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Chronotype and Time of Day do not Influence Mathematical Achievement in Standardised Tests, but Impact on Affect – Results from a Field Experiment

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ABSTRACT

Morning chronotypes have a higher academic achievement. In addition, laboratory studies showed synchrony effects between chronotype and test scores with morning people having a higher test score when tested in the morning and that evening people having higher test score in the afternoon. Field experiments are scarce. We developed a cross-over design and applied two different tests at two different time points during school days. A total of 90 (47 boys, 43 girls) pupils from four different 9th grade classrooms. We used the Composite Scale of Morningness, the Positive and Negative Affect Schedule (PANAS) and two parallelized mathematics tests that had the same content and the same scoring (test A, test B). There was no general effect of time of day (test scores: morning 12.21 ± 2.41; noon: 11.89 ± 2.14; t=1.105; p=0.272). There were no correlations between test scores and the continuous CSM scores, nor were there differences between chronotype classifications, and thus, no synchrony effect. Positive Affect increased between morning and noon in all three chronotypes. Morning types had a higher positive affect than evening types during the morning (F=7.974, p=0.001) and at noon (F= 4.561, p=0.013; Figure 2). Negative Affect remained stable in morning types and evening types but changed significantly in neither types. Negative Affect was not different between the chronotypes (morning: F=0.063, p=0.965; noon: F=0.756, p=0.473). Negative Affect was positively related to test scores in mathematics but only in the morning (morning test: r=0.25, p=0.02; noon test: r=-0.032, p=0.775). We strongly emphasize that there should be more experimental field studies in schools to shed light on this topic before making suggestions for teaching and learning

Keywords:
Circadian preference, chronotype, academic achievement, mathematical achievement, experiment, synchrony effect

Introduction

Chronotype and Achievement

Studies on educational achievement and performance have shown that morning oriented students or early chronotypes have a higher academic achievement, both in university and at school (Preckel et al. 2011, Tonetti et al. 2015). The effects are higher at school compared to university, probably because university students may exert some control over their daily schedule and their start times (Tonetti et al., 2015). Another aspect may be that adolescents in middle school classrooms are amongst the latest chronotypes (Randler, 2011). Most studies rely on some kind of trait or long time measures, such as academic grades, which has the benefit that these are variables with long assessment periods (usually over some months up to a whole school year). In the first works on these topics, bivariate correlations and simple models have been carried out (Randler & Frech, 2006, 2009); but after having established the correlational evidence, increasingly complex assessments of other trait variables have added to our understanding of the relationship between

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chronotype and academic achievement (Díaz-Morales & Escribano, 2013; Preckel et al. 2013, Ruffing et al. 2015, Arbabi et al. 2015, Rahafar et al., 2016). For example, Preckel et al. (2013) showed that evening orientation was still a significant predictor for worse overall grade point average, even when controlling for cognitive ability, conscientiousness, need for cognition, achievement motivation, and gender. Ruffing et al. (2015) reported that personality (openness, agreeableness, conscientiousness) and morningness were significant predictors for elaboration learning strategies. In addition, learning discipline was significantly predicted by conscientiousness and morningness. Arbabi et al. (2015), working with primary school pupils, showed that conscientiousness, motivation, younger age and an earlier midpoint of sleep were positively related to good grades. Díaz-Morales and Escribano (2013) emphasized the role of inductive reasoning. These studies suggest that the influence of morningness-eveningness on school achievement is still significant, above and beyond other factors that are related to school achievement. However, the effect sizes decline with an increasing number of additional variables (which is a well-known statistical effect).

Synchrony Effect

In addition, some laboratory studies showed synchrony effects between chronotype and test scores. These synchrony effects mean that morning people have a higher test score when tested in the morning and that evening people have a higher test score when being tested in the afternoon (Hahn et al., 2012). These authors demonstrated higher test scores when adolescents were tested at their optimal time of day. However, the tests were based on executive functions, which are important aspects of cognition and related to school life, but the tests were not comparable to usual works at the school (like class tests, other kinds of assessment). Goldstein et al. (2007) also reported a synchrony effect of fluid intelligence, with morning types scoring higher in the morning and evening types scoring higher in the afternoon. These valuable experimental lab studies add to our knowledge and complete the picture in combination with the evidence from large scale observational studies.

