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Overlap between individual variation in personality traits and sleep-wake behavior

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Abstract
The efforts to link the individual differences in personality to the individual differences in sleep-wake behavior have a long history. One of the topics of such research might be to determine the strength of association between these two domains of individual variation. This requires the implementation of several inventories designed for integrative multidimensional assessments of a set of broad personality traits and a set of sleep-wake behavioral traits. Four independent samples were collected (in total, 759 individuals) for estimating general overlap between the domains of individual variation in personality psychology and chronobiology. Canonical correlation analyses provided the estimates of general overlap of six broad personality traits assessed with the 172-word RCIP (Rugby Cake Inventory of Personality) with six distinct sleep-wake adaptabilities assessed with the 72-item SWPAQ (Sleep-Wake Pattern Assessment Questionnaire) and the SWAT (Sleep-Wake Adaptability Test) in two, the 60- and 168-item, versions. It was demonstrated that general overlap between individual variation in two domains was significant and replicable albeit rather weak (6%–8%). Moreover, regression analyses of specific overlaps of each of six scales for assessing sleep-wake adaptability with a set of six scales for personality assessment suggested that a score on any of adaptability scales seemed to be a significant predictor of, at least, one of six scores on personality trait scales. Studies in other tongues are desired for the replication of the results indicating the statistically significant general and specific overlaps between personality traits and sleep-wake adaptabilities.

Keywords Diurnal preference · Sleep-wake pattern · Personality psychology · Canonical correlation

Introduction

Studies of individual variation in the domains of personality psychology and chronobiology have many things in common. For instance, in order to assess individual differences in quantitative terms, these studies mostly relay on questionnaires. Moreover, since each trait is associated with typical overt behaviors by which it is manifest and/or judged (Buss &

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Craik, 1983; Eysenck, 1967; Funder & Sneed, 1993), it is natural to suggest that some of such behavioral manifestations and other signs might be shared by one of chronobiological traits and one of personality traits. Therefore, the attempts to establish associations between these two domains of individual variation have a long history. They date back to Eysenk's classical book "The biological basis of personality" (1967). He hypothesized the difference between extraverts and introverts in the daily pattern of arousal. This hypothesis has inspired several studies aimed on testing the prediction that extraverts lag behind introverts in their diurnal arousal rhythm (e.g., Anderson & Revelle, 1994; Blake, 1967; Eysenck & Folkard, 1980; Larsen, 1985; Neubauer, 1992; Revelle, Humphreys, Simon, & Gilliland, 1980; Wilson, 1990; Zuber & Ekehammar, 1988).

In the field of chronobiology, morningness-eveningness had become the first scientifically recognized dimension of individual differences in human daily rhythms. The two extreme types of preferred timing for sleep, wake and work might be assessed with several morningness-eveningness scales. Not surprisingly, there is an extensive literature on personality traits as correlates of a score on such a scale (e.g., Adan & Almirall, 1992; Antúnez, 2020; Díaz-Morales, Randler, Arrona-Palacios, & Adan, 2017; Drezno, Stolarski, & Matthews, 2019; Jankowski & Linke, 2020; Jonason, Jones, & Lyons, 2013; Marques, Castilho, Allen Gomes, & Pereira, 2019; Matthews, 1988; Mecacci, Zani, Rocchetti, & Lucioli, 1986; Milić, Milić Vranješ, Krajina, Heffer, & Škrlec, 2020; Przepiorka, Blachnio, & Cudo, 2020; Randler, Gomà-i-Freixanet, Muro, Knauber, & Adan, 2015; Schredl & Göritz, 2020; Stolarski, Gorgol, & Matthews, 2021; Zajenkowski, Jankowski, & Stolarski, 2019).

The authors of recent research on personality correlates of morning-evening preference mostly utilized the personality inventories developed in the framework of the so-called Big Five taxonomy. This taxonomy has become the dominate paradigm in trait psychology starting from the middle of 1980s. In 1987, McCrae & Costa demonstrated that no recurrent and important dimensions beyond only five factorial dimensions could be recovered by the factoring items of a variety of English-language personality inventories. Similarly, the factoring long lists of personality-relevant English words performed by Goldberg (1990) led to extraction of five factorial dimensions ("Big Five") that were named (numerated as) Extraversion (I), Agreeableness (II), Conscientiousness (III), Emotional Stability (IV), and Intellect (V). More recently, these structural models of personality were extended to the six-factor models in the studies of English personality terms (Ashton & Lee, 2007) and in the cross-cultural studies of a variety of personality lexicons (e.g., De Raad et al., 2014; Saucier, 2003, 2009). For instance, Ashton and Lee (2007) identified a set of traits named "HEXACO" (Honesty-humility, Emotionality, eXtraversion, Agreeableness, Conscientiousness, and Openness to experience), and De Raad et al. (2014) used similar names (Honesty-Humility, Emotional Stability, Extroversion, new version of Agreeableness, Conscientiousness, and Intellect) to propose a partially replicable set of six pan-cultural personality components.

The significant links of some of Big Five constructs to morning-evening preference were already reported and reviewed in several publications (e.g., Adan et al., 2012; Lipnevich et al., 2017; Tsaousis, 2010). A number of reports pointed at dimension III (Conscientiousness) as the most reliable correlate of early chronotype (e.g., Faßl, Quante, Mariani, & Randler, 2019; Jackson & Gerard, 1996; Randler, Schredl, & Göritz, 2017; Tonetti, Fabbri, & Natale, 2009).

Some researchers preferred to focus on development of personality models by basing them on an understanding of the biological basis of personality. A study of factor structure of such psychobiological instrument as the 7-factor Psychobiological Model of Temperament and Character (Cloninger, Svrakic, & Przybeck, 1993) found that some of its dimensions can be related the dimensions of the Big Five taxonomies (e.g., De Fruyt, Van De Wiele, & Van Heeringen, 2000). However, one of the advantageous features of the studies linking morningness-eveningness to the scales on such psychobiological questionnaires (Antúnez et al., 2014,b; Prat & Adan, 2013; Randler et al., 2015; Randler & Saliger, 2011; Tonetti et al., 2016) is in opening a possibility to relate this chronobiological trait to the common neurobiological foundations for both personality and diurnal preference. For instance, Drezno et al. (2019) recently proposed that both morningness-eveningness and personality may include shared biological bases for depression and sleep disturbance, proneness to jetlag, and emotion-regulation mechanisms.

