Age-related decrements in performance on a brief continuous performance test

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Abstract

Research has revealed age-related decrements in performance on a variety of attention-related tasks, including sustained attention, selective attention, and inhibition tasks (e.g., [Armstrong, C. (1997). Selective versus sustained attention: A continuous performance test revisited. Clinical Neuropsychologist, 11(1), 18–33; Chao, L. L. & Knight, R. T. (1997). Prefrontal deficits in attention and inhibitory control with aging. Cerebral Cortex, 7(1), 63–69; Deaton, J. E., & Parasuraman, R. (1993). Sensory and cognitive vigilance: Effects of age on performance and subjective workload. Human Performance, 6(1), 71–97]). The continuous performance test (CPT) is a well-recognized measure of sustained attention and impulsivity [Riccio, C. A., Reynolds, C. R., & Lowe, P. (2001). Clinical applications of continuous performance tests: Measuring attention and impulsive responding in children and adults. New York: John Wiley & Sons, Inc.]. In the following study, the influence of age on CPT performance was assessed. Thirty-two healthy adults (age 19–82) completed a brief K–A version of the CPT under “clear” and “noisy” trial conditions. Under both conditions, participants’ accuracy on the CPT task decreased with age. In both conditions, the number of commission errors (including false alarms) increased significantly as age increased. This relationship differed with omission errors, as age accounted for a significant proportion of variance in omission errors under the noisy condition alone. Overall, this study provides evidence for age-related differences in performance on a brief CPT, particularly for deficits in selective response inhibition.

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1. Introduction

Researchers assessing cognitive abilities have found decrements in performance associated with the normal aging process. Performance on tasks measuring a number of cognitive abilities has been shown to decrease throughout adulthood (e.g., Armstrong & Cloud, 1998; Chao & Knight, 1997; Cherry & Hellige, 1999). One such cognitive ability is attention. The continuous performance test (CPT) is a well-recognized test of sustained attention that has been used to demonstrate attentional deficits in a number of cognitively impaired populations (Riccio, Reynolds, & Lowe, 2001, 2002). The focus of the current study is on the application of a CPT to an older group, in order to assess age-related changes in attention.

Attention is a complex process of sustaining attention, inhibiting responses to certain stimuli (selective attention), and shifting attention (Riccio et al., 2002). Sustained attention refers to the ability to maintain attention and alertness over time (Cicerone, 1997), and is typically equated with vigilance (Berardi, Parasuraman, & Haxby, 2001; Strauss, Thompson, & Adams, 2000). Selective attention refers to the ability to distinguish between relevant and irrelevant information, and to respond to relevant material (Armstrong, 1997).

Sustained attention, selective attention, and inhibition performance decrease with age during adulthood, as reflected in research using non-CPT (and non-visual CPT) tasks. Researchers have observed decreased vigilance over time among older adult versus younger adult groups; particularly when stimuli are degraded (e.g., Deaton & Parasuraman, 1993; Parasuraman, Nestor, & Greenwood, 1989). Bedard et al. (2002) found that selective inhibition performance decreased with age; further, evoked potential (ERP) studies indicate inefficiency in inhibitory mechanisms among older adult groups (e.g., Anderer, Pascual-Marqui, & Semlitsch, 1998; Chao & Knight, 1997). On an auditory CPT task, Armstrong (1997) found that an older adult group (60–94 years) was significantly less successful in responding to auditory discrimination targets than was a younger adult group.

Others, however, suggest that sustained attention ability does not decrease with age. Tomporowski and Tinsley (1996) found similar performance on vigilance tasks among a young and older group. Similarly, Berardi et al. (2001) found no decrement in overall vigilance and sustained attention performance among an older group.

Researchers have explained this inconsistency in findings regarding sustained attention and aging as the result of a number of factors. One line of research suggests that the rate of stimulus presentation and the stimulus quality influence performance more significantly among older individuals (e.g., Bunce, 2001; Deaton & Parasuraman, 1993; Parasuraman & Giambra, 1991; Parasuraman et al., 1989; Rueckert & Grafman, 1998). It has been observed that habituation occurs more frequently when stimuli are presented at a faster rate (Rueckert & Grafman, 1998), which may produce increased reaction time and a greater number of missed targets. Thus, rate of presentation could interact with other factors to produce differential results across studies. Similarly, research suggests that performance differences between older and younger individuals are more likely to occur when stimuli are degraded (e.g., Bunce, 2001; Parasuraman et al., 1989).

