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THE EFFECT OF INCREASED MEMORY CUE DURATION ON DIRECTED FORGETTING PERFORMANCE IN HEALTHY AGING

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ABSTRACT

Although forgetting is usually seen as a memory error, forgetting can actually be an adaptive strategy to manage information in a changing world. A lot of information is important to remember temporarily, such as a parking space at the supermarket, or a dosage of medication. However, later remembering of such outdated information detracts from valuable cognitive resources. Therefore, the brain has cognitive mechanisms in place to expunge once-important information that is now irrelevant, a process called directed forgetting. However, many cognitive control processes, such as directed forgetting, decline with age. To investigate this phenomenon, typical directed forgetting paradigms examine memory for items associated with a memory cue, a signal that instructs participants to either 'remember' or 'forget' an item. Success in this paradigm is indicated through memory compliance – participants later recollect items that were previously associated with a 'remember' cue and forget items associated with a 'forget' cue. Previous research indicates that manipulating the memory cue may enhance the differential encoding and inhibition mechanisms, which contribute to successful memory compliance, in both young (18-30 years) and, more importantly, older (60-85 years) adults. Thus, this study examines the impact of increasing memory cue duration (one, three, and five seconds) on young adult and older adult participants' memory compliance using an item-method directed forgetting paradigm. The eventual goal is to discover strategies that can be employed to enhance memory and cognitive control in aging, compensating for typical age-related cognitive declines. Results indicate that increased processing time improves directed forgetting performance in both young and older populations. Although no significant age-related deficits in directed forgetting were observed between the two age groups (young and older adults), subsequent analyses revealed a significant relationship between older adults' level of cognitive functioning and directed forgetting performance. Furthermore, the expected age-related directed forgetting deficit also emerged in these analyses. In conclusion, this project indicates the importance of characterizing older adults' individual differences in cognitive aging research. In order to elucidate what can be done to preserve cognitive functioning in healthy aging, it is important to investigate why certain populations of older adults do not display expected age-related memory deficits.

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Introduction

We have all experienced the frustration of committing a memory error. At some point, we have likely misplaced our keys, forgotten where we parked our cars, or forgotten the name of a person to whom we had just been introduced. In all these cases, we typically think of forgetting as the culprit. Although incidental, unintentional forgetting is sometimes the explanation behind these errors, the more common explanation is a failure to update memory. Perhaps we misplaced the keys because they were left in a jacket pocket, instead of on their usual hook near the door; we walked to a parking space used the day previously; or we accidentally called a friend's new boyfriend by the former boyfriend's name. If so, then controlled, intentional forgetting of outdated, irrelevant information would have facilitated the updating of memory with current information, and would have prevented those memory errors from occurring.

Although forgetting is typically viewed as an error of memory, intentional forgetting is actually an adaptive, highly prevalent cognitive mechanism to manage constantly changing information in the environment. It is wasteful, sometimes even harmful, to remember outdated information. Therefore, the brain has cognitive mechanisms in place to expunge irrelevant information and to increase the space and resources devoted to maintaining relevant information (Bjork, 1978). This phenomenon, historically referred to as positive, voluntary, motivated, and intentional forgetting (MacLeod, 1998), can be studied in a laboratory setting using an experimental paradigm known as directed forgetting (Bjork, 1972).

Although there have been many variations of this paradigm (see MacLeod, 1998 for a historical overview), the basic premise is to present participants with stimuli associated with memory cues, which instruct the participants to remember certain stimuli and forget others. However, participants are ultimately asked to attempt to remember *all* of the stimuli, regardless of items' memory cue associations (Basden & Basden, 1996; Bjork, 1970; Bjork, 1972; Bjork & Woodward, 1973; Woodward, Bjork, & Jongeward, 1973; see Johnson, 1994 for a review). Based on participants' memory for items designated as to-be-remembered (TBR) and to-be-forgotten (TBF), researchers can thereby gauge participants' success in expunging irrelevant material (TBF stimuli) from and maintaining relevant material (TBR stimuli) in memory. Typically, participants exhibit a ‘directed forgetting effect’: they are able to successfully remember more TBR items and forget more TBF items, indicating intentional remembering and intentional forgetting, respectively (MacLeod, 1998).

Of the many variations of the directed forgetting paradigm (see Johnson, 1994 for a review), the most prevalent and best understood is item-method directed forgetting, in which participants are presented stimuli one-at-a-time, and each stimulus is associated with a randomly ordered memory cue designating it as either TBR or TBF. Many researchers, including Basden and Basden (1996), Bjork and Woodward (1973), and Woodward et al. (1973) describe the item-method directed forgetting paradigm and provide a coherent theory identifying two crucial mechanisms underlying the resulting directed forgetting effect: differential encoding of TBR and TBF items, and set differentiation between TBR and TBF items. When participants are initially presented an item, they do not know whether the subsequent cue will instruct them to remember of forget it. Therefore, they encode it very shallowly, through rote rehearsal, until subsequent presentation of the memory cue (Woodward et al., 1973). At this point, either more elaborative rehearsal of TBR items is executed, or participants cease to rehearse TBF items entirely. This selective rehearsal leads to differential encoding of TBR and TBF items in working memory, which then contributes to set differentiation between TBR and TBF items. Set differentiation reciprocally contributes to selective rehearsal, ultimately resulting in the directed forgetting effect by differentially increasing the accessibility of TBR items, compared to TBF items, through more extensive rehearsal.

However, the previous theorists’ focus on TBR item maintenance paints an incomplete picture of the directed forgetting mechanism. Hasher and Zacks (1988) further contributed to the understanding of the item-method directed forgetting effect through their theory of attentional inhibition and the inhibition deficit of cognitive aging (elaborated in Hasher, Zacks, & May, 1999; Lustig, Hasher, & Zacks, 2007; Zacks & Hasher, 1994). According to this theory, working memory operates best when it contains only the most relevant and important information in a given situation. Therefore, for working memory, the idea that ‘less is more’ applies – limiting the information in working memory by importance allows faster, more efficient retrieval of only relevant information (Hasher et al. 1999). In order to discriminate between relevant and irrelevant information, one of two mechanisms of selective attention might be employed when encountering novel material to be stored in working memory: activation or inhibition. Activation, synonymous with processes of selective rehearsal and differential encoding described earlier, causes goal-relevant information to be maintained in working memory through elaborative rehearsal. Inhibition, on the other hand, suppresses the activation of goal-irrelevant information. In this manner, cognitive resources are not wasted on maintaining irrelevant information in working memory. This conceptualization further defines inhibition as having three major functions: (1) inhibition of access, to prevent the activation of goal-irrelevant stimuli, (2) deletion, to suppress outdated information that was permitted into working memory at some point, but is no longer relevant, and (3) restraint, which prevents the prepotent response, allowing consideration of other options (Hasher et al., 1999, Lustig et al., 2007).

It is easy to see how this theory of inhibitory control applies to and extends the understanding of directed forgetting. Intentional remembering of TBR items and intentional forgetting of TBF items are achieved through separate processes of differential encoding and attentional inhibition. Both TBR and TBF items are allowed to enter working memory on a very shallow level, maintained through rote rehearsal until the presentation of a memory cue (Woodward et al., 1973). Following the presentation of a ‘remember’ memory cue, participants continue rote rehearsal, or perhaps engage in deeper encoding strategies. They thereby maintain TBR items in working memory through more elaborative rehearsal, resulting in differential encoding of TBR items over TBF items, as discussed earlier. On the other hand, following the presentation of ‘forget’ memory cue, inhibition suppresses the preceding item’s representation in working memory through the deletion function. Therefore, participants limit working memory stores to relevant information through the inhibition of irrelevant TBF items (Hasher et al., 1999; Lustig et al., 2007). Both of these mechanisms work in unison to produce the directed forgetting effect.

However, there is another focal part of Hasher and Zacks’ (1988) inhibitory framework that has yet to be discussed (further extended in Hasher et al., 1999, Lustig et al., 2007, Zacks & Hasher 1994). In addition to contributing the attentional inhibition mechanism to the overall explanation for the directed forgetting effect, they also proposed the inhibition deficit theory of cognitive aging. This theory postulates that age-related declines in cognition are ultimately caused by deficient attentional inhibition mechanisms in older adults. They state that older adults are less able to inhibit goal-irrelevant information, resulting in cluttering of working memory with "off-goal path" information. Not only is irrelevant information allowed to enter working memory, but it also receives maintenance in working memory, further detracting from resources typically used to maintain "goal-path" information. Therefore, according to the inhibition deficit theory of cognitive aging, generalized cognitive decline occurs in aging because of inefficient allocation of cognitive resources. The maintenance of important information is deficient due to inappropriate attention to outdated or unimportant information.

This misplaced allocation of cognitive resources has several predictable implications for older adults' directed forgetting performance. In directed forgetting studies, older adults consistently exhibit inhibitory deficits in several ways. Typically, (1) they retrieve fewer items from memory than young adults, (2) they produce more TBF intrusions during retrieval, and (3) the disparity between the percentage of TBR and TBF items retrieved is less than that of young adults (Andrés, Van der Linden, & Parmentier, 2004; Collette, Germain, Hogge, & Van der Linden, 2009; Dulaney, Marks, & Link, 2004; Earles & Kersten, 2002; Feyereisen & Charlot, 2008 Deletion Function (2); Gamboz & Russo, 2002; Hasher et al., 1999; Hogge, Adam, & Collette, 2008; Lustig et al., 2007; Sego, Golding, & Gottlob, 2005; Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996; for meta-analysis, see Titz & Verhaeghen, 2010). According to Hasher and Zacks' (1988) model of inhibition deficit in aging, older adults (1) retrieve fewer items from memory because it is cluttered, reducing all items' accessibility; and (2) produce more TBF intrusions because their impaired inhibitory mechanism cannot expunge irrelevant items from working memory after they have been shallowly encoded. Mathematically, the decrease in TBR item retrieval and increase in TBF item retrieval results in (3) the parity between the percentage of TBR and TBF items retrieved by older adults.

