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Cognitive impairment, retrospective and prospective memory, and visual inattention in chronotype

Związek chronotypu z upośledzeniem funkcji poznawczych: pamięci retrospektywnej i prospektywnej oraz uwagi wzrokowej

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Abstract

Aim of the study was to evaluate cognitive impairment, retrospective and prospective memory, and visual inattention in chronotype personality tendencies.
Methods: A total of 676 students of Bu Ali Sina University were selected in 2017. Subsequently, 150 of them were selected for the second stage according to the scores in the morningness-eveningness questionnaire (MEQ): as a morning person, an evening person, or intermediate. Finally, participants were studied in executive functions, memory function, and visual inattention.
Results: The results showed that there is a significant difference between the morningness-eveningness personality groups in executive functions, memory function, and visual inattention ($p < 0.05$). Participants with eveningness and intermediate personality had higher performance in retrospective memory, prospective memory, general memory, visual/spatial, naming, and attention. This difference was significant ($p < 0.05$). Also, participants with morningness and intermediate traits had higher performance in right and left visual attention ($p < 0.05$).
Conclusions: It can be concluded that morningness tendencies have worse cognitive performance in executive functions and eveningness tendencies have deficiencies in visual attention.

Key words: executive functions, morningness-eveningness, visual attention, retrospective and prospective memory.

Introduction

The concept of executive functions is derived from neuroscience, and it is widely used to describe the conscious functions as well as the processes involved in the control of the conscious thought, action, and emotion. These functions refer to the high-level of executive functions, which is linked to the brain's frontal lobe, including abilities such as planning, organising, problem-solving, working memory, and decision-making (Lezak *et al.* 2004). There are neural processes involved in the acquisition, processing, storage, and use of information (Shettleworth 2010), which were developed due to the need to solve ecological problems (Cnotka *et al.* 2008) and guide complex social environments, and they are also the interface between the behaviour and the structure of the brain (Hill *et al.* 2010). Therefore, the executive functions (EF) usually refer to processes used for self-regulation thoughts and goal-oriented behaviours (Alvarez and Emory 2006). One important factor for executive functions, which has received little attention, is biological dimensions of personality. In terms of psychiatric vulnerability, there is also a difference between these types, so that the evening types are more prone to depression and anxiety (Antypa *et al.* 2016).

The morningness-eveningness trait is known as a biological dimension of personality, which is largely the result of heredity (Adan *et al.* 2012). In addition to physiological differences between morningness-eveningness types (e.g. patterns of secretion of cortisol and melatonin), some psychological differences have been reported between these two types. For example, evening people have shown higher scores in extraversion (e.g. Díaz-Morales 2007; Matthews 1988) and

novelty-seeking (Caci *et al.* 2004; Killgore 2007; Maestripieri 2014).

Circadian cycles are time swings in the physiological and behavioural functions that show approximately a 24-hour cycle. In humans, this cycle is regulated by a biological clock found in the suprachiasmatic nucleus of the hypothalamus, which regulates secretion of melatonin in the pineal gland (Piffer *et al.* 2014). There are individual differences in sleep-wake cycles and circadian time, so some people prefer to wake up early in the morning and go to bed early the night, while others prefer the opposite pattern (Aden *et al.* 2012). These differences in sleep patterns are associated with the difference in peak cognitive performance, so some people reach their peak performance in the morning while others have effective functioning in the late evening and at night (Preckel *et al.* 2011).

In addition to the physiological differences between the morning and evening people (daily patterns of melatonin and cortisol secretion) (Roberts and Kyllonen 1999), a broad range of research has been done on the psychological and personality correlates of morningness-eveningness types (Maestripieri 2014), and some research has been done on the relationship of these constructs with executive functions and intelligence (Nowack *et al.* 2014; Randler 2017; Panev *et al.* 2017). Executive functions are potentially sensitive to the effects of lack of sleep and the time of day, and lead to fluctuations in the cognition circadian cycle (Valdez *et al.* 2010); these differences may be related to the circadian cycle, so that there is a difference between morningness-eveningness peak-time of alertness and performance (Hahn *et al.* 2012).

For the first time, the relations between circadian cycles and cognitive function was expressed by Roberts and Kyllonen (1999), who showed that the eveningness orientation compared with the morningness type had a higher working memory and received higher scores on tasks related to memory and information processing speed. Similarly, some studies have stated that speed and accuracy in cognitive tasks, such as working memory, response inhibition, or tasks related to the reaction time, may be influenced by differences in the circadian cycle (Blatter and Cajochen 2007; García *et al.* 2012; Valdez *et al.* 2010; Wright *et al.* 2002). Considering the role of executive functions in many social and academic situations and the fact that there are few studies investigating the relationship between executive functions based on changes in the circadian cycle, the aim of this study was to investigate different aspects of executive functions, memory, and visual attention on the basis of individual differences in chronotype.

