Intelligence 47 (2014) 107–112

Contents lists available at ScienceDirect

Intelligence

Morningness–eveningness and intelligence among high-achieving US students: Night owls have higher GMAT scores than early morning types in a top-ranked MBA program

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ARTICLE INFO

Article history:
Received 15 January 2014
Received in revised form 15 July 2014
Accepted 2 September 2014
Available online xxxx

Keywords:
Chronotype
Intelligence
MBA students
GMAT scores
Cortisol

ABSTRACT

Individuals with a propensity to wake up early in the morning ("early-morning" types) and those who like to stay up late at night ("night owls") often exhibit distinctive psychological and physiological profiles. Previous research has shown that night owls score higher than early-morning people on different measures of cognitive ability and academic achievement. Baseline cortisol is one of the physiological variables associated with variation in chronotype and cognitive function. In this study we investigated whether a relationship between chronotype and performance is present also in the high range of intellectual ability and academic achievement, namely, among graduate students in a top-ranked MBA program in the US. In addition, we measured baseline cortisol levels in saliva samples collected in the early afternoon and analyzed them in relation to chronotype and GMAT scores. As predicted, GMAT scores were significantly higher among night owls than among early-morning types, regardless of sex. GMAT scores were also significantly higher among men than women, regardless of chronotype. Morningness/eveningness was not significantly associated with variation in sleep amount or in undergraduate or graduate GPA scores, suggesting that the association between eveningness and high GMAT scores was not due to differences in study effort or skills. Sex, chronotype and baseline cortisol jointly accounted for 14% of the total variance in GMAT scores; baseline cortisol, however, did not mediate the effect of chronotype on GMAT scores. Consistent with the results of previous research, our study shows that the effects of chronotype on cognitive ability and academic performance are relatively small but detectable even among high-achieving individuals. The mechanism linking eveningness and high cognitive function remains unclear but the role of personality traits and neuroendocrine function warrants further investigation.

1. Introduction

Circadian rhythms are temporal fluctuations in physiological and behavioral functions that display a cycle of about 24 h. In animals, including humans, these rhythms are regulated by a biological clock located in the suprachiasmatic nuclei of the hypothalamus, which in turn regulates the secretion of melatonin from the pineal gland (e.g., Nelson, 2011). In humans, there are individual differences in the timing of sleep–wake cycles such that some people prefer to wake up early in the morning and go to sleep early in the evening, while others prefer the opposite pattern (e.g. Adan et al., 2012). These differences in sleep patterns are accompanied by differences in the timing of peak cognitive performance, with some people reaching their peak in the morning and others functioning most

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http://dx.doi.org/10.1016/j.intell.2014.09.009
0160-2896/

effectively late in the evening or at night (Preckel, Lipnevich, Schneider, & Roberts, 2011).

The morningness–eveningness trait, also known as chronotype, is distributed on a continuum, with unequivocal early-morning (EM) and night owl (NO) types at the opposite extremes of the distribution while most of the population shows only a weak sleep pattern bias (Adan et al., 2012). Although age and environmental factors (e.g., geographic and seasonal variations, work schedule) can contribute significantly to variation in sleep patterns (e.g. Leonhard & Randler, 2009), interindividual variation in chronotype is generally stable over time and moderately heritable ($h^2 = 0.45$; Hur, 2007; Hur & Lykken, 1998; Klei et al., 2005). Moreover, there are also sex differences in both sleep amount and chronotype, as men, on average, sleep fewer hours (Adan & Natale, 2002; Tonetti, Fabbri, & Natale, 2008) and are more likely to be night owls than women (Randler, 2007; Roenneberg et al., 2004).

