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Chronotype, cognitive abilities, and academic achievement: A meta-analytic investigation☆

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ABSTRACT

Four meta-analyses examined relationships between morningness and cognitive ability (total $N=2177$), eveningness and cognitive ability (total $N=1519$), morningness and academic achievement (total $N=3220$), and eveningness and academic achievement (total $N=700$). The analyses focused on the population effect size (to reveal the effect across studies) and the homogeneity (to determine if the results of the several experiments are sufficiently similar to warrant their combination into an overall result). In all four cases, the aggregated correlations between chronotype and cognitive ability, as well as chronotype and academic achievement were found to be significant. Eveningness was found to be positively related to individuals' cognitive ability ($r=.08$), yet negatively related to indicators of academic achievement ($r=-.14$). Conversely, morningness had a negative relationship with cognitive ability ($r=-.04$) and a positive correlation with academic indicators ($r=.16$). Practical implications, including those pertaining to educational policy, are discussed.

Circadian rhythms, or cyclic fluctuations in physiological and psychological functions, are thought to influence diverse aspects of an individual's life. Study, exercise, eating habits, and adaptability to shift work are just a few domains that are affected by these daily cycles, which generally approach 24 h. Widely acknowledged individual differences in circadian rhythms, commonly called morningness and eveningness, indicate preferences associated with morning or evening activities. A morning-type person is thus someone who gets up easily and is more alert in the morning than in the evening. By contrast, an evening-type person is more alert at night, often sleeping late into the morning. Traditionally, morningness and eveningness have been conceptualized as a trait, lying along a continuum (known as the morningness–eveningness dimension). Most individuals (i.e., around 70%) have a scale position somewhere between the extremes of morningness and eveningness and can be described as a neither (or in some accounts, a combined) type (Achari & Pati, 2007; Cavallera & Giudici, 2008; Cofer et al., 1999; Gaina et al., 2006; Natale & Cicogna, 2002).

Researchers report age and gender differences in individuals' morningness and eveningness. In particular, the inclination towards morningness and eveningness appears to vary across the lifespan. Children are usually predisposed towards morningness. During adolescence a delay of phase preference can be observed (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Crowley, Acebo, & Carskadon, 2007) reaching a maximum shift towards eveningness at around the age of 20 years. After the age of 50, studies document a pronounced shift back towards morningness (Baehr, Revelle, & Eastman, 2000; Diaz-Morales & Sorroche, 2008; Gau, Soong, & Merikangas, 2004; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Monk & Kupfer, 2007; Roenneberg et al., 2007; Shinkoda, Matsumoto, Park, & Nagashima, 2000; Taillard, Philip, & Bioulac, 1999). In regard to gender, results from studies that have investigated sex differences in circadian phases are somewhat inconsistent, although it appears that women tend to have a greater disposition towards morning characteristics than do men (for reviews see Kerkhof, 1985; Tankova, Adan, & Buela-Casal, 1994). A meta-analysis conducted by Randler (2007) suggests a weak but significant effect of gender on morningness with females being more morning oriented than males.

In addition to age and gender, individuals' proclivity toward morningness and eveningness has been shown to relate to a slew of variables, including mood, temperament, productivity, avocational interests, caffeine consumption, and internal temperature (e.g., Andershed, 2005; Preckel, Lipnevich, Ross, & Roberts, 2011; Tankova et al., 1994). In the last decade, a literature has also emerged documenting relations between diurnal preference and cognitive ability, as well as between diurnal preference and academic

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performance (e.g., Killgore & Killgore, 2007; Preckel & Roberts, 2009; Roberts & Kyllonen, 1999; Schmidt, Collette, Cajochen, & Peigneux, 2007). The latter two relationships are the main focus of the current investigation.

1. Findings on the relationship between chronotype and cognitive ability

Recent reviews document time of day effects on basic and more complex cognitive functions that are contingent upon an individuals' chronotype (Carrier & Monk, 2000; Schmidt et al., 2007). Roberts and Kyllonen (1999), for example, reported that individuals high in eveningness were more likely to do well on measures of memory, processing speed, and cognitive ability, even when those cognitive tasks were performed early in the morning. Further, these authors found that working memory capacity (which is often regarded as the best proxy for general intelligence, or psychometric *g* [see Kyllonen & Christal, 1990]) showed the highest correlation with individuals' morningness and eveningness scores. In particular, high scores on the eveningness scale were correlated with higher scores on the working memory task. Kanazawa and Perina (2009) and Wagner and Roberts (2003) present similar findings showing significant correlations between individuals' chronotype and intelligence, favoring (albeit slightly) persons with a proclivity towards eveningness. However, other studies suggest that relations between chronotype and cognitive ability are more variegated. For instance, Killgore and Killgore (2007) reveal correlations between verbal cognitive ability and eveningness (but not between math ability and eveningness). The latter finding was only true for female participants. Similarly, Song and Stough (2000) found a significant eveningness advantage on the Spatial subtest of the Multidimensional Aptitude Battery IQ (MAB-IQ), but not on any other subtest. Overall, research on relationships between chronotype and cognitive ability remains relatively scant and somewhat inconsistent (Killgore & Killgore, 2007; see also Song & Stough, 2000).

