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Diurnal Variations and Weekly Pattern of Cognitive Performances in Tunisian Children

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ABSTRACT

The aim of this study was to investigate the effects of time of day and day of test on cognitive performances in Tunisian children in terms of constant attention (CA) and choice reaction time (RT). The protocol involved 132 children who performed two cognitive tasks, a choice reaction-test, and the barrage test (measuring the CA), at 09:00, 11:00, 14:00 and 16:00 h, over six days of the week (Monday, Tuesday, Wednesday, Thursday, Friday and Saturday). Resting oral temperature was measured at the beginning of each test session. The results showed significant time-of-day effects with both tests and also core temperature with best performances for the choice RT and highest core temperatures at 16:00 h, and best performances for the CA observed at 09:00 h. In addition, our results displayed significant day of test effect on both cognitive performances with best scores in the middle (Tuesday, Wednesday and Thursday) of the week and worst scores in the beginning (Monday) and the end of the week (Friday and Saturday). However, the profiles of the rhythms of core temperatures and cognitive performances were not the same. Therefore, school activities that involve new learning and require vigilance and better cognitive performances should be administered in the middle of the week. Otherwise, tasks which require concentration should be programmed in the morning, while tasks and brief applications which require speed should be administered in the afternoon.

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Keywords:
Time-of-day; day of test; Tunisian child; cognitive performances, school rhythm

Introduction

School rhythm includes periodic endogenous variations of the child (physiological and psychological) in the school situation (Testu, 2008; Touitou et Bégué, 2010). The environmental rhythms which are managed by adults (Janvier et Testu, 2005), are not often synchronized with the biological rhythm of the child (Montagner, 2009, Garcia-Naveira, Locatelli Dalimier & Ruiz, 2015). It was reported that the human mental activity shows daily rhythms which vary in their timing (Folkard, 1990; Testu, 2000). The daily profile of cognitive performance at school is characterized by low values when entering the classroom, improvement until the mid- to late-morning, and then a fall after the lunch break (post-prandial dip); in the afternoon, school performance increases again (Guerin et al., 1993; Délvolvé et Davila, 1999; Leconte- Lambert, 1994; Testu, 2008, 1994a, 1994b, 2000, Feunteun, (2000); Touitou et Bégué, 2010). School performance rhythms may be influenced by many factors related to the type of task, its intensity and conditions of its execution (Testu et al., 1995), and some variables related to the subject itself, such as the individual's age (Janvier et Testu, 2005; Yoon et al., 2000) and chronotype (Yoon et al., 2000 ; Hasher et al., 2005 ; 2007; Wickersham, 2006; Goldstein et al., 2007). It has been shown that school performance varied according to individuals' favored of preferred time of performance (Wickersham, 2006; Carskadon et al., 1993; and Kim et al., 2002). The study of

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Schmidt et al. (2007) showed that a variety of cognitive abilities such as memory, attentional abilities and executive functions depended to the effect of the time of day in favor of preferred time. In the same context, the study of Goldstein et al. (2007) highlights the effect of time of day on the mental schools, performance and behavioral problems of adolescents at various times of the day which varied according to circadian preferences of individuals. In addition, the study by Barthe (2004) provides a decline in vigilance in terms of reaction time and the percentage of error in the morning and a rise during the afternoon. The study of Yoon et al. (2000) using a simple test of word span, also illustrates the impact of time of day on performance of individuals, performance being lower at the individuals' non-preferred time. However, Yoon et al. (2000) stated that not all cognitive functions were subject to this time-of-day effect.

As for the weekly rhythmicity, Monday seems a day of poor performance. In the middle of week (Tuesday, Wednesday and Thursday) school performance improved; the end of week (Friday especially in the afternoon and Saturday) is characterized by a decrease on skills and performance (Beau et al., 1999; Brand, 1996).

The circadian rhythm of core temperature is often used as a marker of the body clock due to its strong endogenous component. Mental performance, including simple and choice reaction times, and mood states are circadian rhythmic, reflecting the existence of 24-h periodicity within the nervous system (Reilly et al. 2007). However, rhythms of complex mental tasks and mood states may not coincide with those of core temperature (Reilly et al. 2007).

In view of the above consideration, the aims of the present study were (i) to investigate the effect of time of day and week period on the attentional abilities of Tunisian children in terms of choice RT and constant attention (CA), and (ii) to relate any changes in these parameters to the circadian rhythm in core temperature. Choosing constant attention and RT tasks reflects the fact that vigilance is required in most tasks performed by children at school.

