International Journal of Social Science And Human Research

ISSN(print): 2644-0679, ISSN(online): 2644-0695

Volume 05 Issue 09 September 2022

DOI: 10.47191/ijsshr/v5-i9-45, Impact factor- 5.871

Page No: 4323-4330

Cognitive Aging and Rhythms Daily Variations in Attentional Performance in Children, Adults and the Elderly

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ABSTRACT: Most of the attentional performance rhythms have been studied in order to organize school peri and extracurricular time in children. The chronopsychological data available on the development of these rhythms are, to our knowledge, rare. It therefore seems necessary, from a developmental and differentia perspective, to address these fluctuations in attentional performance not only in children but also in adults and the elderly. The present study therefore aims to investigate the influence of age and time of day on attentional performance. To do this, 171 participants were divided into three age groups: 88 children (divided into 2 groups: 5-7 years and 9-12 years), 56 adults (divided into 2 groups: 20-35 years and 36-59 years) and 27 seniors (60-72 years). The results indicate that attentional performance varies differently depending on the time of day and that this variation becomes constant and stable with age. Moreover, the level of attention increases with age and this evolution becomes stable from the age of 35.

KEYWORDS: age, attentional performance, chronopsychology, rhythm, barrage test, daily variation, inter-individual variability

I. INTRODUCTION

Research in chronopsychology highlights the existence of behavioral rhythms in human. Such cyclical variations affect the various facets of cognitive activity (Fraisse, 1980; Leconte & Lambert, 1990, Testu, 2000). For example, it has been shown that short-term memorization is better in the morning than in the afternoon, while what is learned in the afternoon is better remembered in the long term than what is learned in the morning (Clarys and al., 2012; Folkard & Monk, 1980). It has also been shown that certain time slots may be particularly unfavorable for the emergence of efficient performance of intellectual activities (Leconte, 2014; Testu & Baille, 1983; Testu and al, 1995). Furthermore, other studies reveal that attention which is viewed as the psychological expression of physiological processes, progresses throughout the day; with the early morning and afternoon (postprandial trough) recognized as two "difficult" times both chronopsychologically and chronobiologically (Bloch, 1973; Montagner & Testu, 1996; 2008). Thus, attentional performance, like intellectual or memory efficiency, is subject to periodic variation. In general, the tests used to measure periodic variations in these performances range from simple self-assessment of vigilance to tests of log-term memory or problem solving in through tests of reaction time or barrage of letters or numbers or geometric shapes.

The so-called barrages tests or psychotechnical tests are the ideal tests for chronopsychologists in the evaluation of attentional performance. The originality of these tests lies essentially in the fact that they are tasks involving visual discrimination that children, adults and even the elderly perform easily. As Gate (1916) pointed out last century, these are tests involving perceptual-motor tasks, since they require speed and accuracy (reaction time, accuracy and rapidity of movements). Monk and Leng (1982) showed that speed and accuracy evolve differently during the day: speed improves from morning to evening, whereas accuracy increases from the beginning to the end of the morning and then decreases until the evening. Moreover, the two parameters (the detectability index "d" and the response criterion index "ß" that underlie these perceptual-motor tasks also evolve differently other the day (Craig, Wilkinson & Colquhoun, 1981, Green & Swets, 1966). Indeed, the "ß" index, concerning the judiciary aspect (decision that the individual makes regarding his or her response), decreases over the course of the day, whereas the detectability index "d", concerning the purely sensory aspect, remains stable. Moreover, these barrage tests have the merit of not involving any elaborate cognitive processing. The automatic cognitive processes that these tests involve are not very costly in terms of effort and resources, do not require a high level of consciousness, and cannot be under the direct control of the subject (Enns & Trick, 2006, Shiffrin & Scheinder, 1984; Wetzel, Widmann, Berti & Schrôger, 2006).

Chronopsychological studies of fluctuations in attentional performance have shown the influence of many factors, including age. Some studies have shown that the procedures and strategies developed to perform these tasks differ according to age: older people differ from younger people in their choice of strategies and in their information processing methods (Logie and al., 2004).