In addition to physiological differences between EM and NO types (e.g., in the diurnal patterns of secretion of melatonin and cortisol), a number of psychological differences have been reported as well. For example, night owls have been reported to score higher than EM types in extraversion (e.g., Díaz-Morales, 2007; Matthews, 1988), novelty-seeking and risk-taking (Caci, Robert, & Boyer, 2004; Killgore, 2007; Maestripieri, 2014), and intelligence (see below). The association between chronotype and cognitive function was first reported by Roberts and Kyllonen (1999) who showed that night owls had greater working memory than EM types and scored higher than them on tasks of memory and processing speed, even when these cognitive tasks were performed early in the morning. Subsequently, Kanazawa and Perina (2009) reported a positive relationship between chronotype and IQ in a sample of US adolescents. This relationship was monotonic and held both for the lowest and the highest IQ groups, after controlling for demographic variables such as age, sex, race, SES, and religion. Although the effect size was very small, individuals with low IQ (<75) rose and went to bed about an hour earlier than individuals with high IQ (>125). A recent meta-analysis (Preckel et al., 2011) of studies on chronotype and cognitive function confirmed this pattern, reporting a small but significant positive correlation between eveningness and intelligence ($r = 0.08$), and a negative relationship between morningness and intelligence ($r = -0.04$). Preckel et al. (2011) also reported a negative relationship ($r = -0.16$) between eveningness and academic achievement in children and college students. In the studies reviewed by Preckel et al. (2011), cognitive ability was measured through a wide range of intelligence tests while academic performance was mainly assessed through grade point average (GPA) and also through exam and essay results in specific courses. In all cases, the relationship between eveningness and cognitive ability was moderated by age, so that it became stronger with increasing age.

Various explanations have been proposed to account for the different cognitive profiles of EM and NO people. According to the training effects hypothesis, evening types have a frequent need to overcome the inconveniences of everyday life caused by conflicts with social demands, (such as the daily schedules of academic institutions that are generally characterized by early starting hours) and this need would in turn lead evening types to develop higher problem solving abilities (Preckel et al., 2011). Another explanation suggests that the association between eveningness and greater cognitive function is a by-product of the fact that night owls generally sleep less than EM types, and that more intelligent people regardless of chronotype tend to require less sleep due to more efficient neuronal recovery during night-time (Geiger, Achermann, & Oskar, 2010). Finally, it has also been suggested that eveningness may have evolved by sexual selection, because being active late in the evening provided more opportunities for reproduction through short-term mating (Piffer, 2010); in this view, the greater intelligence of night owls might be related to their mating intelligence (see Miller, 2001; and Geher & Kaufman, 2013, for a discussion of mating intelligence).

In this study we aimed to expand research on chronotype, intelligence, and academic performance by investigating whether eveningness is associated with higher GMAT scores among MBA students at an elite US university, the University of Chicago. The GMAT (Graduate Management Admission Test) assesses a person's analytical, writing, quantitative, verbal, and reading skills in standard written English in preparation for being admitted into a graduate management program, such as an MBA. Although to our knowledge the GMAT has not been formally validated as a measure of general cognitive ability (*g*), GMAT scores are generally strongly correlated with SAT (Scholastic Assessment Test) scores (e.g., Gottesman & Morey, 2006), which in turn have been shown to be a valid measure of *g* (e.g., Frey & Detterman, 2004), leading to the notion that "like the SAT, the GMAT can be characterized as a traditional measure of intelligence, or a test of general cognitive ability (*g*)" (Hedlund, Wilt, Nebel, Ashford, & Sternberg, 2006). Indeed, several previous studies have already used the GMAT as a measure of general cognitive ability and a proxy for general intelligence (e.g., Kumari & Corr, 1996; Mueller & Curhan, 2006; O'Reilly & Chatman, 1994), and a high score (95th percentile) on the GMAT is accepted by MENSA as qualifying for admission purposes. While the GMAT can be considered a test of general intelligence, it also taps into other aptitudes that predict academic success (Hancok, 1999; O'Reilly & Chatman, 1994; Pesta & Poznanski, 2009), thus providing an opportunity to assess whether chronotype predicts a combined measure of intelligence and academic success.

The MBA program at the University of Chicago is currently ranked as the top MBA program in the US and the GMAT scores of the students admitted to this program are among the highest in the country. Examining the relationship between chronotype and GMAT scores among MBA students in this program provides a unique opportunity to test whether chronotype differentiates intellectual ability also in the high range — in a population of students high in SES, intelligence, and academic achievement.

