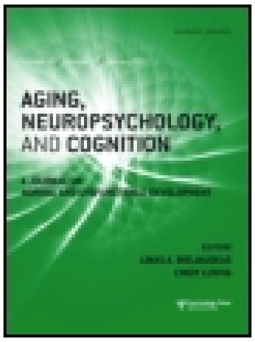

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Effects of age on attention level: changes in performance between the ages of 12 and 90

Dubi Lufi* and Iris Haimov

The Center for Psychobiological Research, The Max Stern Yezreel Valley College, Israel

ABSTRACT

The purpose of the present study was to assess the changes in attention level among individuals between the ages of 12 and 90 years. A cross-sectional design was used, with each participant tested once by means of the Mathematics Continuous Performance Test (MATH-CPT). Participants were 496 males and females who were divided into eight age-groups, with each group spanning a period of ten years. Attention level was assessed through comparison with nine variables assessing attention. As people aged, significant reductions in the quality of performance emerged on the five main measures of the MATH-CPT: Two of the four sustained attention variables showed an improvement with age. The peak attention level was in the 30 to a 40-age range, after that, there was a constant decline in the level of attention. The study offers encouraging results with respect to the effect of aging on cognitive functioning and specifically sustained attention.

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Aging; attention; cognitive functioning; continuous performance test; sustained-attention

The existing literature suggests that aging is associated with cognitive impairment (Chao & Knight, 1997; Cherry & Hellige, 1999; Wilson et al., 2014), and that nearly half of persons aged 60 years and older dwelling in the community express concern about declining mental abilities (Jolles, Verhey, Riedel, & Houx, 1995). Willis et al. (2006) asserted that the decline in cognitive functioning in old age leads to a loss of independence and an increased risk of functional disabilities. Moreover, a longitudinal study has shown an increased risk of mortality in non-demented older adult individuals with cognitive impairments (Bassuk, Wypij, & Berkman, 2000).

Powell (2011) divided the population of able-bodied older adults living in the community in the United States into three levels of cognitive functioning: (1) optimal cognitive aging, characterized by high energy and activity levels; (2) normal cognitive aging, considered average cognitive aging; and (3) high risk for cognitive impairment, characterized by increased risk of cognitive diminishment. These findings point to the fact that there are individual differences in cognitive impairment among older adults.

Recent evidence suggests that one of the cognitive tasks that declines with age is sustained attention (Mani, Bedwell, & Miller, 2005; Vasquez, Binns, & Anderson, 2014; Votruba, Persad, & Giordani, 2016). However, a literature review on this subject revealed

CONTACT Dubi Lufi dubil@yvc.ac.il
*Dubi Lufi is the author of the test that is the subject of the present paper.

that researchers use different terms to describe this cognitive function. Some of the researchers use the term sustained attention as a synonym for attention (e.g., Aase & Sagvolden, 2006; Gobin, Banks, Fins, & Tartar, 2015; Shalev, Ben-Simon, Mevorach, Cohen, & Tsal, 2011), while others consider sustained attention as one component of attention (e.g., Brocki, Tillman, & Bohlin, 2010; Lufi, Bassin-Savion, & Rubel, 2015; Smith, Valentino, & Arruda, 2002). Several studies found a decline in reaction time (RT) as people age (Fortenbaugh et al., 2015; Ratcliff, Thapar, & McKoon, 2001). Armstrong (1997) found that older adults are less successful in responding to auditory discrimination targets than younger adults. Deaton and Parasuraman (1993) and Parasuraman, Nestor, and Greenwood (1989) found decreased vigilance over time among older adults compared to younger adults. Pawlowski et al. (2012) assessed attention and executive functions and found that these cognitive functions decline with age. Bedard, Nichols, and Barbosa (2002) found a decrease in selective inhibition performance in older individuals. Others found that specifically sustained attention or vigilance tasks decline after middle age (Greenberg & Crosby, 1992; Parr, 1995). Using the Continuous Performance Test (a brief K–A version of the CPT), Mani et al. (2005) found that "Overall, this study provides evidence for age-related differences in performance on brief CPT, particularly for deficits in selective response inhibition" (p. 575). One can summarize this issue by concluding that although the definition of sustained attention is not clear, most researchers agree that aging is associated with decline in sustained attention.

In conjunction, other studies reported improvement in attention as people aged; however, most of them were based on self-reports. Giambra, Camp, and Grodsky (1992) reported that older people are less prone to boredom. Cheyne, Carriere, and Smilek (2006) and Giambra (1989) mentioned that people reported less mind wandering as they age. Jónsdóttir, Adólfsdóttir, Cortez, Gunnarsdóttir, and Gústafsdóttir (2007) claimed fewer cognitive and action slips as people get older. Carriere, Cheyne, Solman, and Smilek (2010) assessed sustained attention among hundreds of individuals ages 14 to 77. They found that response speed declines in a linear fashion; also, that anticipation and omissions decrease early in life and then remained unchanged for the rest of their life. They concluded their findings with the following: "Taken together, these findings suggest the interesting conclusion that people tend to disengage less from the task at hand as they get older" (p. 569). These conflicting studies reflected the inconsistent findings explaining the effect of age on attention level.

