Light Exposure Behavior Assessment (LEBA): Development of a novel instrument to capture light exposure-related behaviours

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Abstract

One or two sentences providing a **basic introduction** to the field, comprehensible to a scientist in any discipline.

Two to three sentences of **more detailed background**, comprehensible to scientists in related disciplines.

One sentence clearly stating the **general problem** being addressed by this particular study.

One sentence summarizing the main result (with the words “**here we show**” or their equivalent).

Two or three sentences explaining what the **main result** reveals in direct comparison to what was thought to be the case previously, or how the main result adds to previous knowledge.

One or two sentences to put the results into a more **general context**.

Two or three sentences to provide a **broader perspective**, readily comprehensible to a scientist in any discipline.

Keywords: keywords

Word count: X

Light Exposure Behavior Assessment (LEBA): Development of a novel instrument to capture light exposure-related behaviours

Introduction

- Light exposure is important
- Light exposure Behavior is important
- Table: Overview Existing Related Scales: items in total / items on light exposure (behaviour)
- Existing Scales: Review them in text
- None of these do light exposure behavior.

Methods

Ethical approval

The cantonal ethics commission (Ethikkommission Nordwest- und Zentralschweiz, project ID Req-2021-00488) reviewed this project and issued an official clarification of responsibility (full document see Suppl. Fig X in appendix) stating: "The research project does not fall under the scope of the Human Research Act, because your project is using only anonymised data. An authorisation from the ethics committee is therefore not required and the EKNZ is not responsible for its review."

Data Availability

Survey characteristics

Data was collected in a quantitative cross-sectional approach via a fully anonymous online survey hosted on REDCap (Harris et al., 2019, 2009) by way of the University of

Basel sciCORE. Participants were recruited via the website of a Comic co-released with the survey(Weinzaepflen & Spitschan, 2021) , social media (i.e., LinkedIn, Twitter, Facebook), mailing lists, word of mouth, the investigators' personal contacts, and supported by distribution of the survey link via f.lux software (F.lux Software LLC, 2021).

Completing the online survey took approx. 15 to 20 minutes and was not compensated. The first page of the survey comprised a participant information sheet, where participants' informed consent to participate was obtained before any of the questions were displayed. Underaged participants (<18 years) were urged to obtain assent from their parents/legal guardians, before filling in the survey. Information on the first page included the objectives of the study, inclusion criteria, estimated duration, the use, storage and sharing of the data, compensation (none), and information about the type of questions in the survey. Moreover, participants needed to confirm that they were participating the survey for the first time. To ensure high data quality, five attention check items were included in the survey (e.g., "We want to make sure you are paying attention. What is 4+5?"). The data analysed in this study was collected between 17.05.2021 and 03.09.2021. Questions incorporating retrospective recall were all aligned to the period of "past four weeks," matching the presented LEBA instrument.

In addition to the LEBA questionnaire, which is subject of the current study, the following variables and items were assessed but not included in the analysis:

- Sleep disturbance and sleep-related impairment (adult and pediatric versions) (Bevans et al., 2019; Daniel J. Buysse et al., 2010; Forrest et al., 2018; Harb, Hidalgo, & Martau, 2015; L. Yu et al., 2011)
- Sleep duration, timing, and latency, chronotype, social jetlag, time in bed, work/sleep schedule and outdoor light exposure duration (version for adults and adolescents) (Roenneberg, Wirz-Justice, & Merrow, 2003)
- Sleep environment (Olivier et al., 2016)

- Meal timing & caffeine consumption [custom items]
- Light sensitivity (photophobia vs. photophilia) (Wu & Hallett, 2017)
- Self-reported pubertal stage (only if younger than 18 years old) (Petersen, Crockett, Richards, & Boxer, 1988)

Furthermore, the following 1-item demographic variables were assessed:

- Age
- Sex
- Gender identity
- Occupational Status
- COVID-19 related Occupational setting during the past four weeks
- Time zone & country of residence
- English as native language

