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Morningness-eveningness and educational outcomes: The lark has an advantage over the owl at high school

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Background. Chronotype refers to individuals' preference for morning or evening activities. Its two dimensions (morningness and eveningness) are related to a number of academic outcomes.

Aims. The main goal of the study was to investigate the incremental validity of chronotype as a predictor of academic achievement after controlling for a number of traditional predictors. In so doing, a further aim was ongoing validation of a chronotype questionnaire, the Lark-Owl Chronotype Indicator.

Sample. The sample comprised 272 students attending 9th and 10th grades at five German high schools. Data was also obtained from 132 parents of these students.

Method. Students were assessed in class via self-report questionnaires and a standardized cognitive test. Parents filled out a questionnaire at home. The incremental validity of chronotype was investigated using hierarchical linear regression. Validity of the chronotype questionnaire was assessed by correlating student ratings of their chronotype with behavioural data on sleep, food intake, and drug consumption and with parent ratings of chronotype.

Results. Eveningness was a significant (negative) predictor of overall grade point average (GPA), math–science GPA, and language GPA, after cognitive ability, conscientiousness, need for cognition, achievement motivation, and gender were held constant. Validity evidence for the chronotype measure was established by significant correlations with parent-ratings and behavioural data.

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Conclusions. Results point to the possible discrimination of adolescents with a proclivity towards eveningness at school. Possible explanations for the relationship between chronotype and academic achievement are presented. Implications for educational practice are also discussed.

The goal of finding variables that are related to students' academic success has been high on the priority list of numerous researchers in the field of educational psychology. A variety of comprehensive models aim at mapping constructs related to academic performance and describing relationships among the manifest variables (e.g., Helmke & Weinert, 1997; Kyllonen, Lipnevich, Burrus, & Roberts, 2009; Poropat, 2009). In applied domains, these variables are often considered during the admission process or when evaluating the success or failure of educational programs (Burton & Ramist, 2001; Harackiewicz, Barron, Tauer, & Elliot, 2002). Increasingly, traditional predictors, such as measures of cognitive performance, grade point averages (GPA), and SAT scores have been supplemented by information about students' noncognitive talents, background experiences, and personal dispositions, offering incremental validity evidence and practical usefulness (e.g., Credé & Kuncel, 2008; Cress, Astin, Zimmer-Oster, & Burkhardt, 2001; Willingham, 1985).

Chronotype, or an individuals' preference for morning or evening activities, appears to be one of these 'non-traditional' and promising predictors of academic attainment. Recent research has documented statistically meaningful relationships between chronotype and academic performance and demonstrated that eveningness and academic performance are negatively related, whereas morningness and academic performance are positively related (e.g., Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Kirby & Kirby, 2006; Randler & Frech, 2006; for a meta-analysis see Preckel, Lipnevich, Schneider, & Roberts, 2011). However, chronotype has not yet been investigated systematically in concert with variables traditionally conceptualized as predictors of academic performance. Consequently, to date, no study has been published on the incremental validity of chronotype over and above the more 'classical' predictors of academic attainment. The current study aimed to bridge this gap.

In the following sections, we review the construct of chronotype, focusing initially on definition and measurement. Next, we examine the link between chronotype and academic outcomes. We then present a brief summary of findings related to traditional predictors of academic performance that were statistically controlled in the present study. These include cognitive ability, conscientiousness, gender, need for cognition, and achievement motivation.

Chronotype

Circadian rhythms, or cyclic fluctuations in physiological and psychological functions, are thought to influence diverse aspects of an individuals' life. Study, exercise, eating habits, and adaptability to shift work are just a few domains that are affected by one's daily cycles that usually approach 24 hr (Cavallera & Giudici, 2008). Widely acknowledged individual differences in circadian rhythms, commonly called morningness and eveningness, indicate preferences associated with morning or evening activities. Within this research tradition, a morning-type person prefers morning activities, gets up easily, and is more alert in the morning than in the evening, whereas an evening-type person

prefers afternoon–evening activities, is more alert at night and able to sleep late in the morning. Traditionally, morningness and eveningness have been conceptualized as a trait, lying along a continuum (known as the morningness-eveningness dimension; Cavallera & Giudici, 2008; Gaina *et al.*, 2006; Natale & Cicogna, 2002).