Gender differences in various cognitive variables can be important factors in understanding human functioning. Naglieri and Rojahn (2001) found that girls had better performance than boys did in the task of Planning and Attention Scales of the Cognitive Assessment System. In addition, Girls outperformed boys in the following tasks of the Woodcock–Johnson Revised Tests of Achievement: Letter–Word Identification, Passage Comprehension, Dictation, and Proofing subtests. Maitland, Intrieri, Schaie, and Willis (2000) found that women performed better than men in attention-related tasks: verbal recall and in some ages in perceptual speed, while men performed better than women in spatial orientation. Similar results were found with children (Hyde & Linn, 1988; Maccoby & Jacklin, 1974). When considering attention level of a clinical population of Attention Deficit Hyperactivity Disorder (ADHD) clients, gender differences are even more conspicuous. Gaub and Carlson (1997) found that ADHD girls showed greater intellectual impairment, lower rating of other externalizing behaviors, and lower levels of hyperactivity. Ramzi and Fine (2012) performed a meta-analytic review with the Continuous Performance Test (CPT). They concluded their study by indicating that boys were more impulsive than girls were; however, no differences were found comparing inattention. Based on this knowledge the comparison of gender differences among attention components was included in the present study.

The purpose of the present study was to assess changes in measures of attention across the lifespan, from age 12 to age 90. The present study used a cross-sectional design in which each participant was assigned to one of eight age groups, each spanning ten years, and was tested once using the Mathematics Continuous Performance Test (MATH-CPT; Lufi & Fichman, 2012), which is a computerized CPT-type test designed to assess attention. The MATH-CPT assesses nine different measures of attention, among them four measures of "on the task" sustained attention. Considering the innovations of the present study, to the best of our knowledge, this is the most extensive research assessing attention with such a wide age range and with nearly 500 participants. In addition, we assessed sustained attention; one should note that sustained attention in the present study is a measure comparing the progression of performance throughout the test of four different measures; and not a general name used by many to describe CPT-type tests.

Methods

Participants

A total of 496 participants between the ages of 12 and 90, 238 males and 258 females, completed the study. Seventy-nine percent of the participants were Jews, 20% were Arabs, and 1% were Circassians. All the participants above age 18 completed high school. The participants below age 18 were still in school – middle schools and high schools.

The participants were recruited through advertisements and talks given at middle schools, high schools, universities, nearby factories, and local senior centers. Applicants were asked to complete a clinical history questionnaire. Based on the answers, participants were excluded from the study for any of the following reasons: (a) they had any significant visual or hearing impairments; (b) they had any significant medical or neurological disease, including active cancer (ongoing chemotherapy or other cancer treatment), diabetes, liver, kidney, heart, or lung disease; (c) they had any alcoholism or other drug abuse or dependence; (d) they had any history of significant psychiatric impairment such as major depression or psychosis; (e) they had any history of neurological disorders, ADHD, or learning disabilities; (f) they were taking any neurological or psychiatric medications.

Measures

A clinical history questionnaire

Participants were asked to complete a clinical history questionnaire enabling the researchers to exclude participants who had any of the six health or behavioral difficulties mentioned above.

The MATH-CPT (Lufi & Fichman, 2012) is a computerized CPT-type test designed to assess attention. The MATH-CPT uses a sequence of 450 simple mathematical problems involving addition, subtraction, multiplication, and division. The answer to each problem is never greater than 9 and is projected on a computer screen to serve as a visual stimulus. During the test, one problem appeared on the screen together with a result that is either right or wrong (e.g., 1 + 4 = 5; or 4 × 2 = 7). The participants viewed one problem at a time on the computer screen and had to indicate whether the solution to the problem is correct or incorrect by pressing "1" for a correct answer or "2" for an incorrect answer. The test stimuli are more complicated than most CPT-type tests, so an open RT allowed participants to react at their individual pace of activity, which means that there was no time limit for each question. The test lasted between 10 and 20 min depending on the RT of each participant.

The test included nine measures of attention: one final attention score, four main measures of attention level, and four secondary measures of "on the task" sustained attention level. The final attention score is a special formula that assesses the participant's overall attention level, based on discriminant function between individuals with ADHD and those without ADHD, where the score of two main components are RT and number of correct responses contributing to the overall attention score. The formula used to obtain the final attention score was (Total time × .01) + (Total correct responses × (-.66)) + (Time of 2nd of 3 sections × (-.22)) + (Anticipatory response 9th of 9 sections × .392) + (Anticipatory response 3rd of 9 sections × .705) + (Anticipatory response 8th of 9 sections × .4.18) + (Correct 8th of 9 sections × .173) + (Correct 9th of 9 sections × .13) +10.959.