Methods

Participants and procedure

Due to not manipulating the variables and comparing the groups, this study belongs to descriptive post event researches (causal-comparative). The study participants comprised 676 students who were selected through multi-stage cluster sampling among university students. Inclusion criteria were: being aged 18 or older, and all participants reported that they had not been diagnosed with any medical condition (physical, but not necessarily psychological disorders) by a doctor. Participants with a psychotic disorder, problems with substance, acute suicidality, insufficient language skills, or severe cognitive impairment were excluded.

Participants completed morningness-eveningness questionnaires following an informed consent procedure and were provided with debriefing information on the purpose of the study and given a list of community counselling agencies at the end of the survey.

In accordance with the guidelines for the ethical treatment of human participants of the Iranian Psychological Association, all participants were informed fully about the aims of the research, and formal consent was obtained prior to commencing data collection. Then through cut-off score on morningness-eveningness questionnaires (score $>$ 59 = morningness; score $<$ 42 = eveningness; score $>$ 42 and score $<$ 59 = intermediate) participants were categorised in three groups of morningness, eveningness, and intermediate tendencies. In the next step, the three groups' participants (each group consisted of 50 students) were invited to the Psychology Laboratory to measure cognitive impairment, retrospective and prospective memory, and visual inattention. Then the researcher explained the study's procedure to the participants of the three groups, who were finally studied for cognitive impairment, retrospective and prospective memory, and visual inattention. It should be mentioned that the participants of the second phase were studied individually. Missing data were excluded from the final sample and replaced by new participants. Of all the participants, 344 were female

Table 1. The research participants' demographic characteristics (n = 150)

Group	Gender	Number (percent)	Marital Status		Age *M* (*SD*)
			Married	Single	
Morningness	Women	15 (30)	11	4	21/00 (0/75)
	Men	35 (70)	4	31	19/77 (1/83)
Eveningness	Women	8 (16)	8	0	20/50 (0/53)
	Men	42 (84)	38	4	20/38 (1/83)
Intermediate	Women	6 (12)	6	0	21/66 (2/16)
	Men	44 (88)	38	6	20/16 (1/76)

(50.88%) and 333 were male (49.12%). Respectively, the mean and standard deviation of the students' ages were 20.01 and 1.57 in males, and 21.97 and 1.66 in females. Demographic characteristics of participations in second stage are presented in Table 1.

Measures

Morningness-Eveningness Questionnaire (MEQ)

The MEQ is composed of 19 self-report items. This questionnaire's method of scoring is that some questions are dominated by 5-point, some 4-point, and some 6-point. Each item required individuals to denote the degree to which they agree with the definitions of morningness or eveningness. For example: "Assuming adequate environmental conditions, how easily do you get up in the morning?" (1 – not at all easily, 2 – not very easily, 3 – fairly easily, 4 – very easily) (Horn and Ostenberg 1976). A score higher than 59 indicates morningness type, lower than 42 indicates eveningness type, and between 42 and 59 indicates intermediate type.

Bells Cancellation Test

This test measures visual attention. *The Bells Test* (Gauthier *et al.* 1989) consists of a 21.5 × 28 cm sheet of paper on which seven lines of 35 distractor figures (e.g. bird, key, apple, mushroom, car) and five target figures (bells) are presented. The target figures are arranged so that five of them appear in seven equal columns on the page. The number of distractor figures in each column also remains constant.

Retrospective and Prospective Memory Questionnaire

This test is used to measure retrospective, prospective, and general memory. This questionnaire, with 16 items, contains three subscales of prospective memory, retrospective memory, and a general scale as general memory, which is obtained from subscales. The scoring of the questionnaire is based on *the Likert scale* in a high to low order (5, 4, 3, 2, 1). Crawford *et al.* (2003) reported that the reliability of the questionnaire is acceptable using internal consistency in a prospective, retrospective, and general subscale, and Cronbach's α coefficients of 0/80, 0/84, and 0/89 have been reported for retrospective memory, prospective, and general scale, respectively (Crawford *et al.* 2003).

Executive functions test

This test is one of the tools for evaluating executive functions and attention. This test examines seven areas of cognition through various skills including visual-spatial, naming, orientation, attention, speech, abstraction, and memory (Nasreddine *et al.* 2005).

Data analytic strategy

SPSS version 22 (SPSS IBM, New York) was used to perform statistical analyses. The obtained data was analysed using descriptive indicators, multivariate analysis of variance, and Scheffe's *post hoc* test.

Results

The mean and standard deviation of three personality group variables are listed in Table 2.

