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Matinality / Vesperity Chronotype, Age, Time of Day and Inhibitory Capacities Among Secondary School Pupils

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ABSTRACT

Inhibitory ability may be defined as the ability of our brain to focus our attention and focus on crucial information while ignoring irrelevant information. In this sense, in a school context, inhibition plays an important role in learning and performing a task or activity. On the one hand, it has been shown that this cognitive skill depends on a developmental process; development linked to neurological or cerebral maturation, which occurs early and over a long period of time. On the other hand, it has been noted that our brain state may vary depending on the time of day and that this variation is influenced by inter-individual factors such as age and morning or evening preference (chronotype). This study falls within this differential perspective. It aims to study the influence of age and chronotype on inhibitory capacities using a protocol depending on the time of day (morning and afternoon). To this end, 250 secondary school pupils (6th to final class) were subjected to the revised chronotype questionnaire of Terman and Terman and to the Stroop Victoria test. Precisely, these pupils are divided into two age groups (12 to 15 years old and 16 to 20 years old) and according their chronotype (morning, neutral and evening). The results indicate that pupils' inhibitory performance differed by time of day and age. In addition, the age and chronotype interaction has a significant effect on inhibitory performance when considering the 12 to 15 age group.

Keywords: age, chronotype, executive function, inhibition, time of day.

1. INTRODUCTION

Executive functions, as the name suggests, enable the executive of a cognitive activity. In other words, they regulate and control the other cognitive functions [1]. They allow us to manage our behaviours, thoughts and emotions in a new situation [2]. Working memory, mental flexibility, planning and inhibition are considered to be the main components of executive functions [3; 4]. These cognitive processes are involved in many everyday situations. They make it possible to manage and maintain relevant information (working memory), to alternate between different tasks or strategies and to switch from one to another in a flexible and appropriate manner depending on the demands of the environment (mental flexibility). They also make it possible to resist interference caused by environmental distracters (inhibition) as well as to anticipate and structure our activities (planning) [5; 6; 7; 8; 9].

This way of presenting these different mental skills clearly shows their fundamental role in school, a place for learning, reflection, concentration and social interaction [10]. Thus, in a school context, working memory is essential in the development of language, in the implementation of learning and makes it possible, for example, to retain long instructions, to perform mental calculations and to express oneself with long sentences [11]. Mental flexibility allows pupils to use different strategies, accept changes and have different points of view [12]. The inhibitory capacity, on the other hand, promotes concentration and the ability to act according to the given context [13]. Planning is also necessary in school, since it allows pupils to predict and evaluate their behaviours in order to complete a task or activity [14].

On the one hand, many researches has shown the early and progressive development with age of these different executive skills. Thus, for Diamond and Gilbert [15] and Diamond [16], the first appearances of these processes would be around 9 months, a period during which the baby is able to orient his behaviour towards a goal (object permanence) and inhibit the precious location of an object to search for it in a new location. Other authors rather situate these first manifestations around 24 months [17; 18], to then evolve in different stages: first between 3-4 years, 4-5 years, at 8 years, at 12 years old and then at adolescence, even up to 24 years [19; 20; 21; 22; 23]. This development would be linked to neurological maturation, to an increase in processing speed and in the amount of information that can be inhibited and stored [24; 25, 26; 27; 28]. However, studies of the developmental trajectories of these different executive functions shows that they evolve in distinct ways. For example, inhibition and working memory seem to evolve more rapidly during childhood than flexibility, which evolves even faster than planning [29]. While executive abilities are viewed in terms of increasing with age by some authors, others have found that these abilities stabilise in adulthood and decline in older adults. This evolution is the result of aging, characterised by a cognitive slowing down [30; 31; 32; 33] and a deficit in neuromodulation systems, i.e., a decline in the synthesis and transmission of neurotransmitters [34; 35] Furthermore, to our knowledge, there is still little research on executive functions and age, taking into accounts the level of education. However, it seems that there is a relationship between cognition (which underlies these executive functions) and the level of formal education [36; 37; 38; 39). Reference [40], who compared young and older individuals with three different educational levels to the Stroop test, observed that individuals with different educational levels have different performance patterns and that these patterns vary with age.