Measurement of chronotype

To gauge an individuals' chronotype, researchers typically employ self-report questionnaires. The vast majority of these questionnaires are based on a unidimensional conceptualization of chronotype, that is, one scale represents the continuum from (extreme) morningness to (extreme) eveningness (i.e., Morningness Eveningness Questionnaire, MEQ, Horne & Ostberg, 1976; Diurnal Type Scale, DTS, Torsvall & Akerstedt, 1980; Composite Scale of Morningness, CSM, Smith, Reilly, & Midkiff, 1989). However, the results of an ever-increasing number of psychometric studies call the unidimensionality of the morningness–eveningness construct into question. Thus, three factors representing morning affect, morning effort, and eveningness (or closely related constructs) may be found in studies of the MEQ (Brown, 1993; Caci, Deschaux, Adan, & Natale, 2009; Neubauer, 1992; Smith, Tisak, Bauman, & Green, 1991; Roberts & Kyllonen, 1999), and the Composite Scale of Morningness (Caci, Adan, Bohle, & Natale, 2005). Numerous other studies have also found chronotype measures to exhibit multidimensionality (Brown, 1993; Putilov, 1993, 2000; Putilov & Onischenko, 2005; Putilov & Putilov, 2005; Wendt, 1977). Indeed, it is an intriguing possibility that this multidimensionality permeates the field, because factorial validity has not been the subject of many other studies. Based on these findings and recent inquiries, researchers have begun to conceptualize chronotype as multidimensional with more information possible if one conceptualizes (*a priori*) that morningness and eveningness are two, relatively independent, dimensions. To our knowledge, there are two questionnaires explicitly designed to capture this two-dimensional conceptualization: the Lark-Owl Chronotype Indicator (LOCI; Roberts, 1998) and the Sleep-Wake Pattern Assessment Questionnaire (SWPAQ; Putilov, 1990, 1993).

The validity of self-report questionnaires has been demonstrated in various studies by controlling the congruence of questionnaire results with biological measures (e.g., body temperature: Horne & Östberg, 1976, or Natale & Alzani, 2001; hormone profiles: Bailey & Heitkemper, 2001), sleep diaries (e.g., Neubauer, 1992; Torsvall & Akerstedt, 1980), and actigraph measures or sleep labour research (e.g., Ishihara, Miyasita, Inugami, Fukuda, & Miyata, 1987). In the present study, we also assessed chronotype by a self-report questionnaire. Unlike other studies, we not only validated our questionnaire by data on sleeping behaviour and other behavioural data but also by comparing self-reports and other-reports of chronotype.

Correlates of chronotype

Researchers report age and gender differences in individuals' morningness and eveningness. For example, the inclination towards morningness and eveningness appears to vary throughout life. Children usually have elevated morningness relative to other age groups. During adolescence a delay of phase preference is usually observed (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Crowley, Acebo, & Carskadon, 2007) reaching a maximum in 'lateness' at around the age of 20 (Roenneberg *et al.*, 2004). After the age of 50, studies document a fast increase in morningness (Diaz-Morales & Sorroche, 2008; Roenneberg *et al.*, 2007). In regards to gender, it appears that women tend to have more

morning characteristics than men (see Kerkhof, 1985; Tankova, Adan, & Buela-Casal, 1994 for reviews). Thus, a recent meta-analysis suggests a weak but significant effect of gender on morningness consistent with this assertion (Randler, 2007).

Yet another construct related to chronotype is cognitive performance. Roberts and Kyllonen (1999) found that evening types performed higher on working memory tasks (correlation of morningness and working memory: $r = -.14$) and processing speed (correlation of morningness and processing speed: $r = -.10$). Killgore and Killgore (2007), as well as Kanazawa and Perina (2009), found evidence of the relationship between verbal IQ and eveningness, although their effect sizes were also quite small (cf. Song & Stough, 2000). Indeed, a recent meta-analysis shows a small but significant negative correlation between morningness and cognitive ability of $r = -.04$ and a positive and significant correlation between eveningness and cognitive ability of $r = .08$ (Preckel *et al.*, 2011).

Chronotype and academic performance

Relationships between chronotype and academic performance have been examined in a variety of studies. Researchers consistently show that eveningness and academic performance are strongly and inversely related, whereas morningness and performance in school are positively related. These patterns hold for both school children (Giannotti, Cortesi, & Ottaviano, 1997; Giannotti *et al.*, 2002; Randler & Frech, 2009) and university students (e.g., Beşoluk, 2011; Beşoluk, Önder, & Deveci, 2011; Randler & Frech, 2006). Preckel *et al.*'s (2011) meta-analysis also found small but significant and homogenous correlations between morningness and academic achievement ($r = .16$, 13 studies) and eveningness and academic achievement ($r = -.14$, 6 studies). Thus, morning-oriented students achieved better in academic settings than evening-oriented students. Taking into account the fact that during early adolescence chronotype moves away from morningness towards eveningness (e.g., Kim, Dueker, Hasher, & Goldstein, 2002; Roenneberg *et al.*, 2004) these findings warrant attention.

Traditional predictors of academic performance

Individuals' cognitive ability has been examined in a plethora of studies and has been shown to be one of the best single predictors of academic attainment (e.g., Deary, Strand, Smith, & Fernandes, 2007; Mayes, Calhoun, Bixler, & Zimmerman, 2009). Meta-analysis by Fraser, Walberg, Welch, and Hattie (1987) revealed a correlation of .71 between IQ and academic performance. In a more recent meta-analysis, Strenze (2007) found a corrected correlation between IQ and academic performance (GPA) of .56 (see also Kuncel, Hezlett, & Ones, 2004).