The four main measures in the test are: (1). RT (time taken to respond to all the problems of the test); (2). standard deviation of RT (a measure of RT variability); (3). impulsive responses (defined as the number of responses given at a speed of less than 0.5 s, and the number of incorrect responses given at a faster time than the average RT of the participant; both together are considered as measures of impulsivity); (4). The accuracy of responses (correct answers, considered a measure of attention). The four secondary test measures assessing "on the task" sustained attention are: (1). sustained attention RT (a measure of sustained attention of RT over nine parts of the test); (2). Sustained attention SD (SD of sustained attention of RT over nine parts of the test); (3). Sustained attention correct responses (sustained attention of correct responses over nine parts of the test); (4). Sustained attention impulsivity (a measure of sustained attention of impulsivity over nine parts of the test). These four secondary measures of sustained attention assessed a possible reduction in performance on measures in their respective domains and were based on an algorithm designed specifically to assess these domains. The algorithm to assess sustained attention was based on a calculation of nine blocks. Each block, from the first to the ninth in ascending order, contributed more to the measure of sustained attention, with one final single number assessing sustained attention on the four measures mentioned above. The formula to calculate each sustained attention was based on multiplication of each ninth by an increasing coefficient. The first ninth score was multiplied by 0.1, the second ninth score was multiplied by 0.2, continuing in increments of 0.1, so the ninth part was multiplied by 0.9. Summation of these nine numbers served as the sustained attention score for each of the four sustained score measures. During construction of the MATH-CPT (Lufi & Fichman, 2012), test-retest reliability after one week of testing with the main measures used in the MATH-CPT indicated an average correlation of 0.73. During the development of the MATH-CPT, a discriminant function analysis was used to compare a "normal" control group (without ADHD) to a group with ADHD. The results indicated that the test can correctly identify 90.8% of the participants in both groups. The MATH-CPT was chosen for the study over other commonly used CPT measures because it contains four unique different measures of sustained attention.

Research with the MATH-CPT and other measures of CPT and attention: (1) yielded a significant correlation ranging from .29 to .40 of the attention score of the MATH-CPT with five measures of the d2 Test (a graphic-motoric test of concentration) (Lufi & Fichman, 2012); (2) a significant correlation of .39 between the MATH-CPT attention score with the main measure of another CPT-type test, the Test of Variables of Attention (TOVA) (Lufi & Fichman, 2012); and (3) a significant correlation between the MATH-CPT and a questionnaire, The Brown Scale (Brown-ADD) (Lufi & Pan, 2015). These correlations are similar to other CPT-type measures of attention.

Procedure

The participants were divided into eight age groups, each spanning a period of ten years, except the first group of ages 12 to 19.99 that spanned a period of eight years. The cognitive capacity of each participant was tested individually, at home, using the computerized MATH-CPT test that was installed on a laptop. The participants were instructed to perform the test in a quiet room at their home while there were no people in the room other than the research assistant. This enabled the researchers to monitor cognitive performance in a quiet environment with minimal distractions. Before the test, the participants were asked to practice on 30 sample problems of the MATH-CPT. Following the sample problems, the participants completed the MATH-CPT. A research assistant watched their performance and made sure that there were no interruptions. The participants were informed that they could stop the test at any time.

The study conformed to the principles outlined in the Declaration of Helsinki. The Max Stern Yezreel Valley College Institutional Ethics Review Board approved the complete study protocol. After the study was completely described to all the participants, their written informed consent was obtained, with parental permission for those under the age of 18. Study participants did not receive any monetary compensation for their participation in the study.

Data analyses

SPSS (Version 21) software was used for statistical analyses. Gender differences were assessed by Independent sample t-test. Univariate analysis of variance was used to evaluate the effect of age on the nine variables of the MATH-CPT. Trend analysis was performed to assess changes over age. Due to the many variables used in the analysis, in all the statistical analyses performed in the present study, the significance level was set to 0.01 to reduce possible Type I error.

Results

Using t-tests, the results showed no significant differences in any of the variables when the performance of males and females was compared. Table 1 shows the means and SDs of males and females of the main measures of the MATH-CPT. Similar non-significant results were found in a comparison of gender in the secondary measures of the test (not reported in Table 1 because of space limitation).

Assessment of all the measures of the MATH-CPT showed a significant effect of age on the final attention score ($F_{(7,488)} = 27.79$, $p < 0.01$). In the first three age groups (ages 12–19.99, 20–30, and 30–40) final attention score improved. After that, there was a constant decline in the level of attention up to the age of 90. Figure 1 shows the overall attention level across the eight age groups. Since the different variables used in the MATH-CPT had different scaling measures, in all the graphics presentations a t-Score was used to represent the mean of the variables. This procedure allows easier comparison among the different variables used in the study (the same procedure was used in the studies of Schaie and his associates: Schaie, 1958, 1983, 1996, 2004, Schaie, Willis, & Caskie, 2004).

Table 1. Comparison of gender, males (*N* = 238) and females (*N* = 258). Comparison of the means of the main variables of the MATH-CPT.