Field Studies

Field studies in educational settings, however, are scarce. Vollmer et al. (2013) used an attention test where 1977 adolescents aged 10–17 participated in a study and provided information on their chronotype as well as their gradings. An attention test was also carried out. Earlier chronotypes, or morning types, had a higher attention during the class. The morning types also were slower and more considerate when doing the tests and the evening types were faster and showed a more impulsive strategy (Vollmer et al., 2013). Özturk (2014) went one step further and used an experiment that tested the synchrony effect in real classrooms. He used a reading comprehension test in fifth grade students and applied the first test at 9:00 and the second at 13:15. Tests were delayed by one month; however, he did not use a crossover design with half of the participants receiving the first test at noon and half in the morning. Also, one may consider 9:00 as too late for such an assessment.

Emotional Aspects

Emotions may play a crucial role in academic achievement (Gläser-Zikuda et al., 2005). Positive emotions, such as interest or well-being, are related to a higher educational outcome, while negative emotions, such as anger and anxiety, are related to worse performance. Some studies already assessed the relationship between chronotype and emotions during school settings. Randler et al. (2014) assessed mood and emotions with 40 adjectives during the very first lesson and found that negative mood was higher in evening types and positive mood was higher in morning types. In a follow-up study, Randler and Weber (2015) showed that positive affect was higher in the last lesson of a school compared to the first one. No changes in negative affect could be found. In addition, morning types had a higher positive affect during the whole school day compared to evening types. Negative affect showed no changes during the day and there were no differences between chronotypes. In a Spanish sample, 655 adolescents reported their current pleasantness three times during school days. Similar to our study, mood increased throughout the school day. Morning types showed better mood compared to other chronotypes (Díaz-Morales, Escribano, & Jankowski, 2015). Therefore, assessing mood and/or affect in such experimental settings is important, because it may be a relevant covariate.

Research Aims

Studies about field experiments are scarce (Özturk 2014). We developed a cross-over design to apply two different tests at two different time points during school days. We chose ninth graders because pupils of this age group are amongst the highest evening oriented people (Randler 2011), thus we expected strong effects. Further, we aimed for the very first lesson for the first test (7:45) to capture the most demanding situation (cf. Özturk 2014). Also, we choose two parallelized tests in our study to avoid memory effects when employing the same achievement test twice. When assessing morningness-eveningness, the use of a full scale is always advisable (in this case, the CSM), however, for an assessment of a standardized test, one may also analyze the item (item 8 of the CSM) that deals with the preferred time for a class test. Our research question focus are

i) Is there a general circadian effect (comparing morning vs. noon)?
ii) Are there differential effects (or synchrony effects)?
iii) Do emotions (as measured by PANAS) show a circadian and synchrony effect?

Methods

Participants and Procedure

A total of 90 pupils from four different 9th grade classrooms from the same school participated in this study. There were 47 boys and 43 girls. The school chosen was a convenience sample because one of the authors (KB) had school contacts. The pupils were on average 14.65 ± 0.65 (mean ± SD) years old (range 13-16 years). The data were collected from Realschule (middle stratification level in Germany).

Measures

Circadian preference. The German version of the Composite Scale of Morningness (CSM) was used. This inventory consists of 13 items and measures preferred bed and wake times and morning affect, as well as time preferred for peak performance (e.g., How alert are you during the first half hour after awakening; When would you prefer to get up/go to bed when you are entirely free to choose). Ten items are coded from 1-4, and three items are coded from 1-5, summing up to a minimum score of 13 points and a maximum score of 55 points. High scores indicate high morningness (Tonetti, Adan, Di Milia, Randler, & Natale, 2015). Cronbach's alpha was 0.837 showing a high internal consistency. In addition to the continuous score, we split the sample into 20/60/20 groups with the lowest 20% declared evening types; the highest 20% declared morning types (with 18 participants each). Those left were grouped as neither types.