2. Findings on the relationship between chronotype and academic achievement

Relationships between chronotype and academic achievement (especially grade point average [GPA], but also measures derived from class exams and other achievement indicators) appear to be less contradictory. Studies consistently show that eveningness and indicators of academic achievement are strongly and inversely related, whereas morningness and academic achievement are positively related. These patterns hold for both school children (Cortesi, Giannotti, Mezzalira, Bruni, & Ottaviano, 1997; Giannotti et al., 2002; Giannotti & Cortesi, 2002; Giannotti, Cortesi, & Ottaviano, 1997; Wagner & Roberts, 2003) and university students (Kirby & Kirby, 2006; Randler & Frech, 2006; Smith, Reilly, & Midkiff, 1989). In their study, Preckel and Roberts (2009) demonstrate a significant negative effect of eveningness on academic achievement (teacher assigned school grades averaged over grades in Math, German, English, Physics, and Biology which were *z*-standardized within classes before) in a sample of 270 German secondary school students. These results held after statistically controlling for gender, intelligence, each of the Big Five personality factors, need for cognition, and achievement motivation. Similarly, Giannotti et al. (1997) found a significant, positive correlation between students' performance in school and their proclivity towards morningness. Taking into account that during early adolescence students on average move away from morningness and towards eveningness (e.g., Kim, Dueker, Hasher, & Goldstein, 2002; Roenneberg et al., 2004) these findings warrant closer attention.

3. Measuring chronotype

Several self-report questionnaires have been developed to assess individuals' diurnal preferences. Most of these measures treat chronotype as unidimensional (i.e., Morningness Eveningness Questionnaire [MEQ; Horne & Ostberg, 1976]; Diurnal Type Scale [DTS; Torsvall & Akerstedt, 1980]; Circadian Composite Scale [CCS; Smith et al., 1989]). However, results of psychometric studies call the unidimensionality of the morningness–eveningness construct into question (Brown, 1993; Larsen, 1985; Neubauer, 1992; Putilov, 1993, 2000; Putilov & Onischenko, 2005; Putilov & Putilov, 2005; Roberts, 1999a; Wendt, 1977). Based on recent inquiries, researchers have begun to conceptualize chronotype as multidimensional with more information possible if one conceptualizes morningness and eveningness as two, relatively independent, dimensions. This conceptualization leads to four distinguishable chronotypes (besides morning and evening types, lethargic types and high energetic types). To our knowledge, there are two measures employed by researchers based on this conceptualization of chronotype: The Lark-Owl Chronotype Indicator (LOCI; Roberts, 1998, 1999a) and the Sleep–Wake Pattern Assessment Questionnaire (SWPAQ; Putilov, 1990, 1993). For the purposes of the current investigation, we adopt the two-dimensional view of an individuals' chronotype. Of note, failing to consider these two dimensions may mask relationships of considerable practical significance, such as those currently under investigation (Roberts & Kyllonen, 1999).

4. Aims of the present study

The main aim of the present study was to synthesize findings from a number of prior investigations that examined relationships between chronotype and cognitive ability and chronotype and academic achievement. These relationships are intriguing at the very least. Hundreds of studies demonstrate moderate to high positive correlations between cognitive test performance and academic achievement (Deary, Strand, Smith, & Fernandes, 2007; Neisser et al., 1996; Ones, Viswesvaran, & Dilchert, 2005) and, as described in the introductory section of the present review, chronotype is reported to be related to both of these constructs, but in opposing directions (i.e., eveningness is positively related to cognitive test performance, but negatively to performance in school) (see e.g., Cavallera & Giudici, 2008; Roenneberg, Wirz-Justice, & Merrow, 2003; Sadeh, Gruber, & Raviv, 2003). Hence, it is not too fanciful to speculate that chronotype may attenuate or suppress correlations between intelligence and academic performance. This proposition needs to be interrogated. To achieve this main goal, we used the tool of meta-analysis, combining findings from a research corpus and examining the aggregated effect of relationships among chronotype, cognitive ability, and academic achievement.

As noted earlier in this exposition, chronotype needs to be understood as a two-dimensional construct, with the dimensions of morningness and eveningness treated as relatively independent. Hence, in the current paper we analyzed the relationship of cognitive ability and academic achievement with chronotype separately for morningness and eveningness. Thus, a series of meta-analyses that we conducted explored relationships between the following variables: morningness and cognitive ability, eveningness and cognitive ability, morningness and academic achievement, and eveningness and academic achievement. In total, four meta-analyses were conducted. Based on previous findings, we expected a positive mean correlation between morningness and academic performance, a negative mean correlation between morningness and cognitive ability, a negative mean correlation between eveningness and academic performance, and a positive mean correlation between eveningness and cognitive ability. In our analyses we focused on the population effect size (to reveal the effect across studies) and the homogeneity (to determine if the results of the several experiments are sufficiently similar to warrant their combination into an overall result).

5. Method

5.1. Study collection and coding of study characteristics

To be included in the meta-analyses studies had to meet the following criteria:

a) Studies had to be conducted or published between 1989 and 2010;
b) Participants had to be school or university students;
c) Data collection had to be carried out by trained researchers; and
d) Cognitive ability had to be assessed by standardized tests.

Specific criteria for exclusion were:

1. Lack of relevant statistical information (e.g., correlations or values that could be used to compute it);
2. Participants were from clinical samples or extreme groups; and
3. Chronotype was not assessed using a questionnaire. (While acknowledging alternative measurement approaches could be just as valid, these simply would be difficult to combine in the meta-analysis).

We conducted a thorough search for relevant studies in the following databases: PsycINFO, PsycARTICLES, Pubmed, and PSYNDEX (all databases updated last time in May 2010). We used "morningness," "eveningness," "circadian phase," "owl," "lark," "chronotype," "circadian rhythms," "diurnal preferences," and "sleep" as key words for all the searches. For the topics of cognitive ability and academic achievement these keywords were extended to include "cognitive performance," "intelligence," "school achievement," "cognitive ability," and "school." In addition, the journals "Chronobiology International," "Sleep," and "Journal of Sleep Research" were systematically scanned. The references in every research report were examined to identify other relevant studies. In addition, unpublished studies from the laboratories of the authors were taken into account.