	Attention Score[a]		RT (SEC)[a]		SD[a]		Correct		Impulsive[a]	
Age/Variable	M	F	M	F	M	F	M	F	M	F
12–19.99	−.86	−.71	799	766	.80	.84	431	427	13	15
N =	69	48								
20–29.99	−1.00	−.90	685	725	.79	.98	433	431	12	13
N =	41	75								
30–39.99	−1.29	−.99	688	716	.77	.88	37	436	8	9
N =	29	19								
40–49.99	−.90	−.85	769	735	.99	.84	436	434	11	10
N =	19	15								
50–59.99	−.39	−.65	837	814	1.08	.96	431	432	13	11
N =	21	13								
60–69.99	−.49	−.27	895	1020	1.05	1.36	435	436	10	9
N =	33	51								
70–79.99	1.15	.51	1191	1159	1.22	1.21	428	427	13	11
N =	20	21								
80–89.99	1.39	1.26	1401	1424	1.72	2.44	427	429	16	12
N =	16	16								

[a] Lower score in these variables means better performance.

Notes: **M** = males; **F** = females; **Attention Score** = final attention score; **RT** = reaction time, time taken to respond to the test; **SD** = variability of the RT; **Correct** = total number of correct responses; **Impulsive** = impulsive responses, a combination of the number of anticipatory responses faster than 500 ms and the fast incorrect responses, answered faster than the average response time.

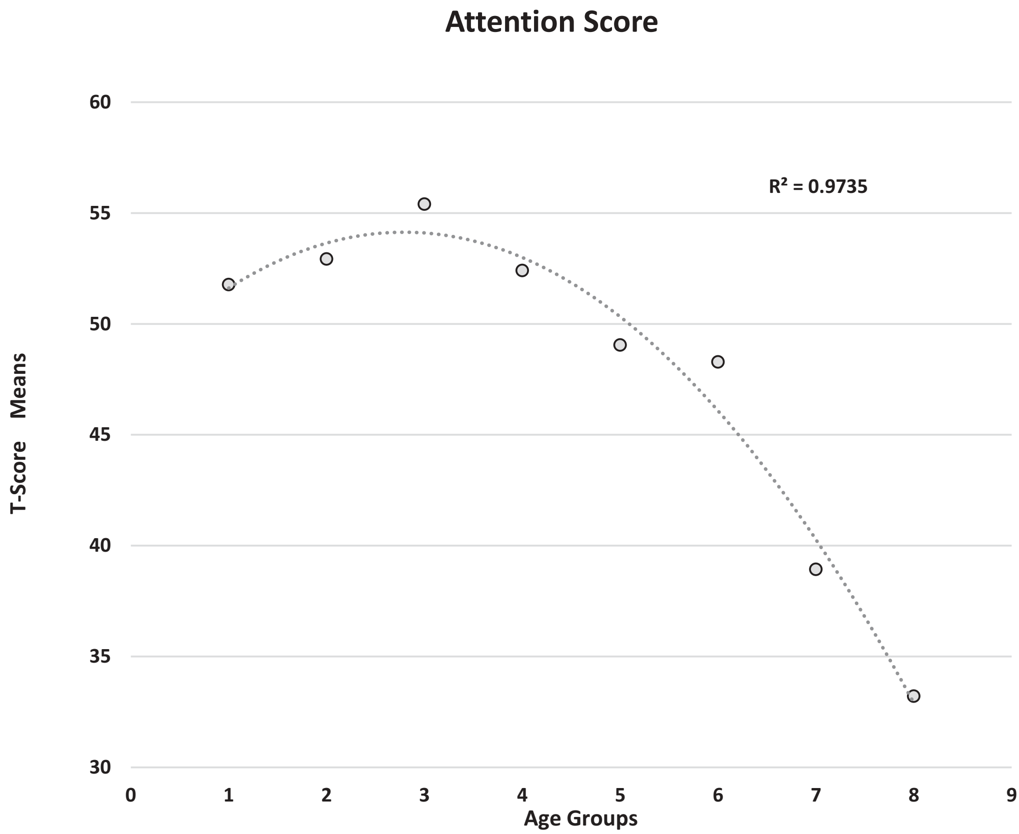

Figure 1. Total attention level scores with a trend line across the eight different age groups.
1 = ages 12.00–19.99, 2 = ages 20.00–29.22, 3 = ages 30.00–39.99, 4 = ages 40.00–49.99, 5 = ages 50.00–59.99, 6 = ages 60.00–69.99, 7 = ages 70.00–79.99, 8 = ages 80.00–89.99

To understand the structure of the MATH-CPT the researchers show how the inter-correlations between the variables used in the study were assessed. The results of the inter-correlations are shown in Table 2.