Another well-investigated predictor of academic performance is conscientiousness, which represents one of the five factors of the Big Five model of personality (Goldberg, 1993) and which is described by such traits as being reliable, hardworking, self-disciplined, and persevering. The link between academic performance and conscientiousness has been examined in several studies (e.g., Furnham & Monsen, 2009; MacCann, Duckworth, & Roberts, 2009; Noftle & Robins, 2007; Preckel, Holling, & Vock, 2006). In a recent meta-analysis (Poropat, 2009), conscientiousness was confirmed as the strongest Big Five predictor of academic performance, faring better in some samples than intelligence (corrected $r = .22$).

Gender has been employed as a predictor of academic performance. Recent results from the PISA 2009 study revealed that in all participating countries girls achieved

significantly better scores in reading (score point differences between 9 and 62 points; on average 39 points) and that in 35 of the participating 65 countries boys did significantly better in mathematics (there were only five countries with an advantage for girls in mathematics; OECD, 2010). Other than for the domain of reading, gender differences in mathematics were found to have small effect sizes ($<d = .15$) and to show considerable variability in direction and magnitude of the effect (Else-Quest, Hyde, & Linn, 2010). In most of the participating countries, there were no gender differences in science performance (OECD, 2010).

The need for cognition, another predictor of academic performance, has been described by Cacioppo and Petty (1982) as the tendency for an individual to engage in and enjoy thinking or thoughtful activity. Since more effortful information processing may result in more and more accessible information, the need for cognition has an effect on the acquisition of knowledge which is performance defining for certain cognitive tasks. Different studies have documented positive correlations between the need for cognition and measures of crystallized intelligence (meta-analytic $r = .35$, Ackerman & Heggestad, 1997). Need for cognition has been shown to be correlated with knowledge and verbal ability (Tidwell, Sadowski, & Pate, 2000), as well as with academic performance (Preckel *et al.*, 2006; Wilhelm, Schulze, Schmiedek, & Süß, 2003). A study by Dwyer (2008) found need for cognition to be significantly related to GPA ($r = .31$) and self-reported grades ($r = .27$) (see also von Stumm, Hell, & Chamorro-Premuzic, 2011).

The predictive validity of achievement motivation for academic performance has been demonstrated in several studies (Hejazi, Shahraray, Farsinejad, & Asgary, 2009; Steinmayr & Spinath, 2009; Urhahne, 2008). Meece, Wigfield, and Eccles (1990), for example, found correlations between competency beliefs and subjective task values and mathematics grades. Several studies that investigated the relation of achievement goal orientations and academic performance found a small positive correlation between learning goal orientation and academic attainment (e.g., Köller, 1998; VandeWalle, Cron, & Solocum, 2001). For performance goal orientation, various studies document positive correlations with performance when combined with an approach orientation but negative correlations with performance when combined with an avoidance orientation (e.g., Rheinberg, 2004; Senko, Durik, & Harackiewicz, 2008 for an overview and Hulleman, Schrager, Bodmann, & Harackiewicz, 2010, for a meta-analytic review).

Clearly, this review of the literature indicates that cognitive ability, conscientiousness, need for cognition, and achievement motivation are quite effective in predicting academic performance. The PISA results indicate that gender predicts language performance (especially reading). Additionally, studies consistently reveal systematic relationships between chronotype and academic performance.

Research objectives of the present study

The main aim of the current study was to investigate the incremental validity of chronotype as a predictor of academic achievement after controlling for a number of traditional predictors (outlined in the previous section). To our knowledge, there are no studies that have investigated the incremental validity of chronotype as a predictor of academic achievement. Therefore, our investigation was exploratory in nature: *Does chronotype provide additional explanation of variance in academic achievement beyond cognitive ability, conscientiousness, need for cognition, achievement motivation, and gender?*

Careful synthesis of existing literature led us to the formulation of the following research hypotheses: Students with higher morningness scores achieve better marks at school as compared to students with a proclivity towards eveningness. Additionally, we expected that students with higher cognitive ability, conscientiousness, need for cognition, and achievement motivation would achieve better marks in general and that girls would achieve better marks in languages.

To gain a better understanding of the functional mechanisms of the relationship between chronotype and academic achievement we controlled for the influence of daytime sleepiness. Students with a proclivity towards eveningness are likely to collect sleep debts over the week (Gau & Soong, 2003; Gau *et al*., 2004): Students with a proclivity towards eveningness go to bed later than students with a proclivity towards morningness but they all have to get up at the same time due to the school schedule. Therefore, students with a proclivity towards eveningness report greater daytime sleepiness, which is by itself associated with lower school achievement (Kirby & Kirby, 2006; Meijer, 2008).

Last, but not least, we aimed to establish validity evidence for the self-report measure of chronotype by correlating self-reports with other-reports (parents) and with behavioural data. We expected positive correlations between self-reports and other-reports. Taking into account the empirical findings on the relation of chronotype with behavioural data like sleeping behaviour or food intake, we expected morningness to be negatively and eveningness to be positively related to daytime sleepiness, bedtime, get up time, breakfast time, and the consumption of stimulating substances like coffee, alcohol, and nicotine (e.g., Andershed, 2005; Bioulac, 1999; Gau & Soong, 2003; Roenneberg, Wirz-Justice, & Merrow, 2003; Tankova *et al*., 1994).

