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Citation	Daffner, Kirk R., Hyemi Chong, Jenna Riis, Dorene M. Rentz, David A. Wolk, Andrew E. Budson, and Phillip J. Holcomb. 2007. “Cognitive Status Impacts Age-Related Changes in Attention to Novel and Target Events in Normal Adults.” Neuropsychology 21, no. 3: 291–300.
Published Version	doi:10.1037/0894-4105.21.3.291
Accessed	February 19, 2015 4:08:59 PM EST
Citable Link	http://nrs.harvard.edu/urn-3:HUL.InstRepos:12605383
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Neuropsychology. Author manuscript; available in PMC 2011 February 28.

Published in final edited form as:
Neuropsychology. 2007 May ; 21(3): 291–300. doi:10.1037/0894-4105.21.3.291.

Cognitive Status Impacts Age-Related Changes in Attention to Novel and Target Events in Normal Adults

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Abstract

This study investigated the relationship between the cognitive status of normal adults and age-related changes in attention to novel and target events. Old, middle-aged, and young subjects, divided into cognitively high and cognitively average performing groups, viewed repetitive standard stimuli, infrequent target stimuli, and unique novel visual stimuli. Subjects controlled viewing duration by a button press that led to the onset of the next stimulus. They also responded to targets by pressing a foot pedal. The amount of time spent looking at different kinds of stimuli served as a measure of visual attention and exploratory activity. Cognitively high performers spent more time viewing novel stimuli than cognitively average performers. The magnitude of the difference between cognitively high and cognitively average performing groups was largest

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among old subjects. Cognitively average performers had slower and less accurate responses to targets than cognitively high performers. Our results provide strong evidence that the link between engagement by novelty and higher cognitive performance increases with age. Moreover, it supports the notion of there being different patterns of normal cognitive aging and the need to identify the factors that influence them.

Keywords

cognitive aging; cognitive performance; novelty; attention

Introduction

Recently, there has been an increasing interest in not only making overall distinctions between 'normal' and diseased aging but also in understanding the potential sources of individual differences within the population of older individuals (e.g., Fabiani & Friedman, 1995; Daffner et al., 2005; Fjell & Walhovd, 2005; Walhovd & Fjell, 2002; Walhovd & Fjell, 2001; Friedman, 2003). One factor that has been proposed to have an impact upon the cognitive status of older individuals is their ongoing level of curiosity and engagement in intellectually stimulating activities (Friedland et al., 2001; Scarmeas et al., 2003; Wilson et al., 2002). Interestingly, older individuals often have been portrayed as being less attracted to the novel components of their surroundings (Blau, 1973; Langer, 1989). Electrophysiological studies have suggested that normal aging is associated with a decreased responsiveness to novelty and with altered processing of rare targets (Fabiani & Friedman, 1995; Friedman, Simpson, & Hamberger, 1993; Yamaguchi & Knight, 1991; Polich, 1996; Anderer, Semlitsch, & Saletu, 1996; Walhovd & Fjell, 2001; Verleger, Neukäter, Kömpf, & Vieregge, 1991; Friedman, Kazmerski, & Fabiani, 1997; Friedman, Kazmerski, & Cycowicz, 1998). However, our previous work using exploratory eye movements, viewing durations, and event-related potentials as dependent variables has suggested that a decrease in the allocation of attention to novelty is not an invariant component of the aging process (Daffner et al., 2006a; Daffner, Scinto, Weintraub, Guinessey, & Mesulam, 1994).

The current study focused on the relationship between the allocation of attention to novelty and the cognitive status of normal adults across the adult lifespan. We employed a subject-controlled variant of the novelty oddball paradigm (Daffner et al., 2000b) in which repetitive standard stimuli, infrequent target stimuli, and unique novel stimuli (e.g., fragmented objects) are presented, and subjects determine the duration of viewing of each stimulus by a button press that leads to the presentation of the next stimulus. Viewing durations serve as an index of visual attention and exploratory behavior (Berlyne, 1960; Daffner et al., 1994). Within this experimental context (as in many real life situations), novel stimuli are not simply distractors from the primary task of identifying targets, but provide an 'opportunity' for individuals to visually explore stimuli of varying degrees of interest or significance.

