Personality and Individual Differences 168 (2021) 110353

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

Single-Item Chronotyping (SIC), a method to self-assess diurnal types by using 6 simple charts

Arcady A. Putilov[a,b,*], Dmitry S. Sveshnikov[c], Alexandra N. Puchkova[b], Vladimir B. Dorokhov[b], Zarina B. Bakaeva[c], Elena B. Yakunina[c], Yuri P. Starshinov[c], Vladimir I. Torshin[c], Nikolay N. Alipov[d], Olga V. Sergeeva[d], Elena A. Trutneva[e], Michael M. Lapkin[e], Zhanna N. Lopatskaya[f], Roman O. Budkevich[g], Elena V. Budkevich[g], Marina P. Dyakovich[h], Olga G. Donskaya[a], Juri M. Plusnin[i], Bérénice Delwiche[j], Clara Colomb[k], Daniel Neu[k,l], Olivier Mairesse[k,l]

[a] Research Group for Math-Modeling of Biomedical Systems, Research Institute for Molecular Biology and Biophysics of the Federal Research Centre for Fundamental and Translational Medicine, Novosibirsk, Russia
[b] Laboratory of Sleep/Wake Neurobiology, Institute of Higher Nervous Activity and Neurophysiology of the Russian Academy of Sciences, Moscow, Russia
[c] Department of Normal Physiology, Medical Institute of the Peoples' Friendship University of Russia, Moscow, Russia
[d] Department of Physiology, Pirogov's Russian National Research Medical University, Moscow, Russia
[e] Department of Physiology, Ryazan State Medical University, Ryazan, Russia
[f] Department of Physiology, Medical Institute of the of Surgut State University, Surgut, Russia
[g] Laboratory of Nanobiotechnology and Biophysics, the North-Caucasus Federal University, Stavropol, Russia
[h] Department of Economics, Marketing and Personnel Management, Angarsk State Technical University, Angarsk, Russia
[i] Department of Public Administration, National Research University Higher School of Economics, Moscow, Russia
[j] Faculty of Psychology and Educational Sciences, Vrije Universiteit Brussel, Brussels, Belgium
[k] Sleep Laboratory and Unit for Clinical Chronobiology, Brugmann University Hospital of the Vrije Universiteit Brussel, Brussels, Belgium
[l] Center for Sleep Disorders, DELTA-CHIREC, Brussels, Belgium

ARTICLE INFO

Keywords:
Chronotypology
Morningness-eveningness
Afternoon type
Afternoon dip
Sleepiness
Alertness
Sleep times
Sleep-wake pattern

ABSTRACT

Research on individual differences in the fields of chronobiology and chronopsychology mostly focuses on two – morning and evening – chronotypes. However, recent developments in these fields pointed at a possibility to extend chronotypology beyond just two chronotypes. We examined this possibility by implementing the Single-Item Chronotyping (SIC) as a method for self-identification of chronotype among six simple chart options illustrating the daily change in alertness level. Of 2283 survey participants, 2176 (95%) chose one of these options. Only 13% vs. 24% chose morning vs. evening type (a fall vs. a rise of alertness from morning to evening), while the majority of participants chose four other types (with a peak vs. a dip of alertness in the afternoon and with permanently high vs. low alertness levels throughout the day, 15% vs. 18% and 9% vs. 16%, respectively). The same 6 patterns of diurnal variation in sleepiness were yielded by principal component analysis of sleepiness curves. Six chronotypes were also validated against the assessments of sleep timing, excessive daytime sleepiness, and abilities to wake or sleep on demand at different times of the day. We concluded that the study results supported the feasibility of classification with the 6 options provided by the SIC.

1. Introduction

The research on individual differences in the fields of chronobiology and chronopsychology mostly focuses on just two - morning and evening – (chrono) types (e.g., reviewed by Adan et al., 2012; Levandovski et al., 2013). These types can be differentiated one from another by using unidimensional questionnaires for self-assessment of either state- or trait-like characteristics of an individual. Such characteristics might include either current sleep times (Roenneberg et al., 2003) or preferred times for important diurnal activities and sleep (Horne & Östberg, 1976). However, several questionnaires for the multi-dimensional self-assessment of the individual variation in the domains of the chronobiology and

Abbreviations: PC, principal component/s; ± 95%CI, 95% confidence interval/s

* Corresponding author at: 11, Nipkowstr, 12489 Berlin, Germany.
E-mail address: putilov@ngs.ru (A.A. Putilov).

https://doi.org/10.1016/j.paid.2020.110353
Received 7 June 2020; Received in revised form 12 August 2020; Accepted 18 August 2020
0191-8869/

chronopsychology were also constructed (Barton et al., 1995; Di Milia et al., 2011; Ogińska, 2011; Preckel et al., 2020; Putilov, 2007; Randler et al., 2016; Rodrigues et al., 2018). The development of these questionnaires suggested that chronotypology could be extended beyond just morning and evening types (reviewed by Putilov, 2017), but such extended classification has not been proposed so far.

We previously supported this possibility in two studies published in this journal. First, 130 participants enrolled in a sleep deprivation experiment were subdivided into four, not two, chronotypes by using an inventory designed for separation of self-assessment of morning and evening components of diurnal preference (Putilov et al., 2015). Each of these types was found to differ from the three other types in the pattern of 24-h variation in self-rated alertness-sleepiness levels. For instance, on the interval from 9 a.m. to midnight, these levels not only either increased or decreased (evening or morning types, respectively), but they also remained permanently high or permanently low in two other types that would be named "energetic" or "lethargic" (Putilov et al., 2015). Second, 1305 participants of an online survey were prompted to predict changes in their sleepiness level throughout 32 h of permanent wakefulness after awakening at 7:30 (Putilov et al., 2019). In addition to morning and evening types, two more chronotypes termed "afternoon" type and "napper" were uncovered by the principal component analysis of the predicted change in the sleepiness level on the time interval from 8 a.m. to 6 a.m. A lowered afternoon sleepiness level combined with rather high morning and evening sleepiness levels was reported by the former type, while an elevated afternoon sleepiness level contrasting with the decreased morning and evening sleepiness levels was reported by the latter type (Putilov et al., 2019).