From the papers we reviewed, 71% met the criteria for inclusion. The literature search yielded eleven studies that examined the relationship between chronotype and cognitive ability, and ten studies that investigated the relationship between chronotype and academic achievement. In addition, seven unpublished studies from the present team of authors were included (of note, the research of Roberts and Preckel was taken from separate labs and non-collaborative studies). In sum, 28 studies were reviewed. In accordance with the aforementioned criteria, eight studies were excluded from the analyses. The excluded studies as well as the respective reasons for their exclusion are presented in Appendix A.

The final meta-analyses were conducted with the following number of studies and sample sizes, respectively: morningness and cognitive ability included eleven independent samples (total $N=2177$); eveningness and cognitive ability, seven independent samples (total $N=1519$); morningness and academic achievement, thirteen independent samples (total $N=3220$); and eveningness and academic achievement, six independent samples (total $N=700$) (see Appendix B for general review).

For each sample, the following information was coded: authors, title of study, country of data collection, year of data collection and of publication, sample size, correlations of chronotype with cognitive ability and/or indicators of academic achievement, gender and age distribution, assessment tool for chronotype, cognitive ability and/or indicators of academic achievement, and reliabilities of the measures involved. If available, correlations between chronotype and cognitive ability and chronotype and academic achievement were taken directly from the publication or computed from other reported statistics. If no correlations or transformable statistics were available, authors were contacted by mail and asked to send primary data. Correlations were then computed using original data sets. Tables 1 and 2 present an overview of variables included in the analyses.

Questionnaires that were used in studies to gauge individuals' chronotype were the Lark–Owl Chronotype Indicator (LOCI; Roberts, 1998, 1999a), the Circadian Composite Scale (CCS; Smith et al., 1989), Horne and Ostberg's (1976) Morningness–Eveningness Questionnaire (MEQ), the Pupils' MEQ (PMEQ; Randler & Frech, 2006), a modified version of the School Sleep Habits Survey by Carskadon, Seifer, and Acebo (1991; see also Carskadon, Seifer, Davis, & Acebo, 1991), and a single item assessment (Meijer, 2008). In the meta-analyses presented in this paper, we combined studies that used chronotype measures based on a one-dimensional conceptualization of the construct and studies that employed a two dimensional conceptualization. Out of the two measures that use a two-dimensional approach toward the measurement of chronotype (LOCI, Roberts, 1998, 1999a; and SWPAQ, Putilov, 1990, 1993) only LOCI was used in a number of the analyzed studies. Hence, our meta-analyses for eveningness relied exclusively on studies that employed the LOCI (Roberts, 1998, 1999a). In our meta-analyses for morningness, we combined the morningness scale of the LOCI with several one-dimensional chronotype measures. Our rationale for this approach was as follows: prior studies that investigated the factor structure of chronotype measures that were based on a one-dimensional conceptualization were often not supportive of the construct's one-dimensional structure (Brown, 1993; Neubauer, 1992; Roberts & Kyllonen, 1999; Smith et al., 1989). At the same time several studies demonstrated that these instruments largely assess morningness with the eveningness dimension being poorly defined. For example, within the CCS eveningness is only presented by a single item (Roberts & Kyllonen, 1999). For the MEQ, most variance is explained by one (Neubauer, 1992) or two morningness factors (Roberts & Kyllonen, 1999). Therefore, in the current study we grouped the LOCI morningness scale with those chronotype measures that are based on a one-dimensional conceptualization, and used them to assess individuals' morningness orientation.

Intelligence measures in the meta-analysis were the Armed Services Vocational Aptitude Battery (ASVAB; U.S. Department of Defense, 1984), the Raven Standard Progressive Matrices (SPM; Raven, 1960), the Berlin Structure-of-Intelligence-Test (BIS 4; Jäger et al., 1997), the Berlin Structure-of-Intelligence-Test for the Assessment of (Gifted) Youth (BIS-HB; Jäger et al., 2006), the Structure-of-Intelligence-Test (IST 2000 R; Amthauer, Brocke, Liepmann, & Beauducel, 2001), the Culture Fair Test (CFT 20; Weiß, 1998), the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), and subscales of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955). The main measure of academic achievement examined in the meta-analysis was grade point average (GPA). Other measures of academic achievement included exam and essay results in specific courses and Tertiary Entrance Rank (a now defunct score that was obtained from subject tests in the final year of schooling to determine suitability of participants to enter Australian universities).

Data were coded independently by two of the authors. Inter-rater agreement was at least 95%. Inconsistencies were resolved by means of discussion. The final list of samples analyzed in the current study along with the coding scheme is available from the authors.

5.2. Data analysis

Computations were carried out with SPSS-16, the Meta-Win 2.0 software (Rosenberg, Adams, & Gurevitch, 2000), and the software Comprehensive Meta Analysis Version 2 (Borenstein, Hedges, Higgings, & Rothstein, 2004). Because of the relatively small sample size the computational procedure was based on a fixed effects model (Schulze & Holling, 2004).

Aims of the meta-analyses of effect sizes r were the determination of (1) the population effect size and (2) the homogeneity. First, each individual effect size r was transformed into Fisher's z. Given that all effect sizes belong to the same universe, it is assumed that each sample effect size r represents a deviation from its population effect size. Effect

Table 1
Meta-analyses of the relationship between chronotype and cognitive ability: studies, sample sizes, mean age of the samples, and scales used with their respective reliabilities.