The subject-controlled variant of the novelty oddball paradigm has been used in the study of healthy young adults (Daffner et al., 2000d; Daffner et al., 2000a; Daffner et al., 1998), patients with focal injury to the CNS (Daffner et al., 2000c; Daffner et al., 2003; Daffner et al., 2000b), and patients with probable Alzheimer's disease (AD) (Daffner et al., 2001). We have found that viewing durations of healthy young adults are much longer in response to novel stimuli than repetitive standard stimuli. Focal injury to prefrontal cortex markedly disrupts attention to novel events (Daffner et al., 2000b; Daffner et al., 2000c) while having a limited impact on the processing of simple target stimuli. In patients with focal damage to posterior parietal cortex, viewing duration of novel stimuli falls between that of frontal patients and normal controls (Daffner et al., 2003). Patients with mild probable AD are

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indifferent to novel stimuli. They spend almost equal amounts of time viewing novel and repetitive standard stimuli during a stage of their illness in which their behavioral responses to target stimuli are relatively well preserved (Daffner et al., 2001; Daffner, Mesulam, Cohen, & Scinto, 1999; Daffner, Scinto, Weintraub, Guinessey, & Mesulam, 1992). In patients with either AD or frontal lobe damage, diminished viewing duration of novel stimuli correlates with the degree of apathy they exhibit, as measured by informant-based questionnaires (Daffner et al., 2000c; Daffner et al., 2001).

Recently, a group of cognitively high performing old subjects and a group of cognitively average performing old subjects participated in the subject-controlled variant of the novelty oddball paradigm (Daffner et al., 2006b). Cognitively high performing old subjects spent much more time looking at novel stimuli and had faster and more accurate responses to target stimuli than cognitively average performing old subjects. It remained unclear whether the differences between cognitively high and cognitively average performing subjects in responses to novel and target stimuli were specific to older individuals or would also be found in middle-aged and young individuals. There are several ways in which the interaction between cognitive status and age may play out. One possibility is that the differences observed between cognitively high and cognitively average old performers would not be seen in middle-aged and young ones. Alternatively, both the pattern and the magnitude of behavioral differences between cognitively high and average individuals found in old subjects may be very similar for middle-aged and young subjects. Finally, although the pattern may be similar, the magnitude of the differences between cognitively high and average subjects may vary across age groups.

In the current study, the impact of cognitive status on age-related differences in attention to novel and target events was addressed by expanding our pool of subjects to include cognitively high performing and cognitively average performing old, middle-aged, and young individuals. We hypothesized that overall, cognitively high performing individuals would be more interested in novel stimuli (as indexed by relatively longer subject-controlled viewing durations of novel stimuli) than cognitively average performing individuals. Furthermore, the magnitude of the difference between cognitively high and average performers would be largest among the old subjects. We also hypothesized that overall, cognitively high performing individuals would have faster, more accurate reactions in response to designated targets than cognitively average performing individuals. Furthermore, the magnitude of the difference between cognitively high and average performing groups would be largest for the old subjects.

Methods

Participants

After completing informed consent, participants underwent an evaluation that included a medical, neurological, and psychiatric history, a formal neurological examination, neuropsychological testing, and completion of questionnaires surveying mood and socioeconomic status. To be included in the study, participants had to be in one of three age groups, 18–28 years old (young subjects), 45–55 years old (middle-aged subjects), or 65–85 years old (old subjects), English-speaking, have ≥ 12 years of education, a Mini Mental State Exam (MMSE) score (Folstein, Folstein, & McHugh, 1975)≥ 26, and an estimated IQ on the American Modification of the National Adult Reading Test (AMNART) (Ryan & Paolo, 1992)≥ 100. Subjects were excluded if they had a history of CNS diseases or major psychiatric disorders based on DSM-IV criteria (American Psychiatric Association, 1994), a history of clinically significant medical diseases, corrected visual acuity worse than 20–40, a history of clinically significant audiological disease, a Geriatric Depression Scale score (Yesavage, Rose, & Lapp, 1981) of ≥ 10 for the old subjects or a Beck Depression

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Inventory (Beck & Steer, 1987) score of ≥ 10 for middle-aged or young subjects, or focal abnormalities on neurological examination consistent with a lesion in the CNS.

For all age groups, cognitive status was operationally defined based on performance on the following six neuropsychological tests: 1) Digit Span subtest of the Wechsler Adult Intelligence Scale-III (WAIS-III) (Wechsler, 1997a); 2) Controlled Oral Word Association Test (COWAT) (Ivnik, Malec, Smith, Tangalos, & Petersen, 1996); 3) Logical Memory II subtest of the Wechsler Memory Scale-III (WMS-III) (Wechsler, 1997b); 4) Visual Retention Test (Benton, 1963; Youngjohn, Larrabee, & Crook, 1993); 5) Boston Naming Test (BNT) (Kaplan, Goodglass, & Weintraub, 1983; Tombaugh & Hubley, 1997); 6) Category (animal) fluency (Spreen & Strauss, 1998). Each of the tests has available norms across a range of ages. Also, the tests evaluate performance in several major cognitive realms, including attention/executive functions (Digit Span, COWAT), verbal memory (WMS-III), visual memory (Visual Retention Test), language (BNT), and semantic access (category fluency). To meet criteria for a cognitively high performer, subjects had to score in the top 3rd (≥ 67th percentile) of published age-matched norms on ≥ 4 of the 6 cognitive tests. To meet criteria for a cognitively average performer, subjects had to score in the middle 3rd (33rd to 66th percentile) of published age-matched norms on ≥ 3 of the 6 cognitive tests. A composite score was computed for each subject by averaging performance (percentile score) on each of the neuropsychological tests. Subjects also completed the AMNART and the Raven’s Progressive Matrices Test (Raven, Court, & Raven, 1995) to determine estimated IQ scores, and the MMSE to obtain a gross measure of current mental state.