Method

Participants

Two hundred and seventy-two students (127 females, 141 males and four providing no information on sex) with a mean age of 15.6 years ($SD = .74$) participated in this study. Students were recruited from nine classes (ninth and 10th grade) at five schools. In the German educational system, students are separated after elementary school (i.e., after grade 4) into three achievement tracks (lower, middle, and upper academic track) according to their level of performance. Of the sample, 123 participants attended the lower track, 50 participants attended the middle track, and 99 participants attended the upper track (57 of them visited special classes for the gifted within this track).

Measures

Demographics and behavioural data

Demographic variables and behavioural data were gathered through student questionnaires. Behavioural data included information on sleeping behaviour (bedtime, get up time, sleep duration; during the week and at weekends), breakfast time (during the week and at weekends), frequency of drug consumption (alcohol, nicotine; response scale from 'never' [1] to 'daily' [5]), and daytime sleepiness (assessed by a single item: 'Are you tired during the day?'; four-point response scale from 'never' [1] to 'often' [4]).

Chronotype

We used the German version of the Lark-Owl Chronotype Indicator (LOCI; Roberts, 1998), which measures morningness (13 items; e.g., 'I find it easy to get up in the morning') and eveningness (13 items; e.g., 'I go to bed after 22:00'). The LOCI was given in both the self- and other-report formats. For self-report data, students were asked to rate the extent to which they agreed with each of the statements on a scale from 'never' (1) to 'always' (6). For other-report data, a parent of the students was asked to rate the extent to which the same statements characterized their child on a scale from never (1) to always (6) (e.g., for morningness: 'My child finds it easy to get up in the morning').

Cognitive ability

We used the Culture Fair Intelligence Test (CFT-20) as a measure of cognitive ability. The CFT-20 is a German adaptation (Weiß, 1998) of the Culture Fair Intelligence Test (Cattell & Cattell, 1960). The paper-and-pencil test assesses fluid intelligence with four types of figural tasks (series, classifications, matrices, and topologies). Tasks were presented in a multiple-choice format. Testing took part under speeded power conditions with generous time limits.

Need for cognition

To measure need for cognition the German short version of the Cacioppo and Petty (1982) scale was used (Bless, Wanke, Bohner, Fellhauer, & Schwarz, 1994). A total of 16 items (e.g., 'I really enjoy a task that involves coming up with new solutions to problems') were rated on a 7-point Likert scale from 'absolutely inapplicable' (1) to 'absolutely applicable' (7).

Conscientiousness

Conscientiousness was assessed by applying the respective scale from a short version of Ostendorf's (1990) Inventar Minimal Redundanter Skalen (MRS; Schallberger & Venetz, 1999). The scale consisted of four bipolar pairs of adjectives such as '*disorderly–orderly*' or '*systematic–unsystematic*'. The students had to indicate how these adjectives applied to them using a 6-point rating scale (sample item: '*disorderly*' (1) very much – (2) kind of – (3) rather || (4) rather – (5) kind of – (6) very much '*orderly*').

Achievement motivation

Achievement motivation was assessed with the Skalen zur Erfassung der Lern- und Leistungsmotivation (Scales for the assessment of learning and performance motivation, SELLMO; Spinath, Stiensmeier-Pelster, Schöne, & Dickhäuser, 2002). The instrument assesses four types of achievement goals: Learning goals (eight items; sample item: 'In school it is important to me to make sense out what I have learnt.'), performance approach goals (seven items; sample item: 'In school it is important to me to get better grades than the other students.'), performance avoidance goals (eight items; sample item: 'In school it is important to me that nobody notices if I do not understand something.'), and a tendency to avoid work (eight items; sample item: 'In school it is important to me to always keep the work load low.'). The response scale included a 5-point Likert scale ranging from '*not true at all*' (1) to '*exactly true*' (5).

Academic performance

Students reported their end of year grades in all school subjects. Thus, self-reported grades did not reflect grades from single tests but represent accumulations of attainments of a whole school term. Recent research suggest that self-reported school grades can be assumed to be valid, since they do not seem to be subject to systematic bias (Dickhäuser & Plenter, 2005). We calculated three different GPA: The overall GPA was calculated across all subjects: mathematics, German (native language), English, French, Latin, physics, chemistry, biology, history, politics, social sciences, music, art, and sports. Additionally, we computed a math–science GPA (mathematics, physics, chemistry, biology) and the GPA for languages (German, English as a foreign language). Teachers frequently use a classroom-related social frame of reference by assigning the best/worst grade to the highest/lowest achieving student in one particular class (Ingenkamp & Lissmann, 2005). Because of this grading-on-a curve phenomenon grades are not comparable over classes. Therefore, for further analyses we standardized all grades within classes to *z*-scores. Grades ranged from 1 (very good) to 6 (insufficient), with higher numbers representing poorer achievement. To allow for coefficients involving these achievement measures to be interpreted in a more intuitive manner, students' grades were reflected so that higher numbers indicate higher achievement levels.

