Published in final edited form as:

Neurosci Lett. 2014 August 8; 577: 6–10. doi:10.1016/j.neulet.2014.05.049.

Does the age-related "anterior shift" of the P3 reflect an inability to habituate the novelty response?

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Abstract

Old adults often generate larger anterior neural responses than young adults when carrying out task requirements. A common finding in the ERP literature is an "anterior shift" of the P3b to targets. Utilizing principal component analysis (PCA), we recently demonstrated that rather than the P3b moving anteriorly, old adults generate a large P3a that temporally overlaps with their P3b. A dominant hypothesis for the age-related increase in anterior P3 is the failure to habituate the brain's novelty response to rare targets. We tested this hypothesis in young and old adults by comparing the amplitude of the PCA factor representing P3a to targets presented in the first versus last of eight blocks of a visual oddball task. If, unlike young adults, old adults are unable to habituate a novelty response, one would expect 1) the P3a amplitude to decrease between the first and last blocks for young, but not old subjects and 2) the difference in P3a amplitude between young and old subjects to be greater in the last than the first block. Our results indicate the amplitude of the P3a was larger in old adults than young adults. However, this effect was not modulated by block. These findings argue against the hypothesis that an age-related increase in the P3a to targets reflects an inability of old subjects to habituate a novelty response. An alternative hypothesis is that the augmented P3a indexes the increased utilization of frontal executive functions to provide compensatory scaffolding to carry out a task.

Introduction

A common finding in the event related potential (ERP) literature on cognitive aging is that old adults recruit an increased amount of anterior resources in response to target stimuli as compared to their younger counterparts [1, 2]. This effect is most frequently seen during the generation of the P3b component, a centro-posterior component peaking between ~400–700

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ms that reflects the categorization of an event according to task demands, the monitoring of decision making, or the updating of working memory once an event has been categorized [3–5]. This phenomenon is commonly referred to as the "anterior shift" of the P3b [6, 7]. Some investigators have argued that the notion of an age-related anterior shift in the P3b is illogical because scalp distribution is one of the fundamental features of an ERP component, and the P3b is in part defined by its centro-posterior maximum [8–10].

In a recent study [11], we investigated whether this "anterior shift" reflected the movement of the P3b to a more frontal location, or if it reflected an increase in the amplitude of a distinct anterior component that temporally overlapped with the posterior P3b. We used principal component analysis (PCA), which is a data driven method that decomposes an ERP waveform into its underlying components. Using PCA, we found that young subjects generated an anterior P3a to target stimuli that was smaller than their posterior P3b, while old subjects generated a P3a that did not differ in amplitude from their P3b. Rather than having a more anteriorly distributed P3b, old subjects produced a large, temporally overlapping P3a.

The P3a, which some researchers label as the novelty P3, has been interpreted as an index of the conscious aspect of the orienting response to novel/salient stimuli, or as a marker of an executive control process, such as evaluating events or tasks to determine whether they merit additional processing or action [12–14]. The P3a was initially characterized as being elicited in response to infrequent stimuli during a two-stimulus oddball task or to identical stimuli presented under an ignore condition [15]. The novelty P3 was originally described as being elicited in response to infrequent non-target events in a three-stimulus oddball task that involved the presentation of highly unusual stimuli [16]. There is growing evidence to suggest that the P3a and the novelty P3 represent the same component [17].

A prominent theory for why old adults exhibit an increased anterior P3a response is that they are unable to habituate a novelty response to rarely occurring target stimuli and therefore generate a large novelty P3 to targets. It has been proposed that the generation of a novelty response is due to an inability of old subjects to maintain a mental template of target stimuli [18]. In the absence of a reliable representation of targets, the presentation of a target stimulus that deviates from the preceding series of repetitive standard stimuli leads to an orienting response. According to this theory, young adults generate a novelty P3 in response to targets, but quickly habituate the response, which results in an overall diminutive P3a. There is supporting evidence that old individuals do not habituate a novelty response to novel stimuli while young adults do [19–21]. These studies employed a method in which the subject's response to novel stimuli during early blocks or trials is compared to their response during late blocks or trials in order to examine the change in the novelty response as the task progresses. There have only been a few studies on aging and habituation to auditory target stimuli [7, 20], and, to the best of our knowledge, there are no studies looking at age-related differences in the habituation of the P3a component to target stimuli in the visual modality.