Indeed, young people would have more recourse to controlled strategies whereas older people would make more use of automatic strategies. The absence and presence of daily fluctuations in performance are associated with automatic and controlled processing (Testu, 1994). Other studies have shown that the daily profile of attention becomes constant and stable with age (Bouati, 2015; Testu, 1979; Méité, 2010). In this vein, two typologies of profiles had been highlighted in children aged 4 to 11 years: on the one hand, so called "classic" profiles (improvement in performance from the beginning to the end of the morning, drop after lunch, then increase again during the afternoon) in children aged 10-11 years and, on the other hand profiles inverted to those of the "classic" profiles, called "reverse" profiles, observed in children aged 4 to 7 years (younger). In other words, the "peaks" and "troughs" sometimes occur at different times of the day when comparing the daily profiles of older children to those of younger children (Janvier &,Testu, 2005 ; 2007 ; Krokfors, 2011 ; Leconte &, Leconte-Lambert, 1994; Méité, 2014 ; Ponce &, Alcorta, 2011 ; Testu, 2015).

Thus, the daily attentional profiles seem to change with age, and the younger we are the more fluctuating the attention tends to be. The proposed study is therefore part of the research on the structuring and maturation of cognitive rhythmicity, the aim being to study the levels and daily variations of attention according to age.

II. METHOD

A. Participants

To determine the influence of age and time of day on attentional performance, 171 participants were divided into three age groups: 88 children (2 groups: G1 = 5-7 years; G2 = 9-12 years) 56 adults (2 groups : G3 = 20-35 years ; G4= 35-59 years) and 27 elderly (G5= 60-71 years) (Table 1). These three age groups were subjected to attention test (number barrage), at different times of the day: beginning (8 am) and end of the morning (12 pm), beginning (2 pm) and end of the afternoon (6 pm).

Also, it should be noted that in order to monitor the quality, efficiency of habitual sleep, sleep disturbances and hypnotic intake of the participants, they filled in the Pittsburg Sleep Quality Index (PSQI).

Table 1. Distribution and Characteristics of Participants by Age

	Children [5-12 years old] N=88		**Adults [20-59 years old] N=56**		**Senior [60-72 years old] N=27**
	Less senior [5-7 years old]	More senior [9-12 years old]	Less senior [20-35 years old]	More senior [36-59 years old]	[60-72 years old]
Participants	42	46	32	24	27
Average age	6.1	10.6	24.9	46.6	64.6
Standard deviation	0,53	0,63	3,6	7,5	3,7

B. Materials

Attention is measured by means of barrage tests. These tests consist of the participant crossing out target numbers each time he or she finds one within a series of number lines. Also known as a pen-and-paper test, the number barrage test is essentially done using a stopwatch, a pen and A4 (21 x 30 cm) size number barrage sheets. Age-appropriate barrage tests were used. For 5-7 year olds, the sheet includes 108 numbers of 1 or 2 digits arranged in 6 lines. Each time contains 18 numbers, 5 of which are target items; children had 30 seconds to detect these 30 target items (2-digit numbers). For older children (9-12 years old), the time limit is also 30 seconds, but the target items are 2-digit numbers (50 numbers) from a set of numbers ranging from 1 to 5 digits. The barrage sheet includes 300 numbers arranged in 16 rows. As for the adults and seniors, the sheet has 600 numbers from 1 to 5 digits arranged in 36 lines. The number of targets is 187, with 2 to 8 numbers randomly distributed per line. The duration of the test is 30 seconds.

C. Procedure

The measurements are collective and take place at the beginning (8 am) and end of the morning (12 pm), at the beginning (2 pm) and end of the afternoon (6 pm). The daily repetition of the measurement led to the use of number barrage sheets in four parallel forms (A, B, C and D), corresponding respectively to these different moments of the day. This was done to avoid a training effect that could lead to learning. A fifth version (form E) is reserved for the pre-test phase.

For the children, the instruction is "you must cross out all the two-digit numbers as quickly as possible. On my signal, you start… stop, it's over!" a correctly crossed out number is scored one point. This coding is valid for adults and seniors. For the latter, the instruction is as follows: "you have a sheet of paper in front of you with four series of numbers on the back. At the given signal, you must turn over this sheet and cross out all the 3-digit number as quickly as possible. You have one minute to complete this exercise. Attention! Are you ready? go ahead !