Participants

Table 1 summarizes the survey participants' demographic characteristics. Only participants completing the full LEBA questionnaire were included, thus there are no missing values in the item analyses. XX participants were excluded from analysis due to not passing at least one of the "attention check" items. For exploring initial factor structure (EFA) , a sample of 250-300 is recommended (Comrey & Lee, 1992; Schönbrodt & Perugini, 2013). For estimating the sample size for the confirmatory factor analysis (CFA) we followed the N:q rule (Bentler & Chou, 1987; Jackson, 2003; Kline, 2015; Worthington & Whittaker, 2006), where ten participants per parameter is required to earn trustworthiness of the result. Our sample size exceeds these requirements: Anonymous responses from a total of *n* = 690 participants were included in the analysis of the current study, split into samples for exploratory (EFA: *n* = 428) and confirmatory factor analysis (CFA: *n* = 262). The EFA sample included participants filling out the questionnaire from 17.05.2021 to XX.XX.XXXX , whereas participants who filled out the questionnaire from YY.YY.YYYY to 03.09.2021 were included in the CFA analysis. Participants indicated filling out the online survey from a diverse range of geographic locations. The ten most common geographic locations included:

- United States - America/New_York (UTC -04:00): 63 (9.1%)
- United Kingdom - Europe/London (UTC): 57 (8.3%)
- Germany - Europe/Berlin (UTC +01:00): 53 (7.7%)
- India - Asia/Kolkata (UTC +05:30): 38 (5.5%)
- United States - America/Los_Angeles (UTC -07:00): 37 (5.4%)
- United States - America/Chicago (UTC -05:00): 30 (4.3%)
- France - Europe/Paris (UTC +01:00): 22 (3.2%)
- Switzerland - Europe/Zurich (UTC +01:00): 21 (3.0%)
- Brazil - America/Sao_Paulo (UTC -03:00): 19 (2.8%)
- Netherlands - Europe/Amsterdam (UTC +01:00): 19 (2.8%)

For a full list of geographic locations, see Suppl. Table X in the appendix.

Age among all participants ranged from 11 years to 84 years [EFA: *min* = 11, *max* = 84; CFA: *min* = 12, *max* = 74], with an overall mean of ~ 33 years of age [Overall: *M* = 32.95, *SD* = 14.57; EFA: *M* = 32.99, *SD* = 15.11; CFA: *M* = 32.89, *SD* = 13.66]. In total 325 (47%) of the participants indicated female sex [EFA: 189 (44%); CFA: 136 (52%)], 351 (51%) indicated male [EFA: 230 (54%); CFA: 121 (46%)] and 14 (2.0%) indicated other sex [EFA: 9 (2.1%), CFA: 5 (1.9%)]. Overall, 49 (7.2%) [EFA: 33 (7.8%); CFA: 16 (6.2%)] participants indicated a gender-variant identity. In a “Yes/No” question regarding native language, 320 (46%) of respondents [EFA: 191 (45%); CFA: 129 (49%)] indicated to be native English speakers. For their “Occupational Status,” more than half of the overall sample reported that they currently work [Overall: 396 (57%); EFA: 235 (55%); CFA: 161 (61%)], whereas 174 (25%) [EFA: 122 (29%); CFA: 52 (20%)] reported that they go to school and 120 (17%) [EFA: 71 (17%); CFA: 49 (19%)] responded that they do "Neither." With respect to the COVID-19 pandemic we asked participants to indicate their occupational setting during the last four weeks: In the overall sample 303 (44%) [EFA: 194 (45%); CFA: 109 (42%)] of the participants indicated that they were in a home office/ home schooling setting, while 109 (16%) overall [EFA: 68 (16%) ; CFA: 41 (16%)] reported face-to-face work/schooling. Lastly, 147 (21%) overall [EFA: 94 (22%) ; CFA: 53 (20%)] reported a combination of home- and face-to-face work/schooling, whereas 131 (19%) overall [EFA: 72 (17%); CFA: 59 (23%)] filled in the "Neither (no work or school, or on vacation)" response option. We tested all demographic variables in Table 1 for significant group differences between the EFA and CFA sample, applying Wilcoxon rank sum test for the continuous variable "Age" and Pearson's χ^2 test for all other categorical variables via the gtsummary R package's "add_p" function (Sjoberg et al., 2021a) . The p-values were corrected for multiple testing applying false discovery rate (FDR) via the "add_q" function of the same package. After p-value (FDR) correction for multiple testing, none of the demographic variables were significantly different between the EFA sample and the CFA sample (all q-values $q \geq 0.2$, indicating equivalence).

Procedure

Item Generation.