An issue with analyzing target stimuli within single blocks of data is the low signal to noise ratio due to relatively few targets per block. One way to separate signal from noise is to use PCA [22]. Additionally, PCA is able to parse temporally and/or spatially overlapping

components, and, as found in our previous study, aids in distinguishing between the P3a and P3b. In the current study, we tested the hypothesis that the increase in anterior P3 generation is a reflection of the inability of old subjects to habituate a novelty response to targets. We studied young and old adults and compared the amplitude of the PCA factor representing the P3a to visual targets presented in the first versus last of eight blocks of a visual oddball task. Block 1 was contrasted with block 8 because the largest differences can be expected to be found by comparing the first and last blocks of data. If, unlike young adults, old adults are unable to habituate a novelty response, one would expect the P3a amplitude to decrease between the first and last blocks for young, but not old subjects, and the difference in P3a amplitude between young and old subjects to be greater in the last block than the first.

Methods

Participants and Experimental Procedure

Detailed methods were described in Alperin, et al. [11]. Briefly, 25 young and 29 old adults, matched for executive function based on a battery of neuropsychological tests, were shown a series of letters, half in the color red and half in the color blue, presented in random order (see Table 1 for subject demographics). They were instructed to pay attention to letters appearing in the designated color while ignoring letters appearing in the other color. They responded by button press to target letters appearing in the designated color only. The task included 800 stimulus trials divided into 8 blocks. The task was preceded by a brief practice block of 50 trials. Target stimuli (7.5% in attend color; 7.5% in ignore color) were designated upper case letters. Each block contained 7–8 target stimuli. Standard stimuli (35% in each color) were any non-target upper case letters. Fillers accounted for the remainder of the stimuli presented. Task demands were made easier for old subjects to help minimize group differences in performance [23]. Young subjects responded to 5 target letters and old subjects responded to 4 target letters.

ERP Recordings

An ActiveTwo electrode cap (Behavioral Brain Sciences Center, Birmingham, UK) was used to hold to the scalp a full array of 128 Ag-AgCl BioSemi (Amsterdam, The Netherlands) “active” electrodes whose locations were based on a pre-configured montage. Electrodes were arranged in equidistant concentric circles from the 10–20 position Cz. In addition, 6 mini bio-potential electrodes were placed over the left and right mastoid, beneath each eye, and next to the outer canthi to check for eye blinks and vertical and horizontal eye movements.

Data Analysis

EEG data were analyzed using ERPLAB [24; www.erpinfo.org/erplab] and EEGLAB [25; <http://scn.ucsd.edu/eeglab>] toolboxes that operate within the MATLAB framework. EEG epochs for the two stimulus types (standard stimuli, target stimuli) across two attention conditions (attend and ignore) were averaged separately for trials with correct responses.

Demographic variables and overall percentile performance on the neuropsychological tests for the groups were compared using t-tests. Mean target accuracy and mean reaction time

(RT) were measured. A response was considered a hit if it occurred between 200–1000 ms after stimulus presentation. Target stimuli correctly responded to (target hits) and stimuli incorrectly identified as targets (false alarms) were measured in order to determine an overall accuracy score (% target hits – % false alarms). Accuracy and RT were analyzed using repeated measures analysis of variance (ANOVA).

Principal Component Analysis (PCA)

A temporospatial PCA (temporal PCA followed by a spatial PCA) was conducted on all subjects' individual ERP averages at all 134 electrode sites using the ERP PCA toolkit 2.39 [26]. ERPs to target and standard stimuli under the attend and ignore conditions were included in the PCA. Only data from the first and last block were entered into the analysis. A parallel test was used to restrict the number of factors generated for each PCA. Factors of interest were selected based on visual inspection of the timing and topography of the output. Any factors that accounted for > 1% of the total variance were considered for further analyses [27]. Factor scores were submitted to statistical analysis using repeated measures ANOVA. Only factor scores to target stimuli under the attend condition were statistically analyzed.

Results¹

Behavior

Target accuracy and mean reaction time (RT) data are presented in Table 2. For accuracy, a 2 block (1st and 8th) × 2 age group (young and old) repeated measures ANOVA revealed a marginal effect of block, $F(1,52) = 3.12$, $p = .08$, no age group effect, $F(1,52) = .01$, $p = .91$, and no age group × block interaction, $F(1,52) = 1.64$, $p = .21$. The marginal block effect was due to the accuracy tending to be higher for block 8 than for block 1.