Univariate ANOVA of the variables assessing the different measures of attention showed that in addition to overall attention score, age had a significant effect on attention measures in the four main variables. The order of these variables indicates the magnitude of change due to age, ranging from the most significant to the least significant: (1) RT, (2) SD of rate of RT, (3) total correct response, and (4) total impulsive responses (anticipatory responses + fast wrong responses). With respect to the four secondary variables, two of the four sustained attention variables exhibited an improvement with age (sustained attention of RT and sustained attention of SD of RT). The two other secondary variables did not exhibit significant changes with age: sustained attention of impulsive responses (anticipatory responses + fast wrong responses) and sustained attention of correct responses. The results depicting the changes in the final attention score, in the performance on the main test measures, and the secondary measures for the eight age groups are shown in Table 3. The results showing the

Table 2. Inter-correlations between the variables used in the study (N = 496).

Variable	Attention[a] Score	RT Time[a] (Sec.)	SD[a] Time	Impul-[a] sivity	Correct Responses	Sust.[b] Time	Sust.[ab] SD	Sust.[a] Impul.	Sust.[a] Corr.
Attention Score [a]	–	.79**	.61**	.38**	−.48**	−.33	−.15**	.10*	.08
RT Time (Sec.)[a]	–	–	.76**	.10*	−.19**	−.34**	−.18**	.01	.08
SD Time [a]	–	–	–	.17**	−.18**	−.41**	−.34**	.01	−.01
Impulsivity[a]	–	–	–	–	−.90**	−.03	−.03	−.16**	.25**
Correct Responses	–	–	–	–	–	−.01	−.02	.12**	.23**
Sust. Time [b]	–	–		–	–	–	– .72**	.08	.26**
Sust. SD [ab]	–		–	–	–	–	–	−.05	−.07
Sust. Impul.[a]	–	–	–	–	–	–	–		−.77**
Sust. Corr.[a]	–	–	–	–	–	–	–	–	–

*p < 0.05. ** <0.01

[a] = Lower score in these variables means better performance.

[b] = Performance in these variables improved as age increased.

Notes: **RT Time** = Time taken to respond to the test; **SD Time** = variability of the RT; **Impulsivity** = a combination of the number of anticipatory responses faster than 500 ms and the fast incorrect responses, answered faster than the average response time; **Correct Responses** = total number of correct responses; **Sust. RT** = sustained attention of RT over nine parts of the test; **Sust. SD** = sustained attention of SD over nine parts of the test; **Sust. Impul.** = sustained attention of impulsive responses. **Sust. Corr.** = sustained attention of correct responses over nine parts of the test.

changes in performance on the four main measures of MATH-CPT across the eight age groups are depicted in Figure 2.

The results showing the changes in performance on the four secondary measures of the MATH-CPT across the eight age groups are depicted in Figure 3.

Results of Univariate ANOVA showing F Values, Significance Level, Partial Eta Squared, Observed Power, and trend of the nine measures of MATH-CPT across eight age groups are shown in Table 4.

Trend analysis revealed that there was a quadratic trend for the final attention score and all the main measures of the Math-CPT. Concerning the secondary measures, a linear trend was found for the Sustained Attention SD of RT and Sustained Attention Impulsivity measures, and no trend was found for the Sustained Attention Correct responses.

Discussion

In the present study, the attention levels of 496 participants ranging in age from 12 to 90 were assessed with a computerized test (MATH-CPT). The participants were divided into eight age groups, each spanning a period of ten years. No gender differences were found, so that gender was disregarded in the analysis. The overall attention score is a summation of the performance on the test and is the single most important indication of attention level on the MATH-CPT. The results revealed a statistically significant quadratic trend, indicating an improvement until the 4th decade (ages 30–39.99) and a decline thereafter. Likewise, the results revealed a similar trend for four attention measures (RT, SD of RT, total correct responses, and total impulsive responses). In two secondary variables, there were no changes with age (sustained attention of impulsive responses and sustained attention of correct responses), and in two secondary variables there was a statistically significant linear trend indicating an improvement with age

Table 3. Means and standard deviations of all the measures of the MATH-CPT by age groups (N = 496).

Age/Variable		Attention[a] Score		RT Time[a] (Sec.)		SD[a] Time		Impul-[a] sivity		Correct Responses		Sust.[b] Time		Sust.[ab] SD		Sust.[a] Impul.		Sust.[a] Corr.	
	N	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
12–19.99	120	−.81	.69	770	170	.82	.40	13.41	7.95	430	10.73	−4.02	9.46	.05	.27	−.24	1.17	.41	1.09
20–29.99	125	−.93	.81	719	223	.92	.51	11.98	7.43	432	10.82	−10.6	11.15	−.09	.27	−.13	1.2	.13	1.2
30–39.99	50	−1.21	.70	691	215	.78	.47	8.44	5.77	437	7.26	−10.51	11.51	−.12	.26	−.06	.93	.22	.74
40–49.99	30	−.87	.89	751	227	.91	.44	10.13	8.66	435	11.63	−13.76	13.31	−.11	.35	−.03	1.56	.41	1.3
50–59.99	30	−.51	1.02	827	231	1.03	.52	12.37	10.60	431	15.42	−6.17	14.82	.16	.51	.09	1.03	−.02	.9
60–69.99	84	−.42	1.12	970	305	1.24	.67	9.06	7.40	436	11.07	−28.19	37.71	−.28	.66	−.20	1.30	.45	1.2
70–79.99	31	.72	1.57	1169	338	1.21	.68	11.58	10.26	427	14.59	−22.93	30.63	−.12	.54	−.22	1.09	.75	1.2
80–89.99	26	1.31	1.43	1415	350	2.16	1.36	11.35	8.19	428	11.54	−19.08	36.76	−.22	.94	−.35	1.74	.34	1.1