Mathematical achievement. We used two parallelized mathematics tests that had the same content and the same scoring (test A, test B). The tests were taken from the VERA comparative study on mathematical achievement. These standardized achievement tests have been parallelized and tested for validity, reliability and objectivity and are used to assess mathematical achievement in broad-scale, nationwide studies in Germany (Heller & Hany, 2002; Pant, Stanat, Schroeders, Roppelt, Siegle & Pöhlmann; 2012). To avoid that the pupils may be prepared for the mathematical test, they were not informed about the test before testing. Also, separating walls were setup in order to avoid that the pupils extract and copy information from their neighbors. The mathematical test was exactly timed for 10 minutes and the pupils had to hand the tests after this time to the experimenter.

Positive and negative affect schedule. This is based on the PANAS (Watson et al. 1998), and has been revised by Thompson (2007) to a short form. The PANAS scales have been widely used to investigate changes in positive or negative affect states (Rossi & Pourtois 2012). The scale was adapted in Germany by Krohne et al. (1996). The original version consists of 20 items, 10 for each construct. In this study, we used the short form (Thompson, 2007). The German items from Krohne et al. (1996) were already used by Randler and Weber (2014). The scale is composed of 10 Likert-type items on a 5-point Likert-type scale (ranging from 1 = never, to 5 = always). It contains 5 items to measure Positive Affect and 5 items to measure Negative Affect. The Cronbach's α were acceptable (PA .75/.81; NA .57/.62). The PANAS was applied two times, always immediately prior to the mathematical achievement test.

Experimental Protocol

The study followed a cross-over design (see Table 1) to correct for the effects of multiple testing (Quinn & McKeough, 2002). For example, if a test is repeated twice, test scores usually increase and are higher in the second test round. Therefore, half of the participants received their first test in the morning (morning group; 7:45) and the other half during noon (noon group: 12:15). The second test was applied during the noon for the morning group and during the morning for the noon group. The time was chosen because school ends around 13:00. Only one test per pupil was applied per day, so no pupil was tested twice during the same day. Half of the participants received test A first, the other half test B. 47 tests were applied in the morning and 43 tests at noon (Table 1). This was because of absence/illness which usual happens in natural school field settings. Tests were carried out in March 2015 at 5th, 9th, 12th, 16th, 18th, 23rd, and 27th. There were difference between the testing times between 3 and 11 days between the 2 tests. This is owed to the fact that it is a field study in a natural setting.

Table 1. Overview over the cross-over experimental design of the study.

Class	Day 1	Test	Day 2	Test
1	morning	A	noon	B
2	morning	B	noon	A
3	noon	A	morning	B
4	noon	B	morning	A

Data Analysis

SPSS (IBM, Version 23) was used for statistical calculation. We did bivariate correlations to assess relationships, and performed t-tests and an ANOVA to analyze differences.

Results

There were no differences between the two different mathematical test, i.e., both can be considered as equal concerning their difficulty (mean scores: test A: 11.82 ± 2.51; test B: 12.29 ± 2.00; t=-1.652, p=0.103). This was expected because the tests have been parallelized. Further, there was no general effect of time of day and, thus, no differences between the two testing times (test scores: morning 12.21 ± 2.41; noon: 11.89 ± 2.14; t=1.105; p=0.272). In addition, there were no correlations between test scores on the one side and the continuous CSM scores (Table 2).

Table 2. Correlations between the raw CSM scores and different testing times and across the different tests.