Therefore, 6 above-mentioned chronotypes ("morning", "evening", "energetic", "lethargic", "afternoon", and "napper") would not be rare in human populations. The last question of the first English-language questionnaire designed for self-assessment of time of day preference (Horne & Östberg, 1976) asks about self-classifying as definitely morning, more morning than evening, more evening than morning, or definitely evening type ("One hears about 'morning' and 'evening' types of people. Which one of these types do you consider yourself to be?"). Turco et al. (2015) reported that the self-determined chronotypes significantly differed in the time course of subjective sleepiness during a representative waking day and in sleep–wake timing (bedtime, sleep onset, wake up, and get up time). The question arises whether not only morning and evening types but also four other types can be self-classified by responding to a single question, and whether, despite such a one-click way of chronotyping, these 6 chronotypes are also significantly different in multi-item self-assessments, including the diurnal changes in subjective sleepiness level throughout the day.

Consequently, we tried to further support the feasibility of extended chronotypology by implementing and validating a novel, single-item instrument for identifying 6 chronotypes. To facilitate such self-identification, an image with 6 chart options was designed and included in the last item (Fig. 1) of an online survey consisting of several questionnaires. We also additionally tested another version of this single-item instrument with the short descriptions of 6 chronotypes instead of this image and the results of such testing are included in Supplementary (Fig. S1 and Table S1).

We examined the following two hypotheses:

1) the results of applying this single-item self-identification of chronotype would show that each of these 6 chronotypes would not be rare in studied populations (e.g., its prevalence would not be lower than 5%), and
2) although these 6 chronotypes types can be self-determined by responding to a single question, they would demonstrate the expected differences in other (multi-item) self-assessments including the time course of subjective sleepiness, proneness to experience excessive sleepiness during the day, and abilities to wake or sleep on demand at certain times of the day.

2. Materials and methods

2.1. Samples

The samples of the present large-scale online survey (n = 2283 in total) were collected via the Moscow and Novosibirsk web-pages (https://docs.google.com/forms/d/e/1FAIpQLSdIEeg00XFqmoULmKj-XMqGI9rtMwpPD4HVwv5ZqYtH-BDMd3A/viewform and www.chronotype.ru, respectively). The Moscow and Novosibirsk collections of responses included 1748 and 535 volunteers (1235 and 535 women, respectively). The vast majority of participants (1981) were university students (see the brief descriptions of all collected samples in Table 1).

2.2. Single-Item Chronotyping (SIC)

In Fig. 1, the last item of each questionnaire battery is illustrated along with the translations of Russian terms into English. Participants are prompted to choose their chronotype from 6 simple charts depicting different levels of their activity (high or moderate or low) at 3 different intervals of the day (morning, daytime, and evening). This procedure referred to as Single-Item Chronotyping (SIC) was designed to account for, in addition to the well-established pair of "morning" vs. "evening" types, two other previously suggested pairs of chronotypes, such as "napper" vs. "afternoon" type (Putilov et al., 2019) and "energetic" vs. "lethargic" types (Putilov et al., 2015). In Russian translation, these types were named "morning" vs. "evening" (a fall vs. a rise of alertness throughout the day), "daytime" (active) vs. "daytime sleepy" (a peak vs. a dip of alertness in the afternoon) and "highly active" vs. "moderately active" (the permanently high vs. low alertness levels throughout the day). It has to be noted that the term "moderate" was used for the last type instead of "low" in accord with the low level shown in the graph due to negative connotations of such terms as "low active type" or "lethargic type" in Russian language (Fig. 1).

Another version of the SIC (with 6 graphs replaced by their 6 short descriptions) was applied in another survey and its results are illustrated in Supplementary (Fig. S1 and Table S1).

2.3. Other self-assessments (VJT, SWAT, ESS, MCTQ) in brief

The Visuo-verbal Judgment Task (VJT) was chosen as the major questionnaire tool for validation of the SIC. It was originally designed for predicting sleepiness at 19 different randomly presented times (Marcoen et al., 2015). On both Moscow and Novosibirsk web-pages, the SIC (Fig. 1) and this 19-item VJT (Figs. 2 and S2, and Tables 2, S2 and S3) were following the reduced (50-item) version of Sleep-Wake Adaptability Test (SWAT) designed for the self-assessment of sleep- and wakeabilities at different times of the day (Putilov, 2016) (Table 3 and Fig. S3). The Moscow web-page additionally included the 8-item Epworth Sleepiness Scale (ESS) to measure sleep propensity (Johns, 1991) and the Munich ChronoType Questionnaire (MCTQ) for self-reporting times of sleep onset and offset for weekdays and free days (Roenneberg et al., 2003) (Table 3 and Fig. S4). The Novosibirsk page included only the questions about bed- and risetimes on weekdays and weekends (Table 4).