Procedure

All assessment instruments were group administered in classrooms during one testing session. Each session was conducted by two trained experimenters and took about 90 min. To control the time of day in all schools the third and fourth lesson (between 10 a.m. and 12 p.m.) were chosen. Students' participation was voluntary, anonymous, and approved by their parents. The study and its material were approved by the data protection commissioner of the school district. Participants took home the parent questionnaire on chronotype and brought it back to school after their parents had filled it out at home.

Results

Validation of the LOCI

Self-reported chronotype showed significant correlations with parent-reported chronotype (ranging from $r = .38$ to .57; see Table 1). Thus, the self-assessments of the students predominantly accorded with their parents' appraisals. The correlations of the LOCI morningness and eveningness scales with behavioural data also supported their validity. Persons with morning orientation went to bed earlier ($r = -.23$), woke up earlier ($r = -.19$) and on weekends slept less ($r = -.30$), and had their breakfast sooner ($r = -.49$) than persons with a proclivity towards eveningness. As expected, eveningness correlated positively with daytime sleepiness while morningness correlated negatively with daytime sleepiness ($r = .16$ and $r = -.30$, respectively). In line with previous findings (e.g., Bioulac, 1999; Tankova *et al.*, 1994), eveningness was positively and significantly correlated with the consumption of alcohol, caffeine, cola, and nicotine ($r_s = .21$–$.40$). In sum, the correlations of the LOCI scales with other ratings of chronotype and behavioural data on sleep, food intake, and drug consumption supported the validity of the LOCI for the present sample.

Table 1. Means and standard deviations of external criteria for the validation of the LOCI and their correlations with the morningness and eveningness LOCI scales

Criteria	*n*	*M*	*SD*	Morningness	Eveningness
Other-reports[a]					
LOCI mother ratings	85	M: 39.98; E: 40.07	M: 10.13; E: 10.95	.53*	.57*
LOCI father ratings	47	M: 39.74; E: 41.77	M: 10.18; E: 9.79	.38*	.50*
Behavioural data					
Day-time sleepiness[b]	269	2.74	.75	−.30*	.16*
Bedtime (weekdays; h)	272	22:31	00:48	−.23*	.56*
Bedtime (weekend; h)	272	1:06	1:46	−.26*	.53*
Get up time (weekdays; h)	271	6:38	1:05	−.19*	.11
Get up time (weekend; h)	268	10:19	1:48	−.49*	.37*
Sleep duration (weekdays; h)	271	7:63	1.00	.06	−.38*
Sleep duration (weekend; h)	271	9:20	1.61	−.30*	−.07
Breakfast time (weekdays; h)	226	7:03	1:03	−.10	.12
Breakfast time (weekend; h)	220	10:46	1:30	−.49*	.44*
Coffee consumption[c]	271	3.68	1.55	−.16*	.21*
Cola consumption[c]	271	3.38	1.80	−.20*	.23*
Alcohol consumption[c]	271	3.31	.97	−.15*	.40*
Nicotine consumption[d]	269	2.42	.87	−.22*	.29*

[a]Reliabilities (Cronbach's α) for the LOCI other-reports in the present sample were $\alpha = .83/.84$ for morningness and $\alpha = .85/.84$ for eveningness (mother-ratings/father-ratings). [b]Response scale from '*never*' (1) to '*often*' (4). [c]Response scale from '*never*' (1) to '*daily*' (5). [d]Response scale from '*never*' (1) to '*regularly*' (3). LOCI = Lark-Owl Chronotype Indicator; M = Morningness; E = Eveningness. *$p < .01$.

Chronotype and academic achievement

Descriptive statistics as well as sample reliabilities (Cronbach's α) and intercorrelations of measures are given in Table 2.

Descriptive findings

Reliabilities of all measures were acceptable, ranging from $\alpha = .72$ for conscientiousness to $\alpha = .93$ for cognitive ability. All variables showed normal means and standard deviations for the group under study.

Correlational findings

Firstly, we discuss some general findings. Secondly, we present the correlational findings that are relevant to our research hypotheses. Morningness and eveningness revealed a small negative relationship ($r = -.18$), indicating distinct dimensions. Both were uncorrelated with gender and cognitive ability. Morningness showed significant positive correlations with conscientiousness ($r = .27$), need for cognition ($r = .24$), mastery goal orientation ($r = .21$), and a significant negative correlation with work avoidance in school ($r = -.15$). Eveningness showed significant negative correlations with conscientiousness ($r = -.17$), performance goal orientations (approach: $r = -.12$; avoidance: $r = -.15$), and a significant positive correlation with work avoidance in school ($r = .13$).

