>superior marginal gyrus</td>
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USE OF EXPLICIT MEMORY CUES IN PATIENTS WITH AMNESTIC MILD COGNITIVE IMPAIRMENT

Introduction

Alzheimer’s disease (AD) is a neurodegenerative disorder categorized by significant memory impairment and clinical dementia (Budson & Solomon, 2012). Before AD destroys the patients’ ability to carry out their daily activities, many patients with mild AD, along with many in a pre-Alzheimer's state called amnestic mild cognitive impairment (aMCI), live independently within the community. While difficulty with memory retrieval has commonly been observed in these individuals, it is now clear that additional memory problems, beyond retrieval alone, can complicate independent living for these individuals.

In a clinical description of behavioral problems associated with AD, Borson (1997) described a high incidence of memory distortions in his patients one specific type of memory distortions occurs when people incorrectly claim to have seen an item or event. Clinically, these false memories can cause a patient to erroneously believe they have taken medication, or locked the door and may prevent patients from living independently (Borson 1997). Budson and colleagues (2007) conducted a study examining memories of personal experiences during the September 11th attacks that demonstrated these false memories quantitatively. Surveys administered at three months and at one year after the attacks found patients with AD to have a significantly higher rate of false memories than control and MCI subjects of similar age and education. For example, patients were found to change the source from which they first heard of the
attacks or their location at the time of the events. The impact these occurrences have on patients and caregivers makes the neurological mechanisms behind false memories of high clinical interest.

False memories, or false recognition, has been studied experimentally in older adults and patients with AD. This research has primarily employed variation of a paradigm developed by Deese (1959) and later revived and modified by Roediger and McDermott (1995). The DRM paradigm utilized study lists containing semantically related words (e.g., candy, sour, sugar, taste, and so forth) that converged on a common theme. The test phase contained words that were thematically similar, but not identical to the study lists (e.g., sweet). Numerous studies using these paradigms demonstrated false alarms made with high confidence across study groups, demonstrating these words to be falsely remembered. (e.g., Brainerd et al., 2003; Gallo et al., 2001; Neuschatz et al., 2003; Robinson and Roediger, 1997; Schacter et al., 1999) Healthy controls and patients with AD demonstrate high rates of false alarms to related test items (Budson et al., 2000).

Unlike controls, patients with AD also show frequent false alarms to unrelated test items as well (Balota, Burgess, Cortese, & Adams, 2002; Bartok et al., 1997; Budson, Wolk, Chong, & Waring, 2006; Snodgrass & Corwin, 1988). Further examination of these false alarms can be achieved by observing the “response bias” of subjects; that is, the tendency of subjects to respond liberally (predominantly answer old) or conservatively (predominantly answering new) on a recognition memory test.

Snodgrass and Corwin (1988) demonstrated AD patients had a liberal response bias on a task of recognition. To rule out effects of poor discrimination, a more recent
study matched discrimination across AD patients and control groups (Budson et al., 2006). Discrimination matching was accomplished by providing controls with a more lengthy study list, effectively lowering their performance to the level of the AD group. While successful at matching discrimination across groups, this manipulation did not create a liberal response bias in the controls. In fact, progressively longer study-test lists did not alter the conservative bias of the controls. The AD group continued to demonstrate a more liberal response bias regardless of study-test list length, answering “old” more frequently than controls and generating a higher rate of false alarms. Thus, response bias is a phenomenon separate from poor discrimination, and is important to our understanding of false memories. Despite its importance to this field and others, response bias is poorly understood. Little work has been done to uncover the physiologic mechanism of response bias and its neuroanatomical localization, and almost no work has been done to understand which brain regions are responsible for altering response bias in patients with AD.

AD produces significant brain damage from plaque and tangle pathology leading to atrophy throughout the brain. Although patterns of atrophy vary by individual, structural imaging and post mortem studies have generally demonstrated bilateral cortical atrophy of the medial temporal lobes (MTL), aspects of the lateral anterior inferior temporal lobes, parietal lobes, and parts of the frontal lobe (Wenk 2003). Lesions in the medial temporal lobe, specifically in the hippocampus, cause an inability to store new memories. (Squire 1992, Cohen 1993, Wolk). Interestingly, patients with damage restricted solely to these areas, do not suffer from false memories any more than a healthy
older individual (Snodgrass & Corwin, 1988). In fact, these amnestic patients have demonstrated a conservative bias, despite their poor discrimination similar to patients with AD (Schacter 1996, Verfallie 2001). These findings suggest the neurological origin of the liberal response bias to be outside of the MTL. Attempts to determine the neuroanatomical regions associated with liberal response bias originally focused on the frontal lobe because patients with frontal lobe lesions have been shown to exhibit elevated levels of false alarms (Budson et al., 2002a; Melo, Winocur, & Moscovitch, 1999; Parkin, Ward, Bindschaedler, Squires & Powell, 1999) although this is not always the case (Verfaille, Rapcsak, Keane & Alexander, 2004). In their study demonstrating that response bias was independent of discrimination, Budson et al. (2006) found no correlation between measures of frontal lobe function and response bias. A lack of correlation was also found in a more recent study of response bias in patients with AD (Deason, Hussey, Budson, Ally, 2012). Current research should include areas beyond the MTL and frontal lobe. The parietal lobe is also affected in aMCI and AD and should be considered in the implication of false memories and origin of liberal response bias.