1. How the items were generated
2. How the literature was reviewed to identify construct adequacy of the items.
3. Discuss the expert panel review process to assess content validity

Analytic Strategies

For our analysis we used R (version 4.1.0), with several R packages. Initially, our tool had six point Likert type response scale (0:Does not apply/I don't know; 1:Never, 2:Rarely; 3:Sometimes; 4:Often; 5: Always). Our purpose was to capture light exposure related behavior and these two response options: “Does not apply/I don’t know” and “Never” were providing similar information. As such we decided to collapse them into one making it a 5 point Likert type response scale. Necessary assumptions of EFA, including sample adequacy, normality assumptions, quality of correlation matrix, were assessed. Our data violated both the univariate and multivariate normality assumptions. Due to these violations and the ordinal nature of our response data, we used polychoric correlation matrix (Desjardins & Bulut, 2018) for the EFA. We employed principal axis (PA) as factor extraction method with varimax rotation. PA is robust to the normality assumption violations (Watkins, 2020). The obtained latent structure was confirmed by another factor extraction method: “the minimum residuals extraction” as well. We used a combination of factor identification method including scree plot (Cattell, 1966), Horn’s parallel analysis (Horn, 1965), minimum average partials method (Velicer, 1976), and hull method (Lorenzo-Seva, Timmerman, & Kiers, 2011) to identify factor numbers. Additionally, to determine the simple structure, we followed the following guidelines recommended by psychometricians (i) no factors with fewer than three items (ii) no factors with a factor loading <0.3 (iii) no items with cross-loading greater than .3 across factors (Bandalos & Finney, 2018). We also conducted psychometric analysis on non-merged response options data (supplementary analysis) and rejected the latent structure obtained as the factors were less interpretable.

Results

Item Analysis

Table 3 summarizes the univariate descriptive statistics for the 48 items. Some of the items were skewed with high Kurtosis values. Our data violated both univariate normality (Shapiro-Wilk statistics; (Shapiro & Wilk, 1965)) and multivariate normality assumptions [Marida's test;(Mardia, 1970)]. Multivariate skew was = 583.80 (p <0.001) and multivariate kurtosis was = 2,749.15 (p <0.001). Due to these violations and ordinal nature of the response data polychoric correlations over Pearson's correlations was chosen (Desjardins & Bulut, 2018). The corrected item-total correlation ranges between .03 -.48. No item was discarded based on descriptive statistics or item analysis.

Exploratory Factor Analysis

Sampling adequacy was checked using Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy (Kaiser, 1974) . The overall KMO vale for 48 items was 0.63 which was above the cutoff value (.50) indicating a mediocre sample (Hutcheson, 1999). Bartlett's test of sphericity (Bartlett, 1954), χ^2 (1128) = 5042.86, p < .001] indicated the correlations between items are adequate for the EFA. However only 4.96% of the inter-item correlation coefficients were greater than .30. The inter item correlation ranged between .44 to .91. And the corrected item-total correlations ranged between .03 to .48.

Scree plot (Figure 3) suggested a six-factor solution. Horn's parallel analysis (Horn, 1965) with 500 iterations also indicated a six-factor solution. However, the minimum average partial (MAP) method (Velicer, 1976) and Hull method (Lorenzo-Seva et al., 2011) suggested a five-factor solution. As a result, we tested both five-factor and six-factor solutions.