Table 2. Means, standard deviations, ranges, sample reliabilities as well as intercorrelations of sex, cognitive ability, conscientiousness, need for cognition, daytime sleepiness, achievement goals, chronotype, and school grade point averages

	1	2	3	4	5	6	7	8	9	10	11	12	13	*M*	*SD*	*Range*
Sex[a]	—															
Cognitive ability[b]	.03	*.93*												114.26	15.11	79–149
Conscientiousness	−.17**	−.08	*.72*											3.85	.89	1–6
Need for cognition	.05	.16*	.26**	*.82*										4.36	.80	1–7
Daytime sleepiness	−.18**	.04	−.11	−.07	—									2.74	.75	1–4
Achievement goals[c]																
Learning	−.02	−.04	.24**	.48**	−.14*	*.78*								3.84	.57	1–5
Performance appr.	.03	−.16*	.11	.14*	−.13*	.38**	*.82*							3.39	.75	1–5
Performance avoid.	.03	−.04	−.09	−.09	−.09	.03	.53**	*.86*						2.75	.78	1–5
Work avoidance	.18**	.00	−.44**	−.39**	.03	−.43**	.02	.33**	*.81*					2.72	.72	1–5
Chronotype dimension[d]																
Morningness	−.07	.04	.27**	.24*	−.30**	.21**	.06	.02	−.15*	*.81*				2.84	.78	1–6
Eveningness	.08	−.07	−.17*	.00	.16**	−.09	−.12*	−.15*	.13*	−.18**	*.75*			3.65	.69	1–6
Grade point average																
Overall	−.07	.44**	.18**	.29**	.00	.16*	.03	−.10	−.18**	.08	−.18**	—		4.38	.52	1–6
Math–sciences	.12*	.40**	.13*	.24**	−.07	.11	.10	−.03	−.07	.07	−.22**	.75**	—	4.09	.82	1–6
Languages	−.14*	.32**	.11	.21**	.10	.09	−.02	−.01	−.12	−.01	−.11	.76**	.42**	4.04	.71	1–6

Notes. *n* varies between 237 and 271. Sample Reliabilities (Cronbach's α) are given in italics along the diagonal. [a]Sex was coded as: 1 = female, 2 = male. [b]CFT = Culture Fair Intelligence Test with IQ norm ($M = 100$, $SD = 15$). [c]SELLMO = assessment scales for learning and performance goal orientation. [d]LOCI = Lark-Owl Chronotype Indicator. appr. = approach; avoid. = avoidance. * $p < .05$. ** $p < .01$.

Contrary to our research hypothesis, students with a proclivity towards morningness did not achieve better marks at school since morningness and grades correlated near zero (r_s between −.01 and .08, $_{\text{one-sided}}\, p_s$ between .09 and .43). However, as expected students with a proclivity towards eveningness achieved significantly lower marks at school with respect to overall GPA ($r = -.18$), math–science GPA ($r = -.22$), and language GPA ($r = -.11$).

We further expected that students with higher cognitive ability, conscientiousness, need for cognition, and achievement motivation would achieve better marks in school. In line with our expectations, students who received higher grades also scored significantly higher on cognitive ability ($r = .32$–$.44$), conscientiousness ($r = .11$–$.18$), and need for cognition ($r = .21$–$.29$). With respect to achievement motivation, learning goal orientation was significantly positively related to the overall GPA ($r = .17$) and math–science GPA ($r = .11$). Work avoidance was significantly and negatively related to overall GPA ($r = -.18$) and language GPA ($r = -.12$). By trend, performance approach goal orientation was positively related to math–science GPA ($r = .10$) and performance avoidance goal orientation was negatively related to overall GPA ($r = -.10$). The other correlations between GPAs and the goal orientation scales did not gain significance ($_{\text{one-sided}}\, p_s$ between .08 and .44). In line with our expectations, girls achieved better marks in languages ($r = -.14$). Additionally, boys received better marks in the math–science domain ($r = .12$).

Regression-analytic findings

The incremental validity of morningness and eveningness for predicting grades in school was tested in a hierarchical linear regression. The first block controlled the influence of gender, cognitive ability, conscientiousness, need for cognition, daytime sleepiness, and all achievement goal subscales on GPAs used as criterion. The second block included morningness and eveningness scores. The results of the regression are depicted in Table 3. Three identical analyses were run with three different GPAs (overall GPA, math–science GPA, language GPA) used as criterion. The pattern of results was similar in all three regressions.

Suppressor effects should be excluded in our data. When analyzing intercorrelations and beta weights (Lancaster, 1999), daytime sleepiness turned out to be a possible suppressor variable because of its zero or small correlations with the GPAs and its significant correlations with the chronotype dimensions. Therefore, we repeated the regression analyses without daytime sleepiness as a predictor but results stayed the same or the negative beta weight of eveningness even increased (standardized betas between −.15 and −.25). Additionally, we repeated the regression analyses without the goal orientation scales or only one chronotype dimension as predictor at a time. The results were comparable to the ones obtained with the full set of predictors.