[a] = Lower score in these variables means better performance.
[b] = Performance in these variables improved as age increased.
Notes: **RT Time** = Time taken to respond to the test; **SD Time** = variability of the RT; **Impulsivity** = a combination of the number of anticipatory responses faster than 500 ms and the fast incorrect responses, answered faster than the average response time; **Correct Responses** = total number of correct responses; **Sust. RT** = sustained attention of RT over nine parts of the test; **Sust. SD** = sustained attention of SD over nine parts of the test; **Sust. Impul.** = sustained attention of impulsive responses. **Sust. Corr.** = sustained attention of correct responses over nine parts of the test.

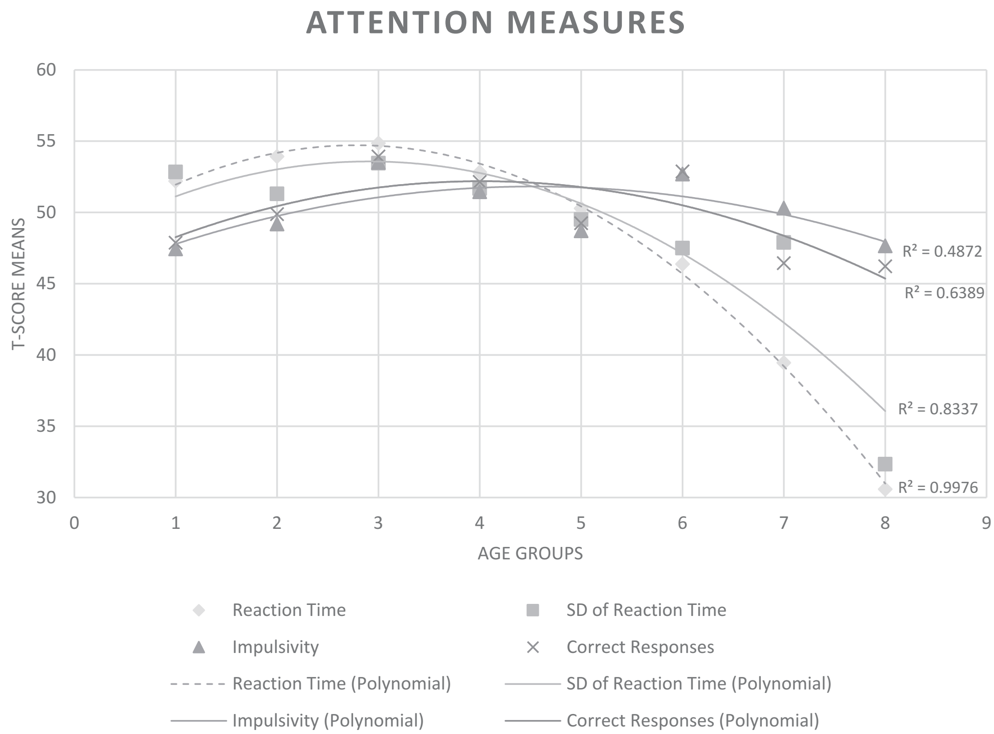

Figure 2. The four main measures of the MATH-CPT with a trend line across the eight age groups. 1 = ages 12.00–19.99, 2 = ages 20.00–29.22, 3 = ages 30.00–39.99, 4 = ages 40.00–49.99, 5 = ages 50.00–59.99, 6 = ages 60.00–69.99, 7 = ages 70.00–79.99, 8 = ages 80.00–89.99

(sustained attention of RT and sustained attention SD of RT). There are similar results in the literature showing decline in some of the attentional variables due to age (Armstrong, 1997; Bedard et al., 2002; Deaton & Parasuraman, 1993; Fortenbaugh et al., 2015; Parasuraman et al., 1989; Ratcliff et al., 2001), while in other studies no significant results have been reported (Giesen, Eberhard, & Rothermund, 2015; Hasher & Zacks, 1988; Porter, Wright, Tales, & Gilchrist, 2012).

As expected, the results of our study revealed that RT, more than other variables, was found to decline with age. Similar results were found by others (Der & Deary, 2006; Dykiert, Der, Starr, & Deary, 2012; Hultsch, Strauss, Hunter, & MacDonald, 2008). In addition, SD of RT, number of correct responses, and the number of impulsive responses also exhibited a significant decline with age.