2.4. Visuo-verbal Judgment Task (VJT)

In more details, the 19-item VJT (Marcoen et al., 2015) was designed to evaluate how sleepy survey participants thought they would be performing a sleepiness-neutral activity (sitting and reading) at different randomly presented times after having habitual night sleep. Such sleep is expected to be terminated at approximately 7:30, either by a waking up signal or due to a spontaneous awakening. The time cues from 8 a.m. to midday and from 8 p.m. to midnight are presented with one-h intervals, while time cues between midday and 8 p.m. and after midnight are presented with two-h intervals (Figs. 2 and S2). Moreover,

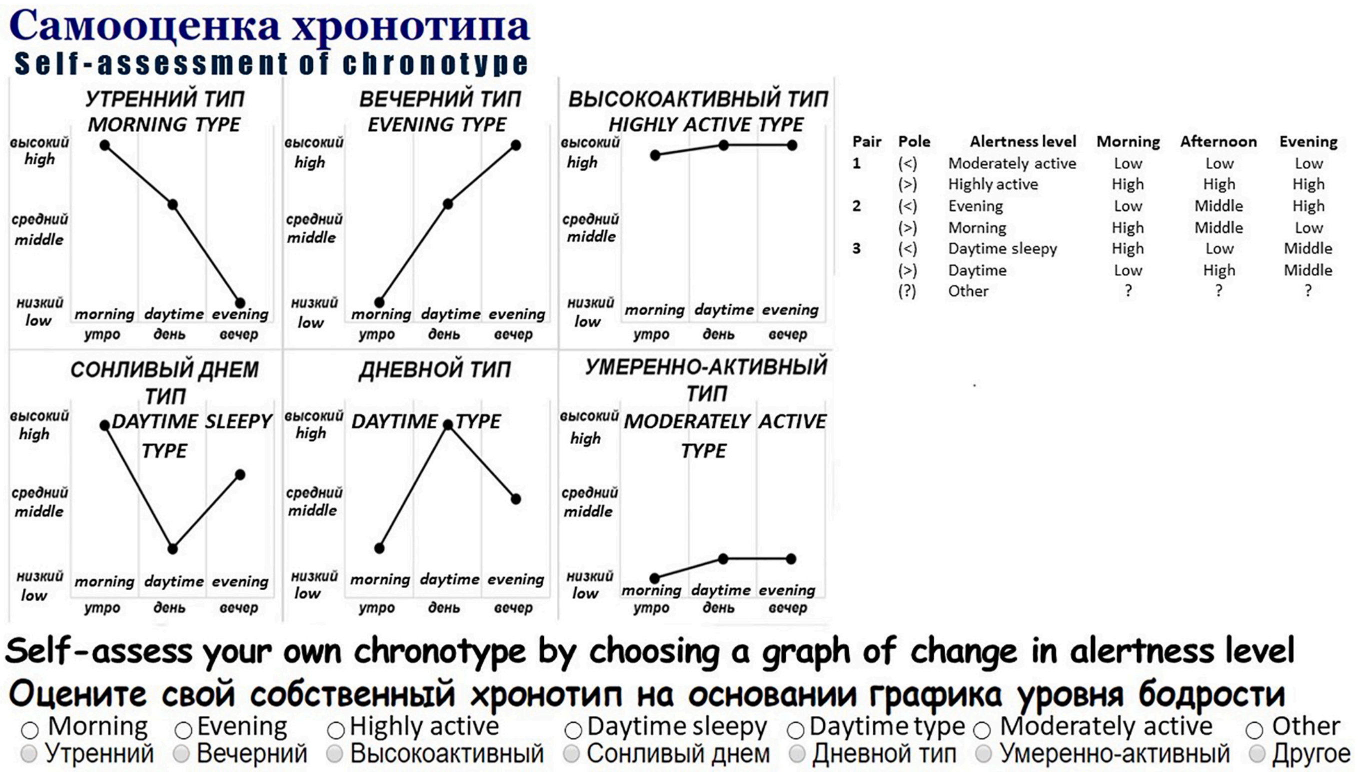

Fig. 1. The SIC, the last item asking to use 6 chart options for choosing chronotype.
Last item of the survey with inserted translations of Russian terms in English and the list of 6 chronotypes. Three pairs of mirror charts are presented, evening (active) type opposes morning (active) type, daytime sleepy type opposes daytime (active) type, and moderately active type opposes highly active type.

Table 1
Percentage of different types in samples collected via two sites.

Type	Site	Moscow					Novosibirsk		Total
	Sample	Peoples'	Pirogov	Ryazan	Surgut	Other	North	Other	
(<)	Moderately active	15	16	15	16	22	14	16	16
(>)	Highly active	11	6	7	9	7	11	7	9
(<)	Evening (active)	25	25	21	20	22	35	18	24
(>)	Morning (active)	14	12	12	12	15	11	20	13
(<)	Daytime sleepy	12	24	23	20	20	14	20	18
(>)	Daytime (active)	15	13	17	18	8	14	15	15
(?)	Other	7	4	5	4	4	1	4	5
	Total	100	100	100	100	100	100	100	100
n	Whole sample	626	314	484	226	98	331	204	2283
	Women	413	239	353	158	72	271	161	1667
Age	Mean, years	19.1	19.2	19.2	20.2	36.5	20.5	41.4	22.1
	Standard deviation	1.5	1.0	1.2	1.6	15.9	1.7	11.8	8.6

Notes. Percentage of answers to the last question asking to choose your own chronotype by using three pairs of mirror graphs illustrating daily variation in activity (Fig. 1). Moscow and Novosibirsk: Samples were collected via the Moscow and the Novosibirsk site https://docs.google.com/forms/d/e/1FAIpQLSdIEeg00XFqmoULmKjXMqGI9rtMwpPD4HVwv5ZqYtH-BDMd3A/viewform and www.chronotype.ru, Peoples', Pirogov, Ryazan, Surgut and Other: Students of two Moscow universities, Peoples' and Pirogov, two universities in other Russian cities, Ryazan' and Surgut, and visitors from staff of several universities and students from several other Moscow universities, respectively, and North and Other: Students of the North-Caucasus Federal University, Stavropol and visitors from the staff of universities and research institutes in Stavropol, Novosibirsk, and Angarsk); n: Number of survey participants in the Whole sample and Women subsample, respectively.

the participants would see on the screen a visual aid that consisted of clock times along the scale illustrating the daily variation in the outdoor illumination level and indicating the duration of the waking period (see Marcoen et al., 2015, for these illustrations and other details). The randomly collected sleepiness self-ratings are then subsequently ordered for constructing a predicted sleepiness curve for each survey participant.