Compared to frontal atrophy, parietal atrophy occurs very early in the progression of AD (Reiman 1996). Studies of recognition memory in patients with parietal lobe lesions do not show reduced discrimination (Ally, Simons, McKeever, Peers & Budson, 2008, Davidson 2008, Simons et al., 2010). Despite this finding, both event related potential (ERP) and functional magnetic resonance imaging (fMRI) studies have identified parietal regions of greater activity for correctly identified old words and false alarms compared to correct rejections and missed words across numerous recognition
memory paradigms (Goldmann et al., 2003; Henson 2005, Wagner 2005, Dobbins 2003). This effect is typically described as the parietal old/new effect. Originally hypothesized to be due to strength of memory, the body of work examining this activity suggests the role may be more complex (for a review, see Wagner et al. 2005). Dorsal and ventral regions of the parietal lobe appear to play different roles in memory retrieval (Vilberg & Rugg, 2008; Wagner, Shannon, Kahn, & Buckner, 2005, Miller & Handy 2001) and theories to explain the observed activity in the parietal lobe have expanded to include the subjective experience of memory retrieval (Ally et al., 2008), retrieval orientation, attention and output buffer hypothesis (see Wagner, 2005 for review) These various hypothesis have different implications for the role of the parietal lobe in recognition memory. A universal component of the recognition memory decision is the determination of criteria. In order to make a recognition judgment, individuals must weight internal and external evidence to determine their response. This setting and changing of criteria could likely be influenced by parietal lobe damage, regardless of which theory is considered.

Determination of an individual’s criterion for recognition judgment has been associated with distinct anatomical regions of the brain, independent from those associated with the processing of memory strength and memory retrieval (Miller, Handy 2001). Miller and colleagues created conditions in which participants’ responses were manipulated on a trial by trial bases and their neural activity was observed using fMRI. Test trials consisted of colored stimuli (red or green) and subjects were instructed to respond liberally to green words and conservatively to red words. None of the regions associated with retrieval success overlapped with the regions shown to be associated with
shifting criterion. Areas of activation associated with criterion shifting included the cerebellum and also the right and left parietal lobe (Miller, Handy 2001). This result seems to be consistent with other functions of the parietal lobe, activation of which is strongly associated with shifts in attention and spatial orientation as well (Corbetta 1998, 2000).

Further localization of parietal activity was achieved in a novel cueing paradigm designed by O'Connor, Han & Dobbins (2010). Cues were presented to subjects prior to each test word, indicating whether the subject should anticipate a new or old item. Cues could be correct (valid) or incorrect (invalid). Neural activity corresponding to a region within the inferior parietal lobule (IPL) appeared to tracked accuracy of the cue, but did not correspond with the accuracy of the recognition judgment. Within the IPL, the supramarginal gyri (SMG) activation tracked the response biases of the subjects. Activation in the angular gyrus of the IPL was also associated with invalid cueing, and was associated with a cortical network distinct from that of the SMG. While the AG and SMG were both activated by these invalid cues, their connections to different PFC networks, dorsomedial and anteromedial respectively, suggest independent function. It is clear that activity seen in areas of the parietal lobe during recognition memory paradigms corresponds with multiple functions. The explanations for parietal lobe activity during these and similar tasks must be more complex than simply a representation of memory strength. Evidence suggests that one role of the parietal activity measured during recognition memory tests may be determining the criteria by which a recognition judgment is reached.

Recent research has demonstrated the parietal lobe may play a role in the
integration of information when processing recognition judgments (Dobbins 2012). In a study examining patients with either frontal or parietal lobe lesions, subjects were given a recognition memory test in which some test trials were paired with anticipatory cues, similar to the ones used by O’Connor Han and Dobbins in their 2010 paradigm. Subjects were told that a “Likely Old” cue indicated an 80% likelihood of seeing an old word and a “Likely New” cue indicated an 80% chance that the next word would be new. Subjects were instructed to incorporate the cues into their recognition judgment to increase their performance. Performance increased when the cues preceding the trial were accurate, and performance decreased when the preceding cues were incorrect for both frontal and control groups. In fact, patients with frontal lobe lesions did not differ significantly in their performance from controls. For patients with parietal lobe lesions, this cue effect was not always observed. When these patients were confronted with never before seen words, the validity of the cues had little effect in two of the conditions. Patients with parietal lobe lesions were not affected negatively by invalid Likely New cues and their performance was not improved with validly cued new item trials. These results suggest that the parietal lobe may play a role in the integration of external information when determining the familiarity versus novelty of an item.

**Current Study**

A common solution to forgetting in healthy adults is the usage of external memory cues. Most people have written a grocery list, or written a note reminding them to complete a task at a later time. Cues can even be incorporated unintentionally, such as
driving past the drug store and remembering you have a prescription to turn in on the table at home. Patients with AD are often unable to use these types of behaviors due to their frequent false memories. Patients may see a note instructing them to take their medication, but feel that they remember already having done so. One possible explanation is that the patients have preset their memory judgment criteria and are unable to modify these criteria even in the presence of an explicit memory cue.

Our review of the literature of fMRI, ERP, and patient lesion work suggests the parietal lobe plays a role in how we set our criteria when making recognition judgments. Thus, parietal dysfunction could play a role in the high rate of false recognition seen in AD. Our aim was to determine whether patients with AD would respond differently from controls when given cues to incorporate during a recognition memory test. We hypothesized that patients with AD would show difficulty effectively utilizing external memory cues, thereby demonstrating a baseline (performance without cues) that was similar to their performance when explicit memory cues with present. Using a paradigm similar to the one used by Dobbins et al. (2012), we tested healthy older adults and a group of patients with aMCI due to the AD pathophysiologic process on a recognition memory test that incorporated a mix of correct (valid) and incorrect (invalid) cues presented before the stimuli in the test phase.