In light of the ubiquitous importance of updating memory, the contribution directed forgetting makes to this cognitive function, and older adults' fundamental directed forgetting deficit, elucidating environmentally valid strategies to enhance directed forgetting could benefit the older adult population as a whole. One potentially effective strategy for improving directed forgetting performance might be to increase processing time (Bancroft, Hockley, & Farquhar, 2012; Fawcett & Taylor, 2008; Hogge et al., 2008). Salthouse (1996) describes and substantiates a theory of cognitive aging that identifies older adults' slowed processing speed (compared to young adults') as a general, widespread deficit ultimately underlying all other observed cognitive deficits. According to this theory of cognitive aging, older adults' slower processing speed prevents them from efficiently executing cognitive operations. In other words, they cannot complete a given task effectively because the cognitive processes contributing to task performance cannot be completed in a given interval. However, increasing time devoted to this task may allow older adults to complete the underlying processes, even with processing speed impairments (Salthouse, 1996; Salthouse, 2000).

By this reasoning, older adults' deficits in directed forgetting performance are likely due to their inability to complete processes of differential encoding and inhibition. When they are presented with the memory cue for an item they have been holding in working memory, older adults have the duration of that cue, before the presentation of a new word, to either selectively, elaboratively rehearse TBR items or inhibit TBF items. If they cannot complete these processes, the lack of delineation between TBR and TBF items precludes the achievement of set differentiation, resulting in older adults' characteristic directed forgetting deficits described above. Therefore, increasing the time provided to older adults to complete differential encoding and inhibitory processes undertaken in response to a memory cue instruction may render these processes more efficient. This premise forms the basis for the current study.

Previous investigations have indicated that increasing processing time might facilitate directed forgetting in the general population, but most have only examined this effect in young adults. Fawcett and Taylor (2008) employed an item-method directed forgetting paradigm and found that post-item reaction time probes for TBF items were longer than those for TBR items. This supports Hasher and Zacks (1988) view of inhibition as an active, effortful cognitive process. If older adults' limited processing speed impairs inhibition of TBF items, then providing more time for the inhibitory process of deletion should result in better exclusion of TBF items from working memory and, therefore, fewer TBF intrusions. In addition, Bancroft et al. (2012) demonstrated that increasing memory cue duration resulted in greater recollection of both TBR and TBF items. The increase in recollection of TBR items with longer memory cue durations is a positive indication for the benefit that increased cue duration may confer to differential encoding processes in older adults. Finally, Hogge et al. (2008) provide the first clue indicating increased processing time as a potential strategy to enhance directed forgetting in older adults. These researchers explored aging, directed forgetting, and other cognitive processes thought to contribute to directed forgetting (i.e., short-term memory capacity, thought suppression, proactive interference, and processing speed). Results indicated that older adults' impaired processing speed might be responsible for their decreased recall of TBR items in this particular study. Therefore, increasing processing time may allow older adults to compensate for this type of age-related directed forgetting deficit.

Although Dulaney et al. (2004) conducted a study examining the effects of increased memory cue duration on directed forgetting in young and older adults, their results were largely inconclusive due to methodological concerns. Specifically, they observed an age-related directed forgetting deficit in recognition memory, but not in recall; they failed to find a directed forgetting effect in either young or older adults at 5000 msec; and they found that the use of deep semantic processing as an encoding aid produced better memory at 1500 and 500 msec, but not at 3000 msec. This confusing pattern of results may be due to the simultaneous manipulation of two independent variables (semantic/non-semantic processing of stimuli and memory cue duration of 1500/3000/5000 msec), which produced indistinguishable and interacting effects. It is impossible to tell if the observed effects were due to the varying memory cue durations or the levels of processing manipulation. Furthermore, trials of the three memory cue durations were presented to participants in random order. Because participants could not predict how much processing time they had for any trial, it was impossible to develop and employ strategies to effectively use the longer time durations to enhance mechanisms of differential encoding and attentional inhibition. The current study addresses these methodological issues and presents a more conclusive conceptualization of how increased processing time affects age-related deficits in item-method directed forgetting. Taken together, the four previously described studies provide a good basis from which to form hypotheses regarding older adults' directed forgetting performance with increased memory cue durations.

The current study was designed to compare young and older adults' directed forgetting performance amongst three memory cue duration conditions: one, three, or five seconds in length. We predict that both young and older adults' directed forgetting effects will improve from increased memory cue duration. We also predict that older adults will exhibit an age-related deficit in directed forgetting (compared to young adults) at the shorter time intervals, and that the increase in memory cue duration will enhance older adults' directed forgetting performance.

Methods

Participants

Thirty young adults and thirty-three older adults participated in the study. Young adults were undergraduates at the Pennsylvania State University, between the ages of 18 and 23 (*M* = 19.13 years, *SD* = 1.41 years; 25 female). Older adults were Centre County community members between the ages of 61 and 80 years (*M* = 69.47 years, *SD* = 5.14 years; 21 female). Young adults received class credit for their participation, while older adults were monetarily compensated. All participants provided informed consent, approved by the Pennsylvania State University Institutional Review Board, for the behavioral testing of human participants.

Cognitive Assessment

Participants completed several cognitive assessment measures to ensure levels of cognitive functioning within a typical range, with no indications of depression. These measures included: the Mini-Mental State Examination (Folstein, Robins, & Helzer, 1983); sections of the Wechsler Adult Intelligence Scale (WAIS-IV) and Wechsler Memory Scale (WMS-IV), including Symbol Search, Digit-Symbol Coding, Symbol Copy, Digit Span, Arithmetic, Letter-Number Sequencing, and Vocabulary (Wechsler, 2008); and either the Beck Depression Inventory (BDI-II) (Beck, Steer, Ball, & Ranieri, 1996), or the Geriatric Depression Scale (GDS) (Sheikh & Yesavage, 1986). WAIS-IV raw scores were scaled to standardized scores based on age at time of assessment. Three older adults were excluded from analysis due to: (1) a failure to use all response options, (2) a high GDS score indicating possible depression, and (3) an error in recording retrieval data from MATLAB.

Design

The current study is a 2 (age: young adult, older adult) X 3 (cue duration: 1 second, 3 seconds, 5 seconds) between-subjects experimental design. Participants completed a typical item-method directed forgetting paradigm (Basden & Basden, 1996), with words as stimuli.

Materials

The stimuli consisted of 364 words, taken from using the MRC Psycholinguistic Database (Coltheart, 1981). The stimuli had a mean Kučera-Francis (1967) written frequency of 108.65 (*SD* = 56.41), and a mean word concreteness rating (Gilhooly & Logie, 1980; Spreen & Schulz, 1966) of 420.49 (*SD* = 101.73). 240 words were used in the encoding portion, which was divided into 3 separate parts. Each part contained 2 blocks of 40 words each. An additional 120 items were added in the final memory test as lures. These resulting 360 items were presenting at retrieval in 5 blocks of 72 words each. The remaining 4 words were used to practice the task prior to beginning encoding.

Participants completed the task on a computer, using a script coded in MATLAB R2009B. Results output to Microsoft Excel, where preliminary graphing and analyses were completed, followed by a more comprehensive statistical analysis using IBM SPSS Statistics Software.

Procedure

Encoding

Refer to Figure 1, in Appendix A, for pictorial representation of the encoding paradigm. In the encoding task, participants were presented with a series of words, displayed one-at-a-time on the computer screen for 1000 msec each. Each word was followed by a brief 2000 msec delay, during which a white fixation cross was presented. Subsequently, a row of colored pound signs appeared on the screen, instructing participants whether they should forget the previous word, or remember the word for a memory test later in the study. TBR items were followed by a row of green pound signs, while TBF items were followed by a row of red pound signs. To ensure that participants were attending to stimulus presentation on the screen, they were instructed to indicate whether each word contained the letter ‘A’, or not. They had the entire trial duration to make this judgment, up until the memory cue disappeared from the screen. A 2000 msec inter-trial interval preceded the next item, during which a blue fixation cross appeared on the screen.

Encoding consisted of three separate portions, each corresponding with a different duration of memory cue: one second (1000 msec), three seconds (3000 msec), or five seconds (5000 msec). Each encoding portion contained two blocks of 40 items. Per encoding portion, 40 TBR and 40 TBF items were presented, a total of 120 TBR and 120 TBF words for the entire encoding portion of the study. The order in which the three encoding portions were presented was randomly counterbalanced across participants.

Retrieval

Refer to Figure 2, in Appendix A, for pictorial representation of the retrieval paradigm. Following a ten-minute interference task [Arithmetic Test (Wechsler, 2008) for young adults, or Matrix Reasoning (Wechsler, 2008) for older adults], participants completed a retrieval task for the words they had previously studied. However, participants were instructed to try to remember ALL items, regardless of whether they had been associated with a remember or a forget memory instruction. All 240 items from encoding, plus an additional 120 lures, were presented one-at-a-time for 2500 msec each. Participants responded with one of three memory responses for each word: remember, know, or new. A ‘remember’ response indicated that a participant had a detailed, specific memory for the word. For instance, he/she might remember what the word made him/her think or feel during encoding. This memory response indicated a strong recollection of the word. The second option, ‘know’, was used for a word that seemed familiar, but lacked the detailed, specific traces of a ‘remembered’ item. This response indicated familiarity. The last option, ‘new,’ was used to indicate a word that participants believed was new and did not appear during encoding. Following retrieval, participants completed a form providing feedback on their effort and attentiveness during the task. They also reported any suspicion they might have had at encoding that they were being deceived. Finally, the researchers debriefed participants and answered any questions regarding the study.