		CSM score
Math-Test_A	Pearson's correlation	-.014
	Significance (two-sided)	.902
Math-Test_B	Pearson's correlation	-.134
	Significance (two-sided)	.227
Morning test	Pearson's correlation	-.056
	Significance (two-sided)	.614
Noon test	Pearson's correlation	-.084
	Significance (two-sided)	.449

Based on the chronotype classification of evening types, morning types and neither types, we found no differences between the groups in test times, and thus, no synchrony effect (morning test: Anova F=0.13, p=0.987; noon test: F=0.22, p=0.978). Concerning item 8 (preference for a given time of day to do a class test), there was no correlation between the preferred time for a class test and test outcomes (morning test: r=-0.045; p=0.687; noon test: r=-0.054, p=0.630).

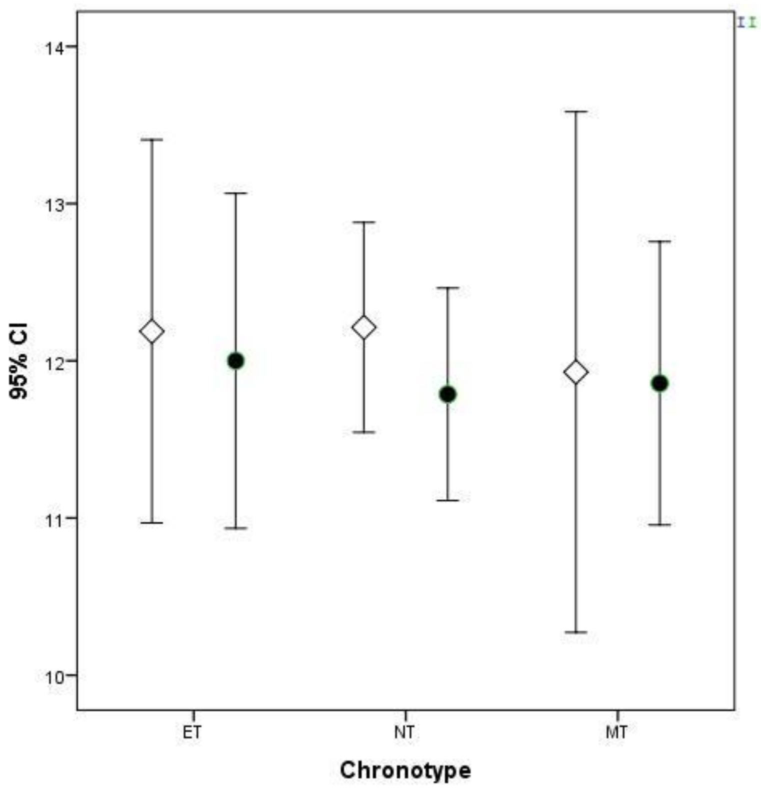

Figure 1. Mean test scores across both testing times (morning, noon) and chronotypes (MT=morning types, NT = neither types, ET = evening types). Rhombs = morning tests, circles = noon test.

Positive Affect increased between morning and noon in all three chronotypes (Table 3). Negative Affect remained stable in morning types and evening types but changed significantly in neither types.

Table 3. Means of Positive and Negative Affect in the morning and at noon across the three chronotypes.

Evening types	Mean	N	SD	T	df	Sig.
PANAS_PA_morning	2.23	16	0.68	-5.18	15	<0.01
PANAS_PA_noon	2.75	16	0.63			
PANAS_NA_morning	1.34	16	0.43	-1.58	15	0.135
PANAS_NA_noon	1.51	16	0.56			
Neither types						
PANAS_PA_morning	2.65	47	0.74	-4.82	46	<0.01
PANAS_PA_noon	3.25	47	0.70			
PANAS_NA_morning	1.26	47	0.44	-3.47	46	0.001
PANAS_NA_noon	1.46	47	0.57			
Morning types						
PANAS_PA_morning	3.24	14	0.55	-2.69	13	0.018
PANAS_PA_noon	3.65	14	0.66			
PANAS_NA_morning	1.23	14	0.25	-0.94	13	0.365
PANAS_NA_noon	1.36	14	0.45			

Positive Affect differed between chronotypes and was related to time of day (Figure 2). Morning types had a higher positive affect than evening types during the morning (F=7.974, p=0.001) and at noon (F= 4.561, p=0.013; Figure 2). Negative Affect was not different between the chronotypes (morning: F=0.063, p=0.965; noon: F=0.756, p=0.473).