For mean RT, a 2 block × 2 age group repeated measures ANOVA revealed no effect of block, $F(1,52) = 1.69$, $p = .20$, an age group effect, $F(1,52) = 8.67$, $p = .005$, and no age group × block interaction, $F(1,52) = .42$, $p = .52$. The age group effect was due to the RT of the young group being faster than that of the old group.

PCA

A temporospatial PCA yielded 162 factor combinations (27 temporal factors, each with 6 spatial factors). There were 149 factor combinations that each accounted for < 1% of the variance and were not considered for further analyses. There was one temporal factor of a priori interest: a positivity peaking at 472 ms (TF2), which accounted for 12.80% of the variance. This was the only temporal factor that occurred during the temporal interval of the P3. A spatial PCA was performed on this temporal factor and 6 spatial factors (SF) were retained. Based on visual inspection of the timing and topography of the factors, one (SF1)

¹Young and old age groups were also divided by executive capacity percentile performance based on age-matched norms on six neuropsychological tests of executive functions. Subjects with a composite score in the middle third (33% – 66%) were considered to have average executive capacity while subjects with a composite score > 67% were considered to have high executive capacity. Task performance and P3a amplitude data were also analyzed with executive capacity group (high and average) as a between subjects factor. There were no significant differences between executive capacity groups in any measures and therefore these statistical analyses were not included in this paper.

was of particular interest to the goals of this study. TF2SF1 accounted for 5.50% of the total variance and had an anterior distribution consistent with the topography of a P3a. Figure 1 depicts the topography of this factor for young and old subjects.

A 2 block $\times$ 2 age group repeated measures ANOVA revealed an effect of age group, $F(1,52) = 6.58$, $p = .01$, such that the old group generated a larger P3a than young subjects. There was no block effect, $F(1,52) = .59$, $p = .81$, or age group $\times$ block interaction, $F(1,52) = .07$, $p = .79$.

Discussion

The aim of the current study was to investigate whether the increased anterior P3a to targets in old adults is a result of their inability to habituate an orienting (novelty) response to repeated targets. We did this by using PCA to examine the change in P3a amplitude in the first versus last block of a visual oddball task. If the age-related increase in the P3a were due to an inability to habituate, one would expect the size of the P3a of young subjects to be larger in the first block than in the last block, and the size of the P3a of old subjects not to change across blocks. As expected, we found that old adults generated an overall larger P3a to target stimuli that was not modulated by block. However, contrary to expectation, the P3a amplitude in young adult subjects did not differ across blocks. These results do not support the hypothesis that the age-related increase in the amplitude of the P3a is due to an inability of old adults to habituate a novelty response to targets. Young adult subjects also did not demonstrate a decline in the size of the P3a component between the first and last block of the task. Additionally, we did not find a larger age-related difference in block 8 than block 1. It seems highly unlikely that the null results simply reflect a lack of power leading to a Type II statistical error. Of note, no pertinent effects or interactions were even suggestive of a trend toward significance, with these analyses yielding F values of less than 1.

There are several reasons why our results may stand in contrast to findings from Fabiani and Friedman [7], who reported that young subjects habituated their anterior P3 response to targets while old subjects did not. First, Fabiani and Friedman [7] did not examine changes in the P3 to targets across blocks within a single task, but rather examined changes between practice trials of a standard auditory oddball task, a full standard auditory oddball task, and a three-stimulus novelty auditory oddball task that were completed in sequential order. Second, the tasks they employed were in the auditory rather than visual modality. Geisler and Polich [28] found that young subjects did not habituate their anterior P3 response to target stimuli in a visual task and suggest that stimulus modality affects habituation patterns. Third, the sequential analysis in Fabiani and Friedman [7] was performed on a relatively small group of 6 young and 7 old subjects, whereas our analyses were performed on a much larger group (25 young and 29 old subjects). Finally, rather than measuring a change in the distribution of the averaged waveforms along midline sites during the temporal interval of the P3, we used PCA to parse the P3a component.

Another way in which the P3a has been characterized is as a marker of executive control processes [12, 14, 29, 30]. Our results support the notion that both young and old adults utilize anterior resources throughout the task. However, young adults are able to manage the

task using limited frontal resources, whereas old adults need to recruit a larger amount. The prefrontal cortex is critical for sustaining attentional focus and executive control [31–33]. Within this framework, the age-related increase in the anterior P3a to targets may represent an augmented utilization of frontal executive control functions to provide compensatory activity to carry out the task rather than an inability to inhibit an orienting response. This thesis is in line with the scaffolding theory of aging and cognition (STAC), which posits that age-related increases in frontal activity may reflect adaptive activation of neural pathways to achieve cognitive goals in response to declining neural structure and function [34].