Participants were instructed that the test would include some trials preceded with hints of 80% accuracy. Patients and controls completed two recognition memory tests, one utilizing a shallow encoding at study and one using a deep encoding. We compared the baseline performance (performance with no cue) to cued performance in order to
determine if the two groups used the cued in a different way. If AD damages processes within the parietal lobe required for utilizing information to set decision criteria, we would hypothesize patients with AD would show a pattern similar to patients with parietal lobe lesions in the study by Dobbins et al. (2012).
Method

Participants

Ten patients (three women) with a probable diagnosis of aMCI due to the AD pathophysiologic process were recruited from the Boston University Alzheimer's Disease Center, and the VA Boston Healthcare System’s Memory Disorders Clinic, both located in Boston, MA. Patients were assessed by one of more clinicians, including neurologists, with an expertise in memory disorders. Patients in the aMCI group fit criteria for MCI due to AD described by the National Institute on Aging and Alzheimer’s Association workgroup (Albert et al., 2011). Ten healthy community dwelling adults (five women) were recruited from the Boston University Alzheimer's Disease Center, or were friends and family the patients. Exclusionary criteria included other brain disorder, cerebrovascular disease, history of traumatic brain injury, history of drug or alcohol abuse, and significant depression. All participants were native English speakers and had normal or corrected to normal vision. The study was approved by the human studies committees of VA Boston Healthcare System, Boston, MA, the Edith Nourse Rogers Memorial Veterans Hospital, Bedford, MA, and Boston University, Boston, MA. Written informed consent was obtained for all participants. Participants were reimbursed 10$/hour for their participation.

The healthy older adults and patients with aMCI completed a brief neuropsychological battery prior to the experimental session. This battery included the MMSE (Folstein, Folstein, & McHugh, 1975), CERAD Word List Memory Test (Morris
et al., 1989), Trail Making Test Parts A and B (Adjutant General’s Office, 1944), Verbal Fluency to letters and categories (Monsch et al., 1992), and the short form Boston Naming Test (Mack, Freed, Williams, & Henderson, 1992). Data from one participant in the patient group were not analyzed due to scoring within the normal range for the CERAD test measure. Table 1 presents demographic and neuropsychological data for the participants.

Although the average age of the patient group was three years older than the control group, this difference was not significant ($p > 0.1$). Differences between years of education also did not vary significantly ($p > 0.5$). Patients were in the very mild states of the disease based on their performance on the MMSE (range 24 -30), with a mean of 27. These values varied significantly from the controls (mean 29.1). Older controls also scored significantly higher on CERAD immediate recall, CERAD delayed recall, lexical fluency, categorical fluency and the Boston Naming Test. Controls performed significantly faster on the Trail Making Test Part B.

**Materials**

Stimuli words were selected from the University of Western Australia MRC Psycholinguistic Database (http://www.psy.uwa.edu.au/MRCDataBasewa_mrc.htm). Parameters used to generate the word list were a Kucera–Francis written frequency of 100–600, word length of 4–7 letters, and a familiarity rating of 400-700. Vulgar, foreign, or highly similar words were removed, with 280 words remaining. The words were then counterbalanced into 12 lists of 24 words each that were equated on frequency, familiarity and number of words. Assignment of lists to experimental conditions was
counterbalanced across participants.

*Procedure*

The experiment was programmed using E-Prime software (Psychology Software Tools Inc.; www.pst-net.com/eprime), and was separated into two blocks (see Figure 1). Each block contained a study and test portion, differing only in encoding type. The first block consisted of a study phase in which the words were accompanied with a deep encoding question, in which participants were asked to decide whether they liked or dislike the study item. The second block used a shallow encoding question, in which words were accompanied with a question asking whether or not the study word contained the letter “e”. Participants were asked to answer “yes” or “no” for each word. In an attempt to equate performance of the aMCI patients in the deep condition with the control group, in the shallow condition, the order of the blocks was constant through all trials. The deep encoding block was administered first to maximize the performance in the deep condition for patients, while the shallow condition was administered second to minimize performance of the controls.

Participants were informed they would perform two blocks, each containing a study and test. Before beginning the study phase, participants were told they would be completing a memory test of the studied words, and that the questions were to assist them in remembering the items. Participants studied forty words in the first study phase, all of which were paired with the like/dislike question. Words were displayed on a laptop computer at a comfortable distance from the participant for 4000 ms at 48pt Times New
Roman font in black on a white background. An interstimulus interval of 500 ms followed each studied word.

The first test phase followed immediately after completion of the study phase. Instructions for the test phase asked participants to answer “old” for studied words and “new” for unstudied words. Participants were informed that either Likely Old or Likely New hints would precede some of the words, and that these hints were 80% accurate. They were instructed to use these hints to increase their performance. Before beginning the test phase, participants were shown examples of both the no hint and hint condition and given a practice question. The test phase consisted of eighty trials in which all forty studied words were randomly intermixed with forty new words. Two thirds of all trials were preceded by hints, with the no hint conditions randomly dispersed throughout. Hints appeared in the upper half of the screen 1500 ms before each test word and remained on the screen above the test words until the next trial. The accuracy of the hints was displayed throughout the test phase by a card placed on the keyboard. Hints were divided evenly between Likely Old and Likely New with 80% of the cues being valid. The total number of trials preceded by hints was sixty with forty-eight of these valid cues. After completion of the first block, participants were given a short break before beginning the second portion of the experiment. The same procedure was followed.
Results

To determine whether there were differences in use of the cues between AD patients and healthy older adults, scatter plots were generated to relate the baseline performance (correct responses on non-cued trials) to cued performance and regression lines were calculated for each condition. Plots with corresponding linear regressions are shown in Figures (2-5) for hits and (Figures 6-9) for correct rejections. When cues are incorporated, validly cued performance should be higher than baseline performance (above the dashed line) and invalid performance lower (below the dashed line). Our analysis aimed to determine whether there was an overall difference in cued performance across the groups, and whether or not a fundamental difference existed in the slopes relating baseline to cued performance between groups.

Across groups there was an increase from baseline during validly cued trials and a decrease from baseline in the invalid condition for hit rates, correct rejection rates and discrimination (see Table 2). Both types of encoding were analyzed to determine if discrimination and performance could be equated between the deep condition for the AD patients and the shallow condition for the controls to control for the effects of poor discrimination—that is impaired memory—on cue usage.