With the initial 48 items we conducted three rounds of EFA and gradually discarded problematic items. (cross-loading items and poor factor loading (<.30) items). Finally, a five-factor EFA solution with 25 items was accepted with low RMSR = 0.08 (Brown, 2015), all factor-loading higher than .30 and no cross-loading greater than .30. We confirmed this five-factor latent structure using varimax rotation with a minimum residual extraction method (TableA1). Table4 displays the factor-loading (structural coefficients) and communality of the items. The absolute value of the factor-loading ranged from -.49 to .99 indicating strong coefficients. The commonalities ranged between .11 to .99. However, the histogram of the absolute values of non-redundant residual-correlations Fig5 showed 26% correlations greater than the absolute value of .05, indicating a possible under-factoring. (Desjardins & Bulut, 2018). Subsequently, we fitted a six-factor solution. However, a factor emerged with only one salient variable loading in the six-factor solution, thus disqualifying the six-factor solution (TableA2). Internal consistency reliability coefficient Cronbach's alpha assumes all the factor-loadings of the items under a factor are equal (Graham, 2006; Novick & Lewis, 1967) which is not the case in our sample. Additionally Cronbach's alpha coefficient has a tendency to deflate the estimates for Likert type data as the calculation is based on pearson-correlation matrix which requires that response data should be in continuous of nature (Gadermann, Guhn, & Zumbo, 2012; Zumbo, Gadermann, & Zeisser, 2007). Subsequently to get better estimates of reliability we reported ordinal alpha which used polychoric-correlation matrix and assumed that the responses data were ordered in nature instead of continuous (Zumbo et al., 2007). Ordinal alpha coefficient value ranges from 0 to 1 and higher value represents better reliability. In the five-factor solution, the first factor contained three items and explained 10.25% of the total variance with a internal reliability coefficient ordinal α = .94. All the items in this factor stemmed from the individual's preference to use blue light filters in different light environments. The second factor contained six items and explained 9.93% of the total variance with a internal reliability coefficient ordinal α = .76. Items under this factor commonly investigated an individual's hours spent outdoor. The third factor contained five items and explained 8.83% of the total variance. Items under this factor dealt with the specific behaviors pertaining to using phone and smart-watch in bed. The internal consistency reliability coefficient was, ordinal α = .75. The fourth factor contained five items and explained 8.44% of the total variance with an internal consistency coefficient, ordinal α = .72. These five items investigated the behaviors related to individual's light exposure before bedtime. Lastly, the fifth factor contained six items and explained 6.14% of the total variance. This factor captured individual's morning and daytime light exposure related behavior. The internal consistency reliability was, ordinal α = .62 . It is essential to attain a balance between psychometric properties and interpretability of the common themes when exploring the latent structure. As all of the emerged factors are highly interpretable and relevant towards our aim to capture light exposure related behavior, regardless of the apparent low reliability of the fifth factor, we retain all the five-factors with 23 items for our confirmatory factor analysis (CFA). Two items showed negative factor-loading (items 44 and 21). Upon inspection, it was understood that these items are negatively correlated to the common theme, and thus in the CFA analysis, we reversed the response code for these two items. Figure 6 depicts the data distribution and endorsement pattern for the included items in our LEBA scale for both the EFA and CFA sample.

Confirmatory Factor Analysis

We conducted categorical confirmatory factor analysis with robust weighted least square (WLSMV) estimator since our response data was of ordinary nature (Desjardins & Bulut, 2018). Several indices are suggested to measure model fit which can be categorized as absolute, comparative and parsimony fit indices (Brown, 2015). Absolute fit assess the model fit at an absolute level using indices including χ^2 test statistics and the standardized root mean square (SRMR). Parsimony fit indices including the root mean square error of approximation (RMSEA) considers the number of free parameters in the model to assess the parsimony of the model. Comparative fit indices evaluate the fit of the specified model solution in relation to a more restricted baseline model restricting all covariances among the idicators as zero. Comparative fit index (CFI) and the Tucker Lewis index (TLI) are such two comparative fit indices. Commonly used

Model fit guidelines (Hu & Bentle, 1999; Schumacker & Lomax, 2004) includes (i) Reporting of χ^2 test statistics (A non-significant test statistics is required to reflect model fit) (ii) CFI and TLI (CFI/TLI close to .95 or above/ranging between 90-95 and above) (iii) RMSEA (close to .06 or below), (iv) SRMR (close to .08 or below) to estimate the model fit. Table 5 summarizes the fit indices of our fitted model. Our fitted model failed to attain an absolute fit estimated by the χ^2 test. However, the χ^2 test is sensitive to sample size and not recommended to be used as the sole index of absolute model fit (Brown, 2015). Another absolute fit index we obtained in our analysis was SRMR which does not work well with categorical data (C. Yu, 2002). We judged the model fit based on the comparative fit indices: CFI, TLI and parsimony fit index:RMSEA. Our fitted model attained acceptable fit (CFI =.94; TLI = .93); RMSEA = .06,[.05-.07, 90% CI]) with two imposed equity constrain on item pairs 32-33 [I dim my mobile phone screen within 1 hour before attempting to fall asleep.;I dim my computer screen within 1 hour before attempting to fall asleep.] and 16-17 [I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.;I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.]. Items pair 32-33 stemed from the preference of dimming electric device's brightness before bed time and items pair 16 and 19 stemed from the preference of using blue filtering or colored glasses during the daytime. Nevertheless, SRMR value was higher than the guideline (SRMR = .12). Further by allowing one pair of items (30-41) [I look at my smartwatch within 1 hour before attempting to fall asleep.;I look at my smartwatch when I wake up at night.] to covary their error variance and discarding two item (item 37 & 26) for very low r-square value, our model attained best fit (CFI =.97; TLI = .96); RMSEA = .05[.04-.06, 90% CI]) and SRMR value (SRMR = .09) was also close to the suggestions of Hu and Bentle (1999). Internal consistency ordinal α for the five factors of LEBA were .96, .83, .70, .69, .52 respectively. We also estimated the internal consistency reliability of the total scale using Mcdonald's ω (total) coefficient which is a better reliability estimate for multidimensional constructs (Dunn, Baguley, & Brunsden, 2014; Sijtsma, 2009). McDonald’s omega(total) coefficient for the total scale was .73.