This perspective is also consistent with the compensation-related utilization of neural circuits hypothesis (CRUNCH), which states that processing inefficiencies cause the aging brain to recruit more neural resources to adequately carry out a task [35]. Due to less efficient processing, old adults rely upon supplemental neural activity at lower demand levels than young adults. There is evidence that as task demands are augmented, young adults also recruit more anterior activity [36–38], which we have shown is reflected in an enhanced anterior P3a [3]. Further validation of this hypothesis could be derived from future research that includes conditions with higher levels of task load. Such an approach would likely augment the demands on frontal executive functions and increase the variance in performance, which would also provide an opportunity for investigators to determine whether larger P3a responses are associated with better task performance and higher executive capacity.

One limitation of this study is that because we did not measure ERP recordings during the practice trials, we were unable to assess the amplitude of the P3a to the very first set of targets presented. However, in contrast to other studies in which subjects are asked to remember one or two target sounds or images, our subjects had to keep several (4–5) different target letters in mind. This meant that during the first block, subjects had not yet been presented with all possible targets, and thus were responding to some of the target stimuli for the first time. In the context of this study design, if the reduced size of the target P3a in young adults mainly reflected the habituation of the novelty response, one would expect a decrease in the size of the P3a from the first to eighth block, which was not observed. Future investigations should explicitly examine the possibility of age-related differences in the habituation to visual stimuli within the first few presentations of the target stimulus. One way to do this would be to employ independent component analysis (ICA) techniques on single trials (as seen in [39]). Finally, it is plausible that age-associated differences in the amplitude of the P3a are related to deficits that occur earlier in the processing stream [3, 40]. Work in the future should examine age-related declines in early processing to investigate the extent to which they may contribute to the observed increased amplitude of the anterior P3a in old subjects.

Acknowledgments

This research was funded in part by NIA grant R01 AG017935 and by generous support from the Wimberly family, the Muss family, and the Mortimer/Grubman family. The authors would also like to thank Christine Dunant for her excellent administrative assistance.

