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# The interaction of chronotype and time of day in a science course: Adolescent evening types learn more and are more motivated in the afternoon☆

Heike Itzek-Greulich [a], Christoph Randler [b], Christian Vollmer [c,*]

[a] Hector Research Institute of Education Sciences and Psychology, University of Tübingen, Europastraße 6, 72072 Tübingen, Germany
[b] Department of Biology, University of Tübingen, Auf der Morgenstelle 28, 72076 Tübingen, Germany
[c] Institute of Psychology, University of Education Heidelberg, Keplerstraße 87, 69120 Heidelberg, Germany

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ABSTRACT

While active labwork in an out-of-school lab with direct ("hands-on") experience may have positive effects on achievement and motivation, it is unclear whether the optimal time of day may intensify these effects. Adolescents' individual diurnal preferences indicate later times of day as optimal but lessons are in the morning. In the present study, the effectiveness of labwork was examined regarding diurnal preference, achievement, and emotional variables ($N = 473$ students; age: $M = 15.3$, $SD = 0.7$) in 18 secondary classes in a morning and an afternoon course. Data were gathered on achievement (starch chemistry, pre and post) and on state motivation. Results indicate a synchrony effect (interaction of time of day and chronotype) in achievement and state motivation. Evening types have worse achievement, lower interest, and lower joy in the morning, but there were no significant associations between chronotype and the outcomes in the afternoon. Since adolescent evening types can learn better and are more motivated in the afternoon, schools should offer more learning opportunities in the afternoon.



## 1. Introduction

In aiming at an increase in students' competencies in STEM subjects (science, technology, engineering, and mathematics), previous research called for more hands-on familiarization with scientific contents (see Itzek-Greulich et al., 2015; Schroeder, Scott, Tolson, Huang, & Lee, 2007) which is assumed to be more likely to result in higher achievement and long-lasting engagement (Swarat, Ortony, & Revelle, 2012; Yager & Yager, 1985). When conducting labwork outside of the students' regular classroom, for example at a science center outreach lab (SCOL), students study a scientific research question for which they prepare, conduct, and review experiments in inquiry-based learning environments (Hempelmann & Haupt, 2014). Some have claimed that SCOLs have a positive impact on the acquisition of knowledge and competences, especially because SCOLs provide an advanced infrastructure (Luehmann & Markowitz, 2007). However, previous research was inconclusive about the effectiveness of SCOLs (Hofstein & Kind, 2012; Itzek-Greulich et al., 2015). While SCOLs offer courses in the morning and in the afternoon, teachers prefer to book the earlier courses and the effectiveness of afternoon courses has not been evaluated before. Therefore, to make the most of a SCOL visit, the present study investigated whether there is a time of day that is best suited for achievement and motivational gains.

Time of day effects can be operationalized in two ways: (a) implementing the same course in the morning and in the afternoon and (b) looking for students' individual preferences, that is, what is a student's preferred time of day for studying, therefore matching the course time with a student's peak of wakefulness. Students' individual preference for either morning or evening activity is often coined morningness-eveningness or chronotype. Morningness-eveningness can be seen as an individual difference characteristic gaining increasing interest in both personality psychology and learning research (Adan et al., 2012). Evening types share worse achievement in school and university, and the effect is stronger in school students probably because

*Abbreviations:* STEM, science, technology, engineering, and mathematics; SCOL, science center outreach lab; ET, evening type; IT, intermediate type; MT, morning type; MSFsc, corrected midpoint of sleep; PA, positive affect; NA, negative affect.

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* Corresponding author.
*E-mail addresses:* heikeitzek@gmail.com (H. Itzek-Greulich), christoph.randler@uni-tuebingen.de (C. Randler), vollmer@ph-heidelberg.de (C. Vollmer).

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university students have some control over their study schedules (Tonetti, Natale, & Randler, 2015). However, there is a diurnal synchrony effect with evening types (ET) performing better than morning types (MT) in the afternoon/evening and vice versa (May, 1999). Yet, these studies were based on laboratory studies (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007; Hahn et al., 2012). These authors tested adolescents aged 11–14 years and found a synchrony effect in fluid intelligence (Goldstein et al., 2007) as well as in executive function (Hahn et al., 2012). adolescents tested at their optimal time of day performed better than at their non-optimal time (Hahn et al., 2012).

The synchrony effect has rarely been tested in school situations (e.g., Díaz-Morales, Escribano, & Jankowski, 2015). These authors asked 12–16 year old adolescents for their mood ratings at different times (8:10–8:30 h, 10:20–11:40 h, 13:50–14:10 h) and found no synchrony effect, but mood increased from morning to noon. Similar effects have been found by Randler and Weber (2015; testing times 7:45, 12:15; age range 11–17 years). Recent findings further indicate complex relations between social jetlag, academic achievement and cognitive performance at school (Escribano & Díaz-Morales, 2014).

The uniqueness of the present study is to test the synchrony effect in a real-life situation where school students were given a structured SCOL programme in a controlled setting: Classes were randomly assigned to a morning and an afternoon course in a SCOL on the topic of starch chemistry. Achievement (pre- and posttest) has been assessed with standardised tests. We provide evidence for chronotype as a differential factor for both achievement and emotional fluctuations with a synchrony effect emerging when lessons at different times of day are compared.