Results

Data analyses from the task indicated the effects of memory cue duration on directed forgetting performance within each age group. Subsequently, the interactions between age and memory cue duration were examined.

Directed forgetting performance is defined in terms of the Remember Effect (R-Effect) and the Forgetting Effect (F-Effect). The R-Effect is a quantitative description of differential encoding processes, obtained by subtracting the number of items incidentally recollected from the number of items intentionally recollected (R-Effect = TBR_R – TBF_R). The F-Effect is a quantitative description of inhibitory processes, computed by subtracting the number of incidentally forgotten items from the number of intentionally forgotten items (F-Effect = TBF_F – TBR_F). Individual R-Effects and F-Effects were calculated for each of the three cue durations, thereby indicating memory compliance for the remember and forget instructions for each condition of the independent variable. Please see Table 1, in Appendix A, for the means and standard deviations of R-Effect and F-Effect values at each cue duration and within each experimental group.

Results were computed using IBM SPSS Statistics by performing repeated-measures analyses of variance (ANOVAs), either within- or between-subjects, as appropriate.

Young Adult Within-Subjects Analysis

Analyses indicated that young adults' differential encoding processes improved with increased memory cue duration. Young adults displayed a significant interaction amongst the three cue durations ($F(2,58) = 10.94$, $p < .0001$). Subsequent t-tests, the results of which are depicted in Figure 3 in Appendix A, showed that they were able to improve their R-Effect from the one-second ($M = .07$, $SD = .16$) to the three-second ($M = .17$, $SD = .15$) memory cue duration ($t(29) = 3.83$, $p = .001$), and from the one-second to the five-second ($M = .18$, $SD = .17$) cue duration ($t(29) = 4.53$, $p < .0001$). However, they displayed no improvement with the increased cue duration from three to five seconds.

With respect to the F-Effect, analyses indicated a significant interaction amongst the three cue durations ($F(2,58) = 3.20$, $p < .05$). Subsequent t-tests indicated that young adults were able to significantly improve their directed forgetting performance from the one-second ($M = .07$, $SD = .13$) to the five-second ($M = .13$, $SD = .11$) cue duration ($t(29) = 2.52$, $p < .02$). However, this improvement was not observed at the intermediate three-second duration ($M = .10$, $SD = .11$). Therefore, young adults' directed forgetting performance indicated improved inhibition with longer cue durations.

Overall, young adults displayed an improvement in directed forgetting performance as a result of increased cue duration, significantly improving R-Effect from one second to three seconds and one second to five seconds, and the F-Effect from one second to five seconds.

Older Adult Within-Subjects Analysis

Older adults, like young adults, improved their directed forgetting performance with increased memory cue durations. Analyses of the R-Effect in the three cue durations indicated a significant interaction amongst the three conditions ($F(2,58) = 12.30$, $p < .001$). T-test results, depicted in Figure 4 in Appendix A, indicated that the value of the R-Effect significantly increased from one second ($M = .05$, $SD = .14$) to three seconds ($M = .13$, $SD = .14$), $t(29) = 2.81$, $p < .0001$; from one second to five seconds ($M = .18$, $SD = .18$), $t(29) = 4.67$, $p < .0001$; and from thee seconds to five seconds, $t(29) = 2.27$, $p < .04$. At each increase in cue duration, older adults were able to utilize the additional time to improve differential encoding.

Unlike young adults, however, older adults were not able to utilize increased cue duration to enhance inhibition mechanisms for intentional forgetting. Data analyses revealed no significant interaction in the F-Effect amongst the three memory cue durations ($F(2,58) = 1.93$, $p > .05$). Therefore, older adults were not able to improve inhibitory mechanisms, despite increased time.

Young Adult vs. Older Adult Between-Subjects Analysis

Typically, older adults, compared to young adults, display an age-related, generalized deficit in memory and cognitive control tasks. However, the results of 2 (age: young/older) X 3 (cue duration: 1/3/5 seconds) between-subjects repeated measures ANOVAs revealed no significant age-related differences in either the R-Effect ($F(2,116) = .95$, $p > .05$) or the F-Effect ($F(2,116) = .06$, $p > .05$), depicted in Figure 5 in Appendix A. Although age-related cognitive deficits are ubiquitous and well documented, it is important to consider the possible contribution of participants' individual differences. Therefore, median split analyses were performed to assess how individual differences in cognitive functioning might have impacted directed forgetting performance.

Median Split Within-Subjects Analyses

Prior to completing the study, all participants were assessed to ensure normal levels of cognitive functioning using various cognitive assessment measures (as described in Methods). A composite score was obtained for each participant by averaging the scaled scores from these assessment measures. Subsequently, participants were split around the median of these z-scores of cognitive functioning into two groups of higher- and lower- cognitive functioning individuals; for these median values, see Table 2 in Appendix A.

Within-group analyses were conducted to determine if older adults' level of cognitive functioning was related to their directed forgetting performance. Lower-functioning older adults displayed no significant interactions amongst the three memory cue durations in either the R-Effect ($F(2,28) = 2.69$, $p > .05$) or the F-Effect ($F(2,28) = .06$, $p > .10$), as depicted in Figure 6 in Appendix A. Therefore, lower-functioning older adults were unable to use increased processing time to improve either differential encoding or inhibition processes.

On the other hand, higher-functioning older adults benefitted greatly from increased cue duration, showing a significant interaction amongst the three cue durations for both the R-Effect ($F(2,28) = 26.25$, $p < .001$) and the F-Effect ($F(2,28) = 4.55$, $p < .05$). Subsequent t-tests, the results of which are displayed in Figure 7 in Appendix A, indicated that higher-functioning older adults improved their R-Effect from one second (*M* = .09, *SD* = .17) to five seconds (*M* = .29, *SD* = .14), t(14) = 6.71, $p < .0001$; and from three seconds (*M* = .15, *SD* = .17) to five seconds, t(14) = 6.10, $p < .0001$, corresponding to the pattern of improvement in R-Effect seen in the overall adult group. In addition, the higher-functioning older adults also showed robust improvement in the F-Effect following the same pattern as the R-Effect; t-test results indicated improvement from one second (*M* = .08, *SD* = .16) to five seconds (*M* = .18, *SD* = .14), t(14) = 2.79, $p < .05$; and from thee seconds (*M* = .11, *SD* = .14) to five seconds, t(14) = 2.35, $p < .05$. This effect is particularly interesting because no significant effects of cue duration on the F-Effect were found in the overall older adult group.

For completeness, the same median split analyses were conducted with the young adult participants. As expected, they did not display a significant difference in directed forgetting performance based on level of cognitive functioning in either the R-Effect ($F(2, 52) = .14$, $p > .05$) or the F-Effect ($F(2,52) = .32$, $p > .05$).

Median Split Between-Subjects Analyses

Older adults' level of cognitive functioning was significantly related to their directed forgetting performance, showing that individual differences in cognitive functioning, a variable completely unrelated to task performance, had a significant relationship with task performance. The results of the between-subjects analyses among young adults, higher-functioning older adults, and lower-functioning older adults are depicted in Figure 8 in Appendix A. To determine if significant differences exist between these two groups, 2 (higher-functioning older, lower-functioning older) X 3 (cue duration: 1/3/5 seconds) between-subjects repeated measures ANOVAs were conducted, which indicated a significant interaction, amongst the three cue durations, between level of cognitive functioning and directed forgetting performance in the R-Effect ($F(2,56) = 7.14$, $p < .01$). Subsequent independent samples t-tests indicated a significant difference in the R-Effect at five seconds between higher-functioning (*M* = .29, *SD* = .14) and lower-functioning (*M* = .07, *SD* = .12) older adults, t(28) = 4.43, $p < .001$. Although the F-Effect ANOVA reported no significant interactions amongst the three cue durations between level of cognitive functioning and directed forgetting performance (*F*(2,56) = 2.67, $p > .05$), subsequent paired t-tests revealed a significant difference, in the five-second cue duration, in directed forgetting performance between higher-functioning (*M* = .18, *SD* = .14) and lower-functioning (M = .07, *SD* = .12) older adults, t(28) = 2.35, $p < .05$.

Subsequently, the higher- and lower- functioning older adult groups from the median split were compared to the young adult group using 3(young, higher-functioning older, lower-functioning older) X 3(cue duration: 1/3/5 seconds) between-subjects repeated measures ANOVAs, which determined if any age-related differences arose following the median split. Results indicated a significant interaction between participant age/level of cognitive functioning and memory cue duration in the R-Effect (*F*(4,114) = 3.91, $p < .01$). Thus, directed forgetting performance in terms of differential encoding is significantly related to participant age and, for older adults, level of cognitive functioning. Independent samples t-tests indicated that significant differences between the three groups emerge within the five-second memory cue duration. Higher-functioning older adults (*M* = .29, *SD* = .14) had a significantly higher R-Effect than young adults (*M* = .13, *SD* = .11) in the five-second condition, t(43) = 2.29, $p < .05$. Therefore, higher-functioning older adults were able to improve differential encoding, at five seconds, to a greater degree than even young adults. In contrast, lower-functioning older adults (*M* = .07, SD = .14) have a significantly lower R-Effect than young adults with a memory cue duration of five seconds, t(43) = 2.09, $p < .05$. Therefore, lower-functioning older adults displayed the expected age-related deficit, and were not able to use the additional time at encoding to improve differential encoding mechanisms to the young adult level.