References

1. Braver TS, Barch DM, Keys BA, Carter CS, Cohen JD, Kaye JA, Janowsky JS, Taylor SF, Yesavage JA, Mumenthaler MS, Jagust WJ, Reed BR. Context processing in older adults: evidence for a theory relating cognitive control to neurobiology in healthy aging. *J. Exp. Psychol. Gen.* 2001; 130:746–763. [PubMed: 11757878]
2. West R, Schwarb H, Johnson BN. The influence of age and individual differences in executive function on stimulus processing in the oddball task. *Cortex.* 2010; 46:550–563. [PubMed: 19720373]
3. Daffner KR, Chong H, Sun X, Tarbi EC, Riis JL, McGinnis SM, Holcomb PJ. Mechanisms underlying age- and performance-related differences in working memory. *J. Cogn. Neurosci.* 2011; 23:1298–1314. [PubMed: 20617886]
4. Donchin E, Coles MGH. Is the P300 component a manifestation of context updating? *Behav. Brain Sci.* 1988; 11:357–374.
5. Knight RT, Scabini D. Anatomic bases of event-related potentials and their relationship to novelty detection in humans. *J. Clin. Neurophysiol.* 1998; 15:3–13. [PubMed: 9502509]
6. Pfefferbaum A, Wenegrat BG, Ford JM, Roth WT, Kopell BS. Clinical application of the P3 component of event-related potentials. II. Dementia, depression and schizophrenia. *Electroencephalogr. Clin. Neurophysiol.* 1984; 59:104–124. [PubMed: 6200305]
7. Fabiani M, Friedman D. Changes in brain activity patterns in aging: the novelty oddball. *Psychophysiology.* 1995; 32:579–594. [PubMed: 8524992]
8. Johnson R Jr, Donchin E. On how P300 amplitude varies with the utility of the eliciting stimuli. *Electroencephalogr. Clin. Neurophysiol.* 1978; 44:424–437. [PubMed: 76551]
9. Donchin, E.; Ritter, W.; McCallum, WC. Cognitive Psychophysiology: The Endogenous Components of the ERP. In: Callaway, E.; Tueting, P.; Kowleslow, S., editors. *Event-Related Brain Potentials in Man*. New York: Academic Press Inc.; 1978. p. 349–411.
10. Spencer KM, Dien J, Donchin E. Spatiotemporal analysis of the late ERP responses to deviant stimuli. *Psychophysiology.* 2001; 38:343–358. [PubMed: 11347879]
11. Alperin BR, Mott KK, Rentz DM, Holcomb PJ, Daffner KR. Investigating the age-related “anterior shift” in the scalp distribution of the P3b component using principal component analysis. *Psychophysiology.* (In press).
12. Barcelo F, Perianez JA, Knight RT. Think differently: a brain orienting response to task novelty. *Neuroreport.* 2002; 13:1887–1892. [PubMed: 12395085]
13. Dien J, Spencer KM, Donchin E. Parsing the late positive complex: mental chronometry and the ERP components that inhabit the neighborhood of the P300. *Psychophysiology.* 2004; 41:665–678. [PubMed: 15318873]
14. Daffner KR, Mesulam MM, Scinto LF, Cohen LG, Kennedy BP, West WC, Holcomb PJ. Regulation of attention to novel stimuli by frontal lobes: an event-related potential study. *Neuroreport.* 1998; 9:787–791. [PubMed: 9579666]
15. Squires NK, Squires KC, Hillyard SA. Two variables of long-latency positive waves evoked by unpredictable auditory stimuli in man. *Electroencephalogr. Clin. Neurophysiol.* 1975; 38:387–401. [PubMed: 46819]
16. Courchesne E, Hillyard SA, Galambos R. Stimulus novelty, task relevance and the visual evoked potential in man. *Electroencephalogr. Clin. Neurophysiol.* 1975; 39:131–143. [PubMed: 50210]
17. Simons RF, Graham FK, Miles MA, Chen X. On the relationship of P3a and the Novelty-P3. *Biol. Psychol.* 2001; 56:207–218. [PubMed: 11399351]
18. Friedman D, Kazmerski V, Fabiani M. An overview of age-related changes in the scalp distribution of P3b. *Electroencephalogr. Clin. Neurophysiol.* 1997; 104:498–513. [PubMed: 9402892]
19. Friedman D, Kazmerski VA, Cycowicz YM. Effects of aging on the novelty P3 during attend and ignore oddball tasks. *Psychophysiology.* 1998; 35:508–520. [PubMed: 9715095]
20. Friedman D, Simpson GV. ERP amplitude and scalp distribution to target and novel events: effects of temporal order in young, middle-aged and older adults. *Brain Res. Cogn. Brain Res.* 1994; 2:49–63. [PubMed: 7812178]