Experimental Procedures

The experimental procedures used were analogous to the ones described in prior reports (e.g., Daffner et al., 2000b; Daffner et al., 2006a). Two hundred and fifty line drawings, white on black background, were presented in 5 blocks of 50, each at the center of a high-resolution computer monitor. All stimuli subtended a visual angle of approximately 2.75° along their longest dimension. There were three categories of visual stimuli: 1) a repetitive Standard Stimulus (a triangle)--70% frequency, 2) a Target Stimulus (upside down triangle)--approximately 15% frequency, and 3) Novel Stimuli, randomly drawn from a set of unusual/unfamiliar line drawings (e.g., impossible or fragmented objects) shown only one time each--approximately 15% frequency, many of which came from the collection of drawings that have been used by Kroll and Potter (1984) and Kosslyn et al. (1994) (Figure 1). Stimuli appeared within a fixation box, subtending a visual angle of approximately 3.5° × 3.5°, that remained on the screen at all times.

Participants were told that the study was investigating how people look at different kinds of line drawings. They were informed that they would be viewing a set of drawings and that they could look at each picture for however long or short they liked. They controlled the viewing duration by pressing a button that led to the erasure of the current stimulus and the onset of a blank screen, followed by the presentation of the next stimulus. Participants were told that they would not be asked questions about the drawings at the end of the experiment. Also, participants were told to respond to the designated target stimulus by pressing a foot pedal (ipsilateral to the button press). Instructions indicated that accuracy was more important than speed. Left and right button press/foot pedal were counterbalanced for all subject groups. Subjects also participated in two other conditions not reported here. The order of the conditions was counterbalanced for all subject groups. Event-related potentials were recorded while collecting the behavioral data, which will be the focus of a separate report.

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Data Analysis

The viewing duration in response to each stimulus type was measured for each subject. Viewing duration was calculated as the temporal interval between stimulus onset and button press. Reaction time (RT) and percent hit rate were measured for target events. RTs were calculated as the duration between stimulus onset and foot pedal between 200 and 1800 ms.

Demographic, neuropsychological, and behavioral data were analyzed using analysis of variance (ANOVA), with age group (old, middle-aged, and young subjects) and cognitive status (high performing, average performing) as the between-subjects variables. For the behavioral data, stimulus type (novels, targets, standards) was used as the within-subjects variable. Bonferroni correction of probability level was applied to follow-up analyses of main effect for age group. Analyses that yielded significant interactions between subject group and stimulus type resulted in planned contrasts between the levels of the variable. The Geisser-Greenhouse correction was applied to all repeated measures with greater than 1 degree of freedom.

Results

Participants

Ninety-six individuals participated in the study. Data from two subjects (one cognitively average performing old and one cognitively average performing middle-aged subject) were not included in the analyses because their behavioral responses (viewing duration of novel stimuli) were more than 3 standard deviations from the mean of their respective groups. The characteristics of each group are summarized in Table 1, including the number of subjects, demographic information, the results on the more global cognitive measures (e.g., estimated IQ), composite percentile scores on the neuropsychological tests, and the pertinent statistical analyses. (Appendix 1 provides results for specific cognitive tests.)

There were no overall differences in age between cognitively high and cognitively average performing subjects. Similarly, there were no overall differences in years of education between cognitively high and average performing subjects. Middle-aged subjects had more years of education than old subjects ($p < 0.05$) and young subjects ($p < 0.01$). Many in the latter group were still in school. All groups had mean estimated IQ scores in the high average to superior range. Overall, cognitively high performing subjects had somewhat higher mean scores than cognitively average performing subjects on the AMNART (3.5 points higher) and the Raven’s (4.9 points higher) (p’s < 0.05). Because of these differences among groups, pertinent ANOVAs were also run using estimated IQ as a covariate. Overall, cognitively high performers had slightly higher MMSE scores than cognitively average performers ($p < 0.01$). All groups were comparable in terms of gender, mood, and self-assessment of level of material comfort and wealth.

Cognitively high performing subjects had a higher mean composite percentile score for the six neuropsychological tests than cognitively average performing subjects (73.2 percentile vs. 48.7 percentile, $p < 0.01$) (Table 1) [1]. There were no age-related differences in composite percentile score within either the cognitively high or cognitively average performing groups.

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[1] Note that the magnitude of the difference between cognitively high and cognitively average performers was much greater for the composite percentile score than for either the AMNART or Raven’s score (group (high vs. average performers) by cognitive test score (composite vs. estimated IQ) interaction, F’s > 65 and p’s < 0.01).