On the other hand, studies have observed circadian variations in these executive functions [9; 41; 42]. However, most of the results of these studies are consistent. For example, regarding studies focusing on inhibition and using a protocol according to the time-of-day, some found that that the inhibitory capacities decreased in the early evening [43] while others indicated a superiority of inhibition at 1:00 p.m. and 7:00 p.m. compared to 1:00 a.m. and 7:00 a.m. [44]. In contrast, others found no significant difference between inhibitory abilities throughout the day (early and late morning and early and late afternoon) [45]. In other studies that used a constant routine protocol, no circadian variations in inhibition could be observed [46] while [47], on the contrary, observed a progression of these same capacities throughout the day and then decreased at night and early morning. The difference between the results of these two research protocols could be explained by factors such as participants' chronotype and sleep [48. 49], i.e., their ability to cope with a cognitive effort performed against their internal biological clock. It is therefore appropriate to analyse these inhibitory circadian variations according to preferred sleep schedules (morning or vesper preference).

The aim of this study is therefore to investigate, from a differential perspective, the influence of age and chronotype on inhibitory capacities using a protocol depending on the time of day.

2. METHOD

2.1 Participants

Two hundred and fifty pupils (142 boys and 108 girls) participate in this study: 113 pupils from the first cycle whose age is between 12 and 15 years and 137 pupils from the first cycle whose age is between 16 and 20 years (Table 1). The participants were all in good health and had no sleep disorders.

Table 1.Distribution and characteristics of participants by age

	Age group 12 to 15 years old	Age group 16 to 20 years old
Number of participants	113	137
Average age	13,20	18,80
Standard deviation	2.1	1,99

Participants were also divided according to their preferred duration of sleep. Three groups were studied: 79 morning pupils, 103 evening pupils and 68 neutral pupils (Table 2).

Table 2.Distribution and characteristics of

participants by chronotype

	Morning	Neutral	Evening
Number of participants	79	68	103
Percentage	31,6%	27,2%	41,2%
Standard deviation	2.4	1,9	2,7

2.2 Materials

2.2.1 General Information Questionnaire

Participants completed an identification form requiring socio-demographic information, including age, gender, level of education doubling / not-doubling status and school schedules. This information also included averages for the first two terms of the current year.

2.2.2 Chronotype Questionnaire

Terman and Terman's Chronotype Questionnaire (revised) [50] was used to highlight preferential sleep schedules. This is a self-administered paper-and-pencil test and easy to administer; because it is easy to understand. It is also short, so less tiring.

The Chronotype Questionnaire consists nineteen scored questions listed targeting wake / sleep pattern. For some items (3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 16, 18 and 19), the pupils must tick one number among the four, referring to the most appropriate response according to him. For example, to the question, "How do you feel during the first half hour following your awakening in the morning?" (Item3), the pupil has a choice between the answers 1) "*Very Difficult* ", 2) "*Somewhat Difficult*" 3) " *Somewhat Easy"* and 4) "*Very Easy*". For other items, including 1, 2, 10, 11, 15 and 17, the pupil chooses on a scale of hours suited best to the question asked. For example, for item 1 "*If you were completely free to plan your day, approximately what time would you get up?*" The pupil has a choice between five answers: 5) "05h00 - 06h30", 4) "06h30 - 07h45", 3) "07h45 - 09h45", 2) "09h45 - 11:00 "and 1) "11:00- 12h00 ".

At the end of the test, the points that the pupil has circled are added up. The results can vary between 16 and 86.The results below 41 correspond to "Night Owls". Scores above 59 correspond to "early risers". Scores between 42 and 58 correspond to "intermediate" or "neutral" types. Thus, the participants can be divided in three categories: "morning types" or "morning pupils", "intermediate types" and "evening types" or "vesper pupils".

2.2.3 Stroop Victoria Test

The Stroop Victoria Test was developed by Reference [51]. It is one of several interference-based inhibition assessment tasks. Its French adaptation (f-SV) was constructed according to instructions provided by [52]. Its validity as a tool for assessing executive functioning has been established [53]. In addition, one of the advantages of using this test is its rapidity of execution, due to the reduced number of items per plank.

The test material consists of three planks corresponding to three conditions, each with a line of four examples and six lines of four colored stimuli. Four colors are used: red, yellow, blue and green. Plank 1 - Color (C) consists of colored dots arranged in lines that the participating must name. Plank 2 - Words (M) consists of the following four coordination conjunctions: "but, for, so, when", written in color. The pupil must not read these words but to name the color of the ink in which they are written. In Plank 3 – Interference (I), the names of the four colors are written with a different colored ink (for example: green is written in red). The participant's task is not to read these colored words but to name the color of the ink in which they are written, from left to right, as quickly as possible and correctly as possible.