The CPT is a reliable and valid measure of sustained attention (e.g., Cornblatt, Risch, Faris, Friedman, & Erlenmeyer-Kimling, 1998; Fallgatter, Mueller & Strik, 1999; Haeger, Wolz, & Gaser, 1998; Halperin, Sharm, & Greenblatt, 1991). It has been used to detect impairment in
attentional performance (e.g., Armstrong, 1997; Fischer, Newby & Gordon, 1995; Gokalsing, Robert, & Lafont, 2000) and to detect inhibition deficits (Fallgatter et al., 1999; Gokalsing et al., 2000). The CPT requires monitoring of a series of visual or aural stimuli while responding to target stimuli only (e.g., responding when an 'X' appears, or when an 'X' is immediately preceded by an 'A') (Ballard, 2001; Halperin et al., 1991; Keilp, Herrera, & Stritzke, 1997; Riccio et al., 2001, 2002; Rosvold et al., 1956). A number of variables derived from the CPT are used to measure attention, including omission errors (failing to respond to targets), commission errors (responding to non-targets), and reaction time (Ballard, 2001; Riccio et al., 2002). ‘Degraded’ versions of the CPT have been used, in which the stimuli presented are less visibly or aurally clear (Ballard, 2001).

While research suggests that performance on sustained attention or vigilance tasks decreases with age, there is little research regarding CPT performance and age-related decrements among older adults, particularly for visual A–X CPT versions. Existing research suggests that CPT performance follows a U-shaped curve across the life span, such that performance improves from childhood through to young adulthood, and declines following middle age (Greenberg & Crosby, 1992 as cited in Riccio et al., 2001). Parr’s (1995) dissertation research indicated that older groups of healthy individuals made significantly more omission and commission errors than did groups of healthy younger individuals. Similarly, Davies and Davies (1975) found that a group of younger adults (18–31 years) had a higher correct hit rate on the X-CPT than did a group of older adults (65–75 years).

It is clear that further research in this area, particularly with a wide age range in late aging, is needed. We conducted the following study, in which the influence of age on CPT performance was assessed. It was hypothesized that variables of attention (omission errors), inhibition (commission errors and false alarms), and reaction time would increase with age. We hypothesized that performance on the noisy (degraded) CPT as opposed to the clear CPT would be worse for participants regardless of age, and that performance on the noisy task would be poorest among older participants.

2. Methods

2.1. Participants

The sample consisted of 32 healthy individuals who were recruited from the local community. There were 32 participants (19 females and 13 males), ranging in age from 19 to 82 years, with a mean age of 51.4 years (S.D. = 15.3). The distribution of age was relatively continuous (see Fig. 1). Twenty-seven of the participants were Caucasian, three were African–American, and two were Asian–American. The WASI Full Scale IQ scores for this sample ranged from 73 to 140, with a mean full IQ of 115 (S.D. = 17.0). None of the participants were on any medication that would affect the CNS. The average number of years of education for this sample was 15.9 (S.D. = 3.15).

Exclusionary criteria included: (1) any individual with a past or present Axis I psychiatric diagnosis (with the exception of a single past major depressive episode; substance abuse occurring over 3 months prior; substance dependence ending before 10 years prior, and social
Fig. 1. Relationship between age and the number of commission errors made (raw scores; noisy condition).

phobia ending before 10 years prior) as determined through a SCID-I diagnostic interview; (2) current use of psychoactive medication; (3) corrected visual acuity less than 20/50 based on the Snellen visual acuity chart; and (4) past or present history of a neurological disorder (as determined by self-report).

2.2. Materials

2.2.1. Visual acuity chart (Snellen scale)

The Snellen scale provides a basic measure of visual acuity, by requiring an individual to read rows of random letters of progressively smaller size. As all participants stood exactly 20 ft from the chart, visual acuity was represented as a ratio of distance needed to adequately focus (e.g., 20/40 was converted to .5). Each ratio was changed into a number (top number divided by the bottom number) to allow for statistical comparisons.