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Viewing Duration

The first question addressed was whether cognitively high and average performers are differentially engaged by novel and target events (as measured by viewing duration), and whether this effect is modulated by age. Figure 2 illustrates the mean viewing durations in response to each stimulus type for all subject groups. Viewing duration data were subjected to 3 (age group: old, middle-aged, young) by 2 (cognitive status: high, average) repeated measures ANOVAs. In response to novel stimuli, cognitively high performing subjects looked longer than cognitively average performing subjects ($F(1,88) = 5.73$, $p < 0.05$), with a trend for this effect to be larger across old subjects (cognitive status by age interaction, $F(2,88) = 2.43$, $p < 0.09$). In response to target stimuli, cognitively average performing subjects looked longer than cognitively high performing subjects ($F(1,88) = 18.03$, $p < 0.01$), with a similar magnitude of effect across all age groups (no cognitive status by age interaction). In response to standard stimuli, there was no effect of age, cognitive status, or age by cognitive status interaction.

Across all groups, subjects looked at novel stimuli longer than standard stimuli ($F(1,88) = 26.59$, $p < 0.01$). This difference was larger for cognitively high than cognitively average performing subjects (stimulus type by cognitive status interaction, $F(1,88) = 5.98$, $p < 0.05$), with the magnitude of this effect tending to be biggest among old subjects (stimulus type by cognitive status by age interaction, $F(2,88) = 2.62$, $p < 0.08$). Across all groups, subjects looked at target stimuli longer than standard stimuli ($F(1,88) = 381.70$, $p < 0.01$). The magnitude of this effect was larger for cognitively average performing than cognitively high performing subjects (stimulus type by cognitive status interaction, $F(1,88) = 20.92$, $p < 0.01$), with a similar pattern across all age groups (no stimulus type by cognitive status by age interaction).

Particularly informative is the comparison between viewing duration of novel and target stimuli, which yielded a significant interaction between stimulus type and cognitive status ($F(1,88) = 14.68$, $p < 0.01$). Cognitively average performing individuals spent much more time viewing target than novel stimuli (targets: 2726.0 (130.4); novels: 1448.8 (406.7), mean (SEM) in ms, $F(1,43) = 31.71$, $p < 0.01$). In contrast, cognitively high performing individuals tended to spend more time looking at novel than target stimuli (targets: 1951.2 (127.6); novels: 2810.8 (398.0), $F(1,45) = 2.95$, $p < 0.094$). The magnitude of this effect was larger for old subjects than their younger counterparts (stimulus type by cognitive status by age interaction, $F(2,88) = 3.37$, $p < 0.05$) (Figure 3). This interpretation was supported by an analysis of the effect size of the interaction between stimulus type and cognitive status for each age group, which revealed the following old subjects: $p < 0.01$, $\eta^2 = 0.24$; middle-aged subjects: $p = 0.21$, $\eta^2 = 0.05$; young subjects: $p < 0.05$, $\eta^2 = 0.14$. Consistent with these findings were the correlations between composite percentile score and viewing duration of novels minus viewing duration of targets within each age group (old subjects: $r = 0.60$, $p < 0.01$; middle-aged subjects: $r = 0.33$, $p < 0.08$; young subjects: $r = 0.45$, $p < 0.05$).

In summary, cognitively average and high performing adults responded to target and novel stimuli differently. Cognitively average performers spent more time viewing target than novel stimuli, whereas cognitively high performers tended to spend more time viewing novel than target stimuli. The magnitude of the differences between cognitively average and high performing adults was largest among old subjects.

Target Reaction Time, Hit Rate, False Alarms

Target reaction time, hit rates, and false alarms to novel and standard stimuli were examined with 3 (age group) by 2 (cognitive status) ANOVAs (Table 2). For reaction time, there was an effect of cognitive status ($F(1,88) = 4.57$, $p < 0.05$), but no effect of age and no age by

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cognitive status interaction. Cognitively high performing subjects had shorter reaction times to targets than cognitively average performing subjects. Similarly, for hit rates, there was an effect of cognitive status ($F(1,88) = 10.21$, $p < 0.01$), but no effect of age, and no age by cognitive status interaction. Cognitively high performers had higher hit rates than cognitively average performers. Regarding false alarms to novel stimuli, there was no effect of age, cognitive status, or age by cognitive status interaction. In summary, cognitively average performing adults had slower and less accurate responses to target stimuli than cognitively high performing adults, with no significant age-related effects.