Measurement Invariance

Measurement invariance (MI) evaluates whether a construct has the psychometric equivalence and same meaning across groups or measurement occasions (Kline, 2015; Putnick & Bornstein, 2016). We used structural equation modeling framework to assess the measurement invariance of our developed tool across two groups: **native English speakers** and **non-native English speakers**. Our measurement invariance testing involved successively comparing the nested models: configural, metric, scalar, and residual invariance models with each others (Widaman & Reise, 1997). Among these nested models configural model is the first and least restrictive model. The configural model assumes that the number of factors and item number under each factor will be equal across two groups. The metric invariance model assumes configural invariance of the fitted model and requires the factor-loadings of the items across the two groups to be equal. Having the factor-loadings equal across groups indicates each item contributes to the measured construct equivalently. Scalar invariance assumes the metric invariance of the fitted model demands the item intercepts to be equivalent across groups. This equity of item intercepts indicates the equivalence of response scale across the groups, i.e., persons with the same level of the underlying construct will score the same across the groups. The residual invariance model assumes metric invariance for the fitted model and adds the assumption of equality in error variances and covariances across the groups. This model is the highest level of MI and assures the equivalence of precision of items across the groups in measuring the underlying constructs. The invariance model fit of our scale was assessed using the fit indices including χ^2 test, CFI and TLI (close to .95 or above), RMSEA (close to .06 or below) (Hu & Bentle, 1999). We excluded SRMR from our consideration as it does not behave optimally for categorical variables (C. Yu, 2002). Table 6 summarized the fit indices. The comparison among different measurement invariance models was made using the χ^2 difference test ($\Delta\chi^2$) to assess whether our obtained latent structure of "LEBA" attained the highest level of the MI. A non-significant $\Delta\chi^2$ test between two MI models fit indicates mode fit does not significantly decrease for the superior model (Dimitrov, 2010) thus allowing the superior level of invariance model to be accepted. We started our analysis by comparing the model fit of the least restrictive model:configural model to metric MI model and continued successive comparisons. Table 6 indicates that our fitted model had acceptable fit indices for all of the fitted MI models. The model fit did not significantly decrease across the nested models up to the scalar MI model. The chi-square value difference between the scalar and residual model is zero, indicating model fit remained the same for both: scalar and residual MI model, indicating the acceptability of the residual MI model.

Sementic Analysis

To find out if our developed scale is overlapping with existing instruments, we subjected the items of LEBA to The "Semantic Scale Network"(SSN)(Rosenbusch, Wanders, & Pit, 2020). The SSN detects semantically related scales and provides cosine similarity index ranging between -.66 to 1 (Rosenbusch et al., 2020). Pairs of scale with a cosine similarity index value of 1 indicates they are perfectly redundant scales. LEBA appeared most strongly related to scales about sleep: "Sleep Disturbance Scale For Children" (Bruni et al., 1996) and "WHO-Composite International Diagnostic Interview (CIDI): Insomnia"(WHO, 1990).The cosine similarities lie between .47 to .51. Two factors of our LEBA tool: "Using phone and smart-watch in bed" and "Using light before bedtime" dealt with light exposure related behavior pertaining to sleep quality. As such the similarity index obtained is expected.