Cognitive ability turned out to be a significant predictor of all GPAs (β_s between .17 and .24). Conscientiousness predicted overall GPA ($\beta = .18$) and language GPA ($\beta = .17$). Examining the motivational scales, performance avoidance goals negatively predicted academic performance for overall GPA and math–science GPA ($\beta_s = -.16$). For the latter, performance approach goals as well as need for cognition positively predicted academic performance ($\beta_s = .18$ and .17). The inclusion of morningness and eveningness in the model significantly increased the amount of explained variance.

Table 3. Predictors of school grade point averages

Predictor	Overall GPA ß	Math–Science GPA ß	Language GPA ß
Step 1: Control variables			
Sex[a]	−.07	.09	−.15*
Cognitive ability[b]	.24**	.20**	.17*
Conscientiousness	.18*	.12	.17*
Need for cognition	.05	.17*	.01
Daytime sleepiness	.00	−.01	.07
Achievement goals[c]			
Learning	.08	.02	.02
Performance appr.	.13	.18*	.01
Performance avoid.	−.16*	−.16*	.01
Work avoidance	.12	.14	−.01
Step 2: Chronotype dimensions[d]			
Morningness	−.04	−.04	−.11
Eveningness	−.20**	−.18*	−.14*
R^2	.16	.16	.12
F	3.68**	3.61**	2.59**
ΔR^2	.04	.03	.02
ΔF	4.49*	3.46*	2.83+

[a]Sex was coded as: 1 = female, 2 = male. [b]CFT = Culture Fair Intelligence Test with IQ norm (M = 100, SD = 15). [c]SELLMO = assessment scales for learning and performance goal orientation. [d]LOCI = Lark-Owl Chronotype Indicator. appr. = approach; avoid. = avoidance. *$p < .05$. **$p < .01$. +$p < .10$.

While morningness did not turn out to be a significant predictor, eveningness negatively affected all three GPAs (β_s between −.14 and −.20). The overall results showed that between 2% and 4% of additional variability in school grades could be explained by eveningness.

Discussion

Chronotype has been shown to be related to academic performance, with morningness showing positive relations and eveningness showing negative relations (Preckel *et al.*, 2011). However, to our knowledge no study has investigated incremental validity of chronotype in prediction of academic performance over and above traditional predictors, such as cognitive ability or conscientiousness. In the present study, we did just that. We investigated the incremental validity of chronotype for the explanation of academic attainment while controlling for cognitive ability, conscientiousness, achievement motivation, need for cognition, gender, and daytime sleepiness. The validity of the chronotype scores was supported by correlations with other-ratings and behavioural data. Eveningness was a significant *negative* predictor of overall GPA, math–science GPA, and language GPA, even after controlling for the other predictors. In other words, when looking at students of equal sex, cognitive ability, achievement motivation, conscientiousness, and need for cognition, eveningness-oriented students received lower school grades.

Possible explanations of the relationship between chronotype and academic performance

The results of the current study partly confirmed our expectations: Eveningness negatively predicted academic performance but morningness had no independent contribution over the other predictors in our study, and was uncorrelated with school grades as a single predictor. In part, this might be attributable to the age of our sample, as adolescents are known to have a more defined eveningness orientation.

Sleep deprivation

Many studies document that sleep deprivation negatively affects academic performance and that eveningness types are at risk of sleep deficits and higher daytime sleepiness (e.g., Kirby & Kirby, 2006; Meijer, 2008; Randler & Frech, 2006). Students with eveningness orientation go to bed later but have to wake up early. This causes them to be more tired during the day and may be reflected in lower academic performance. Students with morningness preference do not accumulate sleep debt and might thus be less affected by daytime sleepiness and its effects on academic performance. In the present study, we controlled for tiredness over the day. Although students' tiredness was positively linked to eveningness and negatively to morningness, it did not correlate with school grades. These dependencies suggest that tiredness over the day does not explain why eveningness-oriented students receive poorer marks in school. Interestingly, tiredness over the day correlated significantly and negatively with achievement motivation (mastery goals: $r = -.14$; performance approach goals: $r = -.13$) and conscientiousness ($r = -.11$) which leads us to the second possible explanation of the relationship between chronotype and academic achievement.

Behavioural problems and poor work ethic

Many studies have demonstrated that persons with a proclivity towards eveningness are more likely to exhibit characteristics that are negatively related to academic attainment. These include negative attitude towards school, anxiety disorders, lower levels of conscientiousness, or higher drug consumption (e.g., Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007). Our study had a cross-sectional design and therefore causal inferences were not possible. However, our results confirmed that eveningness-oriented students consumed more drugs (alcohol and nicotine), showed higher work avoidance, were less conscientious, and less performance motivated than morningness-orientated students. After we controlled for some of these variables (conscientiousness, achievement motivation, work avoidance) eveningness still explained variance in school grades, thus implicating yet another possible explanation of the link between chronotype and academic attainment.