If one or more errors are produced on the third trial, a maximum of two more trials may be proposed. If one or more errors are produced at the third test, the test will still be started. The example line must not be timed. The time taken to complete each plank is timed in seconds. This time continues to be timed even if an error is committed. The time set to perform the example line is not taken into account. It should be indicated that an example of each plank has been added to the original version to ensure that the participant understands the instructions before administering of the task.

2.3 Procedure

The order of administration was as follows: Chronotype Questionnaire (revised), Stroop Victoria Test and General Information Questionnaire. The Chronotype Questionnaire was administered and lasted approximately 20 to 25 minutes. Overall, participants did not have any particular difficulty in understanding the instructions and completing the questionnaire.

Regarding Stroop Victoria test, each test administered individually (approximately three minutes) and for two moments of the day (morning and afternoon).

It should be noted that it was asked to all participants, three days before the experiment, not to consume alcoholic or caffeinated beverages, not to use drugs and not to take any medication that could affect the nervous system and, in turn, does, mask the daily variation in cognitive performance.

3. RESULTATS

The aim of this study was to highlight the influence of time of day, age and chronotype on inhibitory abilities. Inhibitory performance profiles are presented first according to time of day (regardless of age and chronotype), then according to age, then according to the chronotype and finally according to the combined effect of age and chronotype.

Variations in inhibitory performance other the day (morning and afternoon) were analyzed using the paired-sample t-test and a repeated measure analysis (ANOVA) in SPSS.

3.1 Levels and overall daily variation in inhibitory performance

Figure 1 shows the levels of inhibitory performance by time of day, regardless of age and chronotype.

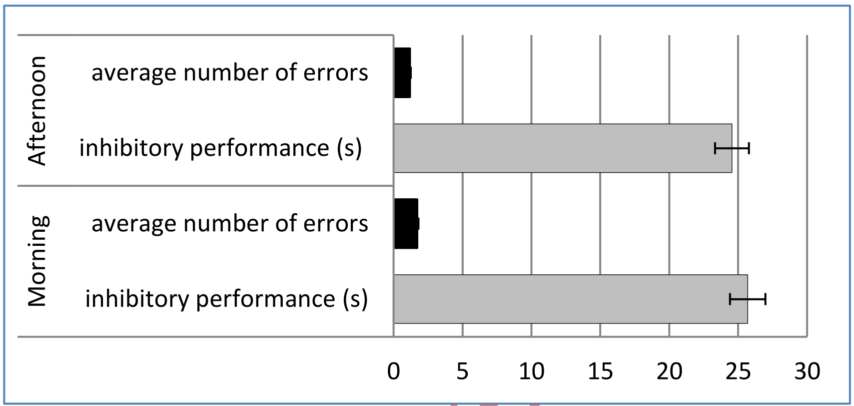

Fig. 1: Inhibitory performance and error levels of pupils by time of day

Analysis of the paired-sample t-test revealed an effect of time of testing, indicating a significant difference between inhibitory performance in the morning and in the afternoon (Figure 1). The paired-sample t-test [t (249) = 3,407, p < .001] shows a superiority of inhibitory abilities in the afternoon over in the morning.

Furthermore, correlational analysis (table below) indicates a positive correlation between inhibitory performance in the morning and in the afternoon (r = 0,558). This suggests a linear progression of inhibitory abilities over the day.

Table 3 correlations between attentional and driving performance profiles

			Inhibitory performance	
			Morning	Afternoon
Inhibitory performance	Morning	Pearson correlation	1	0,558**
		Two-way significance		0,000
		N	250	250
	Afternoon	Pearson correlation	0,558**	1
		Two-way significance	0,000	
		N	250	250

3.2 Levels and daily variation of inhibitory performance by age

The analysis of variance for the within-subjects factor slice, all two moments taken together, shows that there is a significant difference between the inhibitory performance levels of the 12-15 year olds and the 16-20 year olds [F(1,248) = 26,18, p < .001] (Figure 2). The inhibitory abilities of the 12-15 year old pupils are higher than their 16-20 year old counterparts.

Furthermore, when considering the time of day, this difference is also perceived both in the morning [F(1,248) = 26,44, p < .001] and in the afternoon

[F(1,248) = 14,18, p < .001].