The study of the statistical significance of the effect of age and day on attentional performance (raw scores on the barrage tests) was carried out by repeated measures analyses of variation (ANOVA) performed under the Statistica software.

III. RESULTS

In order to show the influence of age on daily attentional performance, three age groups were considered : children (5-12 years), adults (20-59 years), and the elderly (60-72 years). Then each age group was subdivided into two to obtain five subgroups: children 5-7 years and 9-12 years, adults 20-35 years and 36-59 years, and the elderly (60-72 years).

A. Levels and daily variations of attentional performance in children, adults and the elderly

Table 2 shows a comparison of the variations in attentional performance in children, adults and the elderly, depending on the time of day. The attentional performance of the three age groups changes differently over the course of the day. Partial analysis of mean attentional performance, time by time, shows superiority of adults' performance to that of the elderly, who themselves are superior to children: regardless of the time of day: early morning ($F(2,168) = 297,49$; $p < .001$; $\eta^2 = 0,780$) ; late morning : ($F(2,168) = 272,90$; $p < .001$; $\eta^2 = 0,765$) ; early afternoon : $F(2,168) = 239,75$; $p < .001$; $\eta^2 = 0,741$) and late afternoon: ($F(2,168) = 305,32$; $p<.001$; $\eta^2 = 0,784$) (Figure 1).

Table 2. Variations In Mean Attentional Performance In Children, Adults And The Elderly By Time Of Day

	EM	LM	EA	LA
Children / Adults	-37,54***	-36,26***	-36,24***	-39,79***
Children / Seniors	-26,99***	-27,42***	-27,83***	-27,65***
Adults / Seniors	10,55***	8,84***	8,41***	12,14***

***p <.001 (Mean difference is significant at the 0.05 level)

EM : early morning ; LM : late morning ; EA : early afternoon ; LA : late afternoon

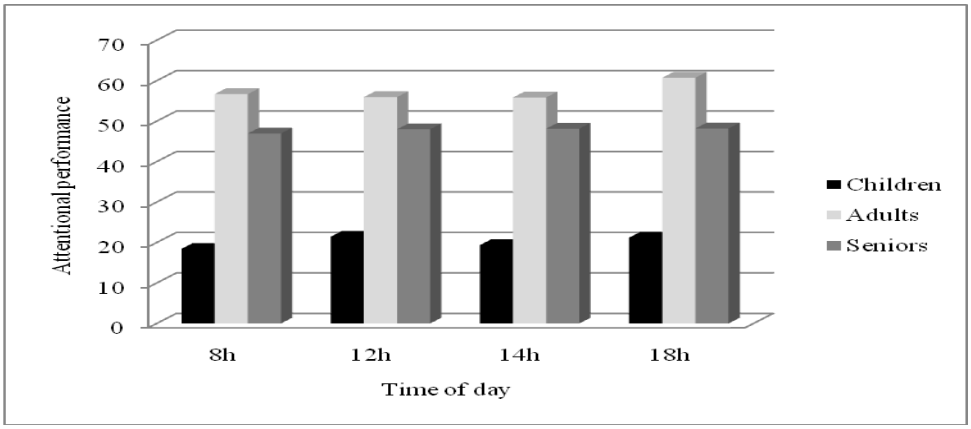

Figure 1. Levels and daily variations of average attentional performance in children, adults and the elderly

The analysis of variance performed on the performance levels shows, for all the moments of passing combined, a significant effect of age on the performance levels ($F(2,168) = 367,954$; $p<.001$; $\eta^2 = 0, 814$) ; indicating that young people are less attentive than adults [*Difference in mean* = -37,46; $p <.001$] and seniors [*Difference in mean* = --27,47; $p <.001$] (Figure 2).

