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How many diurnal types are there? A search for two further "bird species"

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ABSTRACT

Morning and evening types ("larks" and "owls") are most alert in the morning and in the evening, respectively. Because they are also characterized by preference for early awakening–early bedtime and late awakening–late bedtime, respectively, two questions arise: Is it possible to distinguish two additional types preferring early awakening–late bedtime and late awakening–early bedtime? If yes, are they similar to the types of habitual short and long sleepers? One hundred and thirty healthy participants of sleep deprivation experiments were subdivided into four (2×2) types depending upon self-assessed preferences for morning and evening earliness/lateness. The differences between these types in self-assessed morning/evening earliness/lateness were associated with the differences in levels of morning/evening–early night sleepiness. However, self-reports on their pre-experimental wakeups/bedtimes showed that the two additional types were not identical to the types of short and long sleepers. It seems that the four-type classification of morning/evening preference represents pairwise combinations of low/high levels of waking ability during the morning/evening–early night hours, and that such variation in waking ability is irrelevant to individual differences in sleep ability, i.e., variation in sleep need, sleep capacity, sleep quality, napping propensity, etc.

1. Introduction

Two diurnal types or chronotypes nicknamed "larks" and "owls" represent two poles of the dimension of morning/evening preference (Adan et al., 2012; Di Milia, Adan, Natale, & Randler, 2013; Horne & Ostberg, 1977; Kerkhof, 1985). A "lark" or morning type is most alert in the morning, whereas an "owl" or evening type is most alert in the evening. These types are also characterized by preference for early awakening–early bedtime and late awakening–late bedtime, respectively. Two questions then arise: Is it possible to recognize two more diurnal types characterized by preference for early awakening–late bedtime and late awakening–early bedtime? If yes, are they similar to the types of habitual short and long sleepers?

The reviews of the earliest scientific literature on morning/evening preference (Horne & Ostberg, 1977; Kerkhof, 1985) mentioned the publication of Leopold-Levi who as early as in 1932 added "late to bed–early to rise" and "early to bed–late to rise" types to "early to bed–early to rise" and "late to bed–late to rise" types that were suggested by Wuth in 1931. However, the majority of further studies of morning/evening preference in the field of chronobiology interpreted this individual trait as a uni-dimensional rather than two-dimensional construct. The major reason for popularity of strictly uni-dimensional approach might be the widely accepted believe in close association of the self-reported chronotypological differences with underlying uni-dimensional individual variation in the entrained circadian phase that might be set on a relatively earlier or a relatively later clock time (Adan et al., 2012; Kerkhof, 1985).

Consequently, the oldest and still most respected questionnaire instruments for chronotypological self-assessment were proposed in the form of uni-dimensional scales. When factor analysis and other conventional psychometric methods were employed for evaluation of these scales, they yielded 2–3 orthogonal factorial dimensions (Brown, 1993; Larsen, 1985; Monk & Kupfer, 2007; Moog, Hauke, & Kittler, 1982; Neubauer, 1992; Smith, Reilly, & Midkiff, 1989). For instance, even factor analysis of a shortened version of such kind of morning/evening scale, the Diurnal Type Scale (Torsvall & Åkerstedt, 1980), sorted out its 7 items into two rotated factors representing morning and evening habitual traits (Torsvall & Åkerstedt, 1980). Furthermore, similar multi-dimensionality was again reported in the studies of more recently suggested revisions of earlier developed questionnaires. Particularly, three factors were revealed by factor analyzing the 13-item modi-

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fication of earlier proposed morningness–eveningness scales named the Composite Scale of Morningness (Caci et al., 2005; Randler, 2009; Smith et al., 1989), and the analysis of its reduced (7-item) version yielded two factors (Randler, 2009). Only the shortest questionnaire tool for self-assessment of diurnal type, the 5-item Reduced Version of Morningness–Eveningness Questionnaire (Adan & Almirall, 1991), was shown to be uni- rather than multi-dimensional, but its satisfactory reliability contrasts with high levels of reliability (>0.80) consistently reported for larger questionnaires (reviewed by Di Milia et al., 2013).

A fundamental issue of factor models is the correct specification of the number of factors, and this number might be seriously overestimated in factor analysis. However, some other lines of evidence support the suggestion of multi-dimensionality of morningness–eveningness trait. For instance, Martynhak, Louzada, Pedrazzoli, and Araujo (2010) drew attention to a possible additional type of morning/evening preference that can be differentiated from morning, evening, and neither/intermediate types on the pattern of responses to items of chronotypological questionnaires. These "bimodal" types tend to answer some questions as morning types, but answer others as evening types, which in sum provides the same result as for intermediate types (Martynhak et al., 2010; Randler & Vollmer, 2012).

More direct evidence for multi-dimensionality of morning/evening preference was found in two independent studies applying the conventional psychometric procedures (i.e., such as item response analysis) to development of a new chronobiological questionnaire. Both these studies led to construction of two separate – morning and evening – scales for self-assessment of morningness–eveningness (Putilov, 1990, 1993; Roberts, 1998). Nevertheless, the results of such questionnaire studies had not yet stimulated the attempts to find more solid experimental evidence for plausibility of two-dimensional representation of morningness–eveningness trait.

