ACTA UNIVERSITATIS CAROLINAE
KINANTHROPOLOGICA Vol. 50, 1 – 2014 Pag. 100–111

CHARLES UNIVERSITY IN PRAGUE,
FACULTY OF PHYSICAL EDUCATION AND SPORT,
LABORATORY OF SOCIAL PSYCHOLOGY,
DEPARTMENT OF PEDAGOGY, PSYCHOLOGY AND DIDACTICS

RELATIONSHIP BETWEEN AGE COGNITIVE DECLINE AND PERFORMANCE OF COGNITIVE MOTOR TASKS IN SENIORS

JIŘÍ MUDRÁK, PAVEL SLEPIČKA

ABSTRACT

Relationship between the age-related cognitive decline and decline in cognitive processing speed, in a variety of cognitive motor tasks was examined. The sample consisted of 33 well-adjusted older adults (on average 68 years old), recruited from several physical activity programs. The participants performed five cognitive tests selected from the Vienna test system battery. Subsequently, the relationship of their age and the measures of cognitive function was analyzed. It was found that the age of respondents was related only to their performance in complex tasks which included a processing speed component. The participant's performance in simple tasks and in measures unaffected by processing speed was unrelated to age. Results are consistent with the processing speed theory of adult age differences in cognition (Salthouse, 1996). Furthermore, the performance in complex cognitive tasks was influenced by the level of participation in leisure physical activities; this suggests that physically active lifestyle may limit the impact of age on cognitive function.

Keywords: cognitive function, processing speed, aging, Vienna test system, physical activity

INTRODUCTION

As the average age of the world population constantly rises (WHO, 2010), the topic of aging receives ever-growing research attention (e.g. Aldwin, Gilmer, 2013; Cruikshank, 2013; Stepankova, 2012). At present, the main research focus has been, above all, on the factors positivelly influencing the span of active life and the quality of life in older age (Aldwin, Gilmer, 2013; Netz et al., 2005; Nelson et al., 2007) which have been labeled as "active" or "successful" aging (Rove, Kahn, 1997; Hasmanova Marhankova, 2010). One of the most important criteria of the "successful" aging is the lasting preservation of cognitive functions (Albert et al., 1995; Park, Schwarz, 2012; Stepankova et al., 2012). Cognitive functions such as attention, reaction speed, or memory, significantly determine self-sufficiency of older people. At the same time, these cognitive functions seem to be significantly impacted by progressing age (Kallus, Schmitt, Benton, 2005; Hoyer, Verhaeghen, 2006).

The processing speed theory of adult age differences in cognition (Salthouse, 1996; 2000) has been one of the most influential theories which attempt to explain the age related cognitive decline. It assumes that the age related decline in cognitive function is determined by a decline in the processing speed of cognitive processes whereas other aspects of cognitive processes remain relatively unaffected by age. On this basis: the theory also supposes that the efficiency of cognitive functions in older age is especially affected by the difficulty of the solved task, its complexity, and time constraints (Salthouse, 1996). As shown for example by Rogers (2012) in a series of experiments with older adults, the age-related decline of performance is especially prominent in complex tasks which demand divided attention, fast reactions, memory imput, and in which the respondents have only limited experience. However, these are precisely the tasks which people frequently encounter in their daily lives and an inability to sucesfully handle these tasks may significantly impair the self-sufficiency of older adults (Ansley et al., 2005; Owsley et al., 1998).

To date several authors researched cognitive function in older adults (Preiss, Lukavsky, Steinova, 2010; Stepankova et al., 2012; Stepankova, Steinova, 2009). We intend to build on their work and examine the impact of aging on performance in cognitive tasks of varying difficulty which would help us to understand the ways in which the processing speed ability influences the cognifive function in older age. We follow up on some of our previous studies in which we focused on motivation to physical activity of older adults (Mudrak, Slepicka, Elavsky, 2011; 2012) and lifestyle factors influencing the quality of life in older adults (Mudrak, Slepicka, Siska, 2011; Mudrak et al., 2011).

The goal of the study is to explore the impact of aging on cognitive function in older adults. Specifically we focus on the relationship of the processing speed of cognitive functions and aging. On the basis of the processing speed theory of adult age differences in cognition (Salthouse, 1996, 2000; Kallus, Schmitt, Benton, 2005) we expect that 1) the processing speed of cognitive functions declines with age, 2) the impact of age is especially prominent in complex tasks performed in stress or within a time limit, 3) the aspects of cognitive function unrelated to processing speed are much less impacted by aging. Furthermore, we expect that 4) the observed impact of age on cognitive function is limited by physically active lifestyle.