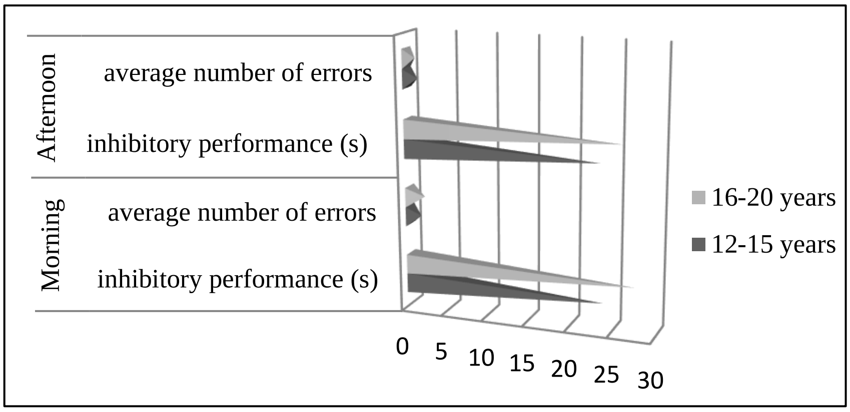

Fig. 2 Inhibitory performance and error levels of pupils according to age

3.3 Levels and daily variation of inhibitory performance according to chronotype

Figure 3 presents the inhibitory performance of pupils according to chronotype; the repeated measures analysis of variance does not indicate an effect of chronotype, all time periods combined, on pupils' inhibitory performance [F(2,244) = 2,09 ; NS]. However, the analysis shows, moment by moment, a significant effect of chronotype in the morning [F (2,244) = 5,88: p < 0,05]. Indeed, the inhibitory performance of vesper pupils is lower that of morning types and intermediate types.

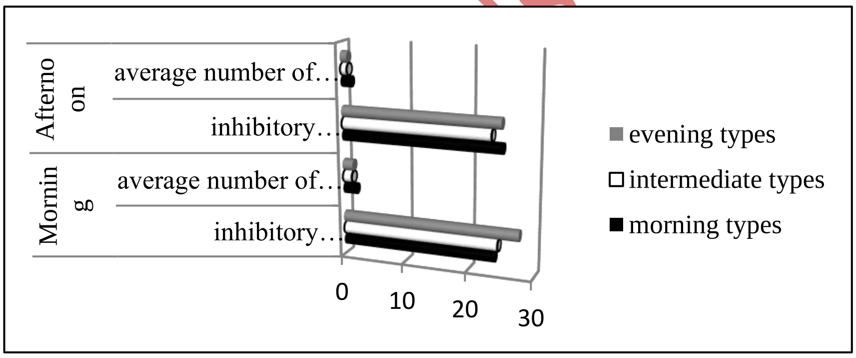

Fig. 3 Inhibitory performance and error levels of pupils according to chronotype

3.4 Levels and daily variation of inhibitory performance according to chronotype and age

The three types of participants (morning, intermediate and evening) were categorized by age, i.e. 12 to 15 years old or 16 to 20 years old (Figure 4). The interaction between age and chronotype was significant only in the afternoon [F (2,244) = 3,05 ; p < .05]. The inhibitory abilities of morning pupils and their evening counterparts aged 16 to 20 years are essentially identical. In contrast, there is a difference between the inhibitory abilities of these two chronotypes when considering the age range 12 to 15 years: vesper pupils ages 12 to 15 years not only have higher inhibitory performance than morning pupils of the same age, but also than morning pupils and vesper counterparts aged 16 to 20 years.

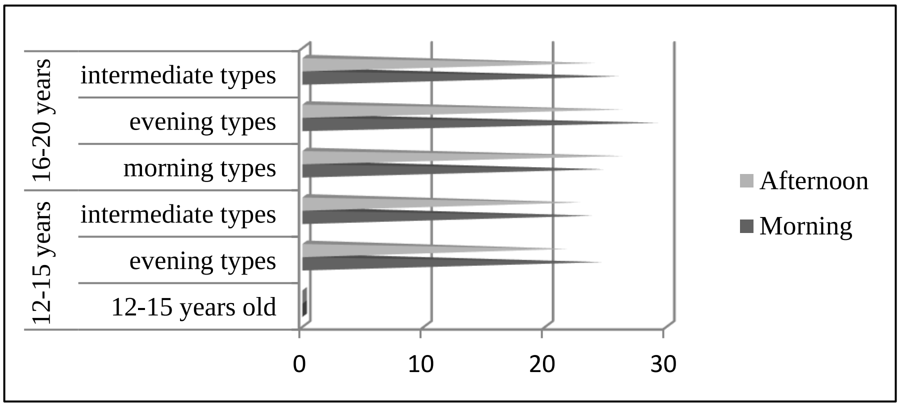

Fig. 4 levels of daily inhibitory performance of pupils according to age and chronotype

4. DISCUSSION

The aim of this study was to show the influence of time of day, age and chronotype on inhibitory performance, using the Stroop test. To do this, inhibition was measured in the morning and in the afternoon, according to age group (12 to 15 years and 16 to 20 years) and preferred sleep times (morning, evening and intermediate types).