No.	Study	N (n of females)	Mean age	Computation of r: constructs	Measure chronotype		Measure cognitive ability	
					Name	Reliability[a]	Name	Reliability[a]
1	Roberts (1997a)	359 (37)	20.17	ASVAB_AFQT × mean M/E	LOCI	M: .88; E: .82	ASVAB	.93
2	Roberts (1999b)	665 (47)	20.42	ASVAB_AFQT × mean M/E	LOCI	M: .84; E: .74	ASVAB	.93
3	Roberts (1997b)	197 (4)	20.22	ASVAB_AFQT × mean M/E	MEQ	.74	ASVAB	.93
4	Roberts and Kyllonen (1999)	359 (63)	20.20	ASVAB_AFQT × mean M/E	MEQ	.72	ASVAB	.93
5	Roberts (1999c)	76 (59)	21.13	Raven raw score × mean M/E	LOCI	M: .84; E: .82	SPM	.96
6	Wagner and Roberts (2003)	84 (74)	21.40	BIS-4-IQ × mean M/E	LOCI	M: .87; E: .84	BIS 4	.95
7	Preckel (2005)	92 (79)	21.45	First unrotated PC of processing speed (BIS-4), reasoning (BIS-4), general knowledge (IST 2000R) × mean M/E	LOCI	M: .88; E: .88	BIS-HB, IST 2000 R	BIS-HB .90 IST 2000 R .90
8	Preckel (2004a)	217 (108)	15.64	CFT 20-IQ × mean M/E	LOCI	M: .81; E: .75	CFT 20	.95
9	Preckel (2004b)	26 (11)	15.19	BIS-HB-IQ × mean morningness/eveningness	LOCI	M: .81; E: .81	BIS-HB	.94
10	Killgore and Killgore (2007)	54 (25)	23.50	WAIS-IQ × sum score M	MEQ	n.r.	WASI	.98
11	Natale et al. (2003)	48 (24)	25.04	First unrotated PC of numerical thinking and mosaic test (WAIS) × sum score M	MEQ	n.r.	WAIS	Numerical thinking .73, mosaic .80

Notes. All 11 studies were included in the meta-analysis with morningness, studies with bold numbers were also included in the meta-analysis with eveningness. n.r. = not reported. M = morningness. E = eveningness. PC = principal component of battery of tests. Abbreviations for chronotype and intelligence scales: LOCI: Lark–Owl Chronotype Indicator (Roberts, 1998), MEQ: Horne and Ostberg's (1976) Morningness–Eveningness Questionnaire, ASVAB_AFQT: general score from the Armed Services Vocational Aptitude Battery (United States Department of Defense, 1984), SPM: Raven Standard Progressive Matrices (Raven, 1960), BIS 4: Berlin Structure-of-Intelligence-Test (Jäger, Süß, & Beauducel, 1997), BIS-HB: Berlin Structure-of-Intelligence-Test for the Assessment of (Gifted) Youth (Jäger et al., 2006), IST 2000 R: Structure-of-Intelligence-Test (Amthauer et al., 2001), CFT 20: Culture Fair Test (Weiß, 1998), WASI: Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), WAIS: Wechsler Adult Intelligence Scale (Wechsler, 1955).
[a] Cronbach's α.

sizes of studies with large sample sizes should deviate less from the population effect size than small N effect sizes. Therefore, in combining all effect sizes, rs were weighted more in large N studies. The weighted average of all correlations was taken as estimate of the population effect size. Note that we did not control for measurement error because reliability coefficients of the chronotype and cognitive ability measures were predominantly adequate. In addition, accounting for measurement errors might create an illusionary situation.

In total, four meta-analyses were conducted (morningness by cognitive ability; eveningness by cognitive ability; morningness by academic achievement; eveningness by academic achievement). For each of these individual meta-analyses, we report the number of studies (k), total N, the estimated average correlation in the population ($\hat{\mu}_\rho$), its p-value, and its 95% confidence interval (CI). Homogeneity of effects was tested by calculating the total heterogeneity of the sample (Q_T) using the formula by Hedges and Olkin (1985) and testing it against a χ^2-

Table 2
Meta-analyses on the relationship between chronotype and academic achievement: studies, sample sizes, mean age of the samples, and scales used with their respective reliabilities.

No.	Study	N (n of females)	Mean age	Computation of r: Constructs	Measure of chronotype		Operationalization academic achievement
					Name	Reliability[a]	
5	Roberts (1999c)	67 (55)	19.24	Tertiary Entrance Rank × mean M/E	LOCI	M: .84; E: .81	Tertiary Entrance Rank
6	Wagner and Roberts (2003)	75 (66)	21.40	Grade Math × sum score M/E	LOCI	M: .87; E: .84	Grade Math
7	Preckel (2005)	91 (78)	21.43	GPA × mean M/E, correlation inverted	LOCI	M: .88; E: .81	GPA (high school graduation)
8	Preckel (2004a)	266 (127)	15.59	GPA × mean M/E, correlation inverted	LOCI	M: .81; E: .81	GPA (4 subjects: Math, German, Physics, English)
12	Roberts and Krause (2001)	82 (64)	18.70	Tertiary Entrance Rank × mean M/E	LOCI	M: .83; E: .81	Tertiary Entrance Rank
13	Roberts (2002)	119 (88)	21.00	PC × mean M/E	LOCI	M: .85; E: .81	First unrotated PC of final exam score and essay mark
14	Giannotti et al. (2002)	946 (60% reported)	n.r. (range 14–16)	Self-estimates × M/E score	School Sleep Habit Survey	.73	Self-estimates of school achievement
15	Guthrie et al. (1995)	454 (218)	22.70	GPA × M score	CSS	.90	GPA (semester Record)
16	Kirby and Kirby (2006)	189 (n.r.)	n.r.	GPA × M score	CSS	.90	GPA (semester Record)
17	Medeiros et al. (2001)	35 (15)	20.54	Exam grade × M score	MEQ	n.r.	Exam grade in one medical test
18	Meijer (2008)	424 (214)	11.00	GPA × chronotype item	One item measure	–	GPA (6 subjects, self reported grades)
19	Randler and Frech (2006)	132 (114)	21.38	GPA × M score	PMEQ	n.r.	GPA (high school graduation)
20	Smith et al. (1989)	485 (n.r.)	n.r.	GPA × M score	CSS	.87	GPA