2.2.2. Continuous performance task

The CPT task was created using the Vigil software package (ForThought Ltd., 1993a). Stimuli were presented using a PC computer and monitor and responses were collected with a standard keyboard. The CPT task was modeled after the A–X version (Wohlberg & Kornetsky, 1973), in which a series of random single letters are presented and the participant is asked to press the spacebar after observing a target sequence of two letters. In this study, the target was when the letter “K” was immediately followed by the letter “A”, which occurred approximately
20% of the time. Stimuli were presented in the middle of the screen at a constant rate of one per 998 ms, with the target appearing for the first 43 ms and a blank screen appearing for the remaining 955 ms. Each letter was approximately 1.2 cm wide and 2 cm high, and each person sat approximately 18 in. from the computer screen. Two conditions were administered in a counterbalanced order. The first, termed the "clear condition," presented white letters on a black background, while the second, termed the "noisy condition," presented white letters on a background of "white noise" (see Fig. 2). The noisy condition was created by degrading the stimulus 25% through the insertion of background (white) noise, which was automatically generated by the software package (see Fig. 2). Since this test was given as part of a larger battery of tests, the length was kept relatively brief: each condition consisted of 150 trials, resulting in condition duration of 2.5 min.

Response to target trials ("K" followed by "A") was considered a correct detection. A response to a trial that is not the target is considered a commission error, while failure to respond to a target trial is an omission error. Each condition also includes 30 "catch" trials in which the stimulus presented was either "K" followed by a letter other than "A" or "A" preceded by a letter other than "K." Response to a "catch" trial is considered a false alarm (a specific type of commission error). Perceptual sensitivity is based on the conditional probabilities of correct detections and false alarms; higher scores reflect better ability to detect signal from noise.

Although this CPT task offers less peer-reviewed data than other CPT versions, construct validity has been established by the developers of the CPT software program used in this study (ForThought Ltd., 1993a) through comparison with performance on tests thought to measure similar constructs. These tasks showed a reasonable degree of correlation with the number of
Table 1
Mean number of omission, commission, and false alarm errors under noisy and clear conditions

<table>
<thead>
<tr>
<th></th>
<th>Noisy</th>
<th>Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean S.D.</td>
<td>Mean S.D.</td>
</tr>
<tr>
<td>Omission</td>
<td>3.63</td>
<td>5.19</td>
</tr>
<tr>
<td>Commission</td>
<td>1.84</td>
<td>2.19</td>
</tr>
<tr>
<td>False alarms</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* Sample size with three outliers removed.

errors of omission and commission on a degraded CPT condition ($r = .45$ to .59) (ForThought Ltd., 1993b). Additionally, reliability of the degraded AX version was demonstrated, with high test–retest correlation (3-month interval) in errors of commission ($r = .70$) and omission ($r = .69$). A study of healthy older individuals reported that the degraded stimuli CPT task was able to distinguish these individuals from younger adults, as older individuals were found to have decreased sensitivity scores (ForThought Ltd., 1993b).

2.2.3. Full Scale IQ estimate
Vocabulary and Matrix Reasoning subtests from the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999) were used to estimate Full Scale IQ. These subtests have been found to be a valid estimate of Full Scale IQ, in that performance on these subtests accounts for approximately 76% of the variance of performance on the full battery of the Wechsler Adult Intelligence Scale-3rd Edition. In addition, the subtests are reliable, as test–retest correlations (over an interval of 1 month) were .85 for the vocabulary subtest and .77 for the matrix reasoning subtest (Wechsler, 1999).

2.3. Procedure
Each individual participated in a 2-h session, in which they were first screened for psychiatric illness and for adequate visual acuity. Participants were asked a series of demographic questions, and the WASI was given. Participants then completed the continuous performance test. Each participant was reimbursed $20 for the average 2 h of research procedures (one session).

3. Results
Participants, regardless of age, performed worse under the ‘noisy’ CPT condition than under the clear CPT condition (see Table 1). Under the noisy condition, participants made significantly more commission errors ($t = 3.0$, $p < .01$), omission errors ($t = 2.7$, $p < .05$), and false alarms ($t = 2.9$, $p < .01$), than under the clear condition. Correlation and regression analyses were run separately for the ‘Noisy’ and ‘Clear’ CPT conditions.
Table 2
Correlations under noisy and clear condition, using raw scores (Outliers included)

