



Of larks and hearts – morningness/eveningness, heart rate variability and cardiovascular stress response at different times of day

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ARTICLE INFO

Article history:

Received 27 October 2011

Received in revised form 16 January 2012

Accepted 30 January 2012

Keywords:

Morningness/eveningness

Heart rate variability

Chronotype

Time of day

Psychological stress

Cardiovascular reactivity

ABSTRACT

Inter-individual differences in the circadian period of physical and mental functions can be described on the dimension of morningness/eveningness. Previous findings support the assumption that eveningness is related to greater impulsivity and susceptibility to stress than morningness. Heart rate variability (HRV) serves as a physiological correlate of self- and emotional regulation and has not yet been investigated in relation to chronotypes. The study explores differences in HRV and other cardiovascular measures in morning- and evening-types at rest and under stress at different times of day (8–11 a.m. or 4–7 p.m.). Students ($N=471$) were screened for chronotype and $n=55$ females (27 morning- and 28 evening-types) were recruited for testing. These participants performed a mental arithmetic task while heart rate (HR) and blood pressure (BP) were recorded. Spectral components and a time-domain measure of HRV were calculated on HR data from resting and mental stress periods. Evening-types had significantly higher HR and systolic BP, but lower HRV than morning-types both at baseline and during stress. Stress induced in the evening had a significantly stronger impact on absolute and baseline corrected physiological measures in both chronotypes. The interaction of chronotype and testing time did not reach the level of significance for any of the dependent variables. The enhanced physiological arousal in evening-types might contribute to increased vulnerability to psychological distress. Hence, previous behavioral findings are supported by the physiological data of this study.

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1. Introduction

In humans and other mammals, many physiological processes, such as the regulation of body temperature or levels of cortisol [1] and melatonin [2] as well as mental processes (e.g. alertness, working memory, or measures of fluid intelligence) [3,4] are affected by circadian rhythms. Individual differences in these chronobiological rhythms can be summarized under the concept of morningness/eveningness (M/E). Morningness and eveningness can be considered two poles on a scale, on which a person's chronotype can be defined. Depending on the diurnal preference, the phase position and period of the circadian rhythms, people may either be morning- or evening-orientated (M- or E-type) or, like most, be a neutral chronotype [5]. In twin studies, between 44 and 54% of the total variance of M/E could be explained by genetic factors [6,7]. Chronotypes differ

with regards to their sleeping behavior [8], personality [9], mental health [10], smoking habits [11] and even their sense of humor [12].

1.1. M/E and self-regulation

Present findings indicate that eveningness is related to a greater susceptibility to stress [13]. E-types are less emotionally stable than M-types [14,15] and have a higher prevalence of psychosomatic symptoms [16], which supports the idea of eveningness being related to increased reactivity to stress, reduced coping abilities, or both. Consequently, one may assume that M/E could have an impact on general well-being, in particular when exposed to chronic stress. Recently, it was shown that morningness correlated positively with life satisfaction [17], and that the relationship was negative between morningness and stress characterized by chronic non-specific arousal [18]. Studying the association of eveningness and Type A personality has led to contradictory results, such that a positive [16] and a negative [19] relationship could be found.

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Studies in adolescents have shown a higher prevalence of behavioral and emotional problems, and habitual substance abuse in evening orientated teenagers [20,21]. Positive relationships have also been found between eveningness and depression [22], the amount of perceived self- and proxy-related problems [23], as well as eating disorders [24,25]. Furthermore, there is evidence for E-types having more situation specific problems than M-types in their capabilities of inhibiting, interrupting and adapting their current behavior [16]. Moreover, eveningness correlated positively with novelty seeking (a personality trait including aspects of impulsivity) and negatively with persistence [26]. The primary reason for the reduced self-regulatory capacity and emotional stability in E-types compared to other chronotypes remains unclear. Buschgens and colleagues [18] hypothesized that a less adaptable central nervous system in E-types might be responsible for their reduced regulatory capacity and that their impaired well-being may in part result from elevated arousal.

1.2. M/E and HRV

HRV is defined as the variability of the time elapsing between two successive heartbeats and serves as an indicator of a person's regulatory abilities regarding physiological, affective and cognitive processes [27]. According to the model of neurovisceral integration [28], prefrontal cortical regions inhibit subcortical structures such as the amygdala. The inhibition of the amygdala is associated with more parasympathetic (suppressive) and less sympathetic (activating) influence on heart rate. It is widely accepted that prefrontal cortical activity is the main correlate of executive functions (e.g. planning, initiating, monitoring and inhibiting behavior, impulse control, priority setting and emotional regulation) [27]. The more a task challenges these executive functions, the more inhibition is required by the prefrontal cortex. Pronounced executive functioning is accompanied by higher parasympathetic influence, which decreases HR and increases HRV. Less advanced executive functioning is accompanied by sympathetic dominance and related to higher HR and lower HRV. These interactions enable individuals to respond to and adapt their level of activation appropriately to environmental demands. Therefore, HRV can be interpreted as an index of an individual's ability to modify and regulate behavior and emotions in a quick, flexible and effective manner [29]. As opposed to the link between increased HRV and effective self-regulation, decreased HRV has been found to be associated with higher negative emotional arousal in response to stress and maladaptive coping strategies [30]. Accordingly, sleep disturbances [31], general anxiety disorder [32], panic disorder [33], and depression [34] were related to diminished vagally mediated HRV.