Synchrony effect

A third explanation for the relationship between chronotype and academic achievement is the assumption that superior cognitive functioning occurs when times for testing or achievement are synchronized with individuals' peak circadian arousal periods (synchrony effect). Synchrony effects could be found for a number of school relevant tasks such as attention and memory (e.g., Clarisse, LeFloch, Kindelberger, & Feunteun, 2010; Hasher, Goldstein, & May, 2005; Intons-Peterson, Rocchi, West, McLellan, & Hackney,

1998; Yoon, May, Goldstein, & Hasher, 2000). According to this hypothesis, people with a preference for morningness have their peak of performance in the morning whereas people with an eveningness preference perform better in the afternoon (Goldstein *et al*., 2007). In the present study it was not possible to experimentally manipulate test-taking time, hence the data were collected during the morning hours. One hint for a possible synchrony effect revealed in our study comes from the finding that chronotype and cognitive ability showed no relationship. As mentioned above, results of single studies as well as recent meta-analytic findings (Preckel *et al*., 2011) consistently document small positive correlations between eveningness and cognitive ability. It is possible that in accordance with the synchrony effect, students with eveningness preference could not perform at their best at the time the data were collected (all participants were assessed between 10 a.m. and 12 p.m.). Moreover, morningness showed a positive correlation with need for cognition. Need for cognition is typically associated with crystallized intelligence (Cacioppo, Petty, Feinstein, & Jarvis, 1996) but also has been found to show a positive relationship with fluid intelligence scores (Fleischhauer *et al*., 2010). However, the association of morningness and need for cognition could also be mediated by shared variance with conscientiousness or the motivational scales.

It is not implausible to assume synchrony effects not only for cognitive variables but also for affective and motivational variables. Future studies should experimentally manipulate testing times to further investigate possible synchrony effects for both cognitive and affective variables.

Limitations

Generalizability of our findings is restricted; it should be taken into account that the sample consisted of ninth- and 10th-grade German students only. Replications with younger and older students are needed. Moreover, further studies are needed to investigate whether our findings can be replicated in other cultures. Compared with other European countries, Germans are rather morning-oriented (Diaz-Morales & Randler, 2007). Furthermore, most measures employed in our study (except for the cognitive ability test) were Likert-based self-reports, which are known to be influenced by factors such as faking and social desirability (Ziegler, MacCann, & Roberts, 2011). Future studies could use alternative assessments, such as situational judgment tests, forced-choice protocols, and other methods. Tiredness, an important construct in the current study, was assessed with a one-item measure. More sophisticated assessments might be used in future inquiries. Finally, the study had a cross-sectional design which does not allow for causal inferences.

Future directions and implications

Reasons for the relationship between chronotype and academic performance are not very well understood. Longitudinal research is needed that would examine associations between chronotype as a precursor for, or manifestation of, performance and learning (Gau *et al*., 2004). Also, reciprocal effect models need to be taken into account. Most studies still conceive of chronotype as a one-dimensional construct. However, as outlined in the introduction, findings on construct validity support the conceptualization of chronotype as a multidimensional construct (e.g., Caci *et al*., 2005; Neubauer, 1992; Putilov & Putilov, 2005). A two-dimensional conceptualization of chronotype is supported by our findings: Correlations of the morningness and eveningness scales with each other were small and their correlations with external criteria were quite distinct.

The findings of the current study warrant attention as they might have important implications for educators and policymakers. Our findings suggest that the relationship between chronotype and academic performance cannot be attributed to students' increased tiredness or more negative work attitudes (conscientiousness, achievement motivation) often evident in eveningness-oriented students. Because in adolescence there is a general shift towards eveningness and school typically starts early in the morning, evening-oriented students are plausibly disadvantaged. Scarce studies attest to this. Klein (2004) investigated 850 seventh to ninth grade students in Israel and found a gradual increase for the level of academic performance from the morning to the afternoon hours. Similarly, Wahlstrom (2002) conducted a 4-year longitudinal study of the impact of changing start time in seven comprehensive high schools from 7:20 a.m. to 8:40 a.m., without changing the length of the school day. The study revealed that students gained an hour's more sleep each school night, with improvements related to daytime sleepiness and attendance. Grades improved, but not significantly. School districts in other US states have implemented similar start time changes, with similar and consistently positive outcomes (Fairfax County School Board Transportation Task Force, 2008). However, starting school later is often not possible due to the organization of the work life in our society and concerns related to student participation in extracurricular activities.

Alternatively, chronopsychological aspects could be integrated into the organization of school schedules (for instance, planning of time tables and testing times, adjustment of teaching methods). A study by Ramirez *et al*. (2006) demonstrated that the phonological and visuospatial memory cycles show a delayed rise during the morning. Due to the fact that mathematics and science classes rely quite heavily on visuospatial memory, it may be particularly important that these classes be offered later in the day.

In general, parents, teachers, and students themselves should learn more about chronopsychology and its effects on everyday life and learning (Azevedo, Sousa, Ketema, *et al*., 2008). The results of the present study indicate it to be worthwhile to invest in basic and applied research in this field as chronotype explained more variability in academic performance than motivational variables.

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