Developing Short form of LEBA

We sought the item response theory (IRT) to develop the short form of LEBA. IRT the conventional classical test theory-based analysis by gathering information on item quality by indices like item difficulty,item discrimination, and item information(Baker, 2017). IRT judges the item's quality on item information in relation to participants' latent trait level (θ). We gathered evidence on item quality by fitting each factor of LEBA with the graded response model (Samejima, Liden, & Hambleton, 1997) to the combined EFA and CFA sample (n =690). Item discrimination indicates the pattern of variation in the categorical responses with the changes in latent trait level (θ), and item information curve (IIC) indicates the amount of information an item carries along the latent trait continuum. Here, we reported the item discrimination parameter and only discarded the items with relatively flat item information curve (information <.2) to develop the short form of LEBA. Baker (2017) categorized the item discrimination in as none = 0; very low =0.01 to 0.34; low = 0.35 to 0.64; moderate = 0.65 to 1.34 ; high = 1.35 to 1.69; very high >1.70. Table 7 summarizes the IRT parameters of our scale. Item discrimination parameters of our scale fell in very high (10 items), high (4 items), moderate (4 items), and low (5 items) categorizes indicating a good range of discrimination along the latent trait level (θ). Examination of the item information curve 8 indicated 6 items (1, 25, 9, 38, 30, & 41) had relatively flat information curves thus discarded creating a short form of LEBA with 5 factors and 17 items.

Test information curve (TIC) (Figure 9) indicate the amount of information an the full-scale carry along the latent trait continuum. As we treated each factor of short-LEBA as an unidmensional construct we obtain 5 TICs (figure **??**). These information curves indicated except blue filter factor, the other factor's TICs are roughly centered on the center of the trait continuum ((θ)). Also the amount of information changed rather steadily with the change of (θ). Thus we conferred the LEBA scale (except blue filter) estimated the light exposure related behavior with precision near the center of trait continuum (Baker, 2017) which is sufficient to discriminate between latent trait measured by the each factor. The blue filter factor had a peak to the right side of the center of latent trait indicating its ability to providing information only for people who already have some preference towards using blue-filters.

Table 8 summarizes the item fit indexes of the items. All the items fitted well to the respective models as assessed by RMSEA value obtained from Signed-χ^2 index implementation. All of the items had RMSEA value <.06 indicating adequate fit. Figure 10 depicts the person fit of out fitted models. Person fit indicates the validity and meaningfulness of the fitted model at the participants latent trait level (Desjardins & Bulut, 2018). We estimated the person fit statistics using standardized fit index Zh statistics (Drasgow, Levine, & Williams, 1985). Zh < -2 should be considered as a misfit. Fig indicates that Zh is larger than -2 for most participants, suggesting a good fit of the selected IRT models.

Next, we generated scale characteristics curve (Figure 11) which plotted estimated theta score against the expected true score. The purpose of this scale characteristics curve is to find the corresponding expected true score for the given estimated theta score.

The overall we can concluded that IRT analysis indicated LEBA is a psychometrically sound measure. Item fit indexes and person fit index for all five fitted model were acceptable. Items had diverse slope parameters indicating a good range of discrimination- the ability to differentiate respondents with different levels of the light exposure related behavior. All-in-all we can recommend the LEBA to be used to capture light exposure related behavior.

Discussion

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Table 1

Releated Scales

Name	Author	Description	Relevant Items
Visual Light Sensitivity Questionnaire-8	Verriotto et al., 2017	Eight-question survey to assess the presence and severity of photosensitivity symptoms	NA
Office Light Survey	Eklundet al., 1996	A survey to assess electrical lighting environment in office	NA
Harvard Light Exposure Assessment Questionnaire	Bajaj et al., 2011	Self-administered semi-quantitative light questionnaire	NA
Hospital Lighting Survey	Dianat et el., 2013	23 items questionnaire to assess light environment in a hospital	NA
Morningness-Eveningness Questionnaire	Horne et al., 1976	19 items questionnaire to understand your body clock	NA

Table 1

Releated Scales (continued)

Name	Author	Description	Relevant Items
Munich Chronotype Questionnaire (MCTQ)	Roenneberg et al., 2003	17 items questionnaire to understand individuals phase of entrainment	NA
Assessment of Sleep Environment	Olivier et.al., 2016	13 items questionnaire measuring your sleep environment quality	NA
The Pittsburgh Sleep Quality Index (PSQI)	Buysse et al., 1989	9 items inventory to measure sleep quality and sleeping pattern	NA
Self-Rating of Biological Rhythm Disorder for Adolescents (SBRDA)	Xie et al., 2021	29 Items questionnaire assessing four dimensions of biological rhythm disorder in adolescents	Item 3,22-25 and 29

Table 1

Releated Scales (continued)

Name	Author	Description	Relevant Items
Photosensitivity Assessment Questionnaire (PAQ)	Wu et al., 2017	16 dichotomous (yes/no) items questionnaire to assess ”photophobia” and ”photophilia”	All itms