Relationship Between Target RT and Viewing Duration of Targets

The finding that cognitively average performing subjects had longer RTs to target stimuli than cognitively high performing subjects might account for their longer viewing duration of targets. To explore this further, the reaction time to targets was subtracted from viewing duration of targets for each subject and the results were examined by a 3 (age group) by 2 (cognitive status) ANOVA. There was an effect of cognitive status ($F(1, 88) = 18.01$, $p < 0.01$), with cognitively average performing subjects having a much larger target difference value than cognitively high performing subjects. There was no effect of age nor age by cognitive status interaction. This provides strong evidence that the differences in engagement by target stimuli between cognitively high and average performing subjects cannot simply be explained by the latter group's slower reaction time to targets.

Estimated IQ as a covariate

To determine whether the major findings of this study could be explained by differences in IQ, pertinent statistical analyses were run again using estimated IQ (based on AMNART and Raven's scores) as covariates. The statistical results had an almost identical pattern and magnitude as those reported earlier for all tests explored, including those involving viewing duration of novel, target, and standard stimuli, target hit rate and RT.

Cognitively average performing subjects with average vs. high estimated IQs

Because the mean estimated IQs of the cognitively average performing subjects were in the above average to superior range, we sought to determine if there were differences in behavioral responses to the various stimulus types between the cognitively average performers with average estimated IQs and those with high estimated IQs. To do so, a median split of the cognitively average performers within each age group was completed based on estimated IQs (average of each subject's AMNART and Raven scores). The estimated IQ for each of the cognitively average performing groups was as follows (mean (SD)): young lower IQ: 109.6 (4.6), young higher IQ: 118.5 (0.89); middle-aged lower IQ: 114.1 (3.8), middle-aged higher IQ: 124.6 (2.8); old lower IQ: 112.4 (9.7); old higher IQ: 124.9 (2.3). As expected, overall, the lower IQ group had lower estimated IQs than the higher IQ group (111.9 vs. 122.5, $p < 0.01$). The lower IQ group also had a lower mean composite percentile score on neuropsychological tests (46.0 percentile vs. 52.7 percentile, $p < 0.05$) and fewer years of education (15.2 years vs. 17.3 years, $p < 0.05$) than the higher IQ group. There was no interaction between age and any of these variables. The lower and higher IQ groups of cognitively average performers did not differ in their mean viewing duration of standard, target, or novel stimuli (no effect of IQ group). There also was no interaction between IQ group and age group. Similarly, the groups did not differ in terms of their mean RT or percent correct response to targets, or in their false alarm rates. In summary, the behavioral performance of cognitively average performers whose estimated IQs were in the average range (within 1 SD of 100) did not differ from cognitively average performers whose estimated IQs were in the high average to superior range (> 115).

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Discussion

The main goal of this study was to investigate age-related differences in attention to novel and target events among cognitively high and average performing adults. The groups were well matched for pertinent variables such as education, gender, mood, and socioeconomic status. Cognitively high and cognitively average performers differed in estimated IQ. However, the differences were relatively small and after controlling for them all of the salient findings of the study remained. Support was found for our two major hypotheses.

As a group, cognitively high performing adults were more engaged by novelty (as measured by viewing duration) than their cognitively average performing counterparts. The magnitude of the differences between cognitively high and average performers was largest among old adults, which suggests that the link between interest in novelty and higher cognitive performance is strongest in old age. These results confirm our first hypothesis. Additional research is necessary to determine whether increased interest in novelty directly leads to better cognitive performance, perhaps by predisposing individuals to participate in and attend more fully to intellectually stimulating activities, or whether a yet-to-be-determined common underlying factor leads to both increased engagement by novelty and better cognitive functioning. Several lines of evidence make a causal link between increased responsiveness to novelty and better cognitive functioning plausible. For example, studies have suggested that when aging animals interact within a more complex environment, it increases dendritic complexity and cortical thickness, and promotes cognitive abilities (Connor, Melone, Yuen, & Diamond, 1981; Kempermann, Kuhn, & Gage, 1997). Older animals who are more engaged by novel stimuli also tend to exhibit greater preservation of cognitive performance (Rowe, Spreekmeester, Meaney, Quirion, & Rochford, 1998). In a mouse model of Alzheimer’s disease, exposure of transgenic mice to an enriched environment has been associated with reduced Aβ levels and amyloid deposition, two components of the neurodegenerative process (Lazarov et al., 2005). In humans, the propensity to allocate attention to novelty is believed to make a major contribution to the cognitive development of children and may play an important role throughout the lifespan (Daffner et al., 1994; Hunt, 1965; Piaget, 1952; Vygotsky, 1968). Several prospective epidemiological investigations have indicated that as humans get older, continued interest in novel aspects of their environment and exposure to intellectually stimulating activities may sustain cognitive functioning, produce a buffer against mental decline, and foster longevity (Friedland et al., 2001; Scarmeas et al., 2003; Swan & Carmelli, 1996; Wilson et al., 2002). One strategy for addressing the issue of causality would be longitudinal studies of older individuals to determine whether for subjects at any given cognitive level, those more engaged by novelty will be less likely to decline cognitively.