Multivariate analysis of variance was used to compare the groups with regard to cognitive impairment, retrospective and prospective memory, and visual inattention. The result of *M box test* showed that the assumption of the dependent variables' variance-covariance's sameness of matrix was true and multivariate analysis of variance could be applied. The results of multivariate tests of Pillai, Wilks' lambda, Hetling, and Roy's Maximum Root are shown in Table 3.

The data of Table 3 imply that there is a significant difference between the three groups, at least in one of the dimensions of cognitive impairment, retrospective and prospective memory, and visual inattention.

Considering the significance of group differences, one-way analysis of variance and Scheffe's *post hoc* test were used to determine in which groups and which levels of variables the differences are, and the results are shown in Table 4.

According to the results in Table 4, it can be said that the comparison of the three groups represented significant differences in some of the aspects of cognitive impairment, retrospective and prospective memory, and visual inattention; the participants with eveningness and intermediate traits had higher performance in retrospective memory, prospective memory, general memory, visual/spatial, naming, and attention. This difference was significant. Also, participants with morningness and intermediate traits had higher performance in right and left visual attention.

Discussion

Morningness and eveningness traits (M/E) are considered as personality dimensions (Matthews 1988); morningness or eveningness refer to individual differences in biological cycles such as sleep-wake and a time that a person feels best, and these differences are determined by several factors such as endogenous genetic factors that influence various psychological dimensions (Adan *et al.* 2012; Archer *et al.* 2003). Accordingly, the aim of this study was to investigate different aspects of executive functions, memory, and visual attention on the basis of individual differences in the morningness-eveningness circadian cycle.

The results of the study of cognitive aspects based on the comparison of morningness and eveningness types showed that participants with eveningness and intermediate traits had higher performance in retrospective memory, prospective memory, general memory, visual/spatial, naming, and attention. This finding is consistent with the results of the study done by Roberts and Kyllonen (1999), who showed that eveningness types received higher scores on some cognitive tasks; and they are also consistent with the studies that expressed a positive relationship between eveningness circadian cycles and cognitive function and intelligence (Preckel *et al.* 2011). This finding also confirms the hypothesis of a link between circadian cycles and executive functions, and that eveningness

Table 2. *M* (*SD*) of the study variables for the three groups

Group	Retrospective memory	Prospective memory	General memory	Visual/ spatial	Naming	Abstraction	Memory	Orientation	Attention	Speech	Left inattention	Right inattention	Centre inattention
Morningness	15/78 (5/14)	15/88 (4/78)	31/66 (9/15)	4/10 (0/86)	2/52 (0/50)	1/64 (0/59)	4/34 (1/09)	5/62 (0/63)	5/18 (0/59)	2/70 (0/46)	14/92 (0/27)	14/92 (0/27)	5/00 (0/00)
Eveningness	19/32 (3/95)	19/92 (4/19)	39/24 (7/96)	4/68 (0/74)	2/76 (0/43)	1/58 (0/64)	3/74 (1/63)	5/72 (0/64)	5/54 (0/50)	2/50 (0/67)	14/76 (0/59)	14/28 (0/88)	5/00 (0/00)
Intermediate	17/26 (4/14)	19/12 (4/44)	36/38 (7/77)	4/58 (0/64)	2/70 (0/46)	1/68 (0/58)	4/20 (1/04)	5/80 (0/80)	5/16 (0/76)	2/54 (0/78)	14/96 (0/19)	17/76 (0/51)	5/00 (0/00)
Total	17/45 (4/64)	18/30 (4/78)	35/76 (8/84)	4/45 (0/79)	2/66 (0/47)	1/63 (0/60)	4/09 (1/30)	5/71 (0/69)	5/29 (0/65)	2/58 (0/65)	14/88 (0/400	14/65 (0/66)	5/00 (0/00)

Table 3. Multivariate analysis of variance of the groups' comparison in study variables

Test's name	Value	Hypothesis *DF*	Error *DF*	*F*	Sig	η^2
Pillai's trace	0/49	22	276	4/13	0/001	0/25
Wilks' lambda	0/54	22	274	4/42	0/001	0/26
Hetling's effect	0/76	22	272	4/70	0/001	0/28
Roy's maximum root	0/64	11	138	8/10	0/001	0/39

Table 4. The results of the three groups' one-way analysis of variance and *post hoc* test