METHODOLOGY

Sample

The research sample consisted of 33 seniors aged between 60–92 years; their average age was 68 years. All participants were retired, on average they spent 7.6 years in retirement. Majority of respondents were women (69.7%), 51.6% of participants had high-school education, 45.2% had university education. 33% of participanrs stated their monthly household income under 10 ths. CZK, 13% of participants stated monthly household income over 30 ths. CZK. 81.3% of participants mentioned at least moderate health problems and using medication. On the other hand, the participants as a whole represented a group of active and well-functioning older adults. The participants were recruited from various physical activity programs for older adults in which they actively participated. 65.6% of respondents can be regarded as physically active according to the WHO standards (WHO, 2010). They stated that on average they weekly participated in 53 minutes of vigorous physical activity, 201 minutes of moderate physical activity and 301 of light physical activity. Average BMI index was 26.8.

Methods

Vienna test system

Vienna test is a comprehensive battery of electronically administered achievement tests which measure a wide range of cognitive functions, such as attention, working memory capacity, reaction speed spatial abilities and also complex cognitive function and personality characteristics. The tests which measured various aspects of the cognitive processing speed were selected from the Viena test system: Determination test (DT), Cognitrone (COG), Reaction test (RT), Visual pursuit test (LVT), and Visual memory test (VISGED).

Determinantion test represents a measure which is especially appropriate to the study. It is a complex instrument measuring attention, short-term memory, and reaction speed in tasks which demand fast and accurate responses to changing visual and auditory stimuli. Due to its structure, the test is suitable for examining cognitive changes taking place in older adults because the ability to solve these tasks seems to be vulnerable to the process of aging (Ansley et al., 2005; Rogers, 2012; Salthouse, 1996). During DT, fast-changing visual and acoustic stimuli are presented on the screen to which the participants have to respond quickly and accurately. The test is adaptive, i.e. the speed of the presentation of the stimuli adjusts to participants' performance which makes the subjective difficulty of the tasks always high and, as a result, the respondents always perform under stress (Schuhfried, 2011). DT appears to be a valid instrument discriminating for example between general population and people at risk of driving accident (Neuwirth, 2001). DT was used in previous studies in the research on aging (Kallus, Schmitt, Benton, 2005). *Cognitrone* is a test which assesses attention and concentration through comparison of figures with regard to their congruence. The respondent's task is to compare an abstract figure with a model and to decide whether the two are identical. *Reaction Test* measures respondents' reaction time divided into the time of the response to stimuli and the motor time (i.e. the time of the execution of the task). The test is based on presentation of coloured stimuli and/or acoustic signals. The participants are instructed to press the reaction key when specific stimuli are presented and, having pressed the key, to return his/her finger immediately to the rest key. The reaction and motor time are measured in miliseconds. *Visual pursuit test* assesses the aspect of visual orientation performance involved in tracking simple visual elements in a relatively complex environment. The respondents are presented with an array of lines and he or she must as quickly as possible find the end of a specified line. The respondent is required to work in a focused way, ignoring distractions, while being placed under time pressure. The test is well suited to the assessment of selective visual attention. *Visual memory test* assesses visual memory performance by measuring how respondents receive and replay visual information presented in the form of symbols on a city map. The respondent is instructed to memorize positions of the individual symbols and recall them correctly afterwards. The adaptive presentation ensures that the respondents are only confronted with tasks corresponding to their performance level (Schuhfried, 2011).

Questionnaire battery

Apart from the Vienna tests, the respondents were also presented with a questionnaire battery in which we inquired about their demographic and lifestyle characteristics (especially their physical activity). Participants were asked to provide basic demographic information, such as gender, age, education, income, marital status, height and weight (which were used to compute the body mass index), and details of their health status. Physical activity was assessed by self-report using two different measures, the Leisure Time Exercise Questionnaire (LTEQ; Godin, Shephard, 1985) and the Physical Activity Survey for the Elderly (PASE; Washburn et al., 1993). The LTEQ measures self-reported average weekly amount of PA over the period of the last four weeks at three intensity levels (strenuous, moderate, light) including time spent sitting. LTEQ is considered a valid and reliable instrument for measuring leisure-time PA and has been used previously with older adults (Godin, Shephard, 1985; Kliman, Rhodes, 2008). The PASE records levels of PA in various domains and also types of PA and their perceived intensity as performed in the past week. Compared to LTEQ, it covers broader range of PA focusing also on PA in work and household and was designed specifically for older adults. PASE is considered a valid instrument for measuring PA in older adults (Washburn et al., 1993).