Additional information on this original version of the VJT and its application into a survey of the Belgian population is included in Supplementary (Fig. S2 and Table S2).

2.5. *Sleep-Wake Adaptability Test (SWAT)*

The 168-item SWAT was originally constructed for testing the predictions of the Three-Dimensional Model of Individual Variation in the Sleep-Wake Adaptability (Putilov, 2016). Cronbach's Alphas (α) were between 0.79 and 0.91 for the 6 28-item SWAT's scales. In the present study, the initial list was reduced to 50 items by merging two scales (Nighttime and Evening Wakeability scales into one, Nighttime Wakeability, scale) and by excluding 118 items with lower item-scale correlations on the result of the analysis of one of the previously collected

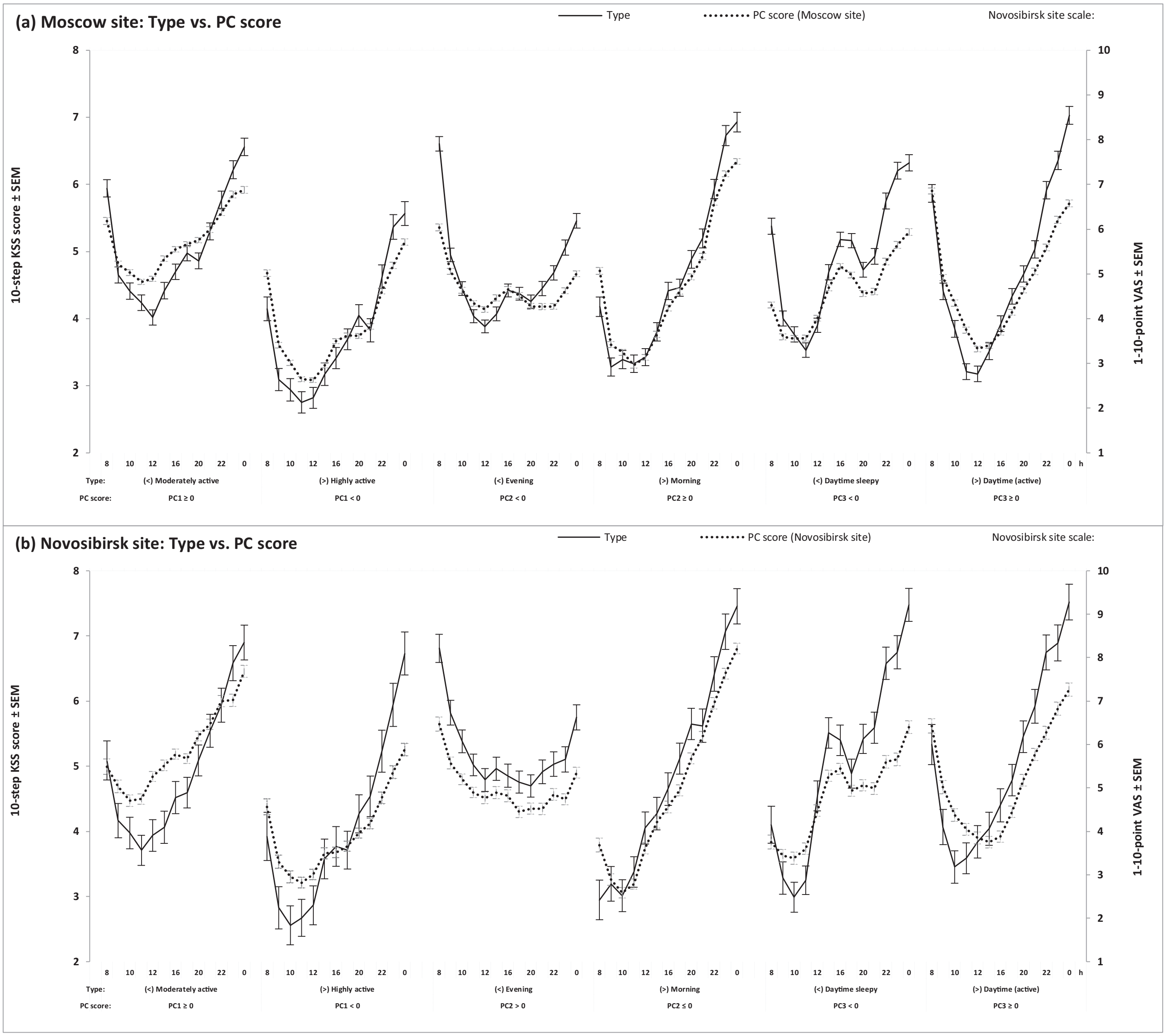

Fig. 2. Change in predicted level of sleepiness between 8:00 and midnight in 6 chronotypes.
The curves of 6 SIC-based types (Fig. 1 and Table 1) are paired with the curves of 6 homologous PC-based types obtained by the sample's division in accord with individual PC score, either 0 < or ≥ 0 (Table 2). (a and b) Sleepiness was reported either as a score on the 10-step KSS, from 1- Extremely alert to 10- Extremely sleepy, can't keep awake (Moscow, $n = 1748$) or by using Visual Analogue Scale (VAS; Monk, 1989) with the words "extremely alert" and "extremely sleepy" assigned to each pole of the two-way arrow, the responses were collected as one of 10 numbers between 1 and 10 (Novosibirsk, $n = 535$); SEM: Standard Error of Mean.

samples of school and university students ($n = 1048$). For the samples collected via the Moscow and Novosibirsk sites ($n = 1748/519$), Cronbach's Alphas attained the values of 0.82 and.84, 0.74 and 0.81, 0.77 and 0.78, and 0.77 and 0.81 for four 10-item scales of interest, Morning Sleepability (MS) and Nighttime Wakeability (NW), Daytime Wakeability (DW) and Daytime Sleepability (DS), respectively (Tables 3 and 4, and Fig. S3d-S3g).