Dependent variable	*F*	Eta (η^2)	Source of comparison	Mean differences	Standard error
Retrospective memory	8/01	0/10	Morningness-Eveningness	**–3/54*** **	0/88
			Morningness-Intermediate	–1/48	0/88
			Eveningness-Intermediate	2/06	0/88
Prospective memory	11/37	0/13	Morningness-Eveningness	**–4/04*** **	089
			Morningness-Intermediate	**–3/24** **	0/89
			Eveningness-Intermediate	0/80	0/89
General memory	10/57	0/13	Morningness-Eveningness	**–7/58*** **	1/66
			Morningness-Intermediat	**–4/72***	1/66
			Eveningness-Intermedia	2/86	1/66
Visual/spatial	8/45	0/10	Morningness-Eveningness	**–0/58*** **	0/15
			Morningness-Intermediate	**–0/48** **	0/15
			Eveningness-Intermediate	0/10	0/15
Naming	3/57	0/05	Morningness-Eveningness	**–0/24***	0/09
			Morningness-Intermediate	–0/18	0/09
			Eveningness-Intermediate	0/06	0/09
Abstraction	0/34	0/01	Morningness-Eveningness	0/06	0/12
			Morningness-Intermediate	–0/04	0/12
			Eveningness-Intermediate	–0/10	0/12
Memory	2/92	0/04	Morningness-Eveningness	0/60	0/25
			Morningness-Intermediate	0/14	0/25
			Eveningness-Intermediate	–0/46	0/25
Orientation	0/83	0/01	Morningness-Eveningness	–0/10	0/13
			Morningness-Intermediate	–0/18	0/13
			Eveningness-Intermediate	–0/08	0/13
Attention	5/74	0/07	Morningness-Eveningness	**–0/36***	0/12
			Morningness-Intermediate	0/02	0/12
			Eveningness-Intermediate	**0/38***	0/12
Speech	1/29	0/02	Morningness-Eveningness	0/20	0/13
			Morningness-Intermediate	0/16	0/13
			Eveningness-Intermediate	–0/04	0/13
Left visual attention	3/62	0/05	Morningness-Eveningness	0/16	0/07
			Morningness-Intermediate	–0/04	0/07
			Eveningness-Intermediate	**–0/20***	0/07
Right visual attention	14/85	0/17	Morningness-Eveningness	**0/64*** **	0/12
			Morningness-Intermediate	0/16	0/12
			Eveningness-Intermediate	**–0/48*** **	0/12
Centre visual attention	0/00	0/00	Morningness-Eveningness	–	–
			Morningness-Intermediate	–	–
			Eveningness-Intermediate	–	–

*** = p < 0.001, ** = p < 0.01, * = p < 0.05.

orientation has higher scores on intelligence and executive functions (Piffer *et al.* 2014). Also, this study is in line with Preckel *et al.* (2013), who showed a negative predictive role of eveningness in academic performance in high-school students. Given that intelligence as a pervasive component includes many executive functions, the present study indicates

a relationship between eveningness type and some cognitive dimensions, which is consistent with the study of Preckel *et al*. (2011).

Participants with morningness and intermediate traits had higher performance in right and left visual attention as well. These findings suggest that morningness and eveningness types are superior in some cognitive tasks. The findings may be explainable using the hypothesis that different brain structures have been organised for specific assignments, thus each of these structures possibly shows a better performance under environmental conditions and in particular circadian cycles, and thus have enabled humans in evolution to have better compatibility. A variety of explanations have been mentioned to describe the differences between morningness-eveningness types in executive functions. According to the hypothesis of educational effects, eveningness types have a greater need to overcome their daily problems caused by the conflict with social requirements, and this need can actually lead to higher scores on cognitive dimensions (Preckel *et al.* 2011). A second explanation suggests that the relationship between eveningness type and higher executive functions is caused due to the fact that eveningness types sleep less in comparison with the morningness types, and regardless of circadian type, more intelligent people tend to sleep less, and the result is that during the night better neurological recovery happens (Geiger *et al.* 2010). Finally, it is stated that the eveningness types may have evolved through sexual selection because activity late at night provides more time to reproduce a baby in a short time (Piffer 2010). From this perspective, higher intelligence in the eveningness types may be linked with intelligence of their sex couples (Miller 2001; Geher and Kaufman 2013).

Another explanation for the above findings has been provided: cyclical fluctuations in executive functions may reflect differences in sleep-wake times, which is associated with the wake-up time and the difference in circulation cycles (Schmidt and Collette 2007). In other words, the hypothesis states that the daily fluctuations in executive functions can reflect the cycles of general arousal patterns. However, this hypothesis cannot fully be confirmed because the data show that the rhythm of cognitive function cannot be the result of cyclical changes in the indicators of physiology (Blatter *et al.* 2005; Frey *et al.* 2004).

In general, the results showed that the performance in executive function tasks is influenced by individual differences in morningness-eveningness circadian cycles. There are several limitations of the current study. First, participants' reports were obtained retrospectively. Therefore, recall bias could impact participants' self-reporting. So, according to what was said, the present study was conducted among student population samples, and since it did not cover all other groups, the results should be treated with caution in generalising. In conclusion, the current study provides empirical support for the role of circadian cycles in executive functions. This is the first known study to examine these relationships, and more studies are needed to more fully understand the underlying mechanisms.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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