Hits

Valid Cues. For hits in the valid Likely Old cue condition performance was similar between the control and patient groups. An ANCOVA model (table 3) that predicted validly cued hits using variable baseline hit rates (baseline), group (controls vs.
patients), and the interaction of baseline and group was used to confirm this relationship. This analysis was based on the analyses used by Dobbins et al. (2012) using a similar paradigm with healthy older adults and patients with parietal and frontal lobe lesions. Displayed in Table 3 as “b x g”, this interaction variable tests whether the interaction between baseline and cued performance varies reliably between the control and patient groups. In the deep encoding condition, consistent with the plots, no significant difference is seen for baseline performance or between groups. For the shallow encoding condition, baseline differences trend towards significance according to the ANCOVA and the plots show a distinctly different pattern of performance. The ANCOVA shows that differences between groups are approaching significance ($t(18) p = .077$) and a significant interaction effect between cue and group is present ($t(18) p = .022$). Visual Comparison of the figures for shallow hit rate shows slopes indicating different Baseline x Group effects for patients and control ($t(8) p = 20.76, t(9) p = 25.88$).

Invalid Cues. For Likely New cues given for old items (or invalidly cued hits) the ANCOVA confirmed what is seen by visual inspection in the plots (Figure 2-5). Both groups were affected similarly by cues in the deep condition. A significant difference is seen between baseline and cued performance in the deep condition, but there is no significant effect of group, and the relationship between group and cued performance also was not significant. In the shallow performance, no effects or interactions reached significance. The plots indicate that baseline performance has a positive correlation with cued performance for controls, however the patient group shows a negative slope.
**Correct Rejections**

Valid cues. Correct rejection rates were also analyzed using a similar model. Validly cued correct rejections correspond with new trials that were preceded by Likely New cues. Performance in the deep condition for these trials was the highest for both groups with controls having an average of 94% accuracy when valid cues were presented (compared to 87.5% at baseline) and patients showing 83% accuracy (compared to 61% at baseline). This obvious benefit of the cue in the patient group suggests that Likely New cues are utilized to adjust the decision criteria of aMCI subjects. The plots (Figures 6-9) show that even for subjects with low baseline accuracy (<50%), performance was around 80%. This is confirmed by the ANCOVA model, which did not show a significant effect of baseline performance. No group or interaction effect was found to be significant. Shallow correct rejections preceded by valid cues show a similar pattern. Plots demonstrated the valid cue to provide a benefit for both groups. The ANCOVA model showed this benefit to be independent of baseline performance or group and found no significant interaction.

Invalid cues. Invalidly cued correct rejections correspond with trials in which new words are preceded by a Likely Old cue. The deep condition did not show significant relationships between baseline performance, group, or an interaction effect. However, performance in the deep condition was near the ceiling for controls, while the patient group presented a very large performance range, spanning from 0 to 1. In the shallow condition, the largest difference was seen between the average performance of controls and patients of any experimental condition (Table 2). Visual inspection of the plots
suggests a clear relationship between baseline and cued performance in invalidly cued correct rejection trials for both groups, consistent with the significant baseline effect ($t = (18), p = .016$). The patient group seems to have a less positive correlation between baseline performance and cued performance, although the effect of group was not significant. There was no b x g interaction.

**Discussion**

The aim of our current analysis was to determine if patients with aMCI due to the AD pathophysiologic process would utilize explicit memory cues in a pattern differently from older controls. Answering this question would help to determine if an inability to integrate external information plays a role in the high incidence of false recognition seen in AD which, in turn, could help explain their high rate of false memories in daily life. Statistically, our results do not show any effects of group, but do show an interaction in the shallow hit condition between baseline and group. Our hypothesis was that cues would show a lesser effect in the patient group. If cues are not properly integrated, they will have a smaller effect on performance. We expected that the patients’ performance when exposed to the memory cues would not increase or decrease from their baseline performance to the same extent as the healthy older adult controls. In the extreme, this inability to properly incorporate the information provided by the hints would result in a pattern of response data that looks like the dotted line ($x=y$) visible on Figures 2-9. This expectation was based on the fact that parietal lobe patients performing a similar paradigm in Dobbins et al. (2012) showed a pattern of responses demonstrating that
Likely New cues did not significantly affect their performance, and the speculation that parietal dysfunction in patients with AD might lead, in part, to their liberal response bias.

**Current Analysis**

Our current analysis is based upon the results of eight ANCOVA statistical analyses. One could argue that *Bonferroni* correction resulting in an alpha value of .00625 (0.05 / 8) should be applied to the ANCOVA models. With this correction, none of our results reach significance. Interpreting our data in this light, it is possible that patients do not integrate cues any differently than healthy older adults. However, there are other explanations for the lack of significant results in this study. It is worth discussing alternative hypothesis for the results, limitations of this current data, and what future work could be done.

Both groups demonstrated a statistically similar benefit for the valid cue condition in both hits and correct rejections. Valid cues contribute a similar benefit to subject performance while invalid cues cause subjects to incur a decrease in performance. Significance was also not seen in the baseline variable, this finding indicates that subjects’ cued performance was not reliably related to their performance at baseline. There is no evidence from the ANCOVA model to indicate that aMCI patients used the cues any differently than controls. This finding would suggest that explicit memory cues are adequately integrated in aMCI patients and therefore does not provide an explanation to the frequency of false recognition. These data do not, however, rule out the role of the parietal lobe in false recognition. Qualitative examination of the data demonstrates a pattern that suggests further work may uncover differences between groups. The
potential reasons for the lack of significance will be discussed below. Some of our data do show significance when the Bonferroni correction is not used. In order to avoid Type II error, and to direct future hypotheses, it is worthwhile to discuss these effects briefly.