2.6. Epworth Sleepiness Scale (ESS)

The ESS (Johns, 1991) is one of the most widely used questionnaires in clinical sleep research for determining subjective sleepiness defined as the propensity to doze off in 8 different daily life situations. This likelihood is quantified with a scale ranging from 0 to 3, where 0 corresponds to none and 3 where dozing off is the most likely. The total score ranges from 0 to 24. Values above 10 are considered to be indicative of significant sleepiness. The psychometric properties of the ESS have been investigated on multiple occasions (e.g., Mairesse & Neu, 2016). Its internal consistency (Cronbach's Alpha) varies between 0.73 and 0.90 (Kendzerska et al., 2014). In the samples collected by using the Moscow site (n = 1748), Cronbach's Alpha attained the value of 0.70 (Fig. S4a).

2.7. Munich ChronoType Questionnaire (MCTQ)

Four self-reported times for sleep onset and offset on weekdays and free days were obtained with the MCTQ (Roenneberg et al., 2003). Additional calculations gave the estimates of differences between free and weekdays in sleep onset and offset (Fig. S4b-S4e). We previously showed that, after averaging over times reported for hundreds of previously published samples, the mean times were almost identical to the times predicted by a sleep-wake regulation model (Putilov et al., 2020). In the

Table 2
Odds ratios for having either negative or positive PC score by different types.

Principal component		1		2		3	
Eigenvalue		4.866		2.367		1.257	
% of explained variance		37.431		18.207		9.667	
Cumulative %		37.431		55.638		65.304	
Type	PC score	≥0	< 0	< 0	≥0	< 0	≥0
(<)	Moderately active	***0.80***	**1.23**	1.05	0.95	0.91	1.09
(>)	Highly active	**1.43**	***0.50***	0.98	1.02	1.13	0.87
(<)	Evening (active)	1.02	0.98	**1.44**	***0.55***	0.83	1.18
(>)	Morning (active)	1.06	0.93	***0.64***	**1.37**	1.31	0.68
(<)	Daytime sleepy	0.91	1.10	0.86	1.14	**1.31**	***0.68***
(>)	Daytime (active)	1.07	0.92	0.68	1.33	***0.62***	**1.40**
(?)	Other	0.80	1.23	**1.26**	***0.74***	1.08	0.92

Notes. Data from the Moscow site (n = 1748). Principal Component (PC) analysis of anticipated sleepiness self-ratings on the time interval from 8 a.m. to midnight yielded three PC with eigenvalue > 1. Consequently, there PC scores were calculated for each survey participant and they were sorted into two groups with either < 0 or ≥0 for each PC. An odds ratio was computed by dividing the probability of having this PC score (< 0 or ≥0) by a survey participant with this picture-based chronotype on the probability of anyone, irrespective of his/her chronotype, to have this score. The highest and lowest of 6 possible odds ratios (printed in bold and ***bold italic***, respectively) provided evidence for the full (one to one) homology between three pairs of picture-based chronotypes and three pairs of PC-based types (Fig. 2).

samples collected via the Moscow site, Cronbach's Alpha attained the value of 0.65 for four sleep times. For four bed- and risetimes collected via the Novosibirsk site, Cronbach's Alpha attained the value of 0.77.

2.8. Statistical analyses

Statistical analyses were performed with the $SPSS_{23.0}$ statistical software package (IBM, Armonk, NY, USA). Factor and Principal Component (PC) analyses were applied to levels of sleepiness self-predicted with the VJT. Factor analysis was performed for the whole interval with 19 time points (Table S2) and PC analysis was performed on the time interval from 8 a.m. to midnight (13 time points for the morning, daytime and evening hours). PC analysis showed how many patterns of changes in sleepiness level account for the main portion of the total variation in sleepiness curves (Tables 2 and S2). PC scores were calculated for each of three PC with eigenvalue > 1 revealed by such an analysis (Fig. S3a-S3c). These scores were used for sorting participants into PC-based types (either < 0 or ≥0 for each PC, this gave 6 PC-based types in total). The sorting allowed the comparison of sleepiness curves obtained for 6 PC-types with sleepiness curves obtained for 6 types provided by choosing among the 6 SIC options. By performing two-way MANOVA with independent factors “Gender” and “Type”, the SIC-based types were compared on three PC1–3 scores, 4 scores on SWAT scales, the ESS score, and sleep times (Fig. S3 and S4). Tables 3 and 4 summarize the significant results of validation of the SIC against these multi-item self-assessments by using the outcomes of this MANOVA.

3. Results

The distribution of responses to 6 charts options of the SIC (Table 1) indicated that only 5% of survey participants (107 of 2283) gave the response “Other” suggesting a failure to find their chronotype among the three pairs of mirror graphs (Fig. 1). Only near one third of the participants identified themselves as either morning or evening types, either 302 or 503, respectively (Table 1). Therefore, two other pairs of chronotypes (either daytime alert and daytime sleepy or highly active and moderately active) were chosen by the majority of survey participants, either by 345 and 413 or by 202 and 361, respectively (Table 1). The distributions of the answers to another version of the SIC had, in general, similar general features as the distribution given in Table 1, and, for instance, the percentage of the response “Other” was even lower (Supplementary Table S1).