The 12-item questionnaire SF-12 (Ware, Kosinski, Keller, 1996) was used to measure psychological and physical health. This questionnaire focuses on self-evaluation of one's health, perceived health limits, or physical, emotional, and social aspects of one's health. The SF-12 questionnaire provides scores of perceived psychological health (mhs) and physical health (phs). It represents a valid and reliable method of health evaluation frequently used in the research on older adults (Ware, Kosinski, Keller, 1996). Satisfaction with life questionnaire (Swl) (Diener et al., 1985) is the most frequently used instrument measuring global life satisfaction. It represents an instrument with good reliability and validity which is suitable for research on older adults (Diener et al., 1985).

The study

The respondents of the study were approached through various organizations for older adults, such as the Czech Association of Sport for All, the University of the Third Age and a physical activity program taking place at the Faculty of physical education, Charles University in Prague. All respondent were examined by the Vienna test system battery; the total test time was about 45 minutes. Subsequently they filled the questionnaire battery; the return rate of the questionnaires was 100%. The data were processed by SPSS 21.0. We computed the descriptive statistics, and Spearman correlational coefficient between the cognitive and other variables.

RESULTS

Age and demographic descriptors

Of all measured demographic variables, the age of respondents was significantly negatively corelated to household income and physical activity. It means that with growing age the respondents made significantly less money and also participated in less everyday physical activity. Interestingly, it seems that their participation in leisure physical activity was unrelated to age (see Table 1).

Table 1. Age and demographic descriptors

		Education	Household income	bmi	PASE	LTEQ
Age	r	.109	–.385*	–.013	–.366*	–.164
	p	.559	.039	.944	.036	.370

r – correlation coefficient; p – significance level

Considering the relationship of age and the quality of life, a significant relationship between age and the objective measures of health, such as the presence of health problems or the number of health conditions was observed. However, there were no significant relationships between the age and the self-evaluation of psychological (mhs) and physical (phs) health, or the life satisfaction (SWL) of our respondents (see Table 2).

Table 2. Age and health status

		Health problems	Number of conditions	phs	mhs	SWL
Age	r	.383*	.420*	–.189	.089	.054
	p	.030	.023	.292	.624	.766

r – correlation coefficient; p – significance level

Age and cognitive processing speed

Cognitrone presented respondents with relatively easy tasks without extensive complexity or time pressure. In this type of tasks the impact of age was not observed. Only in the most difficult Cognitrone task which was the decline of a picture differing from the model (as opposed to accepting a picture the same as the model), the relationship with age bordered on being significant ($p = .075$) (see Table 3).

Table 3. Age and Cognitrone test results

		Average time for "correct hit" (s)	Average time for "correct decline" (s)	"Correct hit" number of responses	"Corect decline" number of responses	Total working time
Age	r	.147	.314	.143	.046	.222
	p	.414	.075	.428	.798	.215

r – correlation coefficient; p – significance level

Reaction test presented responents also with relatively easy tasks in which the time was measured but the task was not very complex and it did not put respondents under time pressure. In this context, neither the average reaction time, nor the average time of motor reaction was related to age. Only a significant relationship between the age of respondents and the variance in reaction time was observed, i.e. the older the respondents the more their respose times fluctuated whereas the reaction times of younger respondents were more consistent (see Table 4).

Table 4. Age and Reaction test results

		Average reaction time	Average time of motor reaction	Reaction time variance	Variance of motoric reaction time
Age	r	.226	–.030	.351*	–.263
	p	.206	.870	.045	.139

r – correlation coefficient; p – significance level

Visual memory test presented respondents with tasks which were especially demanding on the working memory capacity, i.e. an ability to store and retrieve a large number of visual information. However, the task did not require high processing speed as the respondents' response times were measured but not included in the final score. The recorded total working time was more a measure of "cognitive tempo" as a personality characteristic rather than a measure of processing speed as a performance-determining factor. In our sample, this kind of task was unrelated to age (see Table 5).

Table 5. Age and Visual memory test results

		Visual memory performance	Total working time	Total number of items
Age	r	–.084	.152	–.017
	p	.642	.399	.926

r – correlation coefficient; p – significance level

Visual pursuit test was more complex than the previous tests and it also put the respondents under time pressure, as they had to solve the puzzles as fast as possible and the working time was included in their final score. Here, the processing speed was significantly related to the age of respondents with correlational coefficients ranging from r = .353 to .476. Again, the measure that did not include a processing speed component (i.e. Number of correct answers) did not correlate significantly with age (see Table 6).