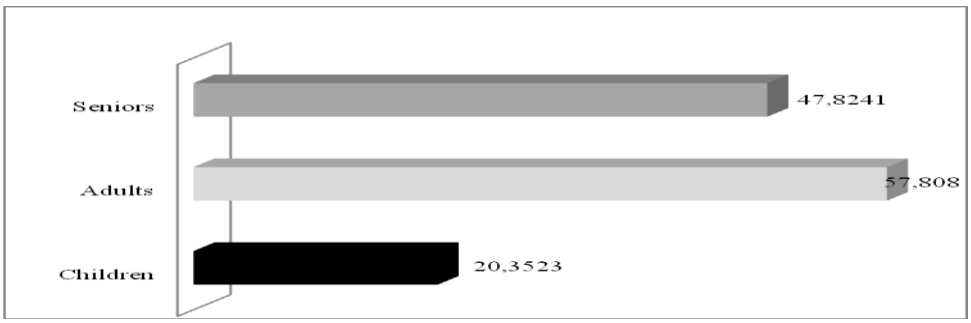

Figure 2. Levels and variations of average attentional performance in children, adults and the elderly across all time points

Intercorrelational analysis indicated a strong positive correlation between participants' chronological age and their level of attention ($r= 0,622$; $p<.01$) (Table 3). Thus, the level of attentional performance increases with age. This positive correlation is

also true for all times of day: early morning: r = 0,588; $p < .01$; late morning: r = 0,607 ; $p < .01$; early morning : r = 0,613 ; $p < .01$; late afternoon : r = 0,607 ; $p<.01$ (Table 3).

Table 3. Matrix Of Intercorrelation Between Age, Time Of Day And Attentional Performance

	1	2	3	4	5	6
1.Age	1					
2. Daily average attentional performance	,622**	1				
3. Average attentional performances **early morning**	,588**	,966**	1			
4. Average attentional performance **late morning**	,607**	,973**	,925**	1		
5. Average attentional performance **early afternoon**	,613**	,971**	,918**	,922**	1	
6. Average attentional performance **late afternoon**	,607**	,972**	,910**	,933**	,929**	1

** The correlation is significant at the 0.01 level (two-tailed)

B. Levels and daily variations of attentional performance in children (5-7 years and 9-12 years)

Daily profiles for younger (5-7 years) and older (9-12 years) children are derived from average attentional performance in the early morning (EM), late morning (LM), early afternoon (EA) and late afternoon (LA). Table 4 shows the difference between these performances.

Table 4. Variations In Children's Attentional Performance By Time Of Day

	Difference in average			
	EM	LM	EA	LA
Children Younger / older	-9,841***	-7,394***	-13,317***	-10,724***

***p <.001 (Mean difference is significant at the 0.05 level)

EM : early morning ; LM : late morning ; EA : early afternoon ; LA : late afternoon

Attentional performance varied significantly over the course of the day for older children [F (3,164) = 4,6 ; p < .001], as it did for younger children [F (3,164) = 4,57; p < .001] (Figure 3). Both profiles evolve in the same way, with two « troughs » (early morning and afternoon) and two "peaks" (late morning and afternoon). However, older children pay more attention than younger children, regardless of the time of day: F (3,164) = 3,8; p <.01; η^2= 0,065.

Figure 3. Daily levels and patterns of attentional performance of children (younger (5-7 years) and older (9-12 years))

C. Levels and daily variations of attentional performance in adults (20-35 years and 36-59 years) and seniors (60-72 years)

Table 5 shows the differences in mean performance between younger adults (20-35 years), older adults (36-59 years) and seniors (over 60 years), by time of day (early and late morning and early and late afternoon)

Table 5. Variations attentional performance of younger adults, older adults, and seniors

	Difference in average			
	EM	LM	EA	LA
Younger adults / Older Adults	11,552***	9,271***	9,573***	7,781**
Younger adults / Seniors	15,506***	12,813***	12,508***	15,471***
Older Adults / Seniors	3,954	3,542	2,935	7,690**

***p <.001 **p <.01 (Mean difference is significant at the 0.05 level)

EM : early morning ; LM : late morning ; EA : early afternoon ; LA : late afternoon

The attentional performance of adults and older adults varies differently throughout the day. Indeed, the performance profiles of older and younger adults change in almost the same way, with stability throughout the morning and a rise between early and late afternoon (OlderAdults $F(3,164)=4,57$; $p<.001$; $\eta^2=0,082$; Younger adults $F(3,164)=4.6$; $p<.001$; $\eta^2=0,078$). In contrast the to adults, attentional performance in older adults remained stable throughout the day [$F(3,164)=0.26$; ns] (Figure 4).