Discussion

The current study indicates four major conclusions. First, increased processing time can benefit differential encoding processes for both young and older adults, which will be discussed in the context of Salthouse's (1996) processing speed theory of age-related cognitive deficits. Second, while young adults were able to enhance attentional inhibition with increased processing time, older adults displayed no significant differences in the F-Effect among any of the cue durations. The finding that young adults can benefit from increased processing time for both differential encoding and inhibition, but older adults are unable to reap the same inhibitory benefit, indicates an age-related change. This change implicates an inherent inability for older adults to improve intentional forgetting, which will be considered with respect to Hasher and Zacks' (1988) inhibition deficit theory of cognitive aging. Third, between-subjects analyses indicated the absence of an age-related deficit in the directed forgetting effect at all cue durations. Due to its inconsistency with previous literature, the lack of an age difference was further characterized through median split analyses based on level of cognitive functioning. Results indicated that higher-functioning older adults showed significantly greater performance in the directed forgetting paradigm compared to the lower-functioning group. Specifically, the higher-functioning group exhibited a significantly better directed forgetting effect, in both the R-Effect and the F- Effect, in the five-second condition. This finding demonstrates the importance of considering individual differences and variability in cognitive aging research (Anstey & Christensen, 2000; Christensen, 2001; Christensen, Mackinnon, Jorm, Henderson, Scott, & Korten, 1994; Christensen, Mackinnon, Korten, Jorm, Henderson, Jacomb, & Rodgers, 1999; Morse, 1993; Nelson & Dannefer, 1992; Shammi, Bosman, & Stuss, 1998). Finally, within-subject analyses of the higher- and lower-functioning older adult groups revealed that lower-functioning older adults were unable to utilize longer cue durations to improve their directed forgetting effect, in terms of both differential encoding and intentional forgetting. However, higher-performing older adults *were* significantly able to utilize additional time to improve *both* differential encoding and attentional inhibition processes. These results further contribute to the discussion of the importance of considering individual differences and variability in cognitive aging research. These conclusions are further elaborated below.

Increased Cue Duration and Differential Encoding in Young and Older Adults

Young adults showed significant R-Effect improvement between the one-second and the three-second memory cue duration, as well as between the one-second and the five-second duration. These results indicate that, generally speaking, the increased processing time offered by longer memory cue durations benefitted young adults' differential encoding processes. At three and five seconds, compared to one second, young adults were better able to intentionally encode items associated with a remember cue, over incidental recollection of items associated with a forget cue. However, this improvement in differential encoding with increased time seemed to level off after the three-second duration, with no memory benefit conveyed with the increased increment of time from three to five seconds. Therefore, we must consider whether or not differential encoding success is directly related to processing time. In other words, it may not be possible for young adults to continuously improve their R-Effect with even more time; rather, they may reach a ceiling past which they cannot improve. Our data suggest that increased processing time only benefits young adults' differential encoding mechanisms up to a certain point.

Similar to young adults, older adults' directed forgetting performance benefitted from increased memory cue duration; however, they displayed a different pattern of significance than young adults, a fact that may help elucidate age-related cognitive changes. Older adults' differential encoding continually benefitted from increased increments of time from one to five seconds. Their R-Effect values significantly increased from one second to three seconds, one second to five seconds, and three seconds to five seconds. Thus, unlike young adults, older adults' differential encoding processes garnered a significant benefit at every interval of increased cue duration.

Young and older adults' differing patterns of differential encoding enhancement in response to increased processing time indicate a relationship between processing speed and task-specific cognitive demands. Salthouse (1996) posited that an inevitable reduction in processing speed is the fundamental deficit underlying age-related cognitive decline. Logically, this reduction in processing speed impairs performance by preventing task completion under limited time conditions. As a result, older adults can only access incomplete, partially processed information, a limitation that manifests as cognitive deficits in a variety of tasks.

This idea formed the basis of the current investigation: if older adults directed forgetting performance shows an age-related decline because they are unable to complete differential encoding and attentional inhibition processes within the given task framework, providing more processing time within the task should allow for complete execution of these processes. Older adults' continual improvement in differential encoding across all cue conditions corroborates this reasoning. At each interval, their performance improved because they were able to more fully execute differential encoding processes. Therefore, older adults' R-Effect performance should continue to improve until an optimal cue duration is reached, at which point differential encoding and attentional inhibition processes are being executed completely. It may be possible that this optimal duration is not five seconds, and that older adults' differential encoding would continue to improve with even longer cue durations.

On the other hand, young adults' R-Effect improvement levels off at three seconds. This ceiling likely occurs because young adults are able to fully complete the requisite cognitive processes underlying differential encoding within three seconds, since they have not yet experienced the age-related decline in processing speed (Salthouse, 1996). Therefore, further increasing processing time to five seconds or beyond would confer no additional R-Effect enhancement to a process that is already complete.

Increased Cue Duration and Attentional Inhibition in Young and Older Adults

Although increased processing time conferred a directed forgetting benefit to differential encoding for both young and older adults, only young adults' F-Effect showed significant improvement as a result of manipulating the duration of the memory cue. Therefore, the increased processing time between one and five seconds conferred a significant benefit to only young adults' attentional inhibition mechanisms. In addition, no ceiling was apparent in regards to the F-Effect; therefore, it is possible that young adults' inhibitory mechanisms could further benefit from cue durations exceeding five seconds.

Based on this result, we can conclude that inhibitory processes seem to operate within a different time window than differential encoding. While differential encoding seems to be a finite cognitive process that is completed within three seconds for young adults, inhibition seems to be more of an ongoing, consistent process of suppression. From one to five seconds, more time was afforded for intentional forgetting. As a result, young adults were able to forget more TBF items, suggesting that these items became less accessible in working memory as the duration of inhibition increased. Consistent with this interpretation, these data suggest, more generally, that the longer information is suppressed in memory, the less accessible it becomes.

Contrastingly, older adult data indicated no significant differences between F-Effect values at any of the cue duration conditions. These incongruent results, in which differential encoding, but not inhibition, can significantly improve as a result of increased processing time, are consistent with the conclusion that differential encoding and attentional inhibition processes differ in their characteristics and in the cognitive demands they incur. With respect to the processing speed theory of cognitive aging (Salthouse, 1996), older adults' inhibitory processes should have improved with increasing cue duration, if attentional inhibition was indeed impaired due to the fact that it lacked sufficient processing time to complete. The fact that the F-Effect did not follow this pattern supports the idea that there is more at play in older adults' directed forgetting performance than processing speed impairments.

Rather, our results suggest that older adults' inhibition processes seem to be fundamentally impaired, such that increased processing time cannot benefit task performance. Such an interpretation is consistent with Hasher and Zacks (1988) inhibition deficit theory of cognitive aging. Similar to Salthouse's (1996) processing speed theory of age-related decline, Hasher and Zacks sought to identify a broad mechanism underlying age-related cognitive decline in many disparate areas. These researchers reached the conclusion that older adults' have a fundamental deficit in their inhibitory mechanisms. In the current study, older adults' attentional inhibition was preserved enough to exhibit a directed forgetting effect. However, consistent with the inhibition deficit framework, they were unable to enhance inhibitory processing past this baseline level of ability due to the inherent decline in inhibitory processes.

Older Adult Variability Contributes to the Lack of an Age-Related Decline

Although age-related cognitive deficits are ubiquitous and well documented, no significant age-related differences in directed forgetting performance, amongst all cue conditions, were observed in the current investigation. However, this absence of an age-related deficit in directed forgetting performance is not unheard of in the literature: researchers such as Gamboz and Russo (2002) were also unable to elicit the expected age-related deficit in the directed forgetting effect. Therefore, it seems that most–but not all–older adult populations exhibit an age-related deficit. This inconsistency may indicate variability between different populations of older adults. In order to explore how individual differences within our population of older adults' may have resulted in the absence of an age-related directed forgetting deficit, median split analyses were conducted based on cognitive functioning, as defined by the z-scores of young and older adults' cognitive assessment measures (described in Methods).

Previous research indicates that variability is greater in older adults than in other populations. Nelson and Dannefer (1992) analyzed 127 existing gerontological studies, concluding that diversity increases with age across a wide variety of domains. Accordingly, Morse (1993) analyzed existing literature comparing young and older adult variability, finding that variability increased with age across domains of reaction time, memory, and fluid intelligence. Consistent with these findings, median split analyses conducted in the current investigation's older adults population revealed large significant differences in directed forgetting task performance between higher- and lower-functioning older adults, but no differences between higher- and lower-functioning young adults. Moreover, the highly disparate performance of higher- and lower-functioning older adults is consistent with research reporting inter-individual variability within populations of older adults. For example, Shammi et al. (1998) reported high levels of inter-individual variability between older adult participants on cognitive and psychomotor tasks. In addition, Christensen and colleagues (1994; 1999; 2001) consistently report greater age-related variability in the domains of memory, fluid intelligence, and speed in both cross-sectional and longitudinal studies, even when excluding low scorers and those with possible dementia.

Therefore, it is well established, and further supported in the current investigation, that individual differences in aging are pervasive factors in the preservation or deterioration of cognitive functioning. Therefore, it is necessary to consider the possible contribution that participants' individual differences might contribute to task performance, in order to provide a more meaningful picture of cognitive aging than is provided through mean-level analyses (Nelson & Dannefer, 1992). Surprisingly, the current study is among the first investigations reflecting upon the contribution of age-related inter-individual variability in cognitive functioning to directed forgetting performance. In order to gain a comprehensive understanding of cognitive aging, similar analyses of individual differences should become an integral, routine step in the reporting process of cognitive aging research.