The changes in the sleepiness levels predicted with the VJT for the 6 SIC types (Fig. 1) showed the expected type-specific characteristics (Fig. 2). The sleepiness curves differed in the level of sleepiness

Table 3
Gender-irrelevant non-overlapping of confidence intervals for pairs of mirror types.

Pole of mirror type	(<)				(>)				Figure
Gender	Men		Women		Men		Women		
± 95%CI	–	+	–	+	–	+	–	+	#
Score or sleep time, h:	(<) Moderately active type				(>) Highly active type				
1st principal component	−0.08	0.37	0.21	0.47	−1.16	−0.72	−0.66	−0.24	S3a
Daytime wakeability	0.28	2.42	−1.13	0.09	5.57	7.66	4.04	6.07	S3f
Epworth sleepiness scale	7.89	9.73	9.33	10.38	5.88	7.68	6.48	8.22[a]	S4a
Sleep offset, free days	10.27	11.12	10.27	10.75	8.98	9.81	9.39	10.19	S4d
Score or sleep time, h:	(<) Evening (active) type				(>) Morning (active) type				
2nd principal component	−0.89	−0.54	−0.61	−0.40	0.02	0.47	0.54	0.83	S3b
3rd principal component	0.09	0.45	0.16	0.38	−0.54	−0.08	−0.46	−0.17	S3c
Morning sleepability	3.24	5.08	4.83	5.94	−4.03	−1.67	−1.44	0.08	S3d
Nighttime wakeability	1.93	3.63	1.19	2.21	−3.49	−1.33	−5.54	−4.15	S3e
Epworth sleepiness scale	8.61	10.08	8.87	9.76	5.53	7.41	7.16	8.38	S4a
Sleep offset, difference	4.11	4.83	4.04	4.48	1.83	2.75	2.49	3.08	S4b
Sleep offset, free days	10.86	11.54	10.76	11.17	8.95	9.82	8.96	9.52	S4c
Sleep onset, free days	25.80	26.46	25.62	26.02	24.34	25.19	23.67	24.22	S4d
Sleep onset, weekdays	24.88	25.51	24.96	25.35	23.61	24.43	23.33	23.85	S4e
Score:	(<) Daytime sleepy type				(>) Daytime (active) type				
3rd principal component	−0.59	−0.19	−0.51	−0.27	0.08	0.54	0.32	0.59	S3c
Daytime wakeability	−1.22	0.71	−3.12	−1.97	2.48	4.64	0.55	1.81[a]	S3f
Daytime sleepability	0.45	2.41	0.85	2.02	−2.85	−0.65	−1.99	−0.71	S3g

Notes. Data from the Moscow site (n = 1748). ± CI95%: 95% Confidence Interval for Score or Sleep time of a picture-based type was calculated separately for Man or Women subsamples. Results were included in table only when, irrespective of Gender, one pair of CI95% obtained for Man and Women of one pole type (<) did not overlap with another pair of CI95% computed for Man and Women of the opposite type (>). Figure #: Supplementary Figs. S3 and S4 illustrate Mean Score/Sleep time with ± SEM (Standard Error of Mean).

[a] The intervals of two chronotypes slightly overlapped due to the drastic difference between genders.

Table 4
Non-overlapping confidence intervals for three pairs of mirror types from two sites.

Site	Novosibirsk				Moscow			
Pole of mirror type	(<)		(>)		(<)		(>)	
± 95%CI	–	+	–	+	–	+	–	+
Score or sleep time, h:	(<) Moderately active type vs. (>) Highly active type							
1st principal component	−0.33	0.31	−1.01	−0.42	0.18	0.41	−0.85	−0.53
Daytime wakeability	0.07	2.87	4.34	6.92	−0.20	1.03	5.11	6.56
Sleep offset, free days[c]	9.18	10.28	8.57	9.59[b]	10.35	10.77	9.31	9.89
Score or sleep time, h:	(<) Evening (active) type vs. (>) Morning (active) type							
2nd principal component[a]	0.61	0.96	−0.75	−0.22	−0.65	−0.47	0.43	0.68
3rd principal component	−0.21	0.19	−0.49	0.10[b]	0.17	0.36	−0.44	−0.19
Morning sleepability	2.98	5.10	−4.68	−1.50	4.57	5.54	−1.96	−0.67
Nighttime wakeability	3.59	5.48	−6.33	−3.49	1.54	2.44	−4.72	−3.53
Sleep offset, difference[c]	2.40	3.07	1.27	2.29	4.13	4.50	2.39	2.89
Sleep offset, free days[c]	10.66	11.34	8.13	9.15	10.85	11.20	9.05	9.52
Sleep onset, free days[c]	25.53	26.21	23.33	24.36	25.73	26.08	23.95	24.42
Sleep onset, weekdays[c]	24.42	25.00	22.81	23.68	25.00	25.33	23.50	23.94
Score:	(<) Daytime sleepy type vs. (>) Daytime (active) type							
3rd principal component	−0.71	−0.24	−0.09	0.49	−0.49	−0.28	0.31	0.53
Daytime wakeability	−1.85	0.22	1.47	4.00	−1.96	−0.84	1.74	2.99
Daytime sleepability	−2.37	0.25	−4.27	−1.08[b]	0.93	1.93	−2.00	−0.90

Notes. Data from the Moscow and Novosibirsk sites (n = 1748 and 535, respectively).
[a] Positive score on the 2nd Principal Component indicates evening type in the data from the Novosibirsk cite and morning type in the data from the Moscow site.
[b] The intervals overlapped in data from the Novosibirsk site.
[c] On this site sleep times were assessed by questioning about risetime and bedtime on free and weekdays.

throughout the day (moderately vs. highly active types), the timing of minimal level of sleepiness (evening vs. morning types), and the waveform of the diurnal rhythm of sleepiness (daytime sleepy vs. daytime types). More specifically, the moderately active ("lethargic") types anticipated to be sleepier than the highly active ("energetic") types at any of the time points from the morning through the afternoon till the evening hours. A relatively low sleepiness level was anticipated by the evening and morning types in the evening and morning hours, respectively (Fig. 2). A relatively low sleepiness level and, in contrast, a rise of sleepiness level were predicted in the afternoon by the daytime sleepy ("napping") types and daytime ("afternoon") types, respectively (Fig. 2).