Notes. All 13 studies were included in the meta-analysis with morningness, studies with bold numbers were also included in the meta-analysis with eveningness. n.r. = not reported. M = morningness. E = eveningness. PC = first principal component of GPA of a variety of school subjects. GPA = grade point average. Abbreviations for chronotype scales: LOCI: Lark–Owl Chronotype Indicator (Roberts, 1998), modified version of the School Sleep Habits Survey by Carskadon, Seifer, and Acebo (1991; see also Carskadon, Seifer, Davis, & Acebo, 1991), CSS: Circadian Composite Scale (Smith et al., 1989), MEQ: Horne and Ostberg's (1976) Morningness–Eveningness Questionnaire, PMEQ: Pupils' MEQ (Randler & Frech, 2006).
[a] Cronbach's α.

distribution with $k-1$ degrees of freedom. A significant Q_T indicates that the variance among effect sizes is greater than expected by sampling error. In addition, the percentage of the total variability in the observed correlation coefficients due to heterogeneity (I^2) was computed. Values of I^2 equal to 0 indicate absence of heterogeneity.

Moreover, data were examined for the presence of publication bias which occurs whenever the results obtained from published studies are not representative of all the research that has been conducted on the respective topic. To address the file-drawer problem, the fail-safe *N* was calculated according to a formula of Rosenthal (1984). This fail-safe *N* informs about the number of non-significant, unpublished, or missing studies that would need to be added to the meta-analysis in order to change the results from significance to non-significance. Publication bias can also take the form of an over- or underrepresentation of particular findings due to their statistical significance. If this form of publication bias is absent one would expect a more or less symmetric (inverted) funnel when plotting the observed correlations against their corresponding sample sizes (Sterne & Egger, 2001). In addition, the presence of publication bias was investigated by correlating effects sizes with sample sizes or variances using Spearman rank-order correlations.

Finally, age was included in the analyses as a possible moderator of the relationship between chronotype and cognitive ability or academic achievement. This is justified by research findings showing that age is an important factor of developmental changes in morningness/eveningness. In addition, the adaptiveness of circadian preferences may depend on demands associated with different stages in the lifecycle. To test for a possible moderator effect of age, a mixed-effects model was applied in which the amount of residual heterogeneity was estimated with the method of moments estimator on the basis of weighted least squares (Raudenbush, 1994). Results are expressed as estimated regression coefficients ($\hat{\beta}$). A significant regression coefficient implies that the moderating variable explains a significant proportion of the variation in effect sizes.

6. Results

6.1. Relationship between chronotype (morningness and eveningness) and cognitive ability

Table 3 presents correlation coefficients between morningness or eveningness and cognitive ability from single studies. Meta-analytic findings are provided in Table 4. The analysis of the relationship between morningness and cognitive ability revealed a significant and homogeneous but small negative population effect ($\hat{\mu}\rho = -.042$, $p < .05$). The analyses of correlations between eveningness and cognitive ability produced a small positive population effect that also reached significance ($\hat{\mu}\rho = .075$, $p < .01$). The test of homogeneity pointed to a heterogeneous effect. Although the mean effect size was significant, the small fail-safe *N* (7) indicated that this finding should be treated with caution.

For both meta-analyses there was no significant publication bias. None of the regression tests for funnel plot asymmetry was significant (morningness: $t = .209$, $df = 9$, $p_{(2\text{-tailed})} = .839$; eveningness: $t = .218$, $df = 5$, $p_{(2\text{-tailed})} = .836$) and effect sizes did not correlate with sample sizes (morningness: $r = .114$, $p = .739$; eveningness: $r = .179$, $p = .702$) or variances (morningness: $r = -.114$, $p = .739$; eveningness: $r = -.179$, $p = .702$). However, for both meta-analyses the fail-safe *N* did not exceed the critical value of $5 \times k + 10$ (Rustenbach, 2003), that is 65 for the meta-analysis with morningness and 45 for the meta-analysis with eveningness.

Age as moderator variable. The effect of age on the correlation between morningness and cognitive ability was not significant ($\hat{\beta} = -.02$; $p = .080$; all 11 studies). However, the effect of age on the correlation between eveningness and cognitive ability was significant ($\hat{\beta} = .04$; $p = .004$; all 7 studies). That is, some part of the heterogeneity in the correlations could be attributed to a varying age within the samples. As indicated by the positive regression coefficient, with increasing age of the sample the correlation between eveningness and cognitive ability also increased.

6.2. Relationship between chronotype (morningness and eveningness) and academic achievement

The correlations between morningness or eveningness and academic achievement from single studies are presented in Table 3. Meta-analytic findings are summarized in Table 4. Both morningness and eveningness showed significant correlations with academic achievement. Both population effects turned out to be small but homogenous. Thus, morningness was positively related to academic achievement ($\hat{\mu}\rho = .156$, $p < .001$). The fail-safe *N* for the relation of morningness and academic achievement significantly exceeded the critical value of 75 indicating a reliable effect. Eveningness, by contrast, was negatively related to academic achievement

Table 3
Correlations between chronotype and cognitive ability or academic achievement in single studies.