<table>
<thead>
<tr>
<th></th>
<th>Acuity</th>
<th>FSIQ</th>
<th>Education</th>
<th>SES</th>
<th>RT*</th>
<th>Omission</th>
<th>Commission</th>
<th>FA**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>−.305</td>
<td>.087</td>
<td>−.076</td>
<td>−.097</td>
<td>.261</td>
<td>.229</td>
<td>−.611**</td>
<td>.320</td>
</tr>
<tr>
<td>Acuity</td>
<td>−.065</td>
<td>.038</td>
<td>−.119</td>
<td>−.080</td>
<td>−.444</td>
<td>−.187</td>
<td>−.491**</td>
<td>−.211</td>
</tr>
<tr>
<td>FSIQ</td>
<td>−</td>
<td>.634</td>
<td>.095</td>
<td>.000</td>
<td>.250</td>
<td>.157</td>
<td>.088</td>
<td>−.102</td>
</tr>
<tr>
<td>Education</td>
<td>−</td>
<td>−.840</td>
<td>−.103</td>
<td>−.327</td>
<td>−.373</td>
<td>−.334</td>
<td>.011</td>
<td>−.216</td>
</tr>
<tr>
<td>SES</td>
<td>−</td>
<td>−</td>
<td>−.128</td>
<td>−.266</td>
<td>.278</td>
<td>.288</td>
<td>−.144</td>
<td>.082</td>
</tr>
<tr>
<td>RT*</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−.356</td>
<td>.482**</td>
<td>−.165</td>
<td>.592</td>
</tr>
<tr>
<td>Omission</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.613**</td>
<td>.530</td>
</tr>
<tr>
<td>Commission</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note: *n* noisy condition; *c* clear condition. All values are Spearman correlations.

* Reaction time.
* False alarms; values were identical to commission errors for noisy condition.
* p < .05.
** p < .01.
3.1. Bivariate analyses

As reported in Table 2, age was not significantly correlated with IQ scores. Since none of the variables (with the exception of age) were normally distributed (Kolmogorov–Smirnov tests), non-parametric correlations (Spearman’s correlation coefficients) were conducted. Visual acuity was found to be correlated with age at the .10 level ($r_s = -0.305, p = 0.09$). Thus, visual acuity was included in hierarchical regression analyses described below, which allowed the influence of age on CPT performance to be assessed independent of this variable. Reaction time, which typically increases with age, did not correlate significantly with age under noisy ($r_s = 0.261, p > 0.15$) or clear ($r_s = 0.229, p > 0.20$) conditions. Therefore, reaction time was not statistically adjusted for in age and CPT analyses. Given their failure to correlate significantly with the CPT variables, the remaining demographic variables (i.e., race, gender, SES, IQ, and years of education) were not included in the regression analyses below.

3.1.1. Noisy condition

Participants’ age correlated significantly with the number of commission errors ($r_s = 0.589, p < 0.01$), the number of omission errors ($r_s = 0.611, p < 0.01$), and the number of false alarms ($r_s = 0.589, p < 0.001$) (see Table 2). Thus, increasing age was associated with increased numbers of commission, omission, and false alarm errors (see Fig. 1 for an illustration of the relationship between age and number of commission errors). Visual acuity also correlated significantly with the number of commission errors ($r_s = -0.491, p < 0.01$), omission errors ($r_s = -0.443, p < 0.05$), and false alarms ($r_s = -0.491, p < 0.01$).

3.1.2. Clear condition

Participants’ age correlated significantly with the number of commission errors ($r_s = 0.494, p < 0.01$) and the number of false alarms ($r_s = 0.507, p < 0.001$), but not with the number of omission errors ($r_s = 0.320, p = 0.074$) (see Table 2). Thus, increasing age was associated with increased numbers of commission and false alarm errors, but not omission errors. Visual acuity was not significantly correlated with any of the CPT variables in the clear condition.

3.2. Regression analyses

To assess the relative contributions of visual acuity and age to CPT performance, we conducted four sets of hierarchical regression analyses, two each for noisy and clear conditions. The visual acuity variable was entered first into the analyses, followed by the age variable. Since the false alarm and commission error variables produced almost identical results, only the age-commission errors and age-omission errors analyses are included below.

Under the noisy condition, age accounted for an additional 14% of variance in predicting omission errors ($R^2 = 0.138, p < 0.05$). Age accounted for approximately the same proportion of variance as visual acuity ($R^2 = 0.136, p < 0.10$). Under the clear condition, age did not account for a significant proportion of variance in predicting omission errors ($R^2 = 0.021, p > 0.10$), nor did visual acuity ($R^2 = 0.001, p > 0.10$).