The PC analyses of the time course of sleepiness on the time interval from 8 a.m. to midnight yielded three PCs with eigenvalues > 1 (see Table 2 for an example of the eigenvalues and other characteristics of these PC1-PC3 in the samples collected via the Moscow site). Cumulatively, these three PC explained almost 2/3 of the total variation in the sleepiness pattern. The result suggesting only three PCs with eigenvalues > 1 was also obtained in the analysis of the previously collected Brussels dataset (see Supplementary).

Odds ratios calculated as the ratio for having either negative or positive PC score by a certain SIC-based type (Table 2) provided the unmistakable identification of the one to one correspondence between each of 6 SIC-based types (Fig. 1) and each of 6 PC-based types (PC score either < 0 or ≥ 0 for each of three PC). Namely, the results (Table 2) revealed the full homology of 6 PC-based types (PC1 < 0, PC1 ≥ 0, PC2 < 0, PC2 ≥ 0, PC3 < 0, and PC3 ≥ 0) to 6 SIC-based types (highly active, moderately active, evening active, morning active, daytime sleepy, and daytime active, respectively). Figs. 2 and S2 illustrate the close resemblance between sleepiness curves of each of 6 types of the SIC and each of 6 homologous types of the PC-based division of the whole samples on two halves with PC score either < 0 or ≥ 0.

A very close similarity was also shown between the sleepiness curves of each of 6 PC-based types obtained from data collected outside Russia, in Brussels (Fig. S2). Moreover, irrespective of the sample, the factorial structure of the 19-item VJT (Table S2) included factors for morning sleepiness (8:00–11:00), daytime sleepiness (12:00–18:00) and evening sleepiness (20:00 and later). This result (see Supplementary for more details) supported the design of the SIC with 6 graphs either illustrating (Fig. 1) or describing (Fig. S1) alertness levels on the morning, daytime, and evening intervals of everyday wakefulness (Fig. 1).

The results of two-way MANOVA pointed at significant differences between 6 chronotypes in scores and sleep times at the level of significance (*p*) below 0.001 ($F_{6/1734}$ ranged from 12.6 to 52.8). In order to emphasize these differences, we highlighted the non-overlapping 95% Confidence Intervals (± 95%CI) of the opposing chronotypes in Table 3, irrespective of gender. Each of these differences suggested the expected gap in certain assessments between the types of each pair. Supplementary Figs. S3 and S4 illustrate the particular differences between the SIC-based types reported in Table 3. The most important of the differences revealed in the analysis of data collected in Moscow (Table 3) were additionally confirmed by the analysis of data collected in Novosibirsk (Table 4).

More specifically, the revealed differences (Table 4) suggested that the types from the pair of moderately active and highly active types can be recognized on a score on PC1 and on a score on Daytime Wakeability scale (Fig. S3a and S3f, respectively). The pair consisting of daytime sleepy types and daytime (active) types can be identified on PC3 score (Fig. S3c) and Daytime Wakeability or Daytime Sleepability score (Fig. S3f and S3g, respectively). The type-specific differences for the pair consisting of evening and morning types included the differences in PC2 score (Fig. S3b) and scores on two SWAT's scales, Morning Sleepability (Fig. S3d) and Nighttime Wakeability (Fig. S3e) that represent the morning and evening components of morning-evening preference in this questionnaire. Moreover, the differences within this pair in sleep times included the differences in sleep onset on weekdays (Fig. S4e), sleep offset and onset on free days (Fig. S4c and S4d) and the free-weekday difference in sleep offset (Fig. S4b).

4. Discussion

The implementation of several multi-dimensional questionnaires into chronobiological and chronopsychological research (Barton et al., 1995; Di Milia et al., 2011; Ogińska, 2011; Preckel et al., 2020; Putilov, 2007; Randler et al., 2016; Rodrigues et al., 2018) suggested the necessity to develop a new chronotypology that is extending beyond just morning and evening types. In this and two previous reports (Putilov et al., 2015, 2019) we provided convergent evidence for the feasibility of such an extension, and introduced a possible variant of such classification including 6 chronotypes.

Notably, these three pieces of evidence methodologically differ one from another. In the 1st study, we applied separate morning and evening scales to detect more than two chronotypes and to validate the 4-chronotype division against experimental alertness-sleepiness curves (Putilov et al., 2015). In the 2nd study, we demonstrated a possibility to classify the participants of an online survey into more than two chronotypes by means of PC analysis of the changes in sleepiness level. Unlike the 1st study, this study did not use any questionnaire scales developed for such multi-dimensional classifications and assessments, and, in addition, this division was validated against other uni- and multi-dimensional questionnaires and demographic data (Putilov et al., 2019). The difference of the present study from two previous studies is in implementing, for the first time, a direct and straightforward assessment of 6 chronotypes with the 1-item instrument named “SIC”. The results suggested that 1) 95% of survey participants were self-assigned to one of 6 distinct chronotypes and 2) only about 1/3 of them chose either morning or evening types (either 13% or 24%), while the majority of participants chose four other types (15%, 18%, 9% and16%, any of 6 percentages was higher than 5%). Thus, the results supported our expectations that 1) because a percentage of each of chronotypes was higher than 5%, each of these 6 chronotypes was quite common in the studied populations, and 2) although these 6 chronotypes were self-determined by responding to a single question, they demonstrated the expected differences in other (multi-item) self-assessments, such as the time course of sleepiness, prevalence of excessive daytime sleepiness, and several abilities to wake or sleep on demand at certain times of the day.