Our second hypothesis also received support. Behaviorally, cognitively average performers were slower to respond to targets than cognitively high performers. This result was not the reflection of differences across groups in the trade-off between speed and accuracy, since the cognitively average performing group also had lower hit rates. The magnitude of the difference between cognitively high and average performers did not increase with age. Perhaps, to observe such an interaction between cognitive status and age requires a more difficult, faster-paced target detection task than was employed here. This possibility can be tested in future research.

One potential limitation of the study is that although the cognitively average functioning individuals performed squarely in the average range (around the 50th percentile) on a battery of neuropsychological tests, they had mean estimated IQs in the above average to superior range, and most had college educations. These characteristics may reduce the extent to which inferences made about our results can be generalized. However, this ‘limitation’ of

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the current study also turns out to be one of its potential strengths: the subject groups, which had been defined by differences in current level of cognitive performance, ended up having very similar levels of estimated IQ and education. Our results suggest that intellectual capacity does not fully account for differences in cognitive performance or in attention allocated to novelty. Further study is needed to determine the extent to which cognitively average performers with high cognitive reserve differ from their counterparts with average reserve. We suspect that there would be considerable overlap between these groups. Carrying out a median split of the cognitively average performers based on estimated IQ suggested that those with IQs in the average range exhibit behavioral responses to novel and target stimuli that are similar to those with IQs in the high range.

We acknowledge that the discrepancy between cognitive performance and cognitive capacity (i.e., IQ) observed among the cognitively average performing adults may have been due to inaccurate measurements of IQ, which were based on performance on the AMNART and the Raven’s Progressive Matrices. Estimated IQ tends to regress scores to the mean, thus making it more difficult to find effects of this variable. Scores from a more extensive IQ test battery, such as the WAIS, that samples a range of cognitive abilities, skills, and knowledge may have suggested that the IQs of cognitively average performers were, in fact, quite different from those of cognitively high performers. It is of note that although tests like the AMNART or the Raven’s provide imperfect estimates of overall intellectual capacity, studies have suggested that they strongly correlate with the Full Scale IQ scores of the WAIS (Blair & Spreen, 1989; Bright, Jaldow, & Kopelman, 2002; Ryan & Paolo, 1992; Hall, 1957; Watson & Klett, 1974; Pringle & Haanstad, 1971; O’Leary, Rusch, & Guastello, 1991; Shaw, 1967). Also, to more fully evaluate underlying intellectual capacity, two measures were employed that assess very different kinds of cognitive abilities. Performance on the AMNART reflects a person’s baseline vocabulary and prior exposure to phonetically irregular words (and tends to correlate more strongly with VIQ than PIQ (Blair & Spreen, 1989; Uttl, 2002; Ryan & Paolo, 1992)). In contrast, performance on the Raven’s test reflects nonverbal reasoning and abstraction (and tends to correlate more strongly with PIQ than VIQ (Hall, 1957; Watson & Klett, 1974)). In the current study, both the AMNART and the Raven’s yielded similar results.

Our study raises several other important issues that have implications for research on normal aging in general. These issues include 1) determining the most informative ways to categorize different subject groups, 2) understanding the discrepancies between estimates of IQ and current level of cognitive performance, and 3) accounting for cognitive status when making comparisons between age groups. Consistent with the strategy recommended by Salthouse and Ferrer-Caja (2003), we categorized subjects based on a composite percentile score that reflected their performance on a range of neuropsychological tests relative to other members of their age group. Different age groups could then be matched in terms of cognitive status (e.g., top third, middle third). This method allows for the comparison of a much larger portion of the population than if different age groups were matched on the basis of having the same absolute scores on neuropsychological tests. Additional research is needed to help determine the most informative ways to define members of subject groups in cross sectional studies of aging investigating questions about individual differences. Although we relied upon the composite percentile score on six neuropsychological tests, in future studies it may be valuable to compare age groups who were matched in terms of performance on a larger number of tests within a specific cognitive realm hypothesized to be the most pertinent to an experimental task (e.g., frontal-executive functions).

Our data raise questions about whether discrepancies between estimated baseline intellectual capacity and current level of cognitive performance can simply be interpreted as an indication of age- or disease-associated decline (Rentz et al., 2004; Rentz et al., 2006;

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Schretlen, Munro, Anthony, & Pearlson, 2003; Schretlen, Buffington, Meyer, & Pearlson, 2005). Such discrepancies were not only found in old adults, but also in young and middle-aged adults. Additional research needs to be done to elucidate the different reasons why some individuals with high estimated IQs only perform in the average range on neuropsychological tests. Potential explanations include a decline in intellectual functioning, a failure to perform up to capacity, and an inaccurate estimate of underlying cognitive ability based on the scores from single tests.