Definitely, there are several traits of sleep-wake behavior behind morningness-eveningness. The assumption of their possible importance for adaptation to temporal environment of the today societies, such as the need to adjust to shift work, has initiated the attempts to develop questionnaires for assessment of other than morningness-eveningness traits (Barton et al., 1995; Díaz-Morales et al., 2017; Folkard, Monk, & Lobban, 1979; Marcoen, Vandekerckhove, Neu, Pattyn, & Mairesse, 2015; Ogińska, 2011; Randler et al, 2016). It is reasonable to expect that such traits would be similar to morningness-eveningness trait in showing specific overlap with some of broad personality traits. However, only few, mostly very recent studies contain the results on linking them to personality (e.g., Carciofo, 2020; Carciofo & Song, 2019; Díaz-Morales et al., 2017; Faßl et al., 2019; You, Laborde, Dosseville, Salinas, & Allen, 2020).

Almost identical sets of six personality factors were revealed by two methodologically distinct studies of the Russian personality lexicon, the implicit study of Shmelyov et al. (1993; Shmelyov, Pokhil'ko, & Kozlovskaya-Teplova,

1991) and the explicit study of Putilov (2010, 2018). Moreover, a way of three-dimensional representation of six factors of either sleep-wake behavior (Fig. 1) or personality (Fig. 2) was previously proposed (Putilov, 2010, 2016, 2018). In this structural model, six factorial dimensions yielded by the conventional factor-analytic approach are viewed as pairwise combinations of just as few as three underlying orthogonal dimensions of sleep-wake behavior or personality. Consequently, these six factorial dimensions can be depicted at a surface of three-dimensional shape and can be used as a system of coordinates for mapping dozens of narrow traits of either sleep-wake behavior or personality (Putilov, 2016, 2018). Six-scale inventories relying on such model-based integrative description of two structures with six factorial dimensions were developed for self-assessment of broad chronobiological and psychological traits (Putilov, 2010, 2016, 2018).

Such six-scale chronobiological inventories provided a possibility to measure not only associations of a set of broad personality traits with one of broad chronobiological trait (e.g., morningness-eveningness), but also to measure the strength of association of the whole set of personality traits with the whole set of chronobiological traits (Putilov, Verevkin, & Donskaya, 2013). In other terms, not only several specific overlaps but also general overlap between two domains of individual variation can be evaluated in the framework of this model by using two (personality and chronobiological) inventories which structures were predicted by this model. Such evaluation can enrich the traditional methodology for testing specific overlaps (e.g., such as evaluation of a link of a score on morning-evening preference scale to several separate scores on personality scales). Previously, we applied canonical correlation analysis to six-score assessments obtained with a pair of multi-dimensional (personality and chronobiological) inventories and found that a set of six scorings representing one of the two domains significantly accounted for individual variation assessed with a set of six scorings representing another domain. The total amount of explained variance did not exceed 10% (Putilov et al., 2013). Given that this result was based on only one pair of inventories administered to only 265 study participants from a single dataset, we noted that "such evaluation must be regarded as preliminary" (Putilov et al., 2013).

More recently, new six-scale chronobiological and personality inventories were published (Putilov, 2016, 2018). Since they are similar to the previously developed pair of