Under the noisy condition, age accounted for an additional 20% of variance in predicting commission errors ($R^2 = 0.201, p < 0.01$). As previously, visual acuity accounted for approxi-
mately the same variance as did age ($R^2 = .199, p < .05$). Under the clear condition, age accounted for an additional 15% of variance in predicting commission errors ($R^2 = .151, p < .05$).

In the clear condition, visual acuity did not account for a statistically significant proportion of variance in predicting commission errors ($R^2 = .074, p > .10$).

### 3.3. Exclusion of outliers

Two individuals made omission errors that numbered well beyond (i.e., well over three standard deviations) the mean number of omission errors, and a third individual had a Full Scale IQ score below 80. In light of this, the CPT scores for these three individuals were subsequently removed, and analyses were re-run.

Age-omission error, age-commission error, and age-false alarm error correlations within the clear condition were found to increase following outlier removal ($r_s = .377, p = .044; r_s = .517, p = .004$; and $r_s = .528, p = .003$, respectively). As previously, moderate correlations were found within the noisy condition ($r_s = .606, p = .001; r_s = .525, p = .004$; and $r_s = .529, p = .004$, respectively). Repeating the regression analyses, age was found to account for a greater proportion of variance in the number of omission errors (9%) and commission errors (17%) within the clear condition. As previously, age accounted for a significant proportion of variance in commission errors, but did not account for a significant proportion of variance in omission errors. Within the noisy condition, age accounted for 26% of the variance in omission errors and 23% in commission errors. These results were statistically significant.

### 4. Discussion

As hypothesized, performance on the noisy (degraded) CPT task was worse than performance on the clear CPT task, regardless of age; this was true for all three measures of CPT performance (i.e., number of commission, omission, and false alarm errors). This finding fits with the observation that varying task conditions (such as stimuli clarity) can produce differential performance (e.g., Deaton & Parasuraman, 1993; Parasuraman et al., 1989; Rueckert & Grafman, 1998).

This study provided a relatively unique contribution to previous research with the inclusion of adult individuals from a broad age range (19–82 years). The relationship between age and reaction time (a variable traditionally associated with age-related decrements) was first assessed. The correlation between age and reaction time was not significant, suggesting that older individuals were not significantly slower at responding to stimuli than younger individuals.

As anticipated, increasing age was associated with increased false alarm and commission errors under both noisy and clear conditions. Thus, it appears that inhibitory difficulties were more apparent among older individuals in the current study. Inhibitory decrements with age are a common finding in research (e.g., Braver, Barch, & Gray, 2001; Chao & Knight, 1997; Levine, Stuss & Milberg, 1997), including significantly more false alarm responses on alternative Go/No-Go tasks among older individuals (e.g., Bokura, Yamaguchi & Kobayashi, 2001; Giambra, 1997).
Regarding the number of omission errors, age was not significantly correlated with the number of omission errors under the clear condition. Under the noisy condition, the age-omission errors correlation was significant. Thus, only when the CPT task was made more difficult did conservative responding (i.e., failing to respond when required) become apparent among older adults. This finding corresponds to previous research (using non-CPT tasks) suggesting that conservative responding may be more common among older adults (e.g., Batsakes & Fisk, 2000; Botwinick, 1984).

Even after the influence of visual acuity was removed via hierarchical regression analyses, however, age was still significantly related to CPT commission errors. Thus, age-related differences in performance were unlikely simply a product of changes in gross visual acuity.

This study had a number of limitations. The length of the CPT task was 150 s, which is shorter than typically done in previous CPT research (e.g., widely used CPT measures typically range from 6 to 22 min duration). Therefore, the CPT measure used here may be best viewed as a measure of focal (versus sustained) attention. As well, the mean IQ of our sample was one standard deviation above the population average. Thus, these results may not generalize to individuals with lower intellectual functioning, although it has been suggested that IQ is unlikely to be a factor in CPT performance for individuals with IQs above 70 (Riccio et al., 2001). Further, age was not correlated with IQ in our sample, and although IQ was included as a covariate in regression analyses, it was not found to account for a significant proportion of variance in CPT performance.

Overall, this study provides evidence for age-related differences in performance on the CPT, a well-known measure of attention. In particular, increasing age was associated with increased numbers of commission and false alarm errors, thus supporting the notion of age-related inhibition difficulties. This study also suggests differential effects by task difficulty. It is clear, however, that further research investigating age-related differences on the CPT is needed, perhaps using varied task conditions and including adult participant groups of varying age and physical health.

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References