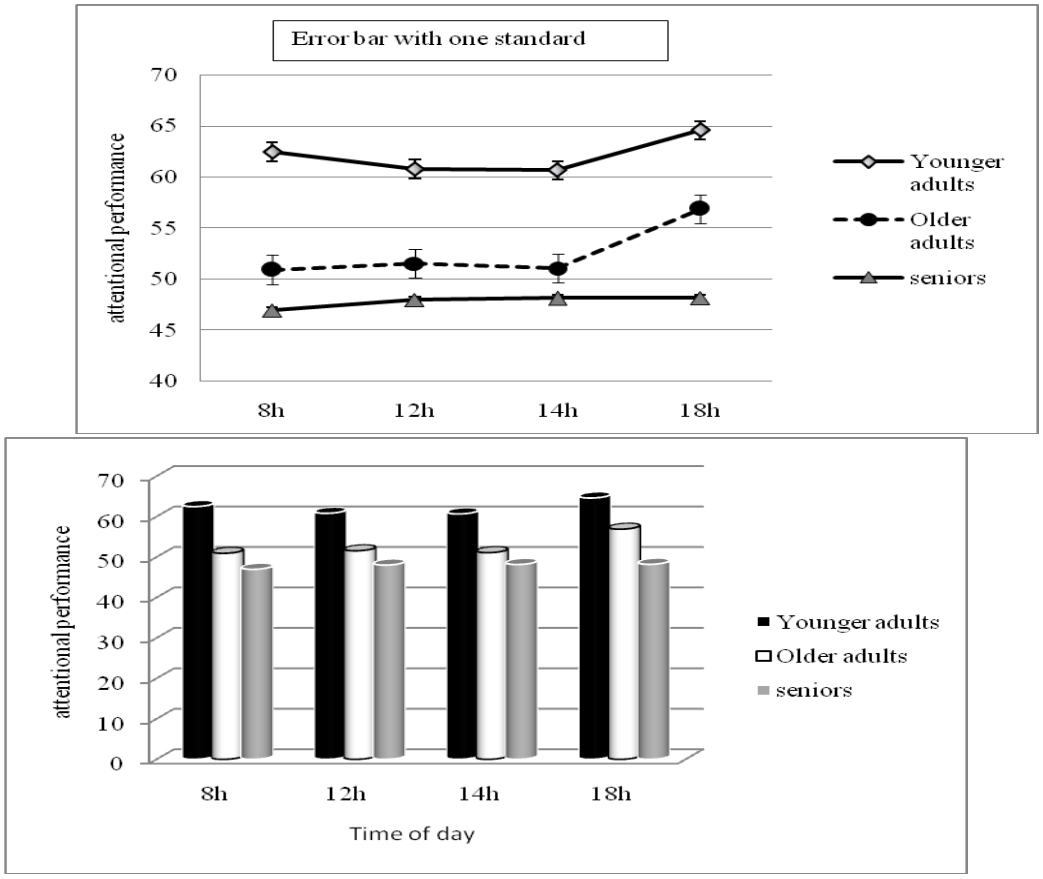

Figure 4. Daily attentional performance levels and profiles of adults (younger (20-35 years) and older (36-59 years) and seniors (over 60 years)

Regarding performance levels, statistical analysis (Tukey Test) shows, across all time points, that the attention levels of younger adults differ significantly from those of older adults Difference in mean = 9,544; p <.001] and seniors [Difference in mean = 14,07436 ; p <.001]. In contrast, the performance levels of the latter (older adults and seniors) are comparable [Difference in mean = 4,53, ns] (Figure 5).