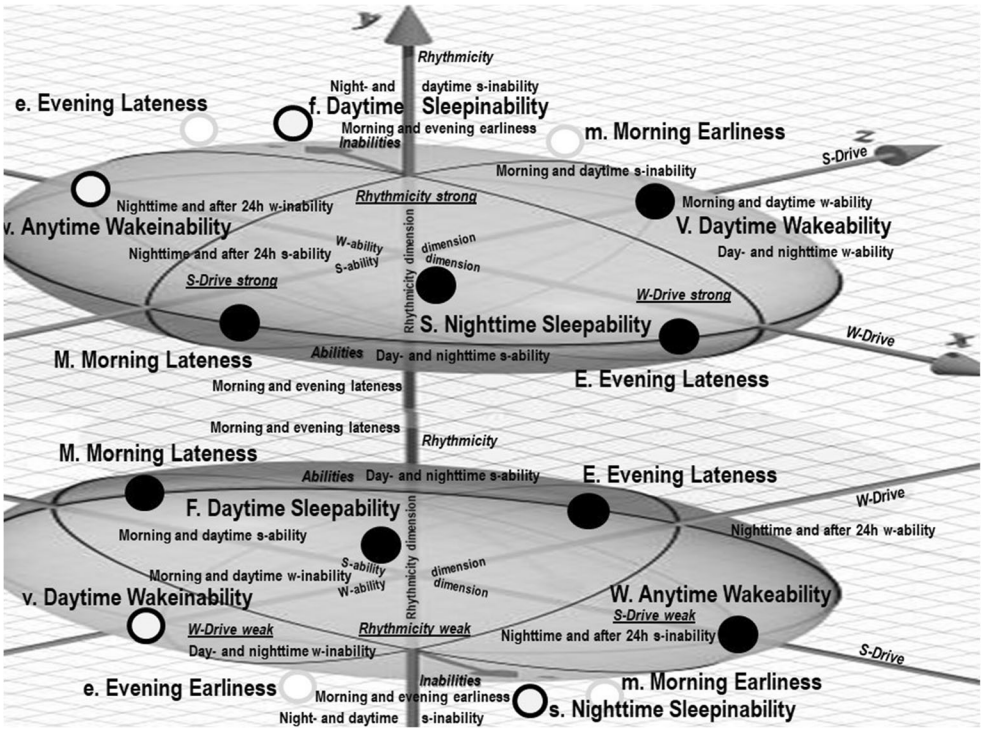

Fig. 1 Rugby cake model of the factorial structure of sleep-wake adaptability. Six factorial dimensions of sleep-wake adaptability were yielded by factorial analysis of a chronobiological inventory, the 72-item SWPAQ (e.g., M/m, Morning Lateness/Earliness, E/e, Evening Lateness/Earliness, *W*/*w*, Anytime Wakeability/Wakeinability, *V*/*v*, Daytime Wakeability/Wakeinability, F/f, Anytime Sleepability/Sleepinability, and S/s, Nighttime Sleepability/Sleepinability). They were interpreted as pairwise combinations of just three underlying dimensions (Putilov, 2010), and they were mapped on the surface of scalene (triaxial) ellipsoid or, simpler, rugby cake (Putilov, 2016). The vertical dimension (along y-axis) differentiates stronger and weaker circadian modulation of the wake and sleep drives, and two other underlying dimensions differentiate stronger and weaker wake and sleep drives (along x-and z-axis, respectively). The locations of positive and negative poles of six sleep-wake adaptability dimensions are indicated by closed and open circles, respectively

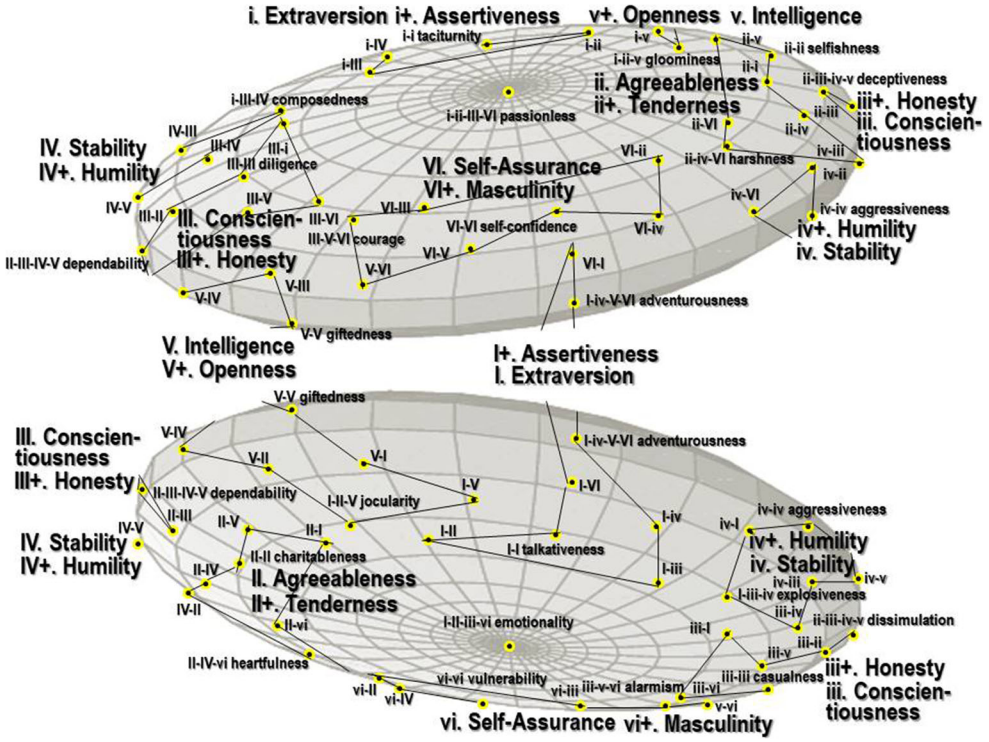

Fig. 2 Rugby cake model of the structure of personality traits. Six dimensions yielded by factorial analysis were mapped on the surface of scalene (triaxial) ellipsoid or, simpler, rugby cake (Putilov, 2018). The vast majority of narrow personality traits predicted by such three-dimensional (rugby cake) model (Putilov, 2016, 2018) can be clustered in a more manageable set of six constellations of narrow personality traits. They can be assessed with six accordant scales, I (Extraversion), II (Agreeableness), III (Conscientiousness), IV (Emotional Stability), V (Intelligence), and Self-Assurance (Putilov, 2010, 2018). Each of six factorial dimensions, I, II, III, IV+, V, and VI, includes a core narrow personality trait and several mixed narrow traits emerged as the combinations of these adjacent dimensions. Each of these six areas of factorial dimensions were paired with one of six intermediate areas, I+, II+, III+, IV, V+, and VI+, respectively. Lines connect the locations of narrow traits mapped within each of six constellations of narrow personality traits (i.e., pairwise combinations in the factorial and intermediate areas). The whole list of 172 example words (RCIP) is shown in Fig. 3

inventories in the capability to provide integrative description of individual variation in the domains of personality psychology and chronobiology, the major purpose of the present study was to utilize these new questionnaires for confirmation of the previously obtained estimates of general overlap between the six-scale personality and chronobiological assessments. Since these new estimates were obtained by using several independent datasets and several pairs of six-scale personality and chronobiological inventories, we hypothesized that, irrespective of sample and inventory, amount of general overlap would be similar to the previously reported amount. Additionally, we tried to provide further evidence for the necessity to additionally measure specific overlap between personality and chronobiological traits by examining whether significant psychological correlates can be reliably identified for other than morningness-eveningness dimensions of individual variation in sleep-wake behavior. We hypothesized that, for the previously unexplored or rare relationships, the strength of such significant correlations might be similar to the strength of well-established relationship between morning-evening preference and some of broad personality traits.

If these hypotheses are confirmed by the present analysis, further research might be aimed on exploring similarities between some of overt behavioral manifestations and other signs of chronobiological and personality traits.

Method

Four questionnaire datasets were collected by administering four paper-and-pencil questionnaires applicable for measurement of overlap between paired sets of scores on six scales representing the structures of personality traits and sleep-wake adaptabilities. In total, 759 individuals simultaneously completed one psychological inventory and either one or two of three chronobiological inventories in a classroom or experimental room (Tables 1, 2, 3 and 4). No special inclusion criteria were applied. However, we did not invite for participation in this study those who reported colds or missed classes/work due to any sickness during the previous week, complained about poor physical condition and functioning, were previously diagnosed and treated from mental or sleep disorder, were currently involved in shift or night work,

crossed several time zones during the previous month, had irregular sleep-wake schedule (i.e., more than 2-h difference in bedtimes during 5 previous workdays), and experienced sleep deprivation (i.e., at least, two days of, at least, partial sleep deprivation in the previous week).