1.3. M/E and cardiac stress response

In a comprehensive review of the literature by Cavallera and Giudici [14], only two studies on M/E included the monitoring of cardiovascular stress response. Nebel and colleagues [35] confronted their male subjects with mental and physical stressors in the morning (7:30 a.m.) and at noon (12:30 p.m.). They found a significant interaction of M/E and testing time for heart rate (HR) and rate by pressure product ($HR \times$ systolic blood pressure, RPP) only during mental stress (a math test and a Stroop color word task). This interaction was evident for absolute levels and for baseline-corrected change scores. M-types exhibited higher HR and RPP during the morning session, whereas E-types had higher levels during the afternoon session.

The second study by Willis and colleagues [36] tried to replicate these findings in a larger mixed sample and found that E-types had significantly higher HR and RPP in the afternoon (1–2 p.m.) than in the morning (8–9 a.m.), at rest and in response to stress, but the interaction effect was not significant for change scores. In neither study, M/E or time of day has a significant main effect on

cardiovascular parameters. Women had higher HR scores and lower systolic BP (SBP) than men, at baseline and during stress.

1.4. Study design and hypotheses

The aim of the current study was to investigate the relationship between M/E and cardiovascular responses to mental stress at different times of day. In addition to cardiovascular parameters, i.e. HR and BP, we focused on HRV because it may mediate and explain findings on psychological and behavioral differences in relation to M/E. Results from several studies on cognitive processes, such as memory performance [37,38] or attention [39], indicate that the peak of performance for E-types does not occur before 4 p.m. Thus, we chose a time window between 4 and 7 p.m., which is considerably later than in previous studies [35,36]. To avoid habituation to the laboratory stressor we chose a between-subjects instead of a within-subjects design. Following Willis and colleagues [36] we used a mental stressor as this has proven more appropriate than physical stress [35].

We hypothesized that (I) E-types would show reduced HRV and increased HR and BP levels compared to M-types at baseline. Further, we predicted (II) cardiovascular reactivity to stress (corrected for baseline levels) to be higher in E- than in M-types and (III) an interaction of M/E and testing time for cardiovascular reactivity to mental stress.

2. Methods

2.1. Design

The study followed a 2 (trial) $\times$ 2 (chronotype) $\times$ 2 (testing time) design with chronotype (morning vs. evening) and testing time (8–11 a.m. vs. 4–7 p.m.) as between-subject factors and trial (baseline vs. stress) as within-subject factor.

2.2. Participants

We screened online $N=471$ students of the University of Würzburg with the German version of the Morningness–Eveningness Questionnaire (D-MEQ, see Section 2.3). Student councils of the University of Würzburg were contacted via e-mail and asked to send the Internet link to the voluntary online survey over the student councils' mailing lists. Screened participants were on average $M=23.18$ years old ($SD=4.00$, range 16–61), and 76.9% ($n=362$) were female. Mean D-MEQ score was $M=50.11$ ($SD=7.24$) and women had significantly higher values than men ($t_{469}=2.45$, $p<.05$). Since the majority of the participants were female, we decided to recruit only women for the experiment. Individuals in the upper and lower 20% of the D-MEQ distribution (D-MEQ scores ≤ 44 for E-type and ≥ 56

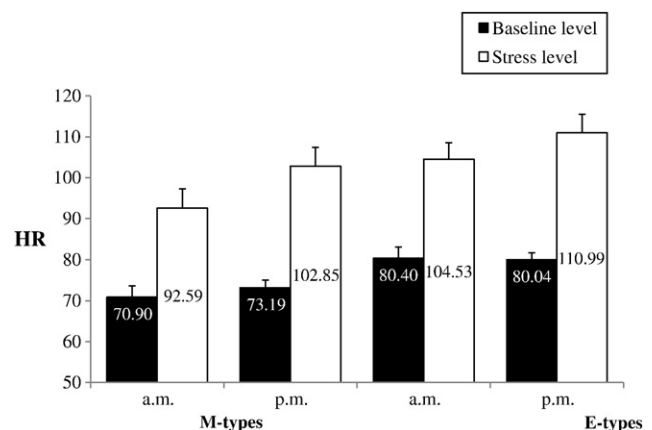


Fig. 1. HR at baseline and stress level. Error bars indicate standard error.

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