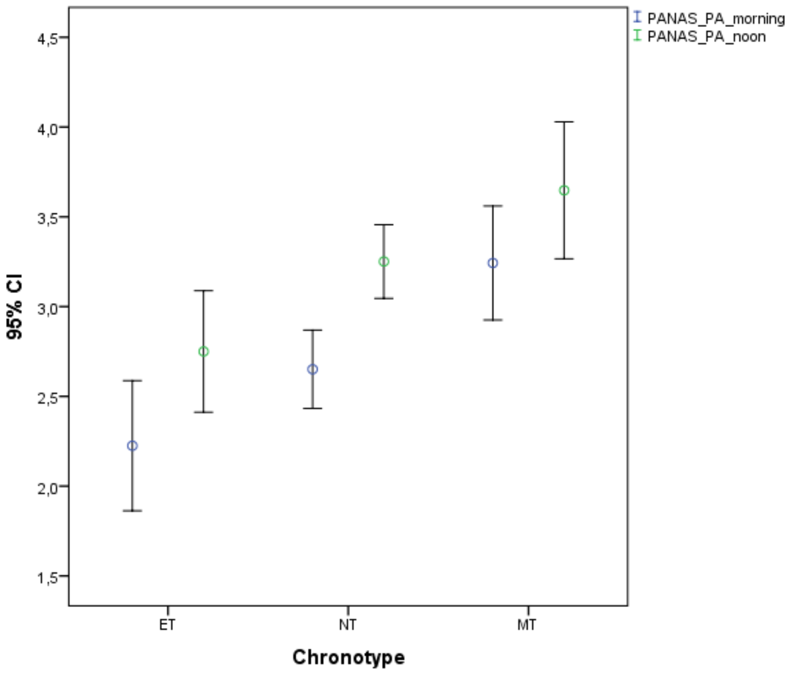

Figure 2. Mean scores of Positive and Negative Affect across both testing times (morning, noon) and chronotypes (MT=morning types, NT = neither types, ET = evening types). Rhombs = morning tests, circles = noon test.

Discussion

Morning types usually perform better in school and at university. However, the reasons are still not clear. Even when controlling for confounding variables or for other aspects that are related to school achievement, chronotype still has an effect on achievement (Preckel et al., 2013; Arbabi et al., 2015; Ruffing et al., 2015). In addition, laboratory studies showed some kind of synchrony effects with evening people scoring higher in the evening and morning people scoring higher in the morning (Goldstein et al., 2007; Hahn et al., 2012). This suggests, that pupils should score higher in a standardized achievement test in the morning when they belong to the morning type. Here, we used a field experiment to challenge this hypothesis. Our data could not support the hypothesis of the synchrony effect in a real life setting. One reason may be that the sample size is too low to detect any effect in the field. This could be the case, because field effects are usually smaller than laboratory effects, which indicate the need for a higher sample.

Second, the mathematical test may not be sensitive enough to detect changes. However, this seems unlikely because the tests of the VERA assessment have been especially developed to test achievement in such comparative situations (Pant et al. 2013). Nevertheless, the tests were also an artificial situation because they were not used for grading purposes.

Another aspect may be the age group. We have selected ninth graders because they are extremely shifted towards eveningness compared to other age groups (Randler, 2011). Therefore, we applied the 80% percentile criterion to assign pupils to the group of morning types (to have a balanced sample). Further studies should use different age groups, which in turn makes it more difficult to assess achievement because tests for 5th and 9th graders have to be different. Another idea might be to rely on a higher sample. Further, an interesting aspect is that the testing time per se also had no influence on the achievement. One could hypothesize that the early morning test should be worse than the noon because it is at the earliest possibility for writing a test. The assessment time of noon (i.e., 12:15) may not enough delayed to highlight a possible time of day effect.