Four datasets included the sample of participants of sleep deprivation studies in Novosibirsk ($N = 100$) and three samples of university students who completed the questionnaires in three Russian cities, Novosibirsk, Stavropol, and Petrozavodsk ($N = 659$). The mean age ± *SD* of 40 male and 60 female participants of the deprivation studies were 39.2 ± 13.7 and 41.4 ± 12.4 years, respectively. They additionally reported sleep history for the previous (pre-experimental) week and self-assessed their mood state during the 2-day experiment. The mean ages ± *SD* of male and female students from Novosibirsk, Stavropol, and Petrozavodsk were 20.4 ± 2.0 and 19.9 ± 1.7, 21.5 ± 2.1 and 21.2 ± 2.0, and 20.0 ± 3.6 and 20.7 ± 4.2 years ($N = 44$ and 154, 58 and 167, and 68 and 168, respectively).

The 172-word Rugby Cake Inventory of Personality (RCIP) (Putilov, 2018) was completed to each of study participants. Of the three chronobiological questionnaires, the 72-item Sleep-Wake Pattern Assessment Questionnaire (SWPAQ) was administered to 398 of these 659 participants. To some of them (students of Petrozavodsk and participants of the deprivation studies), two chronobiological inventories were administered with an interval of one day, the SWPAQ and the Sleep-Wake Assessment Test (SWAT), either in its full or in its reduced version (either 168 or 60 items, $N = 66$ or 34, respectively). Other participants completed only SWAT, either in its full or in its reduced version (Tables 1, 2 and 3).

The 72-item SWPAQ (Putilov, 2010) was previously validated in several studies and their results were, in particular, summarized in Putilov (2010, 2017). The scales of the SWPAQ were also cross-validated using student samples from the Novosibirsk State University and the University of Alaska Anchorage, and reliability of their English and Russian versions were shown to be similar to the reliabilities of the Russian and English versions of several English-language chronotypological questionnaires (Putilov & Putilov, 2005). Six scales of the SWPAQ (Fig. 1) were designed to assess Morning Lateness and Evening Lateness, Anytime Wakeability and Daytime Wakeability, and Anytime Sleepability and Nighttime Sleepability (M and E, W and V, and F and S, respectively). In the studied sample, Cronbach's Alphas for these six 12-item scales (Tables 1, 2 and 3) attaining the values of 0.82 and 0.81, 0.82 and 0.78, and 0.81 and 0.80, respectively.

The 168-item SWAT was developed to test the predictions of three-dimensional model of individual variation in sleep-wake adaptability (Fig. 1). Its full version includes six 28-item scales (Putilov, 2016) while in the reduced version each of the scales was shortened to 10 items by excluding items with relatively low item-scale correlations. Table 1 illustrates that

Table 1 Correlations among and between six-score assessments of individual differences

SWAT (N=272) SWPAQ (N=663)	Morning Sleepability	Evening Wakeability	Nighttime Wakeability	Daytime Wakeability	Daytime Sleepability	Nighttime Sleepability
Morning Lateness	.693***	.212***	.056	−.390***	.138*	−.160**
Evening Lateness	.275***	.689***	.583***	.094	.060	−.225***
Anytime Wakeability	−.284***	.278***	.593***	.155**	.160**	−.167**
Daytime Wakeability	−.374***	.064	.409***	.610***	−.08	.169**
Anytime Sleepability	.159***	.139***	.089*	−.301***	.660***	.197**
Nighttime Sleepability	.126**	.117**	.257***	.040	.299***	.626***
SCIoPS# (N=265) RCIP (N=767)	Extraversion I	Agreeableness II	Conscientiousness III	Stability IV	Intelligence V	Self-Assurance VI
Extraversion I, I+		.396***	.173**	−.148*	.494***	.374***
Agreeableness II, II+	−.018		.467***	.567***	.514***	.013
Conscientiousness III, III+	−.021	.435***		.458***	.496***	.251***
Stability IV, IV+	−.317***	.551***	.501***		.121*	−.291***
Intelligence V, V+	.583***	.287***	.444***	.180***		.492***
Self-Assurance VI, VI+	.521***	−.143***	.278***	−.014	.557***	

Notes. Upper part. On diagonal: Correlations ($N = 66$) between scores on six paired scales of two chronobiological (sleep-wake adaptability) inventories, the 72-item SWPAQ (Sleep-Wake Pattern Assessment Questionnaire) and the 168-tem SWAT (Sleep-Wake Adaptability Test). Above and below the diagonal: Inter-correlations among scores on six scales of the 60-tem SWAT and among scores on six scales of the 72-item SWPAQ, respectively. Lower part. Above and below the diagonal: Inter-correlations among scores on six scales of the 148-item SCIoPS (Spherical Cube Inventory of Personality Structure) and among scores on six scales of the 172-item RCIP (Rugby Cake Inventory of Personality), respectively. #: Six scales of the SWPAQ and six scales of the 148-item SCIoPS were previously used in Putilov et al. (2013) for the estimating general overlap between personality and sleep-wake behavior in 265 study participants (see Table 4). Level of significance for Spearman coefficient of correlation: * $p < .05$, ** $p < .01$, *** $p < .001$. See Figs. 1 and 2 for structural relationships between six scales representing broad dimensions of sleep-wake behavior and personality, respectively

Table 2 Standardized beta coefficients for predictors of each of six chronobiological scores