Previous studies have shown that GMAT scores tend to be higher in male than in female students (e.g., Hancok, 1999) and that the night owl pattern is more common among males than females (e.g., Randler, 2007). We aimed to replicate these sex differences in GMAT scores and chronotype distribution and test the following hypotheses: 1) GMAT scores should be higher among night owls than EM types, both in men and in women; 2) to exclude the possibility that the association between chronotype and GMAT simply reflects differences in study effort, rather than cognitive and academic skills, we tested the prediction that chronotype should not be associated with differences in undergraduate or graduate GPA (i.e., the grade point average the subjects achieved before entering the MBA program and during the MBA program); 3) to exclude the possibility that the association between chronotype and GMAT is a by-product of the association between chronotype and sleep amount (i.e., night owls, on average, sleep less than EM types), we tested the prediction that GMAT should not be significantly correlated with sleep amount.

In this population of MBA students, we previously reported an association between chronotype and average cortisol levels (NO males and NO females had higher cortisol than EM individuals) (Maestripieri, 2014). We also reported that sex, chronotype, and cortisol jointly accounted for a significant fraction of interindividual variation in risk-taking, with some evidence that cortisol mediated the relationship between chronotype and risk-taking (Maestripieri, 2014). Since there is evidence that baseline cortisol levels are higher among well-educated people (Dowd et al., 2011) and that high cortisol can boost cognitive function (e.g. Lupien et al., 2002), here we tested whether sex, chronotype, and baseline cortisol jointly accounted for the variance in GMAT scores and whether the association between chronotype and GMAT scores may be mediated by cortisol, the way it is for risk-taking.

2. Methods

2.1. Participants

Study participants were 201 Master's students (110 males and 91 females) in the Booth School of Business at the University of Chicago. The use of human subjects was approved by the IRB. All students gave informed written consent for their participation in the study and were paid \$20 or more. Undergraduate GPA (u-GPA), graduate GPA (g-GPA), and GMAT scores were obtained from the Booth School of Business. For GMAT, we analyzed only the general scores; data on the subtest scores were not available for this study.

2.2. Procedure

This study was part of a larger investigation in which students were asked to take a 90-min computerized test in which they played games that assessed their economic decision-making tendencies in seven different domains: irrational exuberance (an asset market game that allows players to buy and sell shares of stocks among themselves), trust, competition, cooperation, risk aversion, loss aversion, and hyperbolic discounting (see Sapienza, Zingales, & Maestripieri, 2009). Taking the 90-min computerized test was psychologically stressful for the students (Maestripieri, Baran, Sapienza, & Zingales, 2010). Students were randomly selected to participate in one of two separate afternoon sessions. Starting time for the first session was 1:30 PM and 3:30 PM for the second session.

In addition to this computerized test, the participants completed various questionnaires. In one of these questionnaires, they were asked to estimate how many hours per night they usually slept and then they were asked the question "Are you a night owl or an early morning person?" If participants could not identify themselves as being one pattern or the other, they were given the option of answering "I don't know". This single-item measure for the assessment of chronotype represents a simplification of the 5-item "reduced Morningness–Eveningness Questionnaire" (rMEQ; Adan & Almirall, 1991), which in turn is a validated simplification of the 19-item Morningness–Eveningness Questionnaire (MEQ) developed by Horne and Ostberg (1976). The single-item assessment of chronotype used in this study requires a self-identification of the subjects as a morning or an evening-type, similar to item 5 of the rMEQ (see Maestripieri, 2014, for use of this single-item measure). The single-item measure provides a more conservative assessment of chronotype than the rMEQ (particularly when this scale is used to assign study participants to two groups with a median split) because participants who answer "I don't know" are excluded from data analyses.

Two saliva samples were collected from each student, one before the beginning and one after the completion of the 90-min computerized test. Saliva was collected by passive drool into plastic vials and then stored frozen at −80 °C until assayed in Dr. Chatterton's Endocrinology Laboratory at Northwestern University. On the day of the assay, samples were thawed and centrifuged. Salivary concentrations of cortisol were assayed by radioimmunoassay (RIA) using an antiserum prepared within the lab. Cross-reactivity for cortisol with corticosterone was null. Sensitivity of the assays was 0.07 ng/mL. The intra-assay and inter-assay coefficients of variation were $\leq$10% and $\leq$15%, respectively. For data analysis purposes, we used the pre-test (baseline) concentrations of cortisol adjusted for time of session. Cortisol concentrations were positively skewed and were log-transformed. The adjusted baseline cortisol was calculated as the residuals of the log-transformed baseline cortisol regressed on time of session.