Table 2

Demographics

Variable	Overall, N = 690	1. EFA Sample, N = 428	2. CFA Sample, N = 262	p-value	q-value
Age	32.95 (14.57)	32.99 (15.11)	32.89 (13.66)	0.5	0.5
Sex				0.14	0.4
Female	325 (47%)	189 (44%)	136 (52%)		
Male	351 (51%)	230 (54%)	121 (46%)		
Other	14 (2.0%)	9 (2.1%)	5 (1.9%)		
Gender-Variant Identity	49 (7.2%)	33 (7.8%)	16 (6.2%)	0.4	0.5
Native English Speaker	320 (46%)	191 (45%)	129 (49%)	0.2	0.5
Occupational Status				0.040	0.2
Work	396 (57%)	235 (55%)	161 (61%)		
School	174 (25%)	122 (29%)	52 (20%)		
Neither	120 (17%)	71 (17%)	49 (19%)		
Occupational setting				0.3	0.5
Home office/Home schooling	303 (44%)	194 (45%)	109 (42%)		
Face-to-face work/Face-to-face schooling	109 (16%)	68 (16%)	41 (16%)		
Combination of home- and face-to-face- work/schooling	147 (21%)	94 (22%)	53 (20%)		
Neither (no work or school, or in vacation)	131 (19%)	72 (17%)	59 (23%)		

[1] Mean (SD); n (%)

[2] Wilcoxon rank sum test; Pearson’s Chi-squared test

[3] False discovery rate correction for multiple testing

Table 3

Descriptive Statistics

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item1	2.27	1.39	0.74	-0.81	0.81*	0.19
Item2	2.87	1.59	0.08	-1.60	0.83*	0.28
Item3	3.36	1.38	-0.48	-1.03	0.87*	0.23
Item4	1.47	1.18	2.38	4.00	0.43*	0.24
Item5	4.01	1.40	-1.22	0.07	0.70*	0.17
Item6	2.79	1.55	0.19	-1.48	0.85*	0.13
Item7	2.26	1.25	0.70	-0.60	0.85*	0.32
Item8	2.97	1.20	-0.06	-0.94	0.91*	0.25
Item9	2.94	1.03	-0.12	-0.40	0.91*	0.08
Item10	2.74	1.04	0.09	-0.74	0.91*	0.42
Item11	2.18	0.90	0.60	0.12	0.86*	0.41
Item12	2.36	1.22	0.59	-0.62	0.87*	0.48
Item13	2.73	1.46	0.20	-1.36	0.87*	0.25
Item14	2.14	1.31	0.77	-0.78	0.80*	0.28
Item15	3.26	1.09	-0.26	-0.45	0.91*	0.03
Item16	1.56	1.23	2.00	2.45	0.50*	0.28
Item17	1.54	1.21	2.07	2.75	0.49*	0.21
Item18	1.12	0.49	5.02	27.80	0.25*	0.18
Item19	1.05	0.36	7.23	52.98	0.13*	0.17
Item20	1.04	0.33	8.99	85.28	0.10*	0.16
Item21	1.14	0.59	4.79	24.05	0.25*	0.21
Item22	3.57	1.07	-0.65	-0.17	0.88*	0.20
Item23	2.56	1.27	0.33	-1.00	0.89*	0.08

Table 3 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item24	4.14	0.99	-1.23	1.14	0.79*	0.22
Item25	2.59	1.41	0.27	-1.27	0.86*	0.15
Item26	2.25	1.27	0.69	-0.64	0.84*	0.08
Item27	3.80	1.29	-0.87	-0.42	0.82*	0.17
Item28	3.76	1.14	-0.68	-0.45	0.86*	0.18
Item29	2.44	1.31	0.38	-1.14	0.86*	0.13
Item30	1.48	1.11	2.18	3.35	0.48*	0.13
Item31	3.00	1.62	-0.08	-1.61	0.83*	0.39
Item32	3.55	1.65	-0.60	-1.34	0.76*	0.33
Item33	3.62	1.64	-0.68	-1.25	0.74*	0.37
Item34	3.42	1.83	-0.45	-1.69	0.69*	0.20
Item35	3.86	1.67	-0.99	-0.85	0.65*	0.20
Item36	1.54	1.25	2.13	2.86	0.46*	0.35
Item37	1.33	0.91	3.03	8.43	0.41*	0.09
Item38	4.30	1.08	-1.79	2.53	0.67*	0.32
Item39	1.96	0.98	1.02	0.69	0.82*	0.07
Item40	2.16	1.19	0.71	-0.54	0.84*	0.25
Item41	1.31	0.81	2.75	6.92	0.43*	0.14
Item42	3.93	1.48	-1.06	-0.44	0.71*	0.15
Item43	1.64	1.18	1.79	2.02	0.60*	0.22
Item44	3.51	1.30	-0.70	-0.59	0.85*	0.40
Item45	2.22	1.48	0.71	-1.02	0.76*	0.29
Item46	1.76	1.23	1.35	0.44	0.66*	0.39
Item47	2.11	1.17	0.77	-0.39	0.83*	0.37