72-item SWPAQ 172-item RCIP (*N*=383)	Morning Lateness	Evening Lateness	Anytime Wakeability	Daytime Wakeability	Anytime Sleepability	Nighttime Sleepability
Extraversion I, I+	−0.032	0.029	0.071	0.093	0.076	0.251**
Agreeableness II, II+	−0.018	−0.023	0.101	−0.102	0.017	−0.008
Conscientiousness III, III+	−0.154*	−0.146*	−0.033	0.128	−0.058	0.005
Stability IV, IV+	−0.107	−0.006	0.102	0.193**	−0.021	0.173*
Intelligence V, V+	0.063	0.147	−0.031	0.176*	−0.050	−0.081
Self-Assurance VI, VI+	−0.081	0.085	0.201*	−0.020	0.091	0.028
60-item SWAT 172-item RCIP (*N*=272)	Morning Sleepability	Evening Wakeability	Nighttime Wakeability	Daytime Wakeability	Daytime Sleepability	Nighttime Sleepability
Extraversion I, I+	−0.151	−0.125	0.121	0.197*	0.019	−0.019
Agreeableness II, II+	0.079	0.009	−0.256*	−0.209**	−0.068	−0.109
Conscientiousness III, III+	−0.156	−0.136	−0.092	0.173*	0.106	0.078
Stability IV, IV+	−0.067	−0.032	0.231*	0.239**	−0.015	0.051
Intelligence V, V+	0.221*	0.100	0.086	0.063	0.067	0.040
Self-Assurance VI, VI+	−0.097	0.100	0.007	−0.040	−0.075	0.062
168-item SWAT 172-item RCIP (*N*=200)	Morning Sleepability	Evening Wakeability	Nighttime Wakeability	Daytime Wakeability	Daytime Sleepability	Nighttime Sleepability
Extraversion I, I+	−0.356**	−0.038	0.015	0.277*	−0.050	0.189
Agreeableness II, II+	0.083	0.237*	0.133	−0.125	0.100	0.128
Conscientiousness III, III+	−0.423***	−0.258*	−0.099	0.183	−0.015	0.200
Stability IV, IV+	−0.181	0.005	0.065	0.214*	−0.050	0.094
Intelligence V, V+	0.279*	0.022	0.008	−0.086	−0.009	−0.276*
Self-Assurance VI, VI+	0.111	0.254*	0.252*	0.031	0.151	−0.035

Notes. The set of six scores on six scales of the 172-item RCIP (Rugby Cake Inventory of Personality) significantly predicted scores on the majority of scales of two chronobiological (sleep-wake adaptability) inventories, the 72-item SWPAQ (Sleep-Wake Pattern Assessment Questionnaire) and the SWAT (Sleep-Wake Adaptability Test) in 60- and 168-item versions. Each set of predictors included scores on six personality scales (left column), age and gender. Level of significance for standardized beta-coefficient (t-test): * $p < .05$, ** $p < .01$, *** $p < .001$

the SWAT's scales of Morning Sleepability and Evening Wakeability (MS and EW) closely resemble M and E scales of the SWPAQ designed for assessing earliness-lateness in the morning and evening hours, respectively. Nighttime Wakeability and Daytime Wakeability scales of the SWAT (NW and DW) resemble E, W, and V scales of the SWPAQ for assessing abilities to keep waking on demand in the late evening, at night and during daytime, respectively. Daytime Sleepability and Nighttime Sleepability scales of the SWAT (DS and NS) resemble F and S scales designed to assess abilities to sleep well at daytime and nighttime, respectively (Figs. 1 and 3). Cronbach's Alphas attained the values of 0.91, 0.87, 0.79, 0.81, 0.85, and 0.81 for the full scales of the SWAT (MS, EW, NW, DW, DS, and NS, respectively). Some of the SWAT's scales were recently validated against several other chronobiological and somnological self-assessments (Putilov et al., 2021).

In the preliminary study of general overlap with sleep-wake behavioral traits assessed with the SWPAQ (Putilov et al., 2013), the personality traits were assessed with the previously developed 148-word SCIoPS (Spherical Cube Inventory of Personality Structure) (see Table 4). More recently, a new inventory for self-assessment of six personality traits, the 172-word Rugby Cake Inventory of Personality (RCIP), was constructed to test the predictions of three-dimensional model of individual variation in personality (Putilov, 2018). It consists of personality-relevant nouns distributed into six groups representing six constellations of narrow personality traits (Fig. 2). The words included in any constellation (28 in each) represent one of six factorial dimensions of personality (I-VI) and one of six intermediate broad traits (I + -VI+) each of which is associated with three adjacent factorial dimensions. The coordinates of some of the words from six scales of RCIP included in such constellations are illustrated in Fig. 2. Figure 3 additionally illustrates the results of sorting 168 (6 × 28) of 172 words of the RCIP into these six constellations (see also Putilov, 2018, for more details). Five of six factors of the SCIoPS (Putilov, 2010) and RCIP

Table 3 Standardized beta coefficient for predictors of each of six personality scores

RCIP (*N*=383) 72-item SWPAQ	Extraversion I, I+	Agreeableness II, II+	Conscientiousness III, III+	Stability IV, IV+	Intelligence V, V+	Self-Assurance VI, VI+
Morning Lateness	−0.015	−0.065	−0.136*	−0.095	−0.059	−0.088
Evening Lateness	0.143*	−0.048	−0.029	−0.054	0.136*	0.135*
Anytime Wakeability	0.035	0.082	−0.005	0.035	0.017	0.076
Daytime Wakeability	0.129*	0.066	0.209***	0.143*	0.265***	0.150**
Anytime Sleepability	0.059	−0.037	0.010	−0.052	0.031	0.065
Nighttime Sleepability	0.138*	0.083	0.070	0.102	0.108*	0.083
RCIP (*N*=272) 60-item SWAT	Extraversion I, I+	Agreeableness II, II+	Conscientiousness III, III+	Stability IV, IV+	Intelligence V, V+	Self-Assurance VI, VI+
Morning Sleepability	0.004	0.088	0.007	0.083	0.129	−0.056
Evening Wakeability	−0.094	0.028	−0.043	−0.085	−0.064	−0.001
Nighttime Wakeability	0.132	−0.197**	−0.072	0.026	0.058	0.093
Daytime Wakeability	0.126	0.092	0.265***	0.203**	0.276***	0.136*
Daytime Sleepability	0.028	0.030	0.105	0.015	0.06	0.017
RCIP (*N*=200) 168-item SWAT	Extraversion I, I+	Agreeableness II, II+	Conscientiousness III, III+	Stability IV, IV+	Intelligence V, V+	Self-Assurance VI, VI+
Morning Sleepability	−0.017	−0.138	−0.234**	−0.134	−0.036	−0.013
Evening Wakeability	0.063	0.137	−0.047	0.034	0.012	0.026
Nighttime Wakeability	0.037	0.022	0.012	0.028	0.088	0.114
Daytime Wakeability	0.223*	−0.071	0.122	0.046	0.226*	0.264**
Daytime Sleepability	0.177	−0.073	0.083	−0.045	0.199*	0.274***
Nighttime Sleepability	−0.142	0.189*	0.078	0.150	−0.142	−0.205*