No.	Study	*N*	Cognitive ability		Academic achievement	
			Morningness	Eveningness	Morningness	Eveningness
1	Roberts (1997a)	359	.019	.112		
2	Roberts (1999b)	665	−.058	.087		
3	Roberts (1997b)	197	−.134			
4	Roberts and Kyllonen (1999)	359	−.075			
5	Roberts (1999c)	76	.063	.016	.229	.002
6	Wagner and Roberts (2003)	84	−.010	.280	.190	−.170
7	Preckel (2005)	92	−.047	.131	.182	−.200
8	Preckel (2004a)	217	.032	−.116	.064	−.160
9	Preckel (2004b)	26	.183	.121		
10	Killgore and Killgore (2007)	54	−.190			
11	Natale et al. (2003)	48	−.163			
12	Roberts and Krause (2001)	82			.156	−.101
13	Roberts (2002)	119			.041	−.139
14	Giannotti et al. (2002)	946			.184	
15	Guthrie et al. (1995)	454			.120	
16	Kirby and Kirby (2006)	189			.317	
17	Medeiros et al. (2001)	35			.205	
18	Meijer (2008)	424			.059	
19	Randler and Frech (2006)	132			.230	
20	Smith et al. (1989)	485			.190	

Table 4
2×2 Meta-analysis of correlation coefficients between chronotype (morningness and eveningness) and cognitive ability or academic achievement.

Chronotype	Cognitive ability	Academic achievement
Morningness		
$\hat{\mu}_\rho$ (fixed effects)	−.042	.156
Total *N* (k)	2177 (11)	3220 (13)
p	.049	.000
CI	(−.085; −.000)	(.123; .189)
Q_T (df)	8.634 (10), *p* = .567	16.702 (12), *p* = .161
I^2	.000	28.152
Fail-safe *N*	0	224
Eveningness		
$\hat{\mu}_\rho$ (fixed effects)	.075	−.141
Total *N* (k)	1519 (7)	700 (6)
p	.004	.000
CI	(.024; .125)	(−.214; −.067)
Q_T (df)	12.703 (6), *p* = .048	1.945 (5), *p* = .857
I^2	52.767	.000
Fail-safe *N*	7	13

($\hat{\mu}\rho = -.141$, $p < .001$). Although this effect was significant and homogenous the fail-safe *N* was found to be rather small (13 with a critical value of 40).

For both meta-analyses, no significant publication bias was found. The regression tests for funnel plot asymmetry were not significant (morningness: $t = .347$, df = 11, $p_{(2\text{-tailed})} = .735$; eveningness: $t = .976$, df = 4, $p_{(2\text{-tailed})} = .384$) and effect sizes did not correlate with sample sizes (morningness: $r = .049$, $p = .873$; eveningness: $r = -.600$, $p = .208$) or variances (morningness: $r = -.049$, $p = .873$; eveningness: $r = .600$, $p = .208$). For the meta-analysis with morningness the fail-safe *N* exceeded the critical value 75, but not for the meta-analysis with eveningness.

Age as moderator variable. The effect of age on the correlation between morningness and academic achievement could be investigated for ten studies (for three studies of the original meta-analysis there was no information on age; see Table 2). Meta-analytic results for these ten studies are reported in Appendix C. Age had no moderating effect on the correlation between morningness and academic achievement ($\hat{\beta}$ = .008; $p = .125$). Similarly, age did not moderate the correlation between eveningness and academic achievement ($\hat{\beta} = .000$; $p = .987$; all 6 studies).

7. Discussion

The aim of the present study was to examine the aggregated effect of relationships among chronotype, cognitive ability, and academic achievement by means of meta-analysis. We adopted a two-dimensional view of chronotype, which differentiates morningness and eveningness dimensions. In four meta-analyses, we investigated the relationship between morningness and cognitive ability, eveningness and cognitive ability, morningness and academic achievement, and eveningness and academic achievement. In all four cases, the aggregated correlations between chronotype and cognitive ability as well as chronotype and academic achievement were found to be significant. All aggregated correlations where of small effect size (<.30; Cohen, 1992), which is not an uncommon finding in meta-analyses (Hattie, 2008; Lipsey & Wilson, 1993). According to our findings, chronotype seems to be systematically related to cognitive ability and academic achievement and the direction of the relationship between chronotype and academic achievement seems to be the reverse of that observed between chronotype and cognitive ability.

Eveningness was shown to be positively (albeit weakly) correlated with an individuals' cognitive ability. Conversely, morningness had a weak but negative relationship with cognitive ability. Because of small effect sizes and the small fail-safe *N*, these relationships have to be interpreted with caution, but certainly deserve careful consideration. For eveningness, all single correlations were positive with only one exception (Preckel, 2004a). The latter finding may be attributable to the young age of the participants of this study ($M = 15.64$), with mean age of participants in all other studies falling into 20 to 25 years of age range. This interpretation is supported by the findings of our moderator analysis: with increased age, the correlation between eveningness and cognitive ability increased. However, because of the small number of studies and the limited age range of participants in studies herein reported, these results should be replicated on heterogeneous samples.

For morningness, in the different studies there were both positive and negative correlations with cognitive ability independent of the age of the sample. The effect size of the aggregated correlation was close to zero (i.e., morningness explained only .02% of the variability in cognitive test performance).