Variability in Cognitive Functioning Predicted Utilization of Increased Cue Duration

After establishing a significant difference between higher- and lower- functioning older adults' task performance, within-subjects analyses were conducted to determine if level of cognitive functioning influenced older adults' ability to enhance directed forgetting performance with increased processing time. Higher-functioning older adults significantly improved both differential encoding and inhibition from one second to five seconds, and from three seconds to five seconds. However, lower-functioning older adults showed no significant interactions amongst any of the cue durations for either differential encoding or inhibition. Overall, these within-subjects results suggest that higher-functioning older adults were able to use increased cue duration to improve intentional forgetting, while lower-functioning older adults could not utilize increased cue duration in a beneficial way at all.

In the overall older adult analyses, significant improvement in differential encoding was evident between each memory cue duration condition; however, the previous analysis indicated that only higher-functioning older adults were able to benefit from increased processing time. Therefore, it appears that higher-functioning older adults' disproportionately greater directed forgetting performance elevated the lower-functioning group's scores to such a great degree that the mean R-Effects in the overall older adult group misleadingly indicated a significant directed forgetting benefit of increased processing time, which did not actually exist for the lower-functioning group.

Furthermore, the median split analyses explained the lack of an age-related directed forgetting deficit. Although lower-functioning older adults displayed expected age-related declines in directed forgetting performance in all cue conditions, higher-functioning older adults' directed forgetting performance was actually better than young adults'. As in the previous instance, the higher-functioning older adults' directed forgetting performance elevated the lower-functioning group's values so that there appeared to be no age-related decline in directed forgetting, when certain individuals did in fact display this expected deficit. Therefore, it seems that level of cognitive functioning is predictive of performance in other tasks. However, it is unknown how cognitive functioning has this impact, and what other factors may contribute to variability in age-related cognitive decline.

Previous research has attempted to identify potential sources and predictors underlying older adults' greater degree of variability in performance on cognitive tasks. One of the most prevalent predictors of cognitive performance is degree of education, such that more years of education confers a protective advantage to older adults' cognitive abilities (Anstey & Christensen, 2000; Christensen, 2001; Christensen et al., 1999). Indeed, the current investigation revealed a strong positive correlation ($r = .51$) between degree of education and level of cognitive functioning (see Figure 9 in Appendix A). Previous research has also suggested that variability in speed and reaction time may underlie cognitive deficits, particularly for women (Christensen, 2001; Christensen et al., 1999; Morse, 1993). Therefore, Salthouse's (1996) processing speed theory of age-related decline still validly predicts the results of the current study, given the added consideration that the degree of older adults' processing speed impairment is varies based on the individual. The potential for female's greater variability in speed is also interesting, since the current study's older adult sample was predominantly female. In conclusion, individual differences are important factors to consider in age-related cognitive decline, and definitively characterizing predictors of cognitive functioning in old age is an important area for future research.

Conclusion

Overall, the current study demonstrated that increasing memory cue duration within an item-method directed forgetting paradigm, thereby providing increased processing time for differential encoding and attentional inhibition mechanisms, can improve directed forgetting performance in both young and older adults. Specifically, young adults' differential encoding benefitted from increased time from the one-second to three-second cue duration, and their inhibitory processes benefitted from the one-second to five-second increment. Older adults, on the other hand, only showed enhancement in differential encoding, but displayed a more incremental pattern of improvement than young adults. These results were considered with respect to both Salthouse's (1996) processing speed theory of age-related cognitive decline and Hasher and Zacks' (1988) inhibition deficit theory of cognitive aging. Surprisingly, results failed to indicate the expected age-related deficit in directed forgetting performance. Therefore, although processing speed enhanced directed forgetting performance across the board, we were unable to form conclusions, at that point, regarding the potential efficacy of increased processing time in equalizing age-related cognitive declines.

In order to better characterize the absence of an age-related directed forgetting deficit, we performed median split analyses based on level of cognitive functioning. Results of these analyses indicated that, at five seconds, lower-functioning older adults displayed significantly worse directed forgetting performance, both in terms of differential encoding and inhibition, than higher-functioning older adults. In addition, the lower-functioning group displayed the expected age-related directed forgetting deficit. Finally, only higher-functioning older adults were able to utilize increased cue durations to improve directed forgetting performance with increased cue durations. Therefore, although lower-functioning older adults displayed the typical age-related directed forgetting deficit, they were not able to enhance differential encoding or attentional inhibition with increased processing time. While increased processing time appears to be an effective enhancement strategy in young and higher-functioning older adults, it does not benefit the lower-functioning group most in need of enhancement.

In sum, the current investigation has broader implications for the field of cognitive aging in general. First, we considered both Salthouse's (1996) processing speed theory and Hasher and Zack's (1988) inhibition deficit framework to explain the pattern of results obtained in the study. However, it is likely that these researchers would not have used the same approach; they sought to indentify a unitary cause underlying all aspects of cognitive development. However, the current study and many other researchers question the utility of this catch-all approach to cognitive aging. It is better to consider the combination of age-related deficits, task-specific characteristics, and individual differences (Albinet, Boucard, Bouquet, & Audiffren, 2012). In addition, this study also investigated the impact of individual differences in cognitive functioning on the directed forgetting effect, revealing significant differences between higher- and lower-functioning older adults. Considering and characterizing individual differences is an important area for future research in cognitive aging, especially in old age when inter-individual variability is greater than in other populations (Anstey & Christensen, 2000; Christensen, 2001; Christensen et al., 1994; Christensen et al., 1999; Morse, 1993; Nelson & Dannefer, 1992; Shammi et al., 1998).

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Appendix A: Tables and Figures

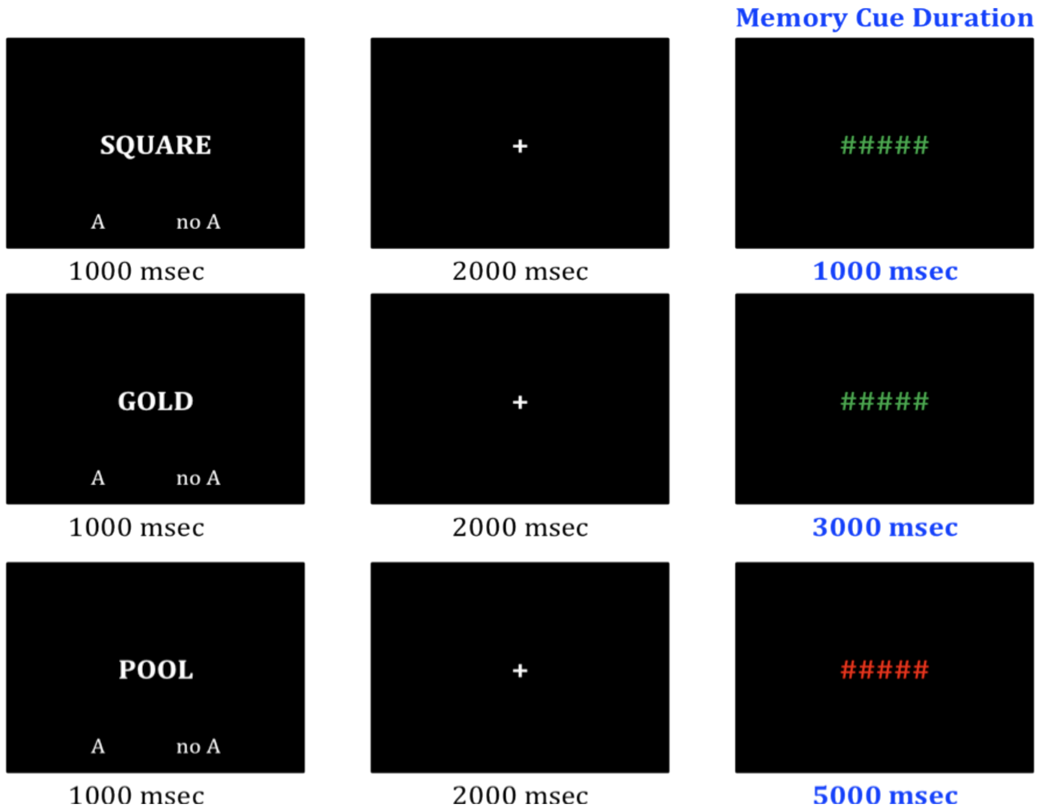

Figure 1: Presented here is a visual summary of the item-method directed forgetting encoding task for each condition of memory cue duration. Participants completed a shallow encoding task for each word presented (Does the word contain the letter 'A' or not?). Subsequently, each word was followed by a memory cue instructing participants to either remember (green) or forget (red) the previous word.