It is widely accepted that, to assess validity of morningness–eveningness scales, such external criteria as self-ratings of alertness–sleepiness and self-reports of wakeup/bedtime can be used (i.e., Díaz-Morales, Dávila, & Gutiérrez, 2007; Kerkhof, Korving, Willemse-v.d. Geest, & Rietveld, 1980; Natale & Cicogna, 1996; Randler, 2009; Vidacek, Kaliterna, Rodosevic-Vidacek, & Folkard, 1988). Therefore, our goal was to provide experimental support for two-dimensional (four-type) approach to structural representation of morningness–eveningness trait. In order to achieve this goal and to explain the possible causes of two-dimensionality of individual variation in morning/evening preference, we analyzed self-reports collected prior to and in the course of experiments on 24-h sustained wakefulness. We hypothesized that four (2×2) chronotypes predicted by the two-dimensional classification of morning/evening preference are also significantly different in the 24-h fluctuations of self-reported alertness–sleepiness levels. We also quantitatively simulated the regulatory processes underlying these 24-h fluctuations of alertness–sleepiness to provide a better understanding of the chronophysiological underpinning of the observed individual variation.

2. Materials and methods

The experimental study was performed in accordance with the ethical standards laid down in the Declaration of Helsinki. Its protocol was approved by the Ethics Committee of the Siberian Branch of the Russian Academy of Sciences. Informed written consent was obtained from each of the study participants. One hundred and thirty healthy individuals were studied as paid volunteers. The median and mean ages of 54 male participants were 23 and 27.4 years (Standard Deviation or SD = 10.1), respectively. For 76 female participants, the mean and median ages were 24 and 30.8 years (SD = 13.4), respectively. In the experimental morning (between 08:00 and 8:30 o'clock), the participants were admitted to a research unit of the institute and remained there until approximately 11:00 the next morning. Over the next 24 h they completed 9 electroencephalographic (EEG) recording sessions divided by 3-h intervals and 5 performance trials. The participants also completed several questionnaires at the time intervals between the performance and EEG measurements. If they did not participate in the research procedures, they were engaged in such activities as reading, writing, playing board and computer games, surfing the Internet, watching TV, listening to music, consuming light snacks and drinks (but not alcohol or caffeinated beverages), etc. The participants were asked to avoid any medications, vigorous physical activity, and exposure to light brighter than 500 lux. The study personnel ensured that they always remained awake.

The 72-item Sleep–Wake-Pattern Assessment Questionnaire or SWPAQ (Putilov, 2007, 2011) was administered twice: prior to the experiment and soon after arriving in the research unit. Two 12-item scales of the SWPAQ, *M* or Morning Lateness and *E* or Evening Lateness, allow separate self-assessment of sleep–wake behavior in the morning and evening–early night hours. Four remaining 12-item scales of the SWPAQ were designed to self-assess waking and sleep abilities (*W* and *V* or Anytime and Daytime Wakeability, and *F* and *S* or Anytime and Nighttime Sleepability). Scorings on two Lateness scales (*M* and *E*) were used for subdivision of the study participants into four (2×2) predicted diurnal types. The participants with lower than averaged score were sorted into type 0, and the remaining participants were sorted into type 1. By combining *M* and *E* typologies, four chronotypes (i.e., 0–0, 0–1, 1–0, and 1–1) were distinguished (see also Tables 1 and 2).

Study participants were asked to keep their regular sleep–wake schedule during a week prior to the experimental day and to report their sleep history for each of these pre-experimental days. The individual mean clock times for going to bed (bedtime) and awakening (wakeup) were averaged over 5 pre-experimental days and used for calculation of midsleep and sleep duration (see the notes to Table 1). Sleep history also included some other self-reports including times of nap episodes, sleep latency (the self-perceived time interval between going to bed and falling asleep), sleep satisfaction (scored from 1 = "was not satisfied at all" to 5 = "was excellent"), etc.

Right after each EEG recording, the participants were asked to determine their self-perceived alertness–sleepiness on the 9-point Karolinska Sleepiness Scale or KSS (Åkerstedt & Gillberg, 1990). Four chronotypes were compared on KSS self-scorings provided for two morning time points (the 1st and 9th at 9:00) and two evening–early night time points (the 5th and 6th at 21:00 and midnight; Table 1). The 24-h time courses of KSS alertness–sleepiness were expressed as deviations from the averaged KSS score (Fig. 1).

All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) version 20.0 (IBM, Armonk, NY, USA). To examine differences between four chronotypes on the time course of KSS score, two-way repeated measure ANOVA (rANOVA) was performed with repeated measure "Time of day" (9 clock times), the independent factor "Chronotype (types 0–0, 0–1, 1–0, and 1–1), and age and sex as covariates. Huynh–Feldt correction of the degrees of freedom was used to control for type 1 error associated with violation of the sphericity assumption, but the original degrees of freedom are reported in the legend to Fig. 1. The Bonferroni multiple comparison test was used in the post hoc analysis to reveal significant pairwise differences between chronotypes in daily mean KSS score. Table 1 illustrates significance of the results yielded by one-way ANOVAs of chronotype-relevant self-reports with the independent factor "Chronotype" and two covariates, and it gives the results of the Bonferroni multi-