Neurological findings regarding a decline in RT and the increased SD of RT in older adults suggests that a decline in the integrity of normal-appearing brain white matter is an important factor. A reduction in white matter integrity was found to be correlated with impaired RT (Kerchner et al., 2012; Madden et al., 2004; Penke et al., 2010; Ystad et al., 2011) and RT variability (Jackson, Balota, Duchek, & Head, 2012) in healthy older adults. Another finding regarding RT and RT variability is that healthy older adults have greater activity in the frontal regions compared to younger adult during attentional task (Tam, Luedke, Walsh, Fernandez-Ruiz, & Garcia, 2015); this suggests a compensation mechanism, maybe for the loss of white matter.

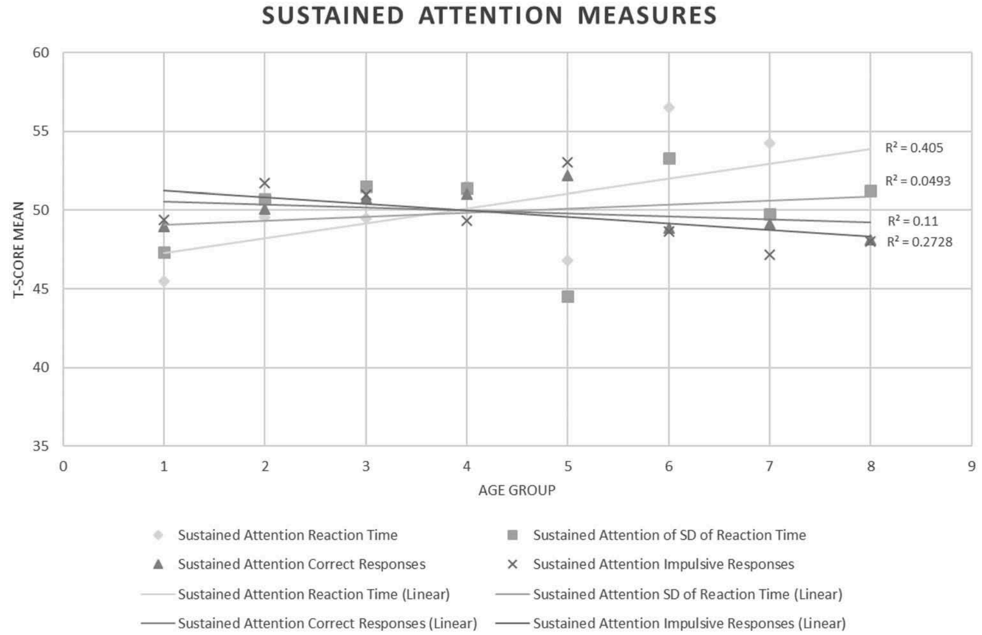

Figure 3. The four secondary measures of the MATH-CPT with a trend line across the eight age groups.

1 = ages 12.00–19.99, 2 = ages 20.00–29.22, 3 = ages 30.00–39.99, 4 = ages 40.00–49.99, 5 = ages 50.00–59.99, 6 = ages 60.00–69.99, 7 = ages 70.00–79.99, 8 = ages 80.00–89.99

Table 4. Results of univariate ANOVA showing F values, significant level, partial eta squared, observed power, and trend of the nine measures of MATH-CPT across eight age groups (*N* = 496).

					Trend	
Variable	F (7,488)	*p*	Partial Eta squared	Power	Linear	Quadratic
Final Attention Score	25.26	< .001	.30	1.00	.001	.001
Main Measures of the MATH-CPT						
Reaction Time	34.70	< .001	.30	1.00	.001	.001
SD Time	15.18	< .001	.20	1.00	.001	.001
Correct Responses	4.70	< .001	.06	.99	.04	.001
Impulsive Responses	3.16	.004	.05	.95	.87	.006
Secondary Measures of the MATH-CPT						
Sust. Att.of RT[a]	11.06	< .001	.13	1.00	.001	.64
Sust. Att. SD of RT[a]	5.32	< .001	.05	.95	.008	.61
Sust. Att. Impulsivity	1.88	.071	.03	.68	.04	.10
Sust. Att. Correct Resp.	.47	.860	.01	.19	.49	.12

[a] = Performance in these variables improved as age increased.

Notes: **Reaction Time (RT)** = Time taken to respond to the test; **SD Time** = variability of the RT; **Impulsive Responses** = a combination of the number of anticipatory responses faster than 500 ms and the fast incorrect responses, answered faster than the average response time; **Correct Responses** = total number of correct responses; **Sust. Att. of RT** = sustained attention of RT over nine parts of the test; **Sust. Att. SD of RT** = sustained attention of SD over nine parts of the test; **Sust. Att. Impulsivity** = sustained attention of impulsive responses. **Sust. Att. Correct Resp.** = sustained attention of correct responses over nine parts of the test.