There was no relationship between the outcome of a test and the preferred testing time. This is interesting since one would expect that pupils that prefer early test times might score higher in the morning and pupils preferring later test times should score higher in the noon. This was not the case.

One of our unexpected results was the correlation between Negative Affect in the morning and a higher score of the achievement test. We are unsure whether the result that Negative Affect was related to mathematical test scores is a spurious one, but we report it here and we suggest that other researchers may try to replicate this result. Usually, positive emotions are related to higher outcomes in tests, and negative emotions, like anxiety, are related to lower scores (Gläser-Zikuda et al., 2005; Rahafar et al., 2016). Thus, here we found unexpectedly the contrary.

The results concerning emotions or affect, we were able to replicate previous findings from Randler et al. (2014), Randler and Weber (2014) and Escribano et al. (2014) which showed that positive emotions increase during the school day, and that morning types have higher positive emotions in the morning and at noon. These positive emotions may act in the long term as a catalyst for higher school achievement. Concerning measurement questions, we suggest that it might be sufficient for future studies to use only the positive affect of the PANAS for chronopsychological assessments.

Limitations

The study is based on self-report of chronotype by the CSM, also the sample is relatively small and we have focused only on one explicit age group (which in turn could be seen as a strength). In addition, the alpha level for Negative Affect is lower than the acceptable limit (.6). Also, the second test should be placed later during the day, but most schools in Germany end around 13:00 usual, so it is not easy to find testing times during the late afternoon, e.g. at 17:00 which should be done in future studies (see, e.g., Itzek-Greulich, Randler, & Vollmer, 2016).

Implications

Our study shows no effect of time of day on standardized test scores, and also no synchrony effect. However, we will not explicate any implications from this study for school teaching. We strongly emphasize that there should be more experimental field studies in schools to shed light on this topic before making suggestions for teaching and learning.

References

Arbabi, T., Vollmer, C., Dörfler, T., & Randler, C. (2015). The influence of chronotype, intelligence, conscientiousness, and motivation on academic achievement in primary school. *Chronobiology International, 32*, 349-357. doi: 10.3109/07420528.2014.980508.

Díaz-Morales, J. F., & Escribano, C. (2013). Predicting school achievement: The role of inductive reasoning, sleep length and morningness–eveningness. *Personality and Individual Differences*, 55, 106-111.

Díaz-Morales, J., Escribano, C., & Jankowski, K. (2015). Chronotype and time-of-day effects on mood during school day. *Chronobiology International,* 32(1), 37-42.

Escribano, C., & Díaz-Morales, J. F. (2016). Are achievement goals different among morning and evening – type adolescents? *Personality and Individual Differences, 88,* 57-61. doi: 10.1016/j.paid.2015.08.032.

Escribano, C., & Díaz-Morales, J. (2014). Daily fluctuations in attention at school considering starting time and chronotype: an exploratory study. *Chronobiology International,* 316), 761-769.

Gläser-Zikuda, M., Fuß, S., Laukenmann, M., Metz, K., & Randler, C. (2005). Promoting students' emotions and achievement–Instructional design and evaluation of the ECOLE-approach. *Learning and Instruction*, *15*(5), 481-495.

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.

Hahn, C., Cowell, J. M., Wiprzycka, U. J., Goldstein, D., Ralph, M., Hasher, L., & Zelazo, P. D. (2012). Circadian rhythms in executive function during the transition to adolescence: the effect of synchrony between chronotype and time of day. *Developmental Science*, *15*(3), 408-416.

Heller, K., & Hany, E. (2002). Standartisierte Schulleistungsmessungen. In F. Weinert, *Leistungsmessungen in Schulen* (S. 87-101). Weinheim und Basel: Beltz Verlag.

Itzek-Greulich, H., Randler, C., & Vollmer, C. (2016). The interaction of chronotype and time of day in a science course: Adolescent evening types learn more and are more motivated in the afternoon. *Learning and Individual Differences*, *51*, 189-198.