**Data Trends**

Within the current data, p values of < .05 were demonstrated for the effect of baseline in the deep Likely New hit condition and the shallow Likely Old correct rejection condition. A significant effect of baseline would suggest that cued performance is reliably related to performance without cues. Intuitively, one can imagine that persons with better baseline performances have stronger memories and would therefore be more likely to notice when the test word was in agreement or violation of its preceding cue. This intuition suggests that we would find a positive correlation with baseline when presented with an invalid cue. Examination of Figures 3-4 and 9-10 shows this to be true for both groups. It is interesting that baseline performance did not have significant effects in the other conditions despite the trend demonstrated by the regression lines in the other Figures 5-8. However, in the Dobbins et al. (2012) study of parietal patients, significant effect of baseline was in only found in one condition in which a significant interaction existed. In their study, interactions between group and baseline were observed when Likely New cues were presented. The one interaction in our current data that did show significance did not follow the patterns of the parietal patients as we originally hypothesized. Instead, the interaction was found between valid Likely Old cues and group for correct rejections in the shallow encoding. An interaction demonstrates that the relationship between baseline performance and cued performance is different
between patients and controls this condition. While no concrete conclusions can be drawn from this one interaction, we can discuss this finding in the context of our current understanding of response bias and consider its implications for directly future study.

The baseline x group interactions anticipated by our hypothesis would have shown the effect to be driven by the patients performing identically with and without cues, whereas controls would receive benefits and costs depending on the condition. Although the baseline x group effect observed in this study may be driven by a different variable. The patients’ trend line demonstrates a negative slope, suggesting that in this case patients with higher baseline performance actually performed worse than patients with lower baseline performance. This may seem counterintuitive, however the patient’s response bias provides one possible explanation. The degree of liberal bias demonstrated by patients has been correlated with disease severity (Budson, Wolk, Chong, Waring, 2006). It is possible that patients who are more impaired are more likely to agree with Likely Old cues, regardless of the cues correctness. Less impaired patients may have higher memory confidence; relying less on the cues to make their recognition judgments. One could argue that this scenario would also result in more impaired patients having an artificially high hit rate in the baseline condition, since baseline performance is not corrected for false alarms. To test if correcting for false alarms in the baseline condition would remove this effect, discrimination (hit rate-false alarm rate) was plotted at the x-axis. No change was seen in the pattern of the plots (data not shown).

Another explanation for the observed b x g interaction is that aMCI patients do not incorporate the Likely Old cue in the same fashion as controls. Most of the aMCI data
points are clustered around the dotted line. This line represents expected results if cues do not influence performance. Due to the small numbers utilized in this current experiment, a few outliers can exert large influence on the results. Do to these small numbers; it is worth discussing trends that can be observed by viewing the graphical representation of the data.

Figures showing the effect of cue for hits in the deep encoding condition demonstrate results for patients that are nearly identical to the dotted line $x=y$. Data points below the line indicate performance was decreased by the cue, while data points above the line indicate an increase in performance. For control subjects, more subjects fell below the line when exposed to invalid cues than in the patient group, suggesting the cues had a stronger effect. The performance of controls for valid cues is also notably higher than that of the patients, with the majority of their valid data points existing well above the $x=y$ line, indicating additional benefit. There is evidence that comparing the hit rates in the shallow condition for the controls with the hit rates in the deep condition for the patients may actually provide a more accurate comparison.

*Effects of Response Bias*

In order to make a true comparison between the effects of cue between groups, it is ideal to match discrimination in order to eliminate a potential effect. Budson et al. (2006) found that patients with mild AD demonstrated a more liberal response bias compared to controls, even when results were matched for discrimination by varying study-test list lengths. Research to determine the source of this liberal bias has implicated the increased usage of familiarity in the patients, one if the two memory processes
described in the dual-process model of recognition memory (Deason, Hussey, Ally, Budson 2012). Familiarity is a more general sense of having encountered an event or item before without recall of the specific context. Recollection on the other hand is reliant on the presence of a detailed memory associated with an item or event and contains contextual details (Jacoby & Dallas, 1981, Yonelinas 2004). Recollection has been shown to be severely impaired in patients with AD, resulting in patients having an overreliance on familiarity. (Budson 2000, Smith and Knight 2002). Longer delays between study and test increase the use of familiarity (Yonelinas 2002). Contrasting with the list-length method used by Budson et al. (2006), Deason et al. (2012) used varying study-test delays in their study to match discrimination between controls and AD patients, effectively forcing controls to rely increasingly on familiarity as the time between study and test was increased. Results demonstrated a more liberal response bias for control subjects in the long delay condition relative to the short delay condition. This finding is relevant to our current student because the same logic can be applied to the effect of encoding. Deep encoding manipulations are more likely to produce recollection in controls than shallow encoding (which is likely to force reliance upon familiarity). Since recollection is reliant on the presence of detailed information, recognition judgments using recollection are less susceptible to manipulation. Conversely, familiarity judgments are made based on the level of evidence/strength of feeling experienced. The absence of group effects seen in the deep condition in our results could possibly result from the patients’ use of recollection. If control subjects were able to use recollection they would not be highly influenced by cue. If we predict that aMCI patients will not optimally incorporate the
cues then it would make sense that no difference of group was observed in the deep conditions. One way to avoid the confounding effect of response bias is to compare the deep performance of the patients with the shallow performance of controls. Observation of the graphs (see Figures 3 and 4) illustrating the shallow hits for controls and deep hits for patients shows data that strongly resemble those predicted by our hypothesis. This observation encourages the data to be reexamined with more subjects. In addition to increasing the power of the study, the incorporation of more impaired subjects, increasing the range of subject impairment from very mild to more moderate, may also yield a clearer pattern of results.