The relationship between chronotype and cognitive ability is interpretable in light of findings that come from various domains of inquiry. One line of thinking suggests that evening types are more intelligent because of training effects in everyday life. Evening types may have difficulty adjusting to the universal schedule of academic institutions that are generally characterized by the early start of the day. This contingency may result in a number of problems (discussed later in this section). At the same time, the frequent need to overcome the inconvenience of everyday life might lead evening types to develop higher problem solving capabilities. At the same time, it is not implausible to assume that more intelligent people use unusual times to carry out their work or study (the evening or night hours) to protect themselves from distractions thus explaining the superior cognitive performance of evening types. Although this proposition might also be applied to individuals with extreme morningness, generally a focus on eveningness is consistent with an evolutionary psychology perspective and the current findings.

For example, Roberts and Kyllonen (1999) state that the majority of models of cognitive ability emphasize the critical importance of individuals' ability to adapt to their environment. Such adaptability is characteristic of individuals with high intelligence (e.g., Sternberg, 1985). Further, Roberts and Kyllonen (1999) refer the reader to the classic study by Richter (1977) that argued that control of fire for lighting and warmth radically changed human activity and enhanced the adaptability of humans beyond that of other animals. Following this logic, it is safe to speculate that those humans who were able to adapt to evening schedules were among the fittest. A similar explanation was presented by Kanazawa and Perina (2009) in their “Savanna-IQ interaction hypothesis”. The researchers speculated that intelligent individuals tended to flourish on tasks that diverged considerably from the activities that humans had undertaken throughout their evolutionary history. The evolutionary new task to engage in an activity at night was facilitated by artificial lighting, which in turn demanded intelligence. Even so, it is worth reiterating that our effect sizes were small and explanations for these contingencies are thus rather speculative.

Correlations between morningness, eveningness, and academic achievement also reached significance. However, the direction of relationships was opposite to that observed between chronotype and cognitive ability. Across all studies, eveningness was found to be negatively related to academic achievement, whereas morningness correlated positively with academic achievement. These relationships were found to be independent of the age of the sample. That is, morningness was adaptive and eveningness was maladaptive for academic achievement within school and university settings alike. There are several possible explanations for this series of findings. One involves a synchrony effect which states that people show better performance at times that match their individual preferences for the time of day. Synchrony effects could be found for a number of school relevant tasks such as attention and memory (e.g., Hasher, Goldstein, & May, 2005; Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; May, 1999; Yoon, May, Goldstein, & Hasher, 2000). However, other researchers reported that time of day did not affect cognitive performance (e.g., Song & Stough, 2000). An alternative explanation focuses on sleep deprivation as a relevant factor for understanding the negative relation between eveningness and academic achievement. Due to an early start to the school day, eveningness-oriented persons are at risk for sleep deficits (e.g., Andershed, 2005; Carskadon et al., 1998). Quality and quantity of sleep are positively related to academic achievement (Meijer, 2008; Meijer, Habekothé, & van Den Wittenboer, 2000). Because of sleep deficit, evening-oriented students may show higher levels of day time tiredness and a higher likelihood of falling asleep (or zoning out) during lessons (Gau et al., 2004; Gau & Soong, 2003). Thus, sleep deprivation might lead to impaired learning and performance. In addition, some studies suggest that behavioral problems are more common in poor sleepers than in their control peers (Sadeh et al., 2003). Thus, a third possible explanation might involve a number of confounding factors, such as behavioral problems. Persons with proclivity towards eveningness appear to be more likely to show some characteristics that are negatively related to scholastic achievement such as lower levels of conscientiousness (Tsaousis, 2010), higher levels of depression and anxiety (Andershed, 2005; Gau et al., 2004), or a negative attitude towards school (Andershed, 2005; Stattin & Kerr, 1999).

7.1. Limitations

Before discussing future research and the educational importance and applicability of the results, we would like to point out some limitations of our study. First, the number of published studies is relatively small and there is a substantial amount of unpublished data sets included in the current meta-analyses. Moreover, the studies aggregated in the current report used a wide range of measures of chronotype, cognitive ability, and academic achievement. Thus, it is all the more noteworthy that despite of this heterogeneity, three of our four meta-analyses revealed homogeneous effects.

In addition, the age of the participants in studies herein analyzed was rather homogeneous, with means ranging from 15 to 25 years of age. Age was found to have a moderating effect on the relationship between eveningness and cognitive ability: with increasing age, correlations increased also. Therefore, studies should be conducted to include younger and older participants. Gender may also be examined as a potential moderator. For the current study, no information on single correlations for the gender variable was available. Future studies should compute and report separate correlations between chronotype and cognitive ability and chronotype and achievement for gender so that they can be used in future meta-analyses.

Another limitation of our study was that all of the data on the eveningness dimension came from investigations that used only one instrument – the LOCI. Although a range of measures would protect against mono-method biases, the use of a sole measure may have made the findings more robust. Prior studies that investigated the factorial structure of the LOCI as well as relationships among the LOCI scales, other-reports of chronotype, biodata and sleep diaries attest to the adequate construct validity of the eveningness scale of LOCI (e.g., Glaser, 2005; Preckel, Lipnevich, Boehme, et al., 2011; Roberts, 1998).

7.2. Future directions and implications

In an attempt to bring these findings together, consider the following results again. People with an evening orientation tend to be, on average, more intelligent, but they do not do as well in school as their morning-oriented counterparts. The reverse is true for individuals with a preference for morningness: they tend to do better in school, yet their cognitive ability tends to be, on average, lower. Since intelligence and academic performance are consistently found to be positively related (Deary et al., 2007; Neisser et al., 1996; Ones et al., 2005) we can surmise that chronotype may serve as a naturally occurring attenuating variable. Future investigations should examine, in concert, relationships between chronotype, achievement, and cognitive ability on the same (preferably large) samples. Additionally, conscientiousness has been shown to be a strong predictor of achievement. Future inquiries may explore this personality trait in conjunction with all the variables listed above. Clearly, chronotype is linked to both performance and cognitive ability, and this relationship should be examined.