The outcome of the current study also reinforces the notion that when drawing inferences about aging, the strategy of comparing normal subjects from various age groups without carefully accounting for differences in level of cognitive performance may be inadequate (Salthouse & Ferrer-Caja, 2003). By way of illustration, if the sample of young adults had been limited to our cognitively high performing group (e.g., as might be recruited by selecting undergraduates enrolled in an advanced psychology course) and the sample of old subjects had been limited to our cognitively average performing group (e.g., as might be recruited through the common selection criterion of being a “non-demented community-dwelling elder”), they would have been reasonably well matched for education and estimated IQ. Analyses would have revealed that compared to the young subjects, the old subjects had shorter viewing durations of novel relative to target stimuli ($p < 0.05$), diminished target detection accuracy ($p < 0.05$), and slower RTs to targets ($p < 0.05$). These results may have led to the conclusion of an age-related decline in attention to novel and target events, when, in fact, the outcome was driven by differences between groups in cognitive status, not age. The usual method of matching different age groups for education or estimated IQ is not sufficient because the age groups studied may still differ in their relative mixture of cognitively high, average, (and low) performing subjects. Our results suggest that cognitively high and cognitively average performing subjects exhibit different patterns of age-related changes in response to novel and target events. Although future research using longitudinal designs will be important to validate the findings, our cross-sectional study strongly supports the notion of different patterns of normal aging and the need to identify the factors that influence these patterns.

Acknowledgments

This research was supported in part by NIA grant 1R01 AGO17935. The authors thank Katherine Ryan and Danielle Williams for their assistance with data collection and analysis.

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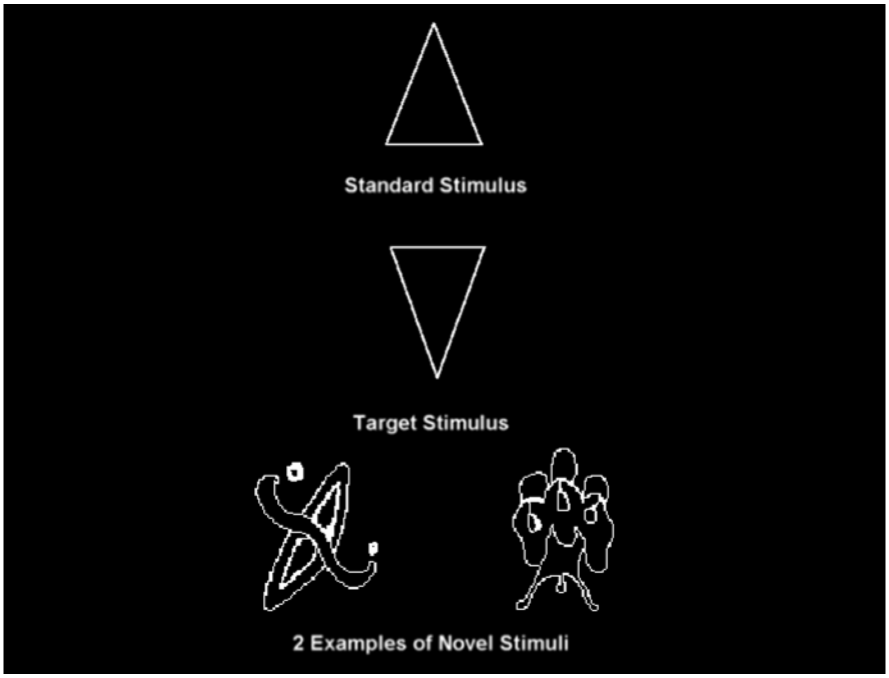

Figure 1.

Repetitive standard stimulus (70% frequency), target stimulus (15% frequency), and two examples of novel stimuli (15% frequency).

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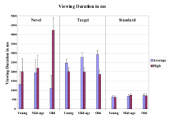

Figure 2.

Viewing duration in ms (mean ± SEM) in response to each stimulus type for all subject groups.

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Table 1

Subject characteristics

		Young		Middle-age		Old		Age Effects within each Cognitive Group	Overall Age Effect	Overall Cognitive Status Effect	Age by Cognitive Status Interaction
Number of Subjects	**Ave.**	**16**		**15**		**15**					
	High	**16**		**16**		**16**					
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value**	**p-value**	**p-value**	**p-value**
Age	Ave.	21.8	2.7	49.2	3.1	70.1	4.3	<.01	<.01	ns	ns
	High	21.5	1.0	50.3	3.4	73.0	4.9	<.01			
Years of Education	Ave.	14.9	1.7	17.7	2.8	16.1	4.0	<.05[a]	<.01[b,c]	ns	ns
	High	15.4	0.6	18.9	4.3	16.5	4.2	<.05[a]			
Gender (male/female)	Ave.	6/10		4/11		7/8		ns	ns	ns	ns
	High	10/6		9/7		7/9		ns			
Raven Estimated IQ	Ave.	110.2	8.4	117.1	9.5	119.5	12.3	<.05[d]	<.01[a,d]	<.05	ns
	High	116.1	11.2	124.4	7.0	120.8	12.3	ns			
AMNART Estimated IQ	Ave.	117.8	6.3	122.5	5.4	116.9	9.6	<.10	<.01[a,b]	<.05	ns
	High	120.6	4.3	125.8	4.1	121.3	8.8	<.05			
MMSE	Ave.	28.9	1.2	28.4	1.4	28.5	1.6	ns	ns	<.01	ns
	High	29.1	0.7	29.4	1.0	29.2	0.8	ns			
Composite Percentile Score	Ave.	47.1	9.7	48.4	11.6	50.5	9.2	ns	ns	<.01	ns
	High	71.5	7.6	76.0	10.3	72.3	9.8	ns			