**Role of Memory Awareness**

In the group of patients participating in this initial study, the overall level of impairment was relatively mild. This fact is important when we consider the rationale for our hypothesis. If parietal lobe damage plays a role in false recognition, then this damage must be consistently present in our subjects for differences of group to be observed. It is clear from observing the patients’ results in the figures for correct rejections that some of the patients are using the cues at a high frequency. The rate of correct rejections in the deep (83%) and shallow condition (74.7%) was fairly high. In the shallow hit condition two patients recorded a zero for hit rate when the trial was preceded by a Likely New cue, indicating 100% cue compliance. It can be noted anecdotally that a few subjects remarked that they knew their memory performance was poor and made the conscious choice at some point during the experiment to agree with the cues. This suggests the
preservation of metamemorial ability within our patient group. Theories of metamemory rely on monitoring and introspection to modify behavior. Memory systems containing errors and distortions, such as those present in patients with AD and aMCI also rely on monitoring and introspection to modify behavior (Nelson 1996). Although memory is impaired early in the progression of AD, some hypothesize that metamemory is spared until more severe stages (Backman, Lipinska, 1993). A paradigm to test whether this preserved metamemory could be used to shift the response bias of patients with AD was constructed by Waring, Chong, Wolk, and Budson (2008). Their experiment evaluated controls and patients with AD in a recognition memory test in which participants were instructed that the test phase consisted of either 30% or 70% previously studied words. Mild AD patients were able to adjust their response bias to be considerably more conservative or more liberal respectively. If mild AD patients were able to shift their overall response bias based on the external information provided in the paradigm described above, it would support our finding that aMCI patients shifted their response bias when presented with Likely New cues. The question as to whether different patterns would emerge in more impaired patients on a similar paradigm has yet to be answered. Data from the debriefing questionnaire administered to subjects upon completion of the paradigm contains interesting results. Participants were asked for their perception on the hint accuracy, and asked to rank the usefulness of the hints. If the data of the two most impaired patients are removed, patients and controls report virtually the same perception of the hints: 71%, 75% for controls and 74%, 74% for patients in the deep and shallow conditions respectively. The two most impaired subjects reported 50% accuracy for both
conditions suggesting they disagreed with the cues more frequently than the rest of the subjects. In addition to perceiving the hints as less accurate, the most impaired subjects ranked the hints less useful and said they used them less frequently than the rest of the patients. While controls gave lower scores for use and usefulness in the deep condition, presumably due to their use of recollection in this condition, their scores for the shallow condition were nearly identical to those of the less impaired patients (both deep and shallow). These lower scores indicated the more impaired patients are less inclined to utilize the explicit memory cues. If metamemorial ability is preserved until later stages of the disease, then more impaired patients more show different results. Patients who can no longer use metamemory will presumably be unable to integrate cues based on self-awareness of a memory deficit.

Awareness of memory deficit may be crucial in whether or not patients retain the ability to shift response bias. In an imaging study with forty-two patients with aMCI individuals were assessed for awareness of their memory deficit (Nobili et al. 2010). Patients were separated into two groups matched for age, gender, education, and neuropsychological test scores, differing only in their awareness of memory deficit. Imaging data found significant areas of hypometabolism in both aMCI groups in regions of the posteromedial parietal cortex (compared to controls), including hypometabolism in both hemispheres of the IPL, with a more severe hypometabolic pattern in the “unaware” memory group (Nobili et al. 2010). Activity in the IPL has been found to correlate with shifting response bias (O’Connor et al. 2010).

*Further Study*
The first step of this work will be to increase the power of the current paradigm by enrolling more subjects. In addition, mild AD patients should also be included in the current paradigm given our hypothesis that with greater impairment there would be less ability to incorporate the cues.

Another important point is that when analyzing data from the current paradigm in the future, a non-linear regression may be incorporated. Our current ANCOVA model is based on a linear regression on the data, however a perfectly linear regression would only occur when baseline performance equaled cued performance. The effect of baseline on healthy subjects does not realistically follow a linear model; therefore a linear analysis of the data may not be able to determine all effects present.

Various aspects of a subject’s performance are often correlated with scores of neuropsychological tests associated with specific brain processes. In the Budson et al. paradigm, they attempted to correlate liberal response bias with measures of frontal lobe functioning. Similarly, neuropsychological measures sensitive to parietal lobe function can be used to determine whether a correlation exists between cue integration and a standard measure of parietal lobe function.

Incorporating electrophysiology into our current paradigm would also provide useful data. ERP data could determine whether the degree of parietal activity observed at cue onset was associated with different response biases, or with different patterns of cue integration.

**Conclusion**

Overall, a definite conclusion cannot be drawn from the current results. Statistical
analysis of the data suggest that there is no difference between our control and patient group in the way explicit memory cues effect decision criteria. Visual examination of data plots show interesting trends in support of our current hypothesis and encourages further study. While it is too early to disregard our original hypothesis the data suggest additional research may show aMCI patients can use explicit memory cues in a pattern different from both controls and parietal patients and patients with AD who are more impaired.

Understanding response bias is of theoretical importance in understanding memory dysfunction in AD. In addition, understanding how external information, such as the explicit memory cues used in this paradigm, are able to influence patients is of great clinical importance. To develop the most effective behavioral interventions, practitioners require a complete understanding of the how memory and decision making processes change as the disease progresses. Tailoring treatment strategies to target intact mechanisms can help patients to remain independent longer, and remove burden from caregivers, ultimately increased the quality of live for individuals with AD.
Table 1: Subject Demographics

<table>
<thead>
<tr>
<th>Test</th>
<th>Older Controls M (SD)</th>
<th>Patient Group M (SD)</th>
<th>F (1,18)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>76.2 (5.80)</td>
<td>79.2 (5.22)</td>
<td>2.61</td>
<td>ns</td>
</tr>
<tr>
<td>Years of Education</td>
<td>15.4 (2.37)</td>
<td>16.3 (3.97)</td>
<td>.215</td>
<td>ns</td>
</tr>
<tr>
<td>MMSE</td>
<td>29.1 (.738)</td>
<td>27.3 (2.45)</td>
<td>6.98</td>
<td>.017</td>
</tr>
<tr>
<td>CERAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td>22.5 (3.63)</td>
<td>14.6 (4.65)</td>
<td>20.7</td>
<td>.000</td>
</tr>
<tr>
<td>Delayed</td>
<td>7.5 (1.12)</td>
<td>3.8 (2.04)</td>
<td>24.4</td>
<td>.000</td>
</tr>
<tr>
<td>Recognition</td>
<td>9.6 (.699)</td>
<td>8.9 (1.10)</td>
<td>2.66</td>
<td>ns</td>
</tr>
<tr>
<td>Trails A</td>
<td>37.4 (14.4)</td>
<td>43.8 (19.6)</td>
<td>1.21</td>
<td>ns</td>
</tr>
<tr>
<td>Trails B</td>
<td>97.0 (38.1)</td>
<td>180.7 (107)</td>
<td>6.47</td>
<td>.021</td>
</tr>
<tr>
<td>FAS</td>
<td>49.1 (12.7)</td>
<td>34.6 (12.1)</td>
<td>6.50</td>
<td>.021</td>
</tr>
<tr>
<td>CAT</td>
<td>45.3 (8.15)</td>
<td>28.3 (14.7)</td>
<td>11.3</td>
<td>.004</td>
</tr>
<tr>
<td>BNT-15</td>
<td>14.6 (.966)</td>
<td>12.0 (2.79)</td>
<td>7.66</td>
<td>.013</td>
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Table 2a: Average Hit Rate