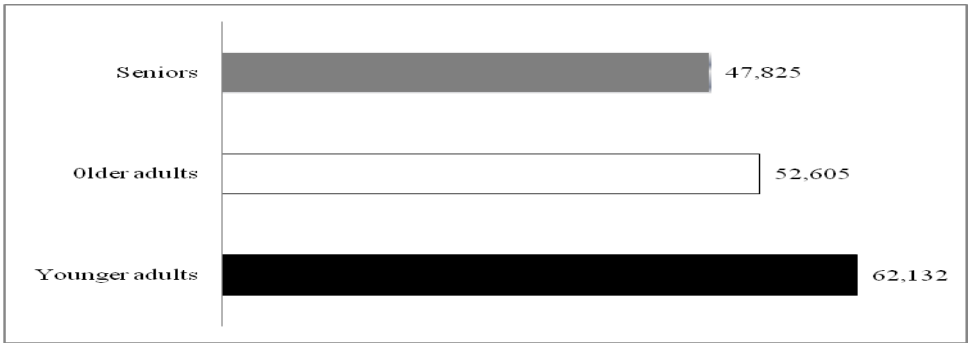

Figure 5. Daily attentional performance levels of younger adults, older adults and seniors, all time points cobined

IV. DISCUSSION

The present study is based on a differential perspective. Thus, in order to better understand inter- and intra-individual differences, the levels and fluctuations of daily attentional performance of the three age groups (children, adults and elderly) were first studied, and then the subgroups were considered children (5-7 years and 9-12 years), adults (20-35 years and 36-59 years) and the elderly (60-72 years).

Concerning the daily profiles, we note that the attentional performances of children, adults and seniors evolve differently during the day. In children (5-7 years and 9-12 years), daily attentional efficiency is more fluctuating, with bathyphases in the early morning and afternoon and acrophases in the late morning and afternoon. This profile reflects Testu's (1979; 2015) type of "classic profile", evidenced in France and other European countries, including German, English, Spanish, and Finnish children (Krokfors, 2011 ; Leconte, 2014 ; Testu, 1994). Moreover, Janvier and Testu (2007), who were able to establish profile typologies among students aged 4 to 11 years, had found this so-called 'classic" profile in 84% of the participants aged 10-11 years. In the case of adults (20-35 years and 36-59 years old), unlike children attentional performances are less fluctuating, since they remain stable throughout the morning. Moreother, this stability is also observed throughout the day for the elderly. Clearly, daily attentional performance varies little with advancing age. These data are therefore consistent with the results of previous studies that have demonstrated changes in the daily attentional profile with are, notably those of Janvier and Testu (2005) with children aged aged 4 to 11 years and those of Méité (2010) with older participants (20 to 60 years and over). The first study described an initially profound change between the ages of 4 and 7, then a global structuring from the age of 11, while the second found that that this daily profile became constant and stable from the age of 60. These results are therefore in line with those that have shown that an individual's attentional capacity evolves with age; this evolution is done either in an integrative way towards an automation of the psychological mechanisms necessary to carry out the tasks, or by the use of increasingly effective strategies according to the degree of maturation of the age considered.

When considering the different levels of attention, there was a strong positive correlation between the chronological age of the participants and their level of attention, regardless of the time of day. This suggests that the level of attentional performance increases with age. The study of the statistical significance of the age effect corroborates this link: younger children (5-7 years) pay less attention than older children (9-12 years) who, in turn, pay less attention than younger adults (20-35 years). The performance levels of older adults (36-59) and older adults are comparable. Thus, it appears that attention increases with age up to age 35. While these results confirm those of Manly and al.,(2001) lower performances observed in the elderly. Indeed, since barrage tests involve the distribution and control of attentional resources, these lower attentional performances could be related either to a deficit in inhibition capacities or in these attentional processes or to a reduction in the attentional resources available in the elderly (Salthouse, 1996). Bouati (2015), on the other hand, had found a particular circadian rhythmicity of cognitive processes in these seniors, very different from that encountered in children and adults. In this perspective, the low level of performance in children could also be explained by the fact that they are less familiar with numbers in the barrage test.

CONCLUSIONS

The present study, carried out with children, adults and seniors, confirmed the results of previous work on daily attentional variations: attentional performance varies differently depending on the time of day and this variation becomes constant and stable with age. This highlights, in the light of other research, a global structuring of attentional rhythmicity with age. The mechanisms underlying this structuring remain to be determined with certainty. Moreover, for out part, all the data concerning the effect of age on the level of this performance has also made it possible to supplement previous work, since it appears that the level of attention increases with age and that this evolution becomes stable from the age of 35. Further studies could examine the variations in this performance over the week in these three age groups and in a systematic approach, use analysis methods that go beyond the use of central indices alone.

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