3. Results

3.1. Sex, age, sleep pattern, and sleep amount

Of the 201 study participants who were asked the question "are you a night owl or an early morning person?" 170 of them were self-identified as being either a NO or an EM person while 31 other people answered "I do not know". Subsequent analyses involved 170 participants, including 68 NO males (age = 29.41 ± 2.40), 21 EM males (age = 28.58 ± 2.01), 48 NO females (age = 27.21 ± 2.08), and 33 EM females (age = 27.73 ± 3.28). The distribution of the two sleep patterns was significantly different in males and females ($\chi^2 = 5.75$, $df = 1$, $p = 0.01$): among males, NOs were more than 3 times as common as EMs (68 vs 21) while among females NOs were approximately 1.5 times as common as the EMs (48 vs 33). There was no significant effect of sleep pattern on the amount of sleep (ANOVA; $F[1, 166] = 0.10$; *NS*) or a significant interaction between sleep pattern, sex, and sleep amount ($F[1, 166] = 2.70$; *NS*; NO males, mean ± SD = 7.08 ± 0.89; EM males = 6.86 ± 0.73; NO females = 7.27 ± 0.90; EM females = 7.53 ± 0.86). Therefore, NO males or NO females did not sleep, on average, more or fewer hours than EM males or EM females.

3.2. Sleep pattern, sex, GMAT and GPA scores

GMAT scores were available for 169 of the 170 study participants (for all except one NO male), undergraduate GPA scores were available for 103 participants (29 NO males, 14 EM males; 35 NO females; 25 EM females), and graduate GPA scores were available for 156 participants (61 NO males, 20 EM males, 46 NO females; 29 EM females). Average GMAT score was 702.6 (SD = 44.5). Average undergraduate GPA score was 3.41 (SD = 0.35). Average graduate GPA score was 3.23 (SD = 0.55).

A two-way ANOVA revealed a main effect of sex (F[1, 165] = 12.87; $p = 0.0004$) and a main effect of chronotype (F[1, 165] = 5.17; $p = 0.02$) on GMAT scores such that males had significantly higher scores than females (Bonferroni–Dunn post hoc; $p < 0.01$) and night owls had significantly higher scores than early morning types (post hoc; $p < 0.05$) (Fig. 1). There was no significant interaction between sex and chronotype (F[1, 165] = 0.02; NS). There were no significant effects of sex and/or chronotype on undergraduate GPA scores (sex: F[1, 99] = 0.79, NS; chronotype: F[1, 99] = 0.49; NS; sex x chronotype: F[1, 99] = 0.08; NS) or on graduate GPA scores (sex: F[1, 152] = 0.35, NS; chronotype: F[1, 152] = 0.09; NS; sex × chronotype: F[1, 152] = 0.01; NS). Sleep amount was not significantly correlated with GPA or GMAT scores (u-GPA: $r = 0.03$, $n = 120$; NS; g-GPA: $r = 0.10$; n = 184; NS; GMAT: $r = 0.02$; $n = 200$; NS).

3.3. Sleep pattern, sex, cortisol, and GMAT

A multiple regression model with GMAT score as the dependent variable and sex, chronotype and baseline cortisol as predictors was statistically significant ($R^2 = 0.14$, $p < 0.001$) and explained 14% of the total variance in GMAT scores. Sex ($b = 22.72$, $t = 3.36$, $p = 0.001$) and chronotype ($b = 14.33$, $t = 2.02$, $p = 0.04$) were statistically significant predictors of GMAT scores, while baseline cortisol failed to reach the cut-off ($b = 27.76$, $t = 1.69$, $p = 0.09$). This analysis thus confirms the significant main effects of sex and chronotype on GMAT scores reported with an analysis of variance, and suggests that cortisol also contributes, albeit more weakly, to variation in GMATs. As Fig. 2 shows, individuals with higher baseline cortisol levels tended to have higher GMAT scores. We conducted a mediation analysis using bootstrapping bias corrected confidence intervals (Preacher & Hayes, 2004) to test the possibility that the effect of chronotype on the GMAT score is mediated by baseline