[a] Key: p<.05 Middle-aged vs. Young,

[b] p<.05 Old vs. Middle-aged,

[c] p<.01 Middle-aged vs. Young,

[d] p<.05 Old vs. Young

See text for information about each of the neuropsychological tests. Raven= Raven's Progressive Matrices Test; AMNART= American Modification of the National Adult Reading Test; MMSE= Mini Mini Mental State Exam; Composite Percentile Score for Digit Span, WAIS-II, Controlled Oral Fluency (FAS), Logical Memory II, WMS-III, Visual Retention Test, Boston Naming Test, and Category Fluency (animals).

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Table 2

Target reaction time, time, hit rates, false alarms

		Young		Middle-age		Old		Age Effects within each Cognitive Group	Overall Age Effect	Overall Cognitive Status Effect	Age by Cognitive Status Interaction
		Mean	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**p-value**	**p-value**	**p-value**	**p-value**
Reaction Time to Targets (ms)	**Average**	965.3	66	989.3	60	989.0	56	ns	ns	<0.05	ns
	High	826.3	42	938.4	50	888.1	55	ns			
% Correct Hits	**Average**	92.9	1.4	92.4	0.9	87.9	2.4	ns	ns	<0.01	ns
	High	96.3	1.2	94.1	2.6	97.0	1.2	ns			
% False Alarm to Novels	**Average**	1.2	0.4	0.7	0.4	0.5	0.3	ns	ns	ns	ns
	High	0.7	0.5	0.3	0.3	0.3	0.2	ns			

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Appendix 1

Performance on individual neuropsychological tests

		Young		Middle-age		Old		Age Effects within each Cognitive Group	Overall Age Effect	Overall Cognitive Status Effect	Age by Cognitive Status Interaction
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value**	**p-value**	**p-value**	**p-value**
Digit Span	Ave.	17.8	2.8	16.2	2.7	15.9	3.5	ns	ns	<.01	ns
	High	20.8	3.3	19.9	3.9	19.6	4.3	ns			
Controlled Word Fluency (COWAT)	Ave.	41.7	9.9	38.9	10.0	29.8	9.9	$<.01^{a,b}$	<.1	<.01	<.05
	High	45.9	14.4	51.8	13.0	48.4	10.8	ns			
Boston Naming Test[1]	Ave.	54.3	2.2	55.7	3.3	54.9	3.3	ns	$<.1^{c}$	<.01	ns
	High	56.5	1.9	58.3	2.5	56.9	3.3	ns			
Category Generate (Animals)	Ave.	18.9	4.2	20.2	3.3	14.5	4.7	$<.01^{d,e}$	$<.01^{g,h}$	<.01	ns
	High	26.6	4.8	24.7	5.0	17.8	5.9	$<.01^{d,f}$			
WMS III Logical III Memory (Delayed Recall)[2]	Ave.	26.1	7.5	28.0	7.3	25.0	7.5	ns	<.1	<.01	ns
	High	34.1	6.7	32.7	6.3	28.8	3.9	$<.05^{e}$			
Benton Visual Retention Test (Correct)[3]	Ave.	7.7	1.3	7.0	1.2	6.3	1.1	$<.01^{b}$	$<.01^{i,j}$	<.01	ns
	High	9.0	0.9	8.6	0.9	6.9	1.3	$<.01^{i,h}$			

[a] Key: $p<.05$ Old vs. Middle-aged,

[b] $p<.01$ Old vs. Young,

[c] $p<.08$ Middle-aged vs. Young,

[d] $p<.01$ Old vs. Middle aged,

[e] $p<.05$ Old vs. Young,

[f] $p<.01$ Old vs. Young,

[g] $p<.01$ Old vs. Middle-aged,

[h] $p<.01$ Old vs. Young,

[i] $p<.01$ Old vs. Middle-aged,

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[j] p<.01 Old vs. Young Maximum score:

[1] 60;

[2] 50;

[3] 10;

See text for information about each of the neuropsychological tests.