In particular, we showed, for the first time, that the responding to a single question allow the self-determination of not only morning and evening types (e.g., Turco et al., 2015), but also four other types and that each of 6 self-determined chronotypes demonstrates the expected differences in the self-assessments provided by three other questionnaire tools. Namely, the introduced methodology for self-classification into morning, evening, daytime, daytime sleepy, moderately active, and highly active types was validated against the multi-item self-assessments collected with the 19-item VJT (6 homologous patterns of diurnal variation in sleepiness level), the 50-item SWAT (scores on 4 wake- and sleepability scales), the 8-item ESS (excessive daytime sleepiness score), and self-reported sleep timing (or bed- and risetimes) on free and weekdays. All established significant differences between the opposing chronotypes (morning vs. evening, daytime vs. daytime sleepy, moderately vs. highly active types) were among expected. Moreover, the analysis of the factorial structure of the VJT consistently revealed three dimensions of the individual variation in diurnal sleepiness curves on the interval from 08:00 to 24:00 (08:00–11:00, 12:00–18:00, and 20:00 or later hours) thus supporting the design of the SIC asking to determine own chronotype by comparing the sleepiness levels in the morning, daytime, and evening hours, respectively.

Further studies are required to test the associations of these 6 types with the earlier proposed scales for multi-dimensional self-assessment of the sleep-wake cycle, sleep habits and the daily fluctuations of alertness-sleepiness level (e.g., Barton et al., 1995; Preckel et al., 2020; Putilov, 2007). Of special interest would be the testing possible associations of some of these types with the scales designed to measure the amplitude dimension of diurnal preference (Di Milia et al., 2011; Ogińska, 2011; Randler et al., 2016; Rodrigues et al., 2018).

While there are some disadvantages of using single-item scales compared to multi-item scales, there is no need to use more than a single item when an attribute is judged to be concrete (Rossiter, 2002). Our results supported the previous report of Turco et al. (2015) indicating that the time course of sleepiness and sleep–wake timing are significantly different in morning and evening chronotypes self-determined by responding to just one question. We extended their results by the demonstration of the validity of the SIC designed for self-classification into as many as 6 chronotypes. Future studies would show whether such Single-Item Chronotyping has practical importance. For instance, it would be implemented in screening settings when the researchers or clinicians are especially interested in the diurnal preference of individuals, but these individuals often complain about the length of the questionnaires assessing many other important things and consequently complete these questionnaires only partially.

The absence of data allowing the comparison of the time course of objective rather than subjective measures of sleepiness in a similarly large sample appears to be the major limitation of the present study. Another limitation is an unequal representation of ages, genders and level of education. Therefore, experiments with participants randomly sampled from the whole population are needed for confirmation of the present results. Future questionnaire and experimental research might be also aimed at exploring whether the changes in temporal environment (e.g., in the timing of light exposure, work, and social interactions) can influence the proportions of these 6 chronotypes in populations and whether these proportions can be significantly influenced by gender and age, mood and health states, night sleep quality and duration, level of physical and mental load, shift and night work, etc.

5. Conclusion

Further support for the likelihood of an extension of human chronotypology beyond just morning and evening types was provided by the development of a straightforward procedure of single-item self-assessment of 6 chronotypes and by the validation of this procedure against various other (multi-item) self-assessments.

Funding

This study was funded by the Russian Foundation for Basic Research (grant number 19-013-00424 for AAP, grant number 19-013-00568 for ROB and EVB, and grant number 19-013-00747 for ANP).

Ethical approval

The survey was conducted in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The survey was approved by ethics committees of all participated medical institutes.

Data availability statement

The dataset is available on reasonable request to the corresponding author.

CRediT authorship contribution statement

Arcady A. Putilov: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing.**Dmitry S. Sveshnikov:**Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software.**Alexandra N. Puchkova:**Formal analysis, Investigation, Methodology, Software.**Vladimir B. Dorokhov:**Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing - review & editing.**Zarina B. Bakaeva:**Data curation, Investigation.**Elena B. Yakunina:**Data curation, Investigation.**Yuri P. Starshinov:**Data curation, Investigation.**Vladimir I. Torshin:**Data curation, Investigation.**Nikolay N. Alipov:**Data curation, Investigation.**Olga V. Sergeeva:**Data curation, Investigation.**Elena A. Trutneva:**Data curation, Investigation. **Michael M. Lapkin:**Data curation, Investigation.**Zhanna N. Lopatskaya:**Data curation, Investigation.**Roman O. Budkevich:**Data curation, Funding acquisition, Investigation, Resources.**Elena V. Budkevich:**Data curation, Investigation.**Marina P. Dyakovich:**Data curation, Investigation.**Olga G. Donskaya:**Data curation, Investigation, Methodology, Project administration, Software.**Juri M. Plusnin:**Conceptualization, Methodology, Resources.**Bérénice Delwiche:**Conceptualization, Data curation, Funding acquisition, Methodology.**Clara Colomb:**Data curation.**Daniel Neu:**Conceptualization, Methodology.**Olivier Mairesse:**Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2020.110353.

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