The practical implications of the findings of the four meta-analyses reported in the current paper are as wide-ranging as diurnal preference factors themselves are pervasive. In educational institutions, changes in students' schedule may result in better achievement. Initial attempts to push start of the school day until later hours resulted in significant academic gains (Wahlstrom, 2002). These gains might be especially prevalent for students with a strong preference for evening activities. We realize that this is a radical proposition, and more research is needed to bolster the argument for such a change. In addition to a later start to the school day, chronopsychological aspects could be integrated into the organization of school schedules (planning of time tables and testing times, adjustment of teaching methods; Klein, 2004). In the future, experimental investigations should be designed to examine whether students with an eveningness orientation benefit from later mornings, and whether their achievement and, possibly, general sense of well-being might be enhanced. If such studies find positive results, policy changes appear justified.

Appendix A

Table A.1
List of studies excluded from the meta-analyses.

Study	Reasons for exclusion
Andershed, A.-K. (2005). *In Sync with Adolescence: The Role of Morningness–Eveningness in Adolescence.* Boston, MA: Springer Science & Business Media Inc.	Achievement was assessed by a certain teacher rating that was not comparable with the other measures of academic achievement.
Giannotti, F., Cortesi, F., & Ottaviano, S. (1997). Sleep pattern, daytime functioning and school performance in adolescence: preliminary data on an Italian representative sample. *Sleep Research, 26*. Retrieved March 20, 2009, from http://www.websciences.org/cftemplate/NAPS/archives/indiv.cfm?ID=19979003.	For this study it could not be clarified if the sample was a subsample of the one in Giannotti et al. (2002), the latter being included in the meta-analysis.

(continued on next page)

Table A.1 (*continued*)

Study	Reasons for exclusion
Goldstein, D., Hahn, C. S., Hasher, L., Wiprzycka, U. J., & Zelazo, P. D. (2007). Time of day, intellectual performance, and behavioral problems in Morning versus Evening type adolescents: Is there a synchrony effect? *Personality and Individual Differences, 42,* 431–440.	This study investigated a very selective sample (only students with very good or very poor grades).
Kanazawa, S., & Perina, K. (2009). Why night owls are more intelligent. *Personality and Individual Differences, 47,* 685–690.	In this study chronotype was operationalized indirectly by asking for the time participants go to bed or get up.
Song, J., & Stough, C. (2000). The relationship between morningness–eveningness, time-of-day, speed of information processing, and intelligence. *Personality and Individual Differences, 29,* 1179–1190.	Relevant statistical information was missing which could not be retained by contacting the authors.
Wagener, D., Baumann, M., & Sirtl, A. (2005). *Intelligenz und Chronizität. Bericht des Experimentalpsychologisches Praktikums* [Intelligence and chronotype: Report from research class in experimental psychology]. University of Mannheim. Retrieved October 19, 2008, from http://www.uni-mannheim.de/fakul/psycho/irtel/lehre/expra/w05/Wagener_Baumann.pdf.	Data collection was not conducted by professionals but by students in a university course.
Wagener, D., Hurst, M., & Ravlie, S. (2003). *Chronotyp und Intelligenz & Validierung des LOCI. Bericht des Experimentalpsychologisches Praktikums* [Chronotype and intelligence & validity studies for the LOCI: Report from research class in experimental psychology]. University of Mannheim. Retrieved October 19, 2008, from http://www.uni-mannheim.de/fakul/psycho/irtel/lehre/expra/w03/ hurst.pdf.	
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Appendix B

Table B.1
Outline of studies examined in the meta-analyses.

No.	Study	M and CA	E and CA	M and AA	E and AA	Published
1	Roberts (1997a)	x	x			
2	Roberts (1999b)	x	x			
3	Roberts (1997b)	x				
4	Roberts and Kyllonen (1999)	x				x
5	Roberts (1999c)	x	x	x	x	
6	Wagner and Roberts (2003)	x	x	x	x	x
7	Preckel (2005)	x	x	x	x	
8	Preckel (2004a)	x	x	x*	x*	
9	Preckel (2004b)	x	x	x*	x*	
10	Killgore and Killgore (2007)	x				x
11	Natale et al. (2003)	x				x
12	Roberts and Krause (2001)			x	x	
13	Roberts (2002)			x	x	
14	Giannotti et al. (2002)			x		x
15	Guthrie et al. (1995)			x		x
16	Kirby and Kirby (2006)			x		x
17	Medeiros et al. (2001)			x		x
18	Meijer (2008)			x		x
19	Randler and Frech (2006)			x		x
20	Smith et al. (1989)			x		x

Notes. M = morningness. E = eveningness. CA = cognitive ability. AA = academic achievement.
ETS = Educational Testing Service. USAF = United States Airforce. * = These studies are combined into one for the analysis of the relation between chronotype and academic achievement.

Appendix C

Table C.1
Meta-analysis of correlation coefficients between morningness and academic achievement for the ten studies for which information on mean age of the samples was available.

Chronotype	Academic achievement
Morningness	
$\hat{\mu}_\rho$ (fixed effects)	.113
Total *N* (k)	1745 (10)
p	.000
CI	(.066; .160)
Q_T (df)	6.639 (9), $p = .675$
I^2	.000
Fail-safe *N*	55

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[1] Note: Studies included into the meta-analyses are marked by an asterisk.

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