Analysis of the daily variation in inhibition reveals a superiority of inhibitory performance in the afternoon over that in the morning. The time of day has a significant effect on inhibitory abilities these results are in agreement with those of [44] who found superiority of inhibition at 1:00 pm and 7:00 pm in a study using a time-of-day protocol. Furthermore, the linear progression or (positive) correlation between inhibitory abilities obtained in the morning and those obtained in the afternoon, highlighted in the study, mirrors the findings of [47] who had shown that inhibitory performance progressed throughout the day and then decreased at night and early morning. This daily rhythm of inhibitory capacity would, according to some authors, be comparable to that of the metabolism modulate the activity of specific brain areas which, in turn, affect one or more basic neuropsychological functions namely cognitive processes and executive functions [41; 49]

In addition, the predictions regarding the effect of age on daily inhibitory performance were validated. The inhibitory performance of older pupils (16 to 20 years old) was found to be superior to that of their younger counterparts (12 to 15 years old), regardless of the time of day. These results suggest a gradual development of executive processes through adolescence, which is linked to a slow maturation of the prefrontal cortex according to [19; 20; 21; 25; 28]. In other words, neurological maturation, i.e., an increase in the number of synaptic connections as well as an increase in myelination, would promote the speed of information transmission and, in turn, participate in the improvement of the use of executive processes and their articulation.

On the other hand, the level of education could be considered a moderating effect of age-related differences on inhibitory abilities, with reference to studies by [36; 38; 39; 40]. These authors have shown that the superior performance obtained by older people may be to the fact that the tests call for knowledge acquired in school or that they are similar to tests with which people with more education are more familiar. In other words, the knowledge acquired during years of formal education allows seniors to perform better on cognitive tests; tests that are too often inspired by school activities. However, our data are not consistent with those of [37], who found that among young people, apart from a slight disadvantage of those with low levels of education in reading, educational level does not affect performance on the Stroop test. This discrepancy could be attributed to the different levels of education considered in the two studies. It should be noted that [47] compared three levels of education: low level or primary (individuals who had been to school up to the maximum age of 12 years), middle level or secondary (maximum age 18 years) and high level or university; whereas the present study considered only one level of education, namely secondary.

Regarding fluctuations in inhibitory performance as a function of morning or vesper preference, we observed that the abilities of morning and vesper pupils differ in the morning where the inhibitory performance of vesper pupils is lower than that of morning and neutral pupils. These results are consistent with the hypotheses of [9] and [49], who suggest that morning types and vesper types differ in the homeostatic regulation of sleep. In other words, the dynamics of the homeostatic sleep process appear to be faster in morning types compared to evening types. This results in a more rapid build-up of sleep pressure during wakefulness in morning type, causing a greater level of fatigue in the evening and thus promoting activity in the morning hours.

The results concerning the interaction between age and chronotype do not show a significant effect. The inhibitory abilities of the morning and evening pupils, both taken together, are comparable, especially for the senior pupils (16 to 20 years old), to contrast, there is a difference between the inhibitory abilities of these two chronotypes when considering the age group 12 to 15: vesper pupils aged 12 to 15 not only have higher inhibitory performance than morning and vesper counterparts aged 16 to 20. These results are consistent with the findings highlighting the moderating effect of age. They are also in agreement with the findings highlighting the moderating effect of age. They are also in agreement with the findings reached by [48], who found a predominance of the evening chronotype in adolescents; the biological clock I, this age group has a markedly delayed circadian phase compared to young children and the elderly.

5. CONCLUSION

It should be noted that the time of day, age and chronotype profile affect inhibitory abilities in adolescents. These different results complements and clarity previous studies, particularly those on the impact of chronotype and level of education on performance on the Stroop test.

Thus, the identification of the afternoon as a time of day that is conducive to the functioning of inhibitory capacities is a major interest of this study. It could undoubtedly contribute to the optimization of school schedules. Moreover, our data reveal that in high school, more specifically in the first cycle, pupils with a vesper time preference have good inhibitory abilities than their counterparts with a morning time preference. This suggests that these extreme evening chronotype are able to control their behaviour, are less distracted in class, have better problem-solving kills, and are able to adapt to the constraints of social and school life.

Although the results obtained seem to shed light on those previously highlighted, future research should be directed towards other tests for the evaluation of inhibition.

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