Table 6. Age and Visual pursuit test results

		Median time for correct answers (sec)	Number of correct answers	Working time	Raw score based on viewing times
Age	r	.413*	–.085	.476**	–.353*
	p	.017	.639	.005	.044

r – correlation coefficient; p – significance level

Determination test has a very strong processing speed component as the respondents have to react as fast as possible to fast-changing stimuli. The task is very complex; the respondents have to employ both hands (on reaction panel) and legs (on reaction pedals) to respond to various kinds of visual and acoustic information. Also, unlike in the other tests, the failure in earlier tasks negatively affects the performance in latter tasks. Similarly to the Visual pursuit test, the processing speed related measures showed significant correlations with age. We observed significant relationship with median reaction time (r = .467), number of stimuli (r = −.432), and number of correct answers (r = −.403). The number of stimuli and the number of correct answers have also a strong processing speed component because, due to the adaptability of the test, the faster the respondents respond, the more stimuli is presented. On the other hand, the age was not related to the number of incorrect and omitted answers. It means that the older the respondents, the slower they worked, the fewer stimuli they were presented and, as a result, the fewer number of correct answers they scored. However, older respondents did not make more mistakes and not omit more responses than the younger ones (see Table 7).

Table 7. Age and Determination test results

		DT Median reaction time	DT Number of stimuli	DT Correct	DT Incorrect	DT Omitted
Age	r	.467**	–.432*	–.403*	–.066	.140
	p	.007	.013	.022	.720	.444

r – correlation coefficient; p – significance level

Impact of leisure physical activity on cognitive functions

The possible impact of physical activity on the cognitive function in older adults was explored by linear regression models in which the age and participation in physical activity as measured by LTEQ and PASE questionnaires predicted cognitive function measured by the Determination test. The Determination test a captured the age-related changes in cognitive function. It was found that the model significantly predicted both DT median reaction time ($F(3, 27) = 4.005$, $p = .018$, $R = .555$, explaining 30.8% of variance DT median reaction time) and the number of correct answers ($F(3, 27) = 5.631$, $p = 0.004$, $R = .620$, explaining 31.7% of variance DT number of correct answers). However, in both measures of physical activity, only LTEQ contributed to the models (beta = −.296 in DT median reaction time and beta = .275 in DT number of correct answers) which suggests that only the participation in leisure physical activity (as opposed to overall physical activity measured by PASE) predicted the level of cognitive function in our respondents.

DISCUSSION

Similarly to previous research studies (Ansley et al., 2005; Rogers, 2012; Salthouse, 1996), the present study also shows that age has a significant impact on cognitive function in older adults. As expected, it was found that the age of respondents was significantly related to their ability to perform on various cognitive tasks. Specifically, the age impacted the processing speed component of the cognitive functions. Across all used cognitive tests we consistently observed that most measures related to the processing speed were significantly related to age, whereas measures unrelated to processing speed (i.e. the tasks which did not include the speed of the response into the final score) did not show a significant relationship with age.

It seems that this relationship was strongly dependent on the complexity and difficulty of the task combined with the time pressure. In an easy task with little complexity (as represented by the Cognitrone test) even the measures related to processing speed were not significantly related to age (with the exemption of the most difficult measure which bordered on significant). Similarly in another easy task, the Reaction test, the only measure which was significantly related to age was the reaction time variance. It means that the response times fluctuated significantly more in older respondents, although in general they did not necessarily responded slower than the younger ones. The measures in the Visual memory test did not include the processing speed component at all and, as expected, they did not show a significant relationship with age. That is particularly interesting in relation to the total working time which in this case did not represent a measure of the test performance but more a measure of "cognitive tempo" as a personality characterisic which was unrelated to age.

The nature of age-related decline of cognitive function has been best captured by the two remaining tests (Visual pursuit test and Determination test). Both tests were complex, difficult and put the respondents under time pressure which appeared as more challenging for older respondents. Nevertheless, even in these tests the age of respondents was not related to all measures of test performance but only to those which included a processing-speed component. It means that although the older respondents performed generally slower in these tests they did not make more mistakes and did not have more difficulties in solving the tasks.

These findings are consistent with the processing speed theory of adult age differences in cognition (Salthouse, 1996; Kallus, Schmitt, Benton, 2005). Salthouse (1996) explains the impact of aging on the processing speed of cognitive functions by two mechanisms. The first one is called the limited time mechanism. When an older person performs a complex task, the time to perform later operations is increasingly restricted due to the time demands of the early operations which results in the performance decline. The second mechanism is called the simultaneity mechanism. In older adults, the products of early processing tend to get increasingly lost by the time the later processing is completed and the results of early operations are not available when needed (Salthouse, 1996). These meachnisms take place predominantly in tasks which require processing a large number of cognitive operations. In such case, the later operations are increasingly distorted by the errors made in earlier operations. The Visual pursuit test and the Determination test in which the impact of age has been most prominent represent the prime examples of this kind of a task.