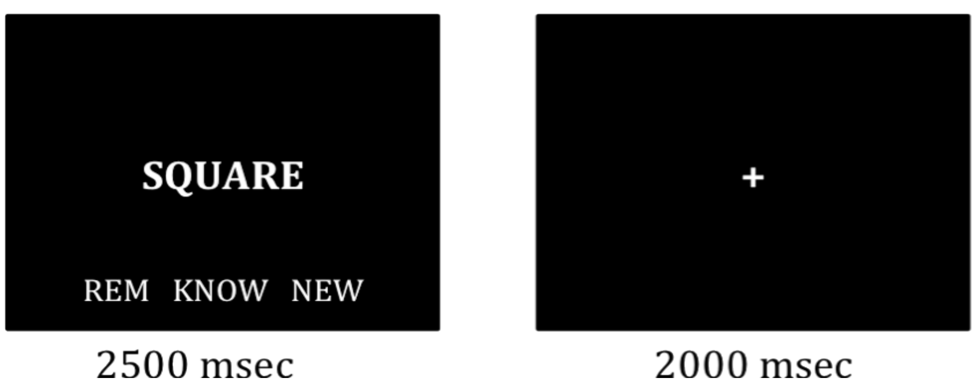

Figure 2: A visual summary of the item-method directed forgetting Remember/Know/New retrieval task for all words from encoding (120 TBR, 120 TBF) and 120 new items. Participants had 2.5 seconds to indicate their memory response to the word using the computer keyboard.

Table 1: Directed forgetting performance in an item-method directed forgetting task that manipulated the duration of the memory cue is summarized below in terms of the R-Effect (i.e., intentional recollection minus incidental recollection; a measure of differential encoding) and the F-Effect (i.e., intentional forgetting minus incidental forgetting; a measure of inhibition).

	1 second		**3 seconds**		**5 seconds**	
	R-Effect	F-Effect	R-Effect	F-Effect	R-Effect	F-Effect
Young adults *M*(*SD*)	.07(.16)	.07(.13)	.17(.15)	.10(.11)	.18(.17)	.13(.11)
Older adults (all) *M*(*SD*)	.05(.14)	.08(.13)	.13(.15)	.10(.13)	.18(.18)	.13(.14)
Higher-functioning older adults *M*(*SD*)	.09(.17)	.08(.15)	.15(.17)	.11(.14)	.29(.14)	.18(.14)
Lower-functioning older adults *M*(*SD*)	.01(.10)	.08(.10)	.10(.14)	.09(.12)	.07(.14)	.07(.12)

Key: *M*, mean; *SD*, standard deviation

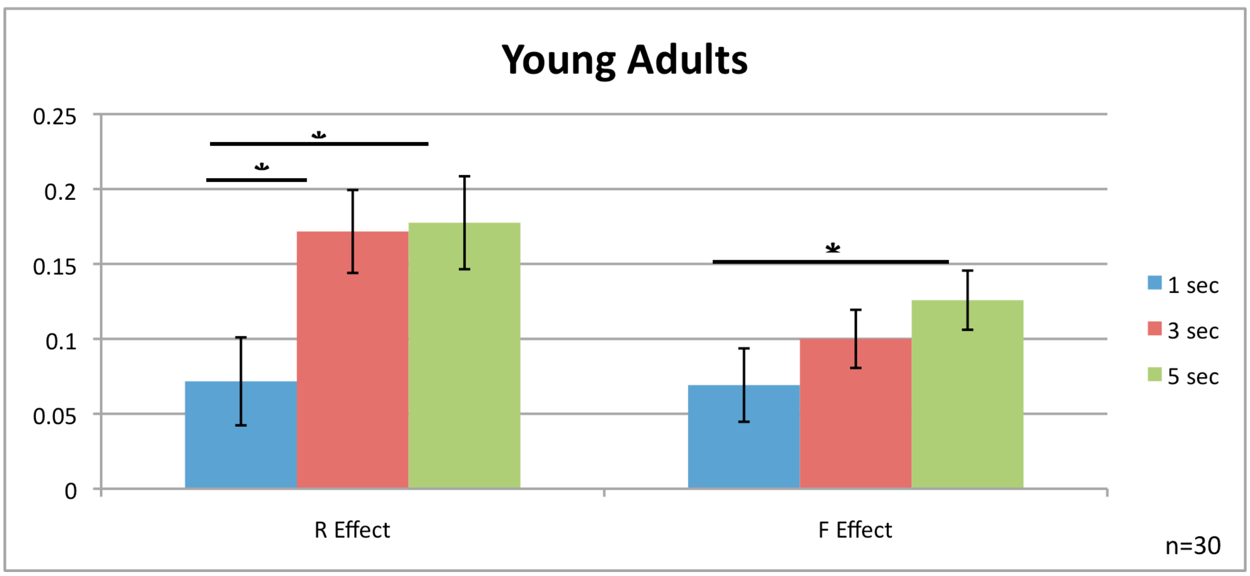

Figure 3: Young adults were able to improve overall directed forgetting performance with increased memory cue duration. Their differential encoding (R-Effect) and inhibitory mechanisms (F-Effect) both improved. However, the lack of improvement between the three-second and five-second R-Effect indicates that young adults likely reach a ceiling at three seconds, past which differential encoding cannot improve. On the other hand, the general upward trend in the F-Effect suggests that young adults may be able to enhance inhibitory mechanisms further with even greater cue duration.

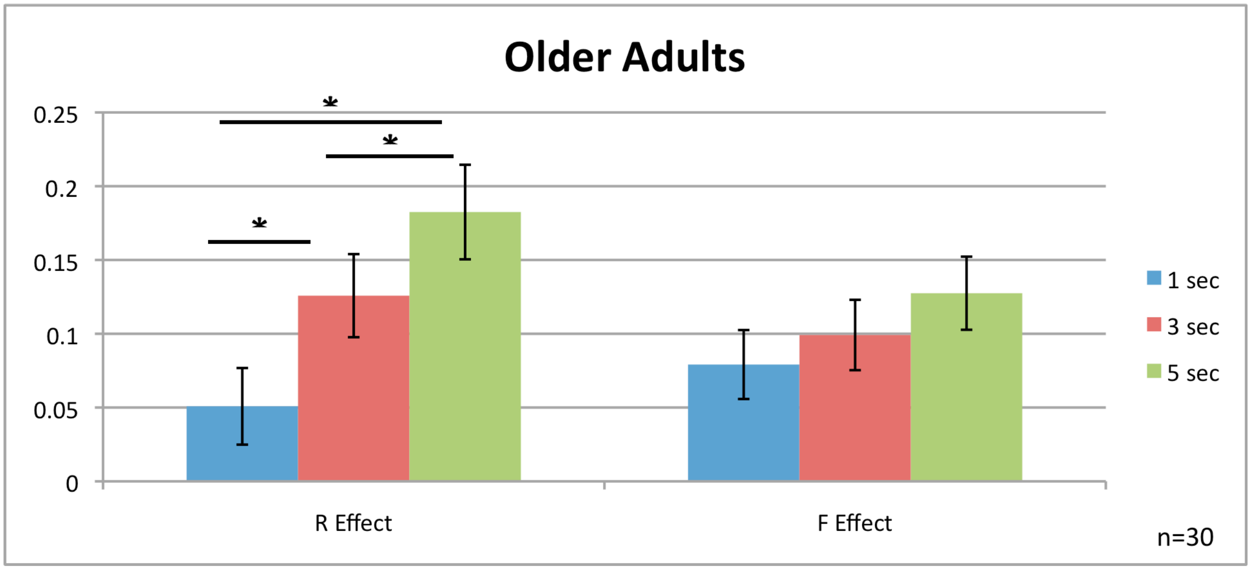

Figure 4: Older adults' differential encoding mechanisms benefitted from increased time at each cue duration interval. The significant improvement from the three-second to five-second cue is particularly compelling, as this difference does not arise in the young adult group. Therefore, it is evident that the increase in duration from the thee-second baseline is beneficial for older adults' directed forgetting. However, no significant differences were found in the F-Effect with increased cue duration, lending credence to the theory of a fundamental age-related deficit in inhibition such that older adults are unable to improve inhibition with greater processing time.

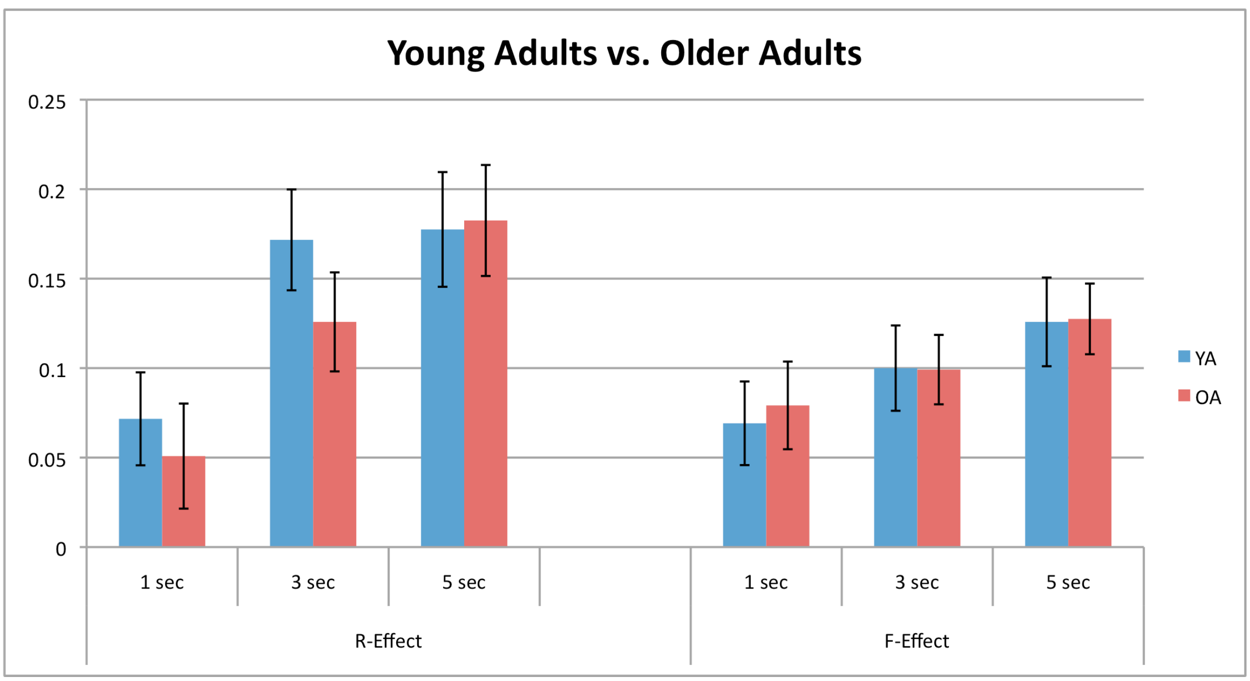

Figure 5: Although age-related deficits in directed forgetting tasks are well established, the current investigation revealed no significant differences between young and older adults' directed forgetting performance. The absence of this age-related deficit spurred subsequent analyses investigating how individual differences among this population of older adults may have contributed to their directed forgetting performance.