<table>
<thead>
<tr>
<th></th>
<th>Valid</th>
<th>Baseline</th>
<th>Invalid</th>
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<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Patients</td>
<td>Controls</td>
</tr>
<tr>
<td>Deep</td>
<td>.750</td>
<td>.713</td>
<td>.714</td>
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<tr>
<td>Shallow</td>
<td>.827</td>
<td>.708</td>
<td>.500</td>
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Table 2b: Average Correct Rejection Rate

<table>
<thead>
<tr>
<th></th>
<th>Valid</th>
<th>Baseline</th>
<th>Invalid</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Patients</td>
<td>Controls</td>
</tr>
<tr>
<td>Deep</td>
<td>.941</td>
<td>.833</td>
<td>.875</td>
</tr>
<tr>
<td>Shallow</td>
<td>.893</td>
<td>.747</td>
<td>.696</td>
</tr>
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</table>

Table 2c: Discrimination (Hit Rate-False Alarms Rate)

<table>
<thead>
<tr>
<th></th>
<th>Valid</th>
<th>Baseline</th>
<th>Invalid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Controls</td>
<td>Patients</td>
<td>Controls</td>
</tr>
<tr>
<td>Deep</td>
<td>.750</td>
<td>.611</td>
<td>.700</td>
</tr>
<tr>
<td>Shallow</td>
<td>.700</td>
<td>.588</td>
<td>.225</td>
</tr>
</tbody>
</table>
Table 3a. ANCOVA aMCI vs. Controls, Deep Encoding

<table>
<thead>
<tr>
<th>Hit Rates (Deep)</th>
<th>Cue Condition</th>
<th>IV</th>
<th>B</th>
<th>SE of B</th>
<th>T()</th>
<th>p=level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Likely Old</td>
<td>Baseline</td>
<td>.324</td>
<td>.224</td>
<td>1.45</td>
<td>.169</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>.179</td>
<td>.247</td>
<td>.726</td>
<td>.479</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>.248</td>
<td>.327</td>
<td>.757</td>
<td>.460</td>
</tr>
<tr>
<td>Invalid</td>
<td>Likely New</td>
<td>Baseline</td>
<td>.703</td>
<td>.249</td>
<td>2.82</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>-.228</td>
<td>.275</td>
<td>-.829</td>
<td>.420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>-.313</td>
<td>.364</td>
<td>-.859</td>
<td>.404</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correct Rejection Rates (Deep)</th>
<th></th>
<th>B</th>
<th>SE of B</th>
<th>T[]</th>
<th>p=level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invalid</td>
<td>Likely Old</td>
<td>Baseline</td>
<td>.450</td>
<td>.526</td>
<td>.855</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>.372</td>
<td>.523</td>
<td>.712</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>.273</td>
<td>.623</td>
<td>.438</td>
</tr>
<tr>
<td>Valid</td>
<td>Likely New</td>
<td>Baseline</td>
<td>.116</td>
<td>.160</td>
<td>.727</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>.063</td>
<td>.159</td>
<td>.396</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>-.035</td>
<td>.190</td>
<td>-.184</td>
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</table>

Table 3b. ANCOVA aMCI vs. Control, Shallow Encoding

<table>
<thead>
<tr>
<th>Hit Rates (Shallow)</th>
<th>Cue Condition</th>
<th>IV</th>
<th>B</th>
<th>SE of B</th>
<th>T()</th>
<th>p=level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Likely Old</td>
<td>Baseline</td>
<td>.176</td>
<td>.124</td>
<td>1.35</td>
<td>.197</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>-.250</td>
<td>.131</td>
<td>1.90</td>
<td>.077</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>-.569</td>
<td>.223</td>
<td>-2.55</td>
<td>.022</td>
</tr>
<tr>
<td>Invalid</td>
<td>Likely New</td>
<td>Baseline</td>
<td>.155</td>
<td>.375</td>
<td>.414</td>
<td>.685</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>-.271</td>
<td>.398</td>
<td>-.68</td>
<td>.506</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>-.738</td>
<td>.677</td>
<td>-1.09</td>
<td>.292</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Correct Rejection Rates (Shallow)</th>
<th></th>
<th>B</th>
<th>SE of B</th>
<th>T[]</th>
<th>p=level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invalid</td>
<td>Likely Old</td>
<td>Baseline</td>
<td>.980</td>
<td>.361</td>
<td>2.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>-.205</td>
<td>.299</td>
<td>-.686</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>-.544</td>
<td>.452</td>
<td>-.121</td>
</tr>
<tr>
<td>Valid</td>
<td>Likely New</td>
<td>Baseline</td>
<td>.091</td>
<td>.194</td>
<td>.468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group</td>
<td>.149</td>
<td>.160</td>
<td>.928</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b x g</td>
<td>.058</td>
<td>.242</td>
<td>.240</td>
</tr>
</tbody>
</table>
Figure Captions

Figure 1

The order of stimuli presented in the study phase is shown in 1a. Shallow encoding followed the same pattern as discussed in the methods section. Stimuli did not differ in presentation during the test phase for the two study conditions.