Methods

Participants

132 healthy Tunisian children took part voluntarily in the investigation (age: 10 ± 0.7 years, height: 141 ± 6.2 cm, weight: 34.2 ± 6.5 kg). All subjects were near-pubescent based on standard criteria (Verlaan, Cantin &Boivin, 2001) and selected from a medium socio-economic group. To have a sample without ''extreme" types, subjects were selected as ''morning type,'' on the basis of their answers to « Children's Morningness-Eveningness Preferences scales (CMEP) » self-assessment questionnaire and its parallel version (CMEPP) (Carskadon et al. 1993) which reported on the child's preferred time of performance; only "morning type" were involved in our study. All subjects had the same quality of the diet, based on the KIDMED (Montero, 2006), and regular sleep schedules, based on the Pittsburgh Sleep Quality Index (PSQI) completed over a one-month period (Buysse et al. 1989). On average (± SD), the subjects woke up at 06:00 ± 00:41 h and went to bed at 21:00 ± 00:22 h. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Ethic Committee of our Research Unit.

Materials and Procedure

Subjects were divided at random into four groups. Following an initial familiarization session when all test procedures were explained and practiced, four test sessions were performed at the following times of day: 09:00, 11:00, 14:00 and 16:00 h, over six days with a recovery period of at least 24-h between successive test sessions. The four groups started at different points in this sequence. During each session, subjects performed the RT test and then the barrage task. At the beginning of each test session, and after laying in a supine position for 30 min, oral temperature was measured using a clinical digital thermometer (Omron®, Paris, France; accuracy ± 0.05°C) inserted sublingually for 3 min.

On the night preceding each test session, subjects were asked to keep to their usual sleeping habits, with a minimum of 8 h sleep. Moreover, they were requested to maintain their habitual physical activity and to avoid strenuous activity in the day before each test session. All players were interviewed before each session to verify compliance with these directions. During the entire experimental period, the mean ambient temperature and relative humidity of the classroom were stable (21.1 ± 1.1 °C and 44.3 ± 7.6%, respectively).

The barrage test (i.e., a paper- pencil test). The barrage test is a psychometric task which measures visual-spatial ability and recognition (Wegener et al. 2006). The subject is required to scan a sequence of numbers and strike out the "target number" shown at the top of the page. This number varies with the test; 5 different forms of the test were used, all of which had been seen during the familiarization session. The duration of the test is 1 min and the score reflects the number of correct responses, higher scores reflecting better performance.

The choice reaction time test (using react's software). Pairs of geometric forms were initially presented to the subject and considered as "targets". For each form, the correct key of the computer had to be pressed when it appeared and the computer calculated the RT. Each subject had 10 target presentations. Scores are expressed in milliseconds (msec), higher times reflecting poorer performance.

Statistical analysis. The statistical analysis was performed on a microcomputer using the Statistica software (StatSoft, France). Values are expressed as mean ± standard deviation (M ± SD). Once the assumption of normality with the Shapiro-Wilk W-test was confirmed, parametric tests were performed. Data were analyzed using a two-way ANOVA analysis [(test-time of day) × (day of test)]. When appropriate, significant differences between means were assessed using the Tukey's HSD test procedure. The Pearson product-moment correlation coefficients were used to determine whether there was a significant relationship between the core temperature and the cognitive performances. A probability level of 0.05 was selected as the criterion for statistical significance.

Results

The results for core temperature are shown in Figure 1; those for choice RT and CA are shown in Table1.

Core Temperature

A significant circadian rhythm was found at rest in oral temperature with a significant main effect for time-of-day ($F_{3,393} = 1266.27$ $p < 0.001$) indicating that core temperature was significantly higher at 16:00 h in comparison with 09:00, 11:00 and 14:00 h ($p < 0.001$) with an amplitude of 1.24 ± 0.31°C.