Table 2: Scaled scores of the measures comprising the cognitive assessment battery were averaged for each participant. Subsequently, these averaged scores were split around the median, described in the table below. The resulting groups of higher- and lower- functioning young and older adults allowed for analyses examining the relationship between cognitive functioning and directed forgetting effect.

	Median Average Cognitive Assessment Scores
Young adults *M*(*SD*)	11.33(1.48)
Older adults *M*(*SD*)	12.33(2.14)

Key: *M*, mean; *SD*, standard deviation

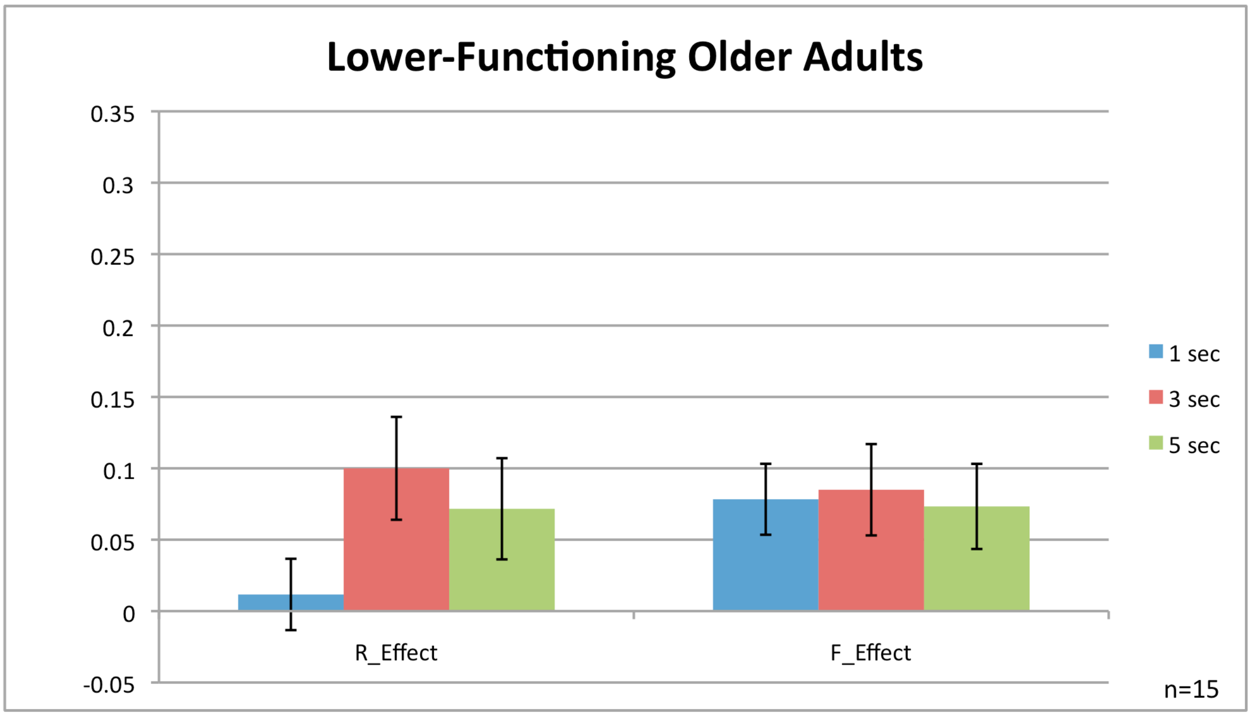

Figure 6: Older adults whose average cognitive assessment scores fell below the median were unable use increased cue durations to improve directed forgetting performance. No significant differences in differential encoding or inhibition were apparent among the three cue conditions.

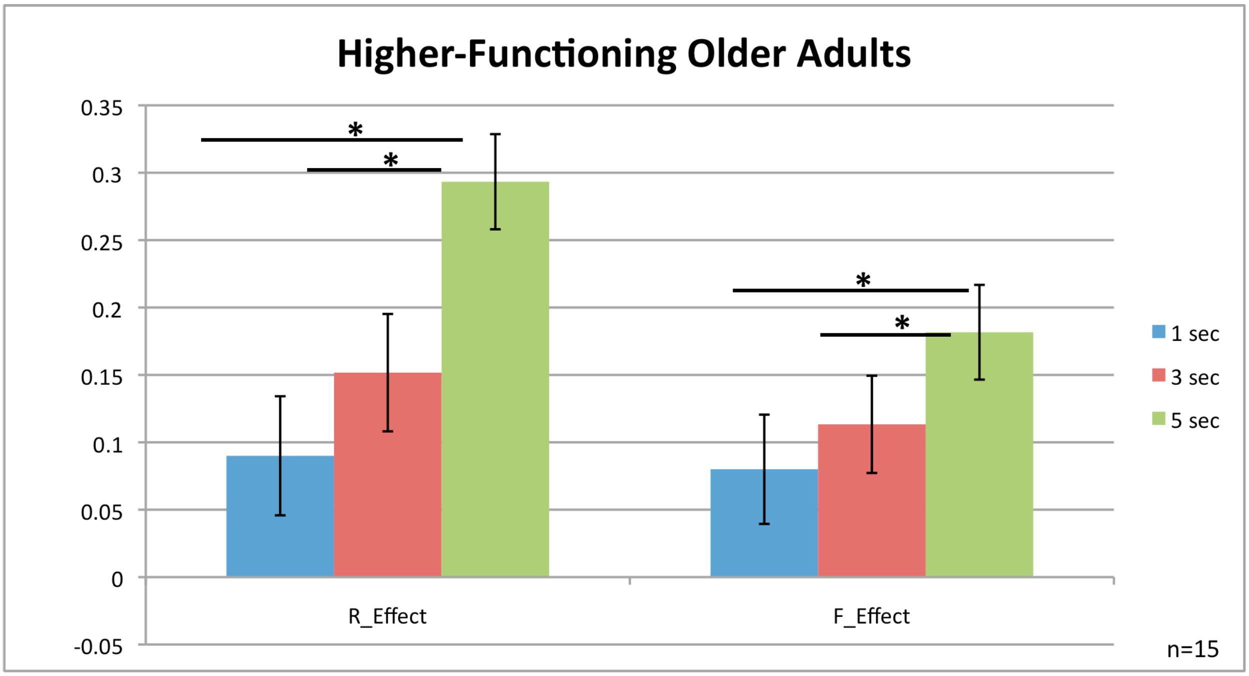

Figure 7: Unlike lower-functioning older adults, those whose average cognitive assessment scores fell above the median were able to greatly improve directed forgetting performance from the increased cue duration at five seconds. The improvement that this group displayed in the R-Effect drives the apparent memory enhancement seen in the overall older adult group. Moreover, this group was able to use the additional processing time from increased memory cue durations to facilitate inhibition mechanisms, an effect not seen in, and sometimes theorized to be impossible for, the overall older adult group.