Notes. Two chronobiological (sleep-wake adaptability) inventories were the 72-item SWPAQ (Sleep-Wake Pattern Assessment Questionnaire) and the SWAT (Sleep-Wake Adaptability Test) in its full (168-item) and shortened (60-item) versions. The scores on scales of these questionnaires significantly predicted each of scores on scales assessing six broad traits with the 172-item RCIP (Rugby Cake Inventory of Personality). Each set of predictors included scores on six sleep-wake adaptability scales (left column), age and gender. Level of significance for standardized beta-coefficient (t-test): * $p < .05$, ** $p < .01$, *** $p < .001$

(Putilov, 2018) that most closely resembled the Big Five factors were labeled by the traditional Roman numerals to denote I (Extraversion), II (Agreeableness), III (Conscientiousness), IV (Emotional Stability), and V (Intelligence or Intellect). The sixth factor (VI) was interpreted as Self-Assurance in Putilov (2010, 2018) and as Toughness in Shmelyov and Pokhil'ko (1993). The set of six broad traits of the SCIoPS and RCIP was found (Putilov, 2018) to be rather similar to the partially replicable set of six pan-cultural personality components (Extroversion, new version of Agreeableness, Conscientiousness, Emotional Stability, Intellect, and Honesty-Humility) of the study reported by De Raad et al. (2014).

The $SPSS_{22.0}$ statistical software package (IBM, Armonk, NY, USA) was used for testing specific overlaps within (Tables 1) and between (Tables 2 and 3) six broad personality traits and six sleep-wake adaptabilities. Spearman correlation coefficients (ρ) were calculated to interrelate six scales within each structure of individual variation (Table 1), and linear regression analyses were run to test associations of any of six personality traits to six sleep-wake adaptabilities and to test the links of any of six sleep-wake adaptabilities to six personality traits (Tables 2 and 3, respectively). The $STATISTICA_{8.0}$ software package (StatSoft Inc., Palo Alto, CA, USA) was used to perform canonical correlation analysis for estimating general overlap between the paired sets of six-scale assessments (Table 4).

Results

The inter-correlation patterns yielded for the sets of six scales of two – previously applied and new - inventories (either chronobiological or psychological) were rather similar (below and above the diagonal in Table 1, either upper or lower part, respectively). Moreover, close associations (any $\rho > .59$) were revealed in comparison of each of six scales of the 72-item SWPAQ with the analogous scale of the reduced (60-item)

Table 4 Canonical correlations between six pairs of six-score assessments

Domain	Chronobiology vs. Personality				Chronobiology	
Inventory	SWPAQ[#]	SWPAQ	SWAT	SWAT	SWPAQ	SWPAQ
Items	72	72	60	168	72	72
TR, %	6.26	6.20	5.87	8.06	53.75	56.26
Inventory	SCIoPS[#]	RCIP	RCIP	RCIP	SWAT	SWAT
Items	148	172	172	172	168	60
TR, %	8.42	7.08	6.06	8.14	54.24	58.65
R	.450	.403	.453	.408	.907	.918
χ^2	91.6^{***}	106.2^{***}	89.8^{***}	80.1^{***}	253.8^{***}	121.4^{***}
N	265	383	272	200	66	34

Notes. Each set of six scores represents one of two Domains of individual variation (either Chronobiology or Personality). Two chronobiological (sleep-wake adaptability) inventories were the 72-item SWPAQ (Sleep-Wake Pattern Assessment Questionnaire) and the SWAT (Sleep-Wake Adaptability Test) in the full (168-item) and shortened (60-item) versions. Two personality inventories were the 148-item SCIoPS (Spherical Cube Inventory of Personality Structure) and the 172-item RCIP (Rugby Cake Inventory of Personality). [#]: The association of the SWPAQ with the 148-item SCIoPS were obtained from the previously collected dataset (Putilov et al., 2013). *TR*, % = Total redundancy in %; *R* = Canonical correlation; $\chi^2 = \chi^2$-test; Significance of the results of assessment of general overlap between two sets of scores: $^{***}p < .001$. See also notes to Table 1

version of SWAT (on the diagonal of upper part of Table 1). In general, the correlations given in Table 1 suggested that, in any of domains (either chronobiology or personality psychology), the inter-correlation patterns obtained for one questionnaire were similar to the patterns obtained for another questionnaire.

We tested the associations between chronobiological and psychological scales using different pairs of inventories, namely, the 172-word RCIP was paired with the 72-item SWPAQ, the 60-item SWAT, and the 168-item SWAT (Tables 2 and 3). Irrespective of chronobiological inventory (e.g., either the SWPAQ or SWAT in any of two versions, regression analyses yielded similar pattern of association between each of six adaptabilities and a set of six personality traits and between each of six personality traits and a set of six adaptabilities (Tables 2 and 3, respectively). For instance, Morning Sleepability/Lateness (MS/M) was negatively associated with Conscientiousness/Conscientiousness-Honesty (iii/iii, iii+) in the analyses of associations between the SWPAQ and the PCIP, and between the SWAT and the PCIP (Table 2). Daytime/Anytime Wakeability (DW/V) was a significant predictor of Self-Assurance/Self-Assurance-Masculinity (VI/VI, VI+) in any of regression analyses (Table 3). Figure 3 summarizes such associations of each of six chonobiological scales with the sets of personality nouns describing broad dimensions of personality. In overall, the results of linear regression analyses suggested that any of six broad sleep-wake adaptabilities showed, at least, one replicable association with, at least, one of six broad personality traits (Tables 2 and 3).