However, although the results of the study show that the age of respondents determines the level of cognitive function by impacting the processing speed ability, we also found that this relationship was mediated by physically active lifestyle, specifically by the participation in leisure physical activity. Also other research studies suggest that the process of aging may be to a large degree determined by the lifestyle factors. For example, the age related decline of cognitive functions can be prevented by cognitive training (Ball et al., 2002; Stepankova et al., 2012). In general, the activity of a person represents a crucial factor in this regard (Newson, Kemps, 2005). Albert et al. (1995) found that vigorous physical activity functions as a preventive measure of the age-related cognitive decline. In a similar fashion, Hultsch et al. (1999) showed that active lifestyle and participation in efortfull cognitive activities may mitigate the negative impact of progressing age. Scarmeas and Stern (2003) argued that active lifestyle and the participation in a large number of leisure activities prevents the age-related cognitive decline. Numerous other studies have also shown that the active lifestyle and the participation in leisure physical activity may serve as a protective factor limiting the negative impact of aging on cognitive function (Gelder et al., 2004; Hultsch et al., 1999; Yaffe et al., 2001). Physical health may also play a significant role in the age related cognitive decline (Salthouse, 2000), as well as the psychological health represented by the absence of anxiety and depression (Jorm, 2000; Wetherell et al., 2002). The factors that influence the lifestyle of older people such as their social economic status (Shankar et al., 2010) or activity related beliefs (Albert et al., 1995; Leon, 1995) should be considered. Nevertheless, due to the relatively small scope of our research we were not able to explore all the mediating effect of these variables on the observed relationship between the age of respondents and the processing speed of their cognitive functions. However, it may be assumed that, apart from the participation in leisure physical activity, also other health, environmental and psychological variables have at least some impact on the cognitive aging which should be explored in the continuation of the project.

CONCLUSION

The results of the study confirmed the proposed hypotheses formulated on the basis of the processing speed theory of adult age differences in cognition. We found that the age related decline of cognitive functions in our respondents may be attributed to the decline in the cognitive processing speed whereas the measures unrelated to the processing speed did not show a significant relationship with age. The age related decline was evident in complex, difficult and time-bound tasks whereas the performance in simple and easy tasks without a time limit remained unaffected by the age of respondents. The age related decline was limited by participation in leisure physical activity which suggests that the concept of "active aging" should be promoted in the population of older adults.

ACKNOWLEDGEMENTS

The article was supported by the research grant of MSMT CR no. MSM 0021620864 and was written in the framework of the scientific branch development programme UK FTVS n. 39 Social-Sciences Aspects of Human Movement Studies.

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STÁRNUTÍ A RYCHLOST ZPRACOVÁNÍ KOGNITIVNÍCH FUNKCÍ

JIŘÍ MUDRÁK, PAVEL SLEPIČKA

SOUHRN

V předkládáné studii se zabýváme některými aspekty věkem podmíněného úbytku kognitivních funkcí. Konkrétně zkoumáme předpoklady vycházející z teorie rychlosti zpracování (Salthouse, 1996) týkající se toho, že věkem podmíněný pokles kognitivních funkcí je dán především poklesem rychlosti kognitivních procesů, což se projevuje především u komplexních kognitivních úkolů. Vzorek v naší studii se skládal z 33 seniorů a seniorek (průměrný věk byl 68 let), které jsme oslovili prostřednictvím několika programů pro seniory. Respondenti byli testováni prostřednictvím pěti testů kognitivních funkcí, které jsme vybrali z testové baterie Vienna test systém. Následně jsme analyzovali vztah mezi výsledky testů a věkem respondentů. Zjistili jsme, že věk respondentů souvisel s jejich výkony v testech pouze v komplexních úkolech, které obsahovaly komponenty rychlosti zpracování. Výkon respondentů v jednoduchých úkolech a v úkolech nezávislých na rychlosti zpracování nevykazoval vztah s jejich věkem. Naše zjištění jsou konzistentní s hypotézami vycházejícími z teorie rychlosti zpracování. Dále jsme zjistili, že výkon při řešení komplexních kognitivních úloh byl ovlivněn účastí ve volnočasové pohybové aktivitě, což naznačuje, že aktivní životní styl limituje dopad stárnutí na kognitivní funkce.

Klíčová slova: kognitivní funkce, rychlost zpracování, stárnutí, Vienna test system, pohybová aktivita

Jiří Mudrák
mudrak@ftvs.cuni.cz