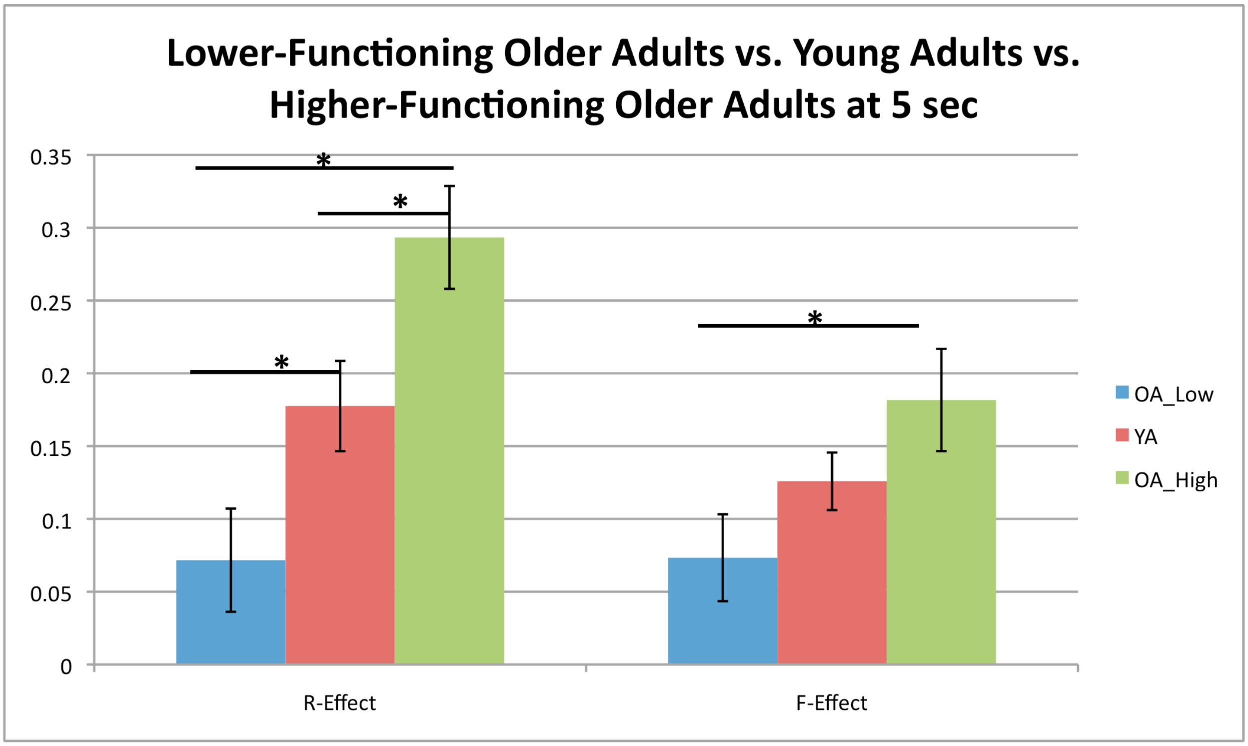

Figure 8: Higher-functioning older adults' directed forgetting performance was significantly better than lower-functioning older adults at five seconds, in both the R-Effect and the F-Effect, displaying that level of cognitive functioning, a measure completely separate from directed forgetting performance, is significantly related to task performance. This illustrates the importance of considering individual differences in cognitive aging research. Furthermore, with five seconds, higher-functioning older adults' differential encoding mechanism (R-Effect) was significantly better than that of young adults. Contrastingly, lower-functioning older adults performed significantly worse than young adults in terms of R-Effect at a five-second memory cue duration.

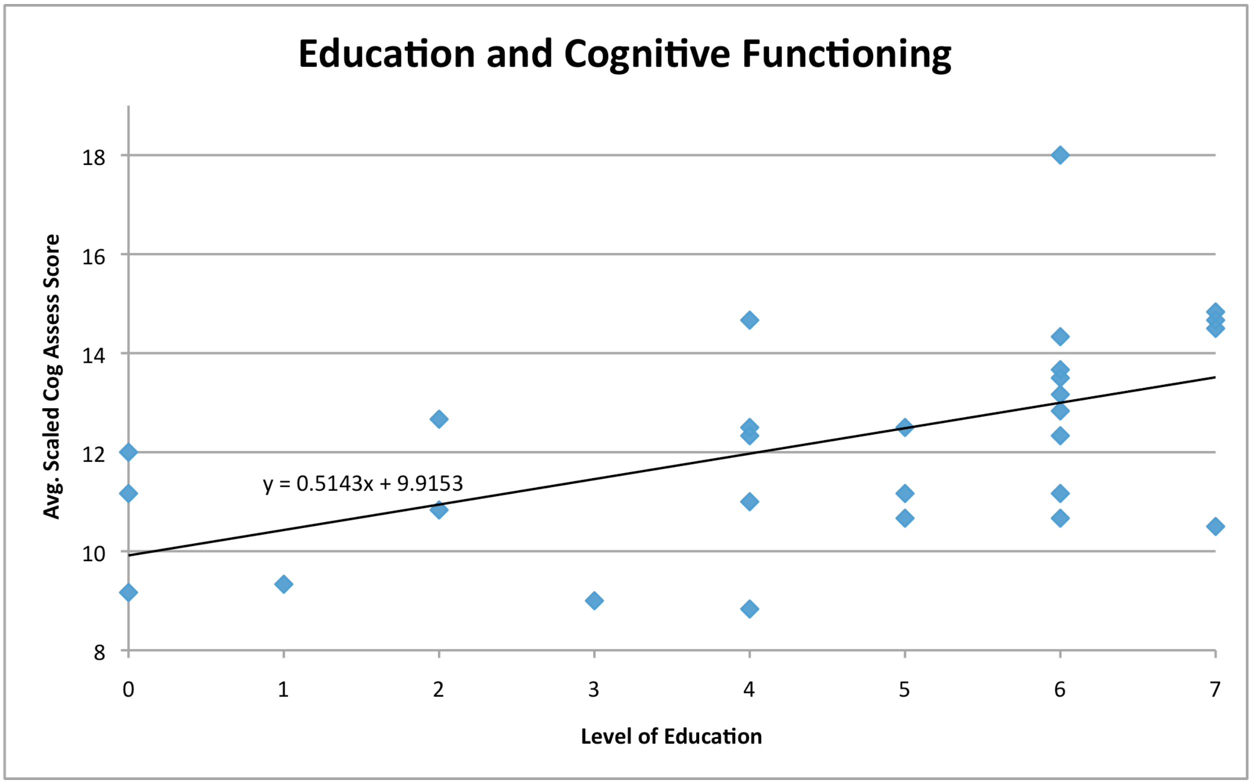

Figure 9: Cognitive assessment performance in older adults showed a strong positive correlation (r = .51) with level of education, consistent with research implicating higher education as a protective factor against age-related cognitive decline. Key: 0, high school; 1, 1 year of college; 2, 2 years of college; 3, 3 years of college; 4, 4 years of college; 5, some post-graduate work; 6, Master's degree; 7, Doctoral degree.

ACADEMIC VITA

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Education

The Pennsylvania State University
Schreyer Honors College
College of the Liberal Arts
B. S. Psychology with Honors (Neuroscience Option), expected May 2013
Minors: Neuroscience, Biology, and Italian
Honors Thesis: *The effect of increased memory cue duration on directed forgetting performance in healthy aging*
Honors Thesis Supervisor: Dr. Nancy A. Dennis

Honors and Awards

- The Phi Beta Kappa Society — 2013 – Present
- Psi Chi International Honor Society in Psychology — 2012 – Present
- Schreyer Honors College — 2009 – Present
- Josephine Rhea Award for Excellence in Italian Studies — April 2013
- Schreyer Honors College Academic Excellence Scholarship — 2009 – 2013
- Army Emergency Relief Scholarship — 2009 –2013
- Dean's List Award — 2009 – 2012
- Clayton H. Schug Forensic Award — May 2012, May 2013
  Department of Communication Arts & Sciences
- Psi Chi Student Research Poster Fair, Honorable Mention — April 2012
- Costello Family Scholarship, Honorable Mention — December 2011
  Department of Psychology

Research Experience

Cognitive Aging and Neuroimaging Lab at Penn State — 2010 – Present
Undergraduate Research Assistant
Adviser: Dr. Nancy Dennis, The Pennsylvania State University

- Collect, analyze, interpret, and report behavioral data in young and older adults for an honors thesis.
- Recruit and schedule young and older adults for research studies.
- Update and maintain participant database, ensuring compliance with ethical requirements of confidentiality.
- Conduct literature searches for background information on studies that may be discussed in lab meeting, or used for eventual publication.
- Assess participants prior to testing using standardized neuropsychological assessment measures.
- Oversee the data collection in behavioral studies investigating the psychological basis of memory and cognitive control in young and older adults.
- Manage the analysis of experimental data to correctly report and interpret studies' findings.

- Present experimental data informally in graduate lab meetings, and formally at university-wide poster presentations.
- Attend regularly scheduled lab meetings, and participate in graduate lab meetings involving behavioral and fMRI data interpretation, preparing articles for publication, and discussing current literature in the field.
- Train new undergraduate research assistants in lab policies, and data collection and analysis.

Research Presentations

Allen, C. M. & Dennis, N. A. (2013, April). *Effects of increased processing time on cognitive control in healthy aging*. Poster to be presented at annual Psi Chi National Honor Society Undergraduate Research Conference in University Park, PA, and at annual Penn State Undergraduate Exhibition in University Park, PA.

Allen, C. M., Rizio, A., & Dennis, N. A. (2012, April). *Time to Forget: The effect of memory cue duration on item-method directed forgetting*. Poster presented at annual Psi Chi National Honor Society Undergraduate Research Conference in University Park, PA, received honorable mention.

Allen, C. M., Dennis, N. A., & Rizio, A. (2011, April). *The effect of deep encoding and cue placement on successful directed forgetting*. Poster presented at annual Penn State Undergraduate Exhibition in University Park, PA.

Skills and Qualifications

- **Software:**
  SPSS Statistical Analysis Software, E-Prime, MATLAB, SPM8 fMRI analysis, Microsoft Excel, Microsoft PowerPoint, Microsoft Access, Irfan View, Photoshop, Microsoft Word
- **Research Training:**
  Clinical assessments: Mini Mental State Examination (MMSE), Wechsler Adult Intelligence Scale IV (WAIS-IV), Wechsler Memory Scale (WMS-IV), Beck Depression Inventory II (BDI-II), Geriatric Depression Scale (GDS)
  MRI Safety Trained
- **Languages:**
  English, Italian proficiency, some French
- **Other:**
  Extensive leadership experience, great communication and public speaking skills, strong writer, highly organized, excellent problem-solving skills

Other Experience

- **Italian Tutor, Penn State Learning Center** — **2012 – Present**
- **Schreyer Honors College Office of Student Programming**
  Gateway Orientation Lead Mentor — 2011 – 2012
  Schreyer Honors Orientation Lead Mentor — 2010 – 2011
  Schreyer Honors Orientation Mentor — 2009 – 2010
- **Participant, Penn State PNC Leadership Assessment Center** — **2011**
- **Penn State Conference Services** — **2011**
  Summer Conference Assistant
  Commons Desk Attendant