Even much more replicable results were obtained for the estimates of general overlap between the six-score assessments of personality and adaptability (Table 4). Any of four canonical correlations were higher than 0.40 but not higher than 0.45, and the range was always found to be within 5.9% and 8.1% for total redundancy (*TR* is synonymous with explained variance and equivalent to R^2 of regression analysis). Such results indicated that individual variation assessed with one set of six scores explained 6%–8% of total variation in another set of six scores. Despite being rather small, general overlap between chronobiological and personality traits was always highly significant ($p < .0001$).

As expected, much stronger general overlap between the six-score assessments was obtained in analysis of two inventories developed for evaluation of individual differences in the same domain, i.e., sleep-wake behavior (right side of Table 4). The canonical correlations were as high as .91 and .92, and the total redundancies reached 54% and 59% for the overlaps between the SWPAQ scorings and the scorings obtained with two versions of SWAT (Table 4).

Discussion

The attempts to evaluate associations between individual differences in personality and sleep-wake behavior lasted for more than a half of century, but the vast majority of them focused on a search for personality correlates of one of the traits of such behavior, early-late phase of the sleep-wake cycle (e.g., Adan & Almirall, 1992; Blake, 1967; Díaz-Morales et al., 2017; Jankowski & Linke, 2020; Jonason et al., 2013; Matthews, 1988; Mecacci et al., 1986; Randler et al., 2015; Revelle et al., 1980; Zajenkowski et al., 2019; Zuber & Ekehammar, 1988). A single study has been previously designed to test a possibility to examine general overlap between these two domains of individual variation by using two inventories for integrative multidimensional assessment of individual variation in the areas of personality psychology and sleep-wake behavior (Putilov et al., 2013). The reported results were regarded as being preliminary because, to estimate general overlap between self-assessments of personality traits and sleep-wake adaptabilities, only one pair of multidimensional inventories was administered to a sample consisting of 265 individuals (Putilov et al., 2013). Therefore, here we tried to replicate these preliminary results by collecting four new samples (in total, $N = 759$) and by administering three new inventories (the RCIP and the full and reduced versions of the SWAT). The results confirmed that a variation in one set of scores can significantly predict a variation in another set of scores. They also showed that, as

DW/V. **Daytime Wakeability**	EW/E. **Evening Wakeability/Lateness**	ms/m. **Morning Wakeability/Earliness**, DW/V. **Daytime Wakeability**
I. **Extraversion:** I. eloquence talkativeness friendliness gregariousness boisterousness restlessness cockiness theatricality i. taciturnity terseness reticence secretiveness pensiveness quietness modesty prudishness I+. ***Assertiveness:*** I+ adventurousness hazardousness hardiness refractoriness assertiveness eagerness i+ reservedness shyness bashfulness timidity inhibition lethargy	II. **Agreeableness:** II. charitableness kindness generousness responsiveness affability understanding compassionateness trustfulness ii. selfishness stinginess distrustfulness suspiciousness boorishness tough-mindedness coldness sternness II+. ***Tenderness:*** II+. heartfulness tender-mindedness forgiveness meekness cordiality unpretentiousness ii+. harshness ruthlessness spitefulness stiffness self-assumption haughtiness	III. **Conscientiousness:** III. diligence orderlines gravity seriousness efficiency purposefulness austerity perfectionism iii. carelessness casualness frivolousness tomfoolery idleness laziness laxity negligence III+. ***Honesty:*** III+. dependability scrupulousness dutifulness frugality benevolence fidelity iii+. deceptiveness unconscientiousness insubordination irresponsibility dissimulation slyness
DW/V. **Daytime Wakeability**, NS/S. **Nighttime Sleepability**	DW/V. **Daytime Wakeability**	DW/V. **Daytime Wakeability**, DS/F. **Daytime/Anytime Sleepability**, EW/E. **Evening Wakeability/Lateness**, NW/W. **Nighttime/Anytime Wakeability**
IV+. ***Stability:*** IV+. composedness sedateness patience tranquility moderation temperance iv+. explosiveness hot-temperedness ill-temperedness nervousness fickleness volatility IV. **Humility:** IV. calmness peacefulness humbleness mildness tactfulness tolerance compliance manageability iv. aggressiveness hostility forwardness quarrelsomeness crudity rudeness rebelliousness willfulness	V. **Intelligence**: V. giftedness inventiveness inquisitiveness versatility perspicacity wisdom prudence sanity v. commonness ordinariness ignorance immaturity illogicality light-mindedness light-heartedness rashness V+. ***Openness:*** V+. exuberance jocularity artistry wittiness emancipation relaxedness v+. gloominess moodiness backwardness impersonality constraint restraint	VI. **Self-Assurance**: VI. rigidity self-confidence coolness imperturbability inflexibility toughness headstrongness imperiousness vi. indecisiveness vulnerability sentimentality susceptibility flabbiness hopelessness docility submissiveness VI+. ***Masculinity:*** VI+. courage masculinity ambitiousness leadership competitiveness resourcefulness vi+. alarmism cowardice dependence obsequiousness clumsiness incompetence
I II III vi. Emotionality: I II III vi. emotionality oversensitivity i ii iii VI. impartiality passionless		

Fig. 3 Associations of six sleep-wake adaptabilities with nouns included in the RCIP. Most of nouns (168 from 172) were grouped into six constellations to assess broad personality traits representing six factorial dimensions (I, II, III, IV+, V, VI) and six intermediate areas, i.e., areas between three adjacent factorial dimensions (I+, II+, III+, IV, V+, and VI+)

compared to the link between two sets of chronobiological self-assessments provided by two different questionnaires (54%–59% of explained variance), the link between the sets of psychological and chronobiological self-assessments was relatively weak (6%–8% of explained variance). High extent of similarity of the results provided by analyses of different datasets and different pairs of chronobiological and personality questionnaires indicated replicability of such estimates of general overlap.