21. Richardson C, Bucks RS, Hogan AM. Effects of aging on habituation to novelty: an ERP study. *Int. J. Psychophysiol.* 2011; 79:97–105. [PubMed: 20869996]
22. Dien, J.; Frishkoff, GA. Principal component analysis of ERP data. In: Handy, TC., editor. *Event-related potentials: A methods handbook*. Cambridge, MA: Massachusetts Institute of Technology; 2005.
23. Haring AE, Zhuravleva TY, Alperin BR, Rentz DM, Holcomb PJ, Daffner KR. Age-related differences in enhancement and suppression of neural activity underlying selective attention in matched young and old adults. *Brain Res.* 2013; 1499:69–79. [PubMed: 23313874]
24. Lopez-Calderon J, Luck SJ. ERPLAB: an open-source toolbox for the analysis of event-related potentials. *Front. Hum. Neurosci.* 2014; 8
25. Delorme A, Makeig S. EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J. Neurosci. Methods.* 2004; 134:9–21. [PubMed: 15102499]
26. Dien J. The ERP PCA Toolkit: an open source program for advanced statistical analysis of event-related potential data. *J. Neurosci. Methods.* 2010; 187:138–145. [PubMed: 20035787]
27. Dien J. Applying principal components analysis to event-related potentials: a tutorial. *Dev. Neuropsychol.* 2012; 37:497–517. [PubMed: 22889342]
28. Geisler MW, Polich J. P300 habituation from visual stimuli? *Physiol. Behav.* 1994; 56:511–516. [PubMed: 7972401]
29. Daffner KR, Scinto LF, Weitzman AM, Faust R, Rentz DM, Budson AE, Holcomb PJ. Frontal and parietal components of a cerebral network mediating voluntary attention to novel events. *J. Cogn. Neurosci.* 2003; 15:294–313. [PubMed: 12683359]
30. Barcelo F, Escera C, Corral MJ, Perianez JA. Task switching and novelty processing activate a common neural network for cognitive control. *J. Cogn. Neurosci.* 2006; 18:1734–1748. [PubMed: 17014377]
31. Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. *Annu. Rev. Neurosci.* 2001; 24:167–202. [PubMed: 11283309]
32. Corbetta M, Shulman GL. Control of goal-directed and stimulus-driven attention in the brain. *Nat. Rev. Neurosci.* 2002; 3:201–215. [PubMed: 11994752]
33. Gazzaley, A.; D'Esposito, M. Unifying prefrontal cortex function: Executive control, neural networks, and top-down modulation. In: Miller, B.; Cummings, J., editors. *The Human Frontal Lobes*. New York: Guildford Productions; 2007. p. 187–206.
34. Park DC, Reuter-Lorenz P. The adaptive brain: aging and neurocognitive scaffolding. *Annu. Rev. Psychol.* 2009; 60:173–196. [PubMed: 19035823]
35. Reuter-Lorenz PA, Cappell KA. Neurocognitive aging and the compensation hypothesis. *Curr. Dir. Psychol. Sci.* 2008; 17:177–182.
36. Nagel IE, Preuschhof C, Li SC, Nyberg L, Backman L, Lindenberger U, Heekeren HR. Performance level modulates adult age differences in brain activation during spatial working memory. *Proc. Natl. Acad. Sci. U. S. A.* 2009; 106:22552–22557. [PubMed: 20018709]
37. Cappell KA, Gmeindl L, Reuter-Lorenz PA. Age differences in prefrontal recruitment during verbal working memory maintenance depend on memory load. *Cortex.* 2010; 46:462–473. [PubMed: 20097332]
38. Mattay VS, Fera F, Tessitore A, Hariri AR, Berman KF, Das S, Meyer-Lindenberg A, Goldberg TE, Callicott JH, Weinberger DR. Neurophysiological correlates of age-related changes in working memory capacity. *Neurosci. Lett.* 2006; 392:32–37. [PubMed: 16213083]
39. Jung TP, Makeig S, Westerfield M, Townsend J, Courchesne E, Sejnowski TJ. Analysis and visualization of single-trial event-related potentials. *Hum. Brain Mapp.* 2001; 14:166–185. [PubMed: 11559961]
40. Daffner KR, Sun X, Tarbi EC, Rentz DM, Holcomb PJ, Riis JL. Does compensatory neural activity survive old-old age? *Neuroimage.* 2011; 54:427–438. [PubMed: 20696255]

Highlights

- Old adults produce a much larger P3a to target stimuli than young adults
- One theory suggests old adults fail to habituate an orienting response to targets
- PCA was used to compare P3a size in the first vs. last block of a visual oddball
- No evidence of habituation of the P3a was found in young or old adults
- Age-related increase in P3a may reflect reliance on frontal compensatory mechanisms

Figure 1.

Waveform and scalp topographies of PCA factor TF2SF1 representing the P3a component.

Table 1**Subject Characteristics (Mean (SD))**

	Young	Old
Number of subjects	25	29
Gender (male:female)	13:12	14:15
Age (years) ^a	22.60 (2.25)	72.83 (3.86)
Executive Capacity (%ile)	66.66 (16.67)	68.61 (15.87)
Years of Education	15.12 (1.56)	16.19 (3.20)
AMNART (estimated IQ)	116.60 (6.79)	118.31 (9.77)
MMSE ^b	29.84 (.37)	29.41 (.82)

^a effect of age group, $t(52) = -57.58$, $p < .001$ (young < old)

^b effect of age group, $t(52) = 2.38$, $p = .02$ (young > old)

Executive Capacity = Average (composite) percentile performance using age-appropriate norms on the following tests: Digit Span Backward, Controlled Oral Word Association Test, Letter-Number Sequencing, Trail-Making Test Parts A and B, and Digit-Symbol Coding.

AMNART = American National Adult Reading Test

MMSE = Mini Mental State Exam

Table 2

Accuracy and Mean RT (Mean (SD))

	Young	Old
Accuracy (%)		
Block 1	89.10 (16.07)	86.02 (12.71)
Block 8	90.15 (9.87)	92.63 (10.41)
Mean RT (ms) ^a		
Block 1	588 (89)	641 (68)
Block 8	608 (57)	647 (78)

effect of age group, $F(1,52) = 8.67$, $p = .005$ (young < old)