### *1.1. Chronotype*

Chronotype describes an individual diurnal preference on a continuum from early to late sleep and wake times. We here used a clock-based measure that was put forward by Roenneberg, Daan, and Merrow (2003). Evening types (ET) are people that go to bed late and get up late, and usually reach their peak performance, physically and mentally, in the late afternoon and evening, while morning types (MT) go to bed and get up early, and prefer morning hours for intellectual and physical activity. Chronotype is independent of sleep duration (Roenneberg et al., 2004), and the measurement of midpoint of sleep (MSFsc) is used as a single phase-marker to characterise individuals. For example, a person going to bed at 24:00 and getting up at 6:00 has his/her MSFsc at 3:00, a person going to bed a 23:00 and getting up at 7:00 has the same MSFsc although this person sleeps 8 instead of 6 h, and thus is a similar chronotype, while going to bed at 23:00 and getting up at 5:00 indicates an earlier MSFsc (2:00). Although this seems a rather simple measurement, it has a valid psychobiological basis, and measurements of subjective circadian phase correlate best with the peak of melatonin secretion ($r = 0.68$), a hormone that is secreted during sleep, and also with the daily fluctuations of body temperature (Kantermann, Sung, & Burgess, 2015). Chronotype can also be measured by variety of other questionnaires, but these correlate usually with around 0.4 to 0.6 with each other and with measures of real behaviour (Di Milia, Adan, Natale, & Randler, 2013).

Chronotype changes significantly during the lifespan (Randler & Truc, 2014; Roenneberg et al., 2004). At the younger age (kindergarten and preschool), children are strongly morning oriented and there occurs a turn toward eveningness around the age of puberty. At the end of the adolescence, people progressively become more morning oriented again (Roenneberg et al., 2004). Thus, typical adolescents are among the most evening oriented persons, which conflicts with early school start times. Chronotype has also been linked with many personality and health-related measures, e.g., MT were more conscientious when using the Big Five inventory, or reported more favourable health-related behaviour and less depressive symptomatology (for an overview, see Adan et al., 2012). Thus, chronotype is an important, yet largely neglected variable in educational research.

### *1.2. Achievement*

#### *1.2.1. Chronotype and achievement*

In large-scale cross-sectional studies, morningness was linked with better academic achievement (Escribano, Díaz-Morales, Delgado, & Collado, 2012). This has been shown in many studies (meta-analysis by Preckel, Lipnevich, Schneider, & Roberts, 2011; Tonetti et al., 2015). Tonetti et al. (2015) summarised 30 studies comprising about 30,000 participants and found an average effect size of 0.14, with ET having worse school achievement. The effect size was higher in adolescents than in university students. However, chronotype was not addressed in a specific, standardised learning setting.

Referring to these previous findings, we hypothesize that chronotype has an influence on STEM achievement with MT generally scoring higher (H1).

#### *1.2.2. Synchrony effect in achievement*

The basic ideas go to back to Kleitman (1963), who showed a strong evidence for a parallelism between body temperature and time-of-day effects for simple repetitive tasks (Adan et al., 2012). Several hours after awakening, there was a decrease in reaction time response, which was correlated with an increase in body temperature (also known as arousal model, see Colquhoun, 1971). Following this model, it is supposed that the variation in circadian performance is based on the underlying circadian rhythm in the basal arousal level (Adan et al., 2012). This has two consequences: Because generally, body temperature increases during the day (Refinetti & Menaker, 1992), logically the performance efficiency should increase during the day (Carrier & Monk, 2000; Dills & Hernández-Julián, 2008). However, on an individual differences basis, MT and ET differ significantly in their body temperature fluctuations, and ET reach their nadir and acrophase of body temperature on average about 2 h later compared to MT (Baehr, Revelle, & Eastman, 2000) and therefore MT perform better in the morning while ET perform better in the evening (review: Cavallera, Boari, Giudici, & Ortolano, 2011). This leads to the hypothesis that afternoon classes (in grade 9 with students being 15 years of age) should generally perform better than morning classes (because students of this age group are late chronotypes), and also, that ET should outperform MT on afternoon classes and vice versa, which was identified in laboratory settings as synchrony effect (Hahn et al., 2012; May & Hasher, 1998; overview in Adan et al., 2012). Adan et al. (2012) advocated measuring such effects in the normal day-night schedule to reflect realistic conditions rather than in lab settings.

Therefore, we hypothesize that performance is generally better in the afternoon (H2), and we expect a synchrony effect in STEM achievement: interaction between chronotype and treatment time (H3).

### *1.3. Emotions and situational interest*

Out-of-school learning produces immediate emotional responses (Priemer & Pawek, 2014). These activity-related emotions are emotions felt during work and learning (Pekrun, Elliot, & Maier, 2006) and can have a positive valence (e.g., joy) or a negative valence (e.g., anger or boredom). Moreover, students' activity-specific perceived competences during a half-day SCOL visit should be targeted. Previous studies on the emotional and motivational gains of out-of-school learning have indicated positive motivational effects such as increased situational interest in the activities at the SCOL (Dairianathan & Subramaniam, 2011; Seybold, Braunbeck, & Randler, 2014) and more positive state emotions (Randler, Ilg, & Kern, 2005).

The person-object theory of interest (Krapp, Hidi, & Renninger, 1992) can be used to obtain a broader understanding of students' situation- and person-specific reactions to lab-work learning environments (situational interest and situational competence). Situational interest refers to a rather temporary feeling (Krapp et al., 1992).