The present results on specific overlaps between personality and morningness-eveningness dimensions corroborated the findings pointing at personality dimension III (Conscientiousness) as the most reliable correlate of morning-evening preference (Jackson & Gerard, 1996; Rahafar, Castellana, Randler, & Antúnez, 2017; Randler et al., 2017; Tonetti et al., 2009; Tsaousis, 2010, etc.). Moreover, it has to be noted that the results were also in agreement with some of earlier published reports suggesting that a positive association between earliness and Conscientiousness might be mostly revealed for morning rather than for evening component of this multidimensional construct (Faßl et al., 2019; Lipnevich et al., 2017; Putilov et al., 2013). The results also confirmed the existence of other, similarly significant and reliable relationships, not limited to the well-established link between Conscientiousness and morningness-eveningness. In particular, Conscientiousness seemed to be also a reliable correlate of Daytime Wakeability (Table 3). Although such other relationships were previously highlighted (Pljusnin & Putilov, 1993; Putilov et al., 2013), the reports on the associations between broad personality traits and other than morningness-eveningness traits remain scarce. A number of scales were already suggested for evaluation of such other chrionobiological traits, e.g., languidness/vigorousness and flexibility/rigidity of sleeping habits (Barton et al., 1995), time awareness and strength of diurnal preference (Di Milia, Folkard, Hill, & Walker Jr., 2011), amplitude characteristics of diurnal rhythm (Díaz-Morales et al., 2017; Dosseville, Laborde, & Lericollais, 2013; Ogińska, 2011). Further studies might be aimed on confirmation of the recently established associations

of these scales with personality (Carciofo, 2020; Carciofo & Song, 2019; Díaz-Morales et al., 2017; Faßl et al., 2019; You et al., 2020).

In such future studies, a model-based approach (Figs. 1 and 2) might help in advancing the classification, generalization, prediction, and explanation of data on the personality correlates of sleep-wake behavior. The 3-D models of personality and sleep-wake adaptability structures predict significant associations among some pairs of six dimensions that have not been explored so far. Therefore, the results on a relationship between a personality trait and a trait of sleep-wake behavior that was previously well-known from the literature might be used to predict similar relationships for other correlated pairs of dimensions. For example, the mentioned above results on the association of Conscientiousness with Daytime Wakeability might be predicted from the findings on the relationship between Conscientiousness/Unconscientiousness and morning/evening preference. The result suggesting the correlation with Daytime Wakeability is expected because morning preference seems to be, in turn, a correlate of Daytime Wakeability in accord with the close positions of Morning Earliness/Lateness and Daytime Wakeability/Inability at the surface of 3-D structure (Fig. 1).

The overlap between the structures of individual variation in personality and sleep-wake behavior require explanation. It is reasonable to expect that it occurs because some of behavioral manifestations might be shared by a chronobiological and a personality trait. For instance, given that an early person and a conscientious person are often characterized by several very similar overt behavioral manifestations, it seems not to be very surprising to find that Conscientiousness is significantly associated with morning-evening preference (Faßl et al., 2019; Jackson & Gerard, 1996; Rahafar et al., 2017; Randler et al., 2017; Tonetti et al., 2009; Tsaousis, 2010). In particular, a link with its morning component (Faßl et al., 2019; Lipnevich et al., 2017; Putilov et al., 2013) might be partly explained by a wide spread tendency of such persons to arrive without delay to school/working place in the scheduled morning hour, sometimes even earlier. Therefore, further studies might be aimed on identification of possible similarities between overt behavior manifestations of chronobiological and personality traits as the causes of partial but significant overlap between chronobiological and personality trait structures.

Besides, they might be purposed on further testing the possibility to relate chronobiological and personality traits to their common neurobiological foundations. Such testing was already initiated in the framework of a search for the associations of morningness-eveningness with subconstructs of several psychobiological questionnaires (Antúnez et al., 2014,b; Prat & Adan, 2013; Randler et al., 2015; Randler & Saliger, 2011; Tonetti et al., 2016). Notably, personality may include shared biological bases for depression and sleep disturbance, etc. not only with morningness-eveningness (e.g., Drezno et al., 2019), but also with several other traits of the sleep-wake behavior. Therefore, such advantageous feature of these studies of the personality correlates of sleep-wake behavior as their orientation at the establishment of a link with their common neurobiological foundations might help to uncover the mechanisms underlying the overlap between individual variation in the domains of chronobiology and personality.

The limitations of our research include a rather narrow age range of the majority (university student) participants and the absence of any information on whether they fulfill all criteria for inclusion/exclusion. The profound change in sleep-wake pattern across ages does not allow the generalization of the results to the whole lifespan. Because some of several questionnaires implicated in the study were only recently developed, they are still waiting for the results of studies confirming their validity. It has to be noted that a remarkable similarity between the findings based on the previously and more recently developed inventories votes for their validity. The questionnaire tools originally developed in Russian language were implemented into this and previous (Putilov et al., 2013) studies of Russian-speaking participants. Therefore, studies in other tongues are desired for replicating the results of these studies.

Conclusions

Several inventories designed for multidimensional assessment of broad personality traits and sleep-wake adaptabilities provided the possibility of integrative description of individual variation in the domains of personality psychology and chronobiology thus allowing a quantitative evaluation of general overlap between these domains. We found that general overlap was week but significant and replicable. It was also found that any of six sleep-wake adaptabilities can significantly predict, at least, one broad personality trait.

Availability of Data The dataset is available from the first author on a reasonable request.

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Declarations

Conflict of Interest No potential conflict of interest was reported by the authors.

Ethical Approval The studies were conducted in accordance with the ethical standards laid down in the Declaration of Helsinki. The study

protocols were approved by the ethics committees of the research institutes and universities.

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