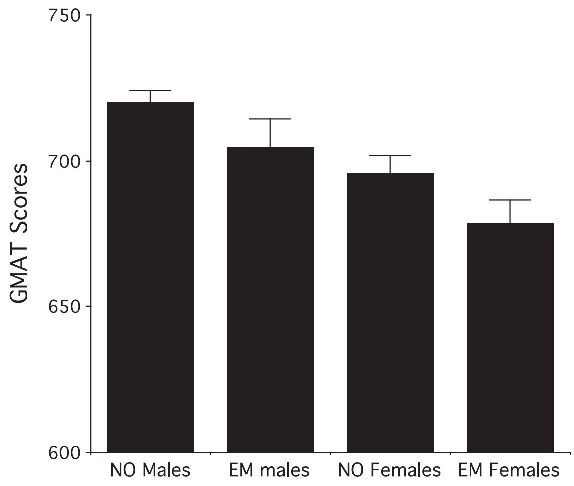

Fig. 1. Mean (and SE) GMAT scores in male and female night owls (NO) and early-morning (EM) types.

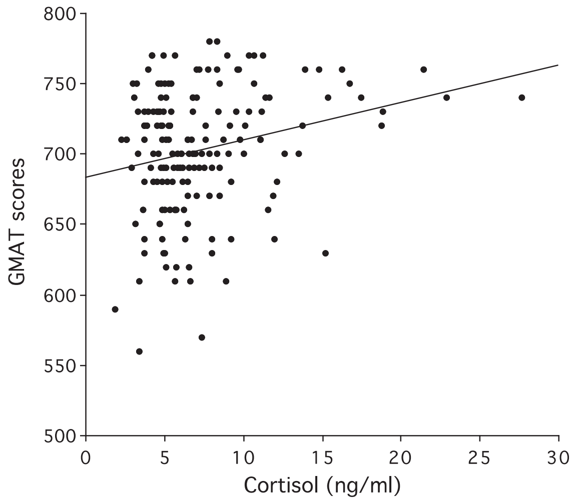

Fig. 2. Baseline cortisol levels in relation to GMAT scores across 169 study participants.

cortisol. The results showed that cortisol does not mediate the effects of sleep patterns on the GMAT score (95% CI [−.23; 5.93]).

4. Discussion

After replicating the previously reported findings that the night owl pattern is more prevalent in men than in women and that men have higher GMAT scores than women, we also found a significant main effect of chronotype on GMAT scores, such that night owls had significantly higher GMAT scores than early morning types, regardless of sex. The main effects of sex and chronotype on GMAT scores appeared to be largely independent from each other and are likely due to different mechanisms. It has been argued that the GMAT test is designed to favor particular sex- and culture-biased analytical skills (Aggarwal, Goodell, & Goodell, 2013) and it is possible that the sex difference in GMAT scores results from males outperforming females on math-related tasks (e.g., Hancok, 1999; Hedlund et al., 2006). Similar biases are present also in many other intelligence tests (e.g., Nisbett et al., 2012). Examining the origins of sex differences in GMAT scores is beyond the scope of this paper. In this context we interpret chronotype-related differences in GMAT scores as reflecting differences in "intelligence", without implying anything as to whether these differences are "innate" or "environmental". It is highly unlikely, however, that the chronotype-related differences in GMAT scores reported here result from biases in the design of this test, which favor night owls relative to early-morning types. Rather, unlike differences between men and women, differences in GMAT scores between night owls and early-morning people are likely to reflect chronotype-related differences in cognitive function.

The higher GMAT scores among male and female night owls reported in this study are consistent with differences in the same direction reported by previous studies using different measures of intelligence and different subject populations, including children, adolescents, and college students (Preckel et al., 2011). This result confirmed our hypothesis that the relationship between chronotype and intelligence is present also in the high range of intellectual ability and academic achievement. The average GMAT score in this MBA student population was 702.6, which corresponds to the 90th percentile. The 50th percentile corresponds to a GMAT score of about 560 in the normative tables and the mean is 545.6. Since the lowest score in our subject population was 560, all individuals had above average scores. Moreover, the average score of 702.6 is close to the score of 730 (corresponding to the 95th percentile) required for admission into MENSA.