Figures 2-9

The validly cued trials are demonstrated using blue diamond shaped data points and invalid cued performance demonstrated using red square data points. If cues do not have an effect on subject performance it would then be expected that responses would fall along a diagonal line (y=x) because baseline performance would not differ from cued performance. A green dashed line is marked on the figures at y=x.
Figure 2:

Controls: Hit Rate, Deep

Cued Performance vs Baseline Performance

- Likely Old
- Likely New
Figure 3.

aMCI: Hit Rate, Deep

![Graph showing the relationship between baseline performance and queued performance for likely old and likely new cases.](image-url)
Figure 4.

Controls: Hit Rate, Shallow

![Graph showingcontrols hit rate and shallow performance](image)
Figure 5.

aMCI: Hit Rate, Shallow

![Chart showing aMCI: Hit Rate, Shallow with Likely Old and Likely New categories.](image-url)
Figure 6.

Controls: Correct Rejection Rate, Deep

![Graph showing the relationship between Baseline Performance and Cued Performance for Likely New (Valid) and Likely Old (Invalid) categories.](image-url)
aMCI: Correct Rejection Rate, Deep

Figure 7.
Controls: Correct Rejection Rate, Shallow
Figure 9.

**aMCI: Correct Rejection Rate, Shallow**

![Graph showing the relationship between baseline performance and cue performance for likely new and likely old items.](image-url)


Vita

KARA KLEBER

1986

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Tel: (412) 370-7622 ktkleber@gmail.com

EDUCATION:

Boston University School of Medicine – Division of Graduate Medical Sciences 2013
M.A. Anatomy & Neurobiology, GPA: 4.0/4.0
Masters Student Representative, Graduate Student Counsel (2012-2013)
Student Advisory Committee – Medical Histology (2012)

University of Pittsburgh 2009
B.S. Neuroscience, Chemistry Minor, Certificate: Conceptual Foundations of Medicine

RESEARCH EXPERIENCE:

Center for Translational Cognitive Neuroscience
Masters Thesis Research 2013
• Constructed a novel paradigm to examine parietal lobe function in Alzheimer’s disease
• Designed and piloted paradigm using EEG for the study of false recognition
• Collaborated on an ongoing project to determine if EEG patterns can be used as a biomarker for chronic traumatic encephalopathy and Alzheimer’s disease
• Increased personal knowledge of how medical practice informs translational research by working with clinicians in both clinical and research settings

Nyakahanga Hospital, Karagwe Tanzania
Ethnographic Research Fellowship 2008
• Executed original field research in a fully-funded anti-retroviral clinic focusing on barriers to treatment adherence faced by the local community
• Conducted extensive community interviews and observations
• Analyzed and presented data in a report titled “Access to Adherence, Anti-Retroviral Treatment Barriers at Nyakahanga Hospital”
• Volunteered within Nyakahanga hospital and on a mobile health clinic conducting health screenings for the local community

Children’s Hospital of Pittsburgh
Student Research Fellow 2006-2007
• Collaborated on cutting edge stem projects using stem cells for the treatment of Duchene muscular dystrophy.
• Developed skills with PCR, cell culture, immuno staining and FACS analysis
TEACHING EXPERIENCE:

Boston University School of Medicine
Teaching Fellowship
Clinical Application of Anatomy 2013
- Collaborated with clinicians to explain anatomy relevant to practitioners working with older adults
- Developed original lecture material for vertical integration of the anatomy curriculum into clinical medical education

Boston University School of Medicine
Tutor and Tutor Coordinator 2012-2013
Gross Anatomy, Medical Histology, Medical Neuroscience
- Advised medical and graduate students through individualized tutoring
- Assigned and supervised student and tutor relationships

Lab Instructor
Gross Anatomy 2012
- Conducted group teaching sessions and office hours for medical and graduate students
- Supervised class dissections, emphasized anatomical concepts relevant to clinical practice

Boston University School of Dental Medicine
Tutor Anatomy and Neuroscience

Boston University School of Graduate Medical Sciences
Teaching Assistant Biostatistics

University of Pittsburgh
Teaching Assistant 2008
Honors Introduction to Neuroscience

LEADERSHIP EXPERIENCE:

Harvard Family Van
Youth Outreach Coordinator 2012
Engaged in direct community outreach in Boston neighborhoods with high numbers of at risk youth
- Developed innovative programs to directly address the needs of youth clients
• Administered health screening and counseling services via mobile health clinic including blood pressure, glaucoma, cholesterol, blood sugar, and HIV testing

**PERSAD**
*After School Program Mentor* 2011
- Provided activities, mentorship, supervision, and tutoring for youth
- Directed outreach events designed to reach high risk populations

**Shadyside Academy**
*Varsity Lacrosse Coach* 2010-2011
- Planned and executed practice drills and scrimmages for 35 high school players
- Directed play during league competitions
- Assisted interested players with individual instruction and recruitment

**PRESENTATIONS:**

**American Association of Anatomists Conference** 2013
*Poster Accepted for presentation April 26th*
“Integrating Geriatrics with Anatomy: An educational collaboration between basic science and primary care.”

**Boston University Medical Center** 2012
*Geriatricians Grand Rounds: Invited Speaker*
“Aging Anatomy: Focus on Swallowing and the Pelvic Floor”

**Children’s Hospital of Pittsburgh** 2006/2007
*Student Research Conference*
“Development of Hematopoietic and Endothelial cells from Human Stem Cells in Chick Embryos”
“In vitro Myogenesis of Human Fetal Placenta Blood Vessel Derived Cells “

**WORK EXPERIENCE:**

**Guardian Angel Ambulance Service**
*Emergency Medical Technician* 2009-2011
- Emergency response for Verona, Resolve Crisis Center, Allegheny County Jail, and nursing homes in Pittsburgh
- Collaborated with paramedics, and clinicians on advanced transports and advanced life support emergencies
- Compiled reports to receiving facility and maintained documentation of all trips

**MEMBERSHIP TO PROFESSIONAL ORGANIZATIONS**

**American Association of Anatomists**
2013

**Charles River Association for Memory**
2012 - 2013