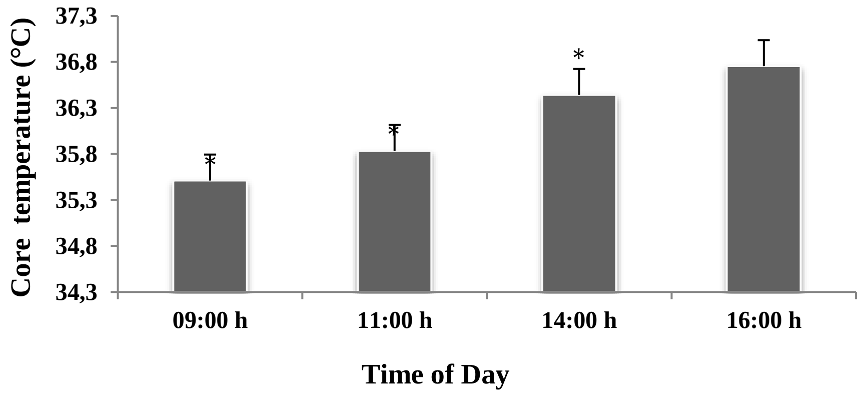

Figure1. Core temperature recorded at 09:00 h, 11:00 h, 12:00 h and 16:00 h * Significant difference in comparison with 16: 00 h.

Choice Reaction Time

There was a significant time-of-day effect on RT ($F(3, 1572) = 31.64$ $p<.001$). There was a significant week period effect ($F(3,524) = 43.42$; $p<.001$).There was also a significant test-time-of-day × week period interaction ($F(9, 1572) =2.96$; $p<.001$). The post-hoc test revealed a decrease of the RT from 09:00 h to11:00 h, then followed by an improvement in the afternoon (14:00 h and 16:00 h) ($p<.001$) with an amplitude of -8.94 ± 25.83%. Likewise, the RT was significantly better in the middle of the week (Tuesday, Wednesday and Thursday) in comparison with beginning (Monday) and the end of week (Friday and Saturday) ($p < .001$).

Otherwise, the RT was significantly higher during the end of the week than the beginning of the week (p < .001).

Constant Attention

There was a significant time-of-day effect on CA (F (3. 1572) = 79, 76; p<.001). There was a significant week period effect (F (3,524) =339.87; p<.001).There was also a significant test-time-of-day × week period interaction (F (9, 1572) =14.17; p<.001). The post-hoc test revealed a decrease of the CA from 09:00 h to11:00 h, then followed by an improvement in the afternoon (14:00 h and 16:00 h) (p<.001) with an amplitude of -3.16 ± 14.12%. Likewise, the CA was significantly better in the middle of the week (Tuesday, Wednesday and Thursday) in comparison with beginning (Monday) and the end of week (Friday and Saturday) (p < .001). Otherwise, the CA was significantly higher during the beginning of the week than the end of the week (p < .001).

Table 1. Mean and SD values for the RT and constant attention (n=132) measured at 09:00 h, 11:00 h, 12:00 h and 16:00 h over six days.

		09:00 h	11:00 h	14:00 h	16:00 h
Beginning (Monday)	RT	974,8± 225,09*	1009,7± 230,9* µ	944,2± 186,8*	868,2± 92,5 µ
	CA	51,9± 3,7*	49,9± 4,4* µ	50,2± 4,3* µ	51,7± 3,7 µ ω
Middle(Tues-Wed-Thurs)	RT	867,4± 93,9*	890,5± 122,6* µ	864,9± 98,6*	783,9± 86,3 µ
	CA	58,2± 5,4*	52,7± 3,8* µ	54,8± 3,6* µ	58,6± 4,5 µ
End (Frid-Sat)	RT	956,1± 191,1*	998,07± 215,05* µ	976,2± 207,07*	935,5± 175,2 µ
	CA	48,08± 4,5*	45,1± 5,3* µ	45,63± 5,6* µ	46,04± 5,9 µ ω

** Significant difference in comparison with 16:00 h; p<.001*
µ Significant difference in comparison with 09:00 h; p<.001
ω Significant difference in comparison with the middle of the week; p<.001

Discussion

The main finding of this study is that cognitive performance (i.e. choice RT and CA) parameters of Tunisian children are time-of-day and day of test interaction dependent. Cognitive performance decreased in the morning (from 09:00 h to11:00 h), then increase in the afternoon (14:00 h and 16:00 h) whatever the day of test. Previous reports have shown significant time-of-day effects on school performance (Goldstein et al. 2007), and Schmidt et al. (2007) showed that different cognitive abilities such as memory, attentional abilities and executive functions were subject to the effect of time of day. Moreover, best scores of both cognitive performances are done in the middle (Tuesday, Wednesday and Thursday) of the week and worst scores in the beginning (Monday) and the end of the week (Friday and Saturday). It seems that cognitive performances are more affected by the end of the week than its beginning.