Inter-correlations among all the variables of the MATH-CPT in the present study indicated that three variables contributed more to the attention score (see Table 2). These variables were RT (r with Attention Score = .79); SD of RT (r with Attention

Score = .61); and Correct responses (r with Attention Score = .48). Additional intercorrelations can be found in Table 2. Other studies have found similar results; for example, Mani et al. (2005) found that the number of false alarm and commission errors on a CPT-type test increase with age, while Reuter-Lorenz and Park (2010) reported that older age causes a failure in the ability to suppress task-irrelevant cognitive information. Following the same line of research, Ben-David and Schneider (2010) found a reduction in selective attention as a result of aging. Schaie et al. (2004) tried to answer the question of when decreased ability can be reliably detected. Their answer was: "Data collected during the first three cycles of the SLS suggested that average age decrements in psychometric abilities could not be demonstrated prior to age 60, but that such reliable decrement may be found for all abilities by age 74" (p. 310). In the present study, the peak attention level was at ages 30 to 39.99, while a noticeable decline in attention can be seen after the age of 60. This may indicate that attention measures start to decline approximately at the same age as the other cognitive abilities measured by Schaie et al. (2004).

Contrary to findings in the literature (Ben-David & Schneider, 2010; Mani et al., 2005), in our study four measures of "on the task" sustained attention exhibited no decline because of growing older. Two of these measures exhibited no reduction due to aging (sustained attention correct responses and sustained attention impulsivity) while another two of these measures exhibited a significant improvement with increasing age (sustained attention RT and sustained attention SD of the RT). A possible explanation for this is that the results with respect to sustained attention probably were influenced mostly by the slower RT as age increases. It seems that it is easier to maintain an adequate level of performance of RT, SD of RT, impulsive responses, and correct responses when one responds more slowly to the stimuli. It should be noted that the measures of sustained attention in the present study assess individual performance, taking into account the nine parts of the test from beginning to end and assessing whether performance improved, declined, or stayed the same. When the person tested response more slowly to the stimuli, they may be influenced less by being tired. Still, it should be remembered that slower RT does not directly help improve sustained attention. Nevertheless, it may be one of the explanations for the current results. Our results support similar findings of Carriere et al. (2010) who claimed the following explanation for the slower RT: "Even though sustained attention abilities remain unchanged throughout middle and later life, the older adults appear to be more likely to adopt a slower response mode, thus preventing critical errors normally caused by task disengagement" (p. 573).

Sustained attention is often called vigilance or vigilance decrement. Green (1996) considered sustained attention to be a neurocognitive function crucial for adequate skill acquisition, problem-solving, and social skills. Other researchers (Sohlberg & Mateer, 2001; Tsal, Shalev, & Mevorach, 2005) considered sustained attention to be one of the most important components of attention. Sustained attention can be explained based on the boredom or mindlessness theory (Smallwood et al., 2004), according to which a person loses focus of attention and starts to treat the task automatically. Another possibility is the resource depletion theory (Helton, 2009; Helton & Russell, 2010; Warm, Parasuraman, & Matthews, 2008), according to which, attention resources decline, thus causing a decrease in performance efficiency. The present study cannot support either the boredom/mindlessness theory or the depletion theory. Still, it can point to the possibility that our results of no reduction in sustained attention can be explained by the rate of response, which should be taken as an important factor in the explanation for the effect of age on sustained attention.

Regardless of why older people exhibit relatively good performance on sustained attention, in comparison to the reduction of attention, it is encouraging to see that as we grow older, we are still able to maintain our attention level for relatively long periods of time. Considering that the present study found a substantial decline in the final attention score and on four other attention measures, the knowledge that the performance level of sustained attention remains intact and even increases, is encouraging.

Limitations of the study

The study has a few limitations. First, attention level was measured only with one test: the MATH-CPT. Although this test utilized different variables assessing attention, the use of additional measures could help generalize the results. Second, using participants from one culture precludes assessing cultural diversity among participants and its influence on attention level. Having more culturally diverse participants could shed light on the issue of cultural aspects and aging. Third, the current research is cross-sectional in nature, using longitudinal procedure could give more in-depth information about the effect of aging on attention. Additional control variables could have helped to make our findings clearer. Fourth, a measure of premorbid IQ would have been very helpful to explain the effect of intellectual ability on attention across the lifespan, especially as performance across the sample begins to decline. Fifth, addition of personal background information, such as level of education, used as covariates could provide additional information about possible influence of these variables on attention level at old age.

Implications

The results of the present study indicate that there is a conspicuous effect of aging on all the main measures of attention, similar to the decline we see in other cognitive domains. The findings of our research are in accordance with previous findings that cognitive functioning declines as people age (Chao & Knight, 1997; Cherry & Hellige, 1999; Wilson et al., 2014). However, interestingly, our results revealed that "on the task" sustained attention did not decline during aging; moreover, there was an improvement in two measures of sustained attention during aging. What makes our study unique is that no decline due to old age was found in four "on the task" measures assessing different cognitive capabilities: time, SD-time, impulsivity, and correct responses. Even with the knowledge that slower RT may help maintain sustained attention, the results indicating that there is no decline in four measures of sustained attention are striking and point to the unique human ability to keep certain cognitive functions intact. Such findings should be seen as a small step toward understanding how to add quality of life to longevity.

Disclosure statement

No potential conflict of interest was reported by the authors.

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