Krohne, H., Egloff, B., Kohlmann, C., & Tausch, A. (1996). Untersuchungen mit einer deutschen Version der "Positive and Negative Affect Schedule" (PANAS). *Diagnostica,* 2, 139-156.

Öztürk, E. (2014). The effect of circadian rhythm on elementary students' reading comprehension. *Biological Rhythm Research,* 45 (6), 861-868.

Pant, H., Stanat, P., Schroeders, U., Roppelt, A., Siegle, T., & Pöhlmann, C. (2013). *IQB-Ländervergleich 2012 - Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe 1.* Münster/New York/München/Berlin: Waxmann Verlag.

Preckel, F., Lipnevich, A. A., Schneider, S., & Roberts, R. D. (2011). Chronotype, cognitive abilities, and academic achievement: A meta-analytic investigation. *Learning and Individual Differences, 21,* 483-492. doi: 10.1016/j.lindif.2011.07.003.

Preckel, F., Lipnevich, A. A., Boehme, K., Brandner, L., Georgi, K., Könen, T., Mursin, K., & Roberts, R. D. (2013). Morningness-eveningness and educational outcomes: The lark has an advantage over the owl at high school. *British Journal of Educational Psychology, 83,* 114-134. doi: 10.1111/j.2044-8279.2011.02059.x.

Quinn, G., & Keough, M. (2002). *Experimental Design and Data Analysis for Biologists.* Cambridge, New York, Melbourne, Madrid, Kapstadt, Singapur, Sao Paulo: Cambridge University Verlag.

Rahafar, A., Maghsudloo, M., Farhangnia, S., Vollmer, C., & Randler, C. (2015). The role of chronotype, gender, test anxiety, and conscientiousness in academic achievement of high school students. *Chronobiology International, 33,* 1-9. doi: 10.3109/07420528.2015.1107084.

Randler, C., & Frech, D. (2006). Correlation between morningness-eveningness and final school leaving exams. *Biological Rhythm Research*, *37*, 233-239. doi: 10.1080/09291010600645780.

Randler, C. & D. Frech (2009). Young people's time of day preferences affect their school performance. *Journal of Youth Studies, 12,* 653-667.

Randler, C. (2011). Age and gender differences in morningness-eveningness during adolescence. *Journal of Genetic Psychology, 172,* 302-308.

Randler, C., Rahafar, A., Arbabi, T., & Bretschneider, R. (2014). Affective state of school pupils during their first lesson of the day – effect of morningness-eveningness. *Mind, Brain & Education, 8*, 214-219.

Randler, C. & Weber, V. (2015). Positive and negative affect during the school day and its relationship to morningness-eveningness. *Biological Rhythm Research*, *46*, 683-690.

Rossi, V., Pourtois, G. (2012). Transient state-dependent fluctuations in anxiety measured using STAI, POMS, PANAS or VAS: a comparative review. *Anxiety, Stress & Coping, 25*, 603–645.

Ruffing, S., Hahn, E., Spinath, F. M., Brünken, R., & Karbach, J. (2015). Predicting students' learning strategies: The contribution of chronotype over personality. *Personality and Individual Differences, 85,* 199–204.

Thompson, E. R. 2007. Development and validation of an internationally reliable short-form of the positive and negative affect schedule (PANAS*). Journal of Cross-Cultural Psychology, 38*, 227–242.

Tonetti, L., Adan, A., Di Milia, L., Randler, C., & Natale, V. (2015). Measures of circadian preference in childhood and adolescence: A review. *European Psychiatry, 30(5*), 576-582.

Tonetti, L., Natale, V., & Randler, C. (2015). Association between circadian preference and academic achievement: A systematic review and meta-analysis. *Chronobiology International, 32(6*), 792-801.

Vollmer, C., Pötsch, F., & Randler, C. (2013). Morningness is associated with better gradings and higher attention in class. *Learning and Individual Differences, 27*, 167-173.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology, 54(6),* 1063-1070.