The present study indicates that core temperature was time-of-day dependent with highest values observed at 16:00 h. These results agree with those of Nicolas et al. (2005) and Souissi et al. (2012a,b), where highest body temperatures were observed at the end of the afternoon. Also, the present results showed the absence of significant correlations between oral temperature and cognitive performances. These findings support those from a previous report which found no association between the rhythm of the core temperature and that of cognitive performance (Jarraya et al. 2014).The present results indicate that Tunisian children achieve their best performances in the choice RT test in the afternoon (around 16:00 h). These, results are consistent with previous studies which reported that cognitive performances are time of day dependent with higher values at the end of the afternoon (Guerin et al., 1993; Montagner 2009; Testu 2008; Touitou and Bégué 2010). Moreover, the present results agree with those of Kline et al. (2010), who found better choice RT scores in the afternoon (between 14:00 h and 20:00 h) than at the beginning of the day. In this context, Barthe (2004) reported that vigilance was higher in the afternoon than the morning hours.

In addition, our results showed significant time-of-day effects for CA, with better performance at 09:00 h. However, these results are in agreement with the results found by Jarraya et al. (2012) who showed that cognitive performance in handball goelkeepers were time-of-day dependent, with the best values observed in the morning for selective and constant attention. Garcia Naveira et al. (2015) determined that adolescents who are involved in high performance sports, such as athletics show a morningness chronotype, which differ with other normal adolescent studies (Collado Mateo et al. 2013; Diaz Morales et al. 2007; Diaz Morales & Gutierrez, 2008). The difference could be in the life rhythm they have (school, training, and competitions during the weekends). All these external aspects could be considered *zeitzbergs* . Locatelli Dalimier, (2012) also found some chronotype differences in football players respect the normal adult populations. The advantage of the CA during the morning (09:00 h) compared to the afternoon (16:00 h) in the present study, could be due to the circadian preference of the Tunisian child. In fact, previous reports highlights that cognitive performance varied according to circadian preferences of individuals (Schmidt et al., 2007). In the same extension, the investigation achieved by Goldstein et al. (2007) showed the effect of time of day on the mental schools, performance and behavioral problems of adolescents at different times of the day which varied according to circadian preferences of individuals. These results are quite consistent with those made by Wickersham (2006), Carskadon et al. (1993) and Kim et al. (2002), Garcia Naveira et al. (2015) who demonstrated that young children have optimal capacity early in the morning. Concerning gender differences in circadian cognitive performances, Garcia Naveira et al. (2015) have mentioned that no differences between women and men adolescents, while other studies argues the opposite (Collado – Mateo et al., 2013; Diaz Morales et al., 2008 . These discrepancies could be du e to the differences in the populations age or the proposed tasks.

Cognitive performance of the subjects decreased from 09:00 h to11:00 h and this might be due to boredom and the accumulation of fatigue, both of which would cause cognitive performance to decline. In this context, Edwards et al. (2007) reported the accumulation of fatigue throughout the day in their study of accuracy in throwing darts. In addition, this difference in the peak times of cognitive performances might be due to the nature of the tasks. There were also significant day of test effects for the choice RT and CA tasks, both scores showing better performance at the middle (Tuesday, Wednesday and Thursday) of the week compared to its beginning (Monday) and its end (Friday and Saturday). These results agree with those found by Beau et al. (1999) and Brand (1996) and Jarraya et al. (2015) which reported that better physical performances of Tunisian children were observed in the middle of the week and worst outcomes in the beginning and the end of the week. Our results advance that cognitive performances are more affected by the end of the week than its beginning and this could be explained by the accumulation of fatigue throughout the week and the possible rupture of the child's rhythm caused by the weekend (Testu, 1994b; Délvolvé et Jeunier, 1999). The weekly pattern is intimately linked to weekend placement; the inverse trends were found after the study by Sharifi (1994) who led the investigation into Iran where Friday is the rest day.

The practical application of the present findings is that, since cognitive performances were better in the middle of the week, so school activities that involve new learning and require vigilance and better cognitive performance should be administered in the middle of the week; by contrast, consolidation tasks should be programmed in the beginning and the end of week. In addition, tasks which require concentration should be programed in the morning, while tasks and brief applications which require speed should be administered in the afternoon.

Conclusion

The present study showed that cognitive performance of Tunisian children are time-of-day dependent, with the best values observed in the morning for CA and best one in the afternoon for choice RT. These cognitive performances are also day of test dependent, with the best values observed in the middle of week and worst one in the beginning and the end of week. Nevertheless, these rhythms of cognitive performance are desynchronized from the rhythm of core temperature.

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