Unlike GMAT scores, neither undergraduate nor graduate GPAs were significantly affected by chronotype. Chronotype was not significantly correlated with sleep amount (the average number of hours of sleep per night), and sleep amount was not significantly correlated with GMAT or GPA scores. Since GPA scores are presumably related to both academic skills and study effort, and sleep amount may be related to study effort (i.e., some students may sleep less because they study more; Tsai & Li, 2004), these results suggest that the association between chronotype and GMAT scores does not primarily reflect study effort (i.e., night owls sleep less and study more than early morning people). Although some previous studies reported a negative correlation between sleep amount and IQ (Geiger et al., 2010), our results do not support the hypothesis that the greater cognitive skills of night owls are due to the fact that they sleep less than the early morning people.

Interindividual variation in baseline cortisol levels contributed, albeit more weakly than sex and chronotype, to variation in GMAT scores. Specifically, sex, chronotype, and cortisol jointly accounted for 14% of the total variance in GMAT scores. Study participants with higher baseline cortisol levels had higher GMAT scores, although the correlation only approached statistical significance. While we previously reported that cortisol mediated the relationship between chronotype and risk-taking (night owls reported higher risk-taking propensities, Maestripieri, 2014), there was no evidence in this study that cortisol mediated the association between chronotype and GMAT scores. Since baseline cortisol levels have been shown to differ in early-morning and night owl types (Maestripieri, 2014) and some previous research has shown that higher baseline cortisol is associated with higher academic accomplishment (Dabbs & Hopper, 1990; Dowd et al., 2011) and with greater cognitive performance in laboratory tasks (e.g., de Kloet, Oitzl, & Joels, 1999; Lupien et al., 2002), the possible relationship between chronotype, cortisol, and intelligence warrants further investigation.

The present study has some important limitations, which should be acknowledged. Although the use of a subject population consisting of MBA students at an elite private university provided a unique opportunity to investigate the relation between chronotype and cognitive function in a population of students high in SES, intelligence, and academic achievement, this may limit the generalizability of results. Our use of GMAT scores as a measure of cognitive function may also limit the generalizability of our results to other studies of intelligence in which IQ is measured. Finally, our use of a single-item measure of chronotype may have contributed to the particular chronotype distribution observed in our subject population, while the exclusion of individuals who did not clearly self-identify as being early-morning types or night owls reduced our sample size and may have masked the significant effects of cortisol or other variables. Our methodological approach for assessing chronotype, however, is more conservative than those of other studies, and it is remarkable that effects of chronotype on cognitive function (which are in the same direction as those reported by previous studies) were detected even with this conservative approach.

The effects of chronotype on cognitive function may be small but are worthy of further consideration. In light of recent evidence from brain imaging studies showing that morningness and eveningness are associated with differences in brain structure (Rosenberg, Maximov, Reske, Grinberg, & Shah, 2014) and that the personality characteristics of night owls and early-morning people entail different vulnerability to risky and addictive behaviors (e.g. smoking and drug and alcohol abuse; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002), further research on the relationship between chronotype and cognition, including intelligence can enhance our understanding of brain function in general and have important implications for theories of intellectual development as well as practical implications for education and research. Although the precise mechanisms underlying the effects of chronotype on cognitive function remain to be established, such effects are likely to be generally consistent with theories of intellectual development and education that emphasize the importance of personality traits, motivation, and cognitive style for academic achievement and expertise (e.g., Ackerman, 1996; Ackerman, Beier, & Boyle, 2002). Our study, in fact, suggests that differences in cognitive performance between early-morning types and night owls are not simply the byproduct of differences in sleep amount or study effort; rather, they may be related to other psychological characteristics, such as working memory, which influence the process by which information is acquired, retained, and retrieved. From a practical standpoint, the relation between chronotype and cognitive function may have implications for the choice of the time of day at which tests are administered in educational settings (e.g., individuals at opposite extremes of the chronotype distribution may be tested at different times of the day, when their cognitive performance is optimal); furthermore, information about an individual's chronotype and about the chronotype distribution in a particular population may contribute to explaining variations in cognitive performance both at the individual and at the population levels.

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