Table 3 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item48	2.60	1.25	0.29	-0.86	0.89*	0.36

Note. *p<.001

Table 4

Factor loadings and communality of the retained items

item	PA1	PA2	PA3	PA4	PA5	Communality	Uniqueness
item16	0.99					0.993	0.007
item36	0.94					0.899	0.101
item17	0.8					0.658	0.342
item11		0.79				0.642	0.358
item10		0.76				0.592	0.408
item12		0.65				0.465	0.535
item7		0.5				0.267	0.733
item8		-0.49				0.252	0.748
item9		0.32				0.113	0.887
item27			0.8			0.658	0.342
item3			0.8			0.682	0.318
item40			0.65			0.464	0.536
item30			0.45			0.353	0.647
item41			0.36			0.329	0.671
item33				0.74		0.555	0.445
item32				0.73		0.624	0.376
item35				0.66		0.454	0.546
item37				-0.39		0.174	0.826
item38				0.38		0.178	0.822
item46					0.6	0.422	0.578
item45					0.59	0.374	0.626
item25					0.41	0.193	0.807
item4					0.41	0.219	0.781
item1					0.4	0.17	0.83
item26					0.35	0.165	0.835
% of Variance	0.1	0.1	0.09	0.08	0.06		

Note. Only loading higher than .30 is reported

Table 5

Fit indices of CFA

Model	Chi-Squre	df	CFI	TLI	RMSEA	RMSEA 90% Lower CI	RMSEA 90% Upper CI	SRMR
Five factor model:25	448.51	222.00	.94	0.93	0.06	0.05	0.07	0.12
Five factor model:23	346.59	221.00	.97	0.96	0.05	0.04	0.06	0.09

Note. df: Degrees of Freedom; CFI: Comparative Fit Index; TLI: Tucker Lewis Index;RMSEA:Root Mean Square Error of Approximation; CI: Confidence Interval; SRMR: Standardized Root Mean Square

Table 6

Invariance Analysis

	Chi-Square	df	CFI	TLI	RMSEA	RMSEA 90% Lower CI	RMSEA 90% Upper	Chi-Square Difference	df difference*	p
Configural	632.20	442.00	0.95	0.94	0.06	0.05	0.07	-	-	-
Metric	644.58	458.00	0.95	0.95	0.06	0.05	0.07	18.019a	16	0.323
Scalar	714.19	522.00	0.95	0.95	0.05	0.04	0.06	67.961b	64	0.344
Residual	714.19	522.00	0.95	0.95	0.05	0.04	0.06	0c	0	NA

Note. a = Metric vs Configural; b = Scalar vs Metric; c = Residual vs Scalar; d = Structural vs Residual;* = df of model comparison

Table 7

IRT Item parameters for the LEBA Scale

	a	b1	b2	b3	b4
item16	28.55	0.78	0.90	1.06	1.40
item36	4.49	0.94	1.08	1.23	1.40
item17	2.81	0.97	1.11	1.38	1.62
item11	3.27	-0.79	0.65	1.54	2.31
item10	3.07	-1.27	-0.09	0.82	2.00
item12	1.72	-0.67	0.44	1.28	2.11
item7	1.09	-0.50	0.73	1.63	2.97
Ritem8	1.19	-2.26	-0.48	0.64	1.91
item9	0.91	-2.63	-0.96	1.11	3.49
item27	2.21	-1.88	-1.19	-0.73	0.30
item3	3.03	-1.24	-0.77	-0.20	0.66
item40	1.55	-0.51	0.46	1.32	2.22
item30	0.49	3.27	3.74	4.64	6.52
item41	0.51	3.87	4.78	6.39	8.91
item32	1.62	-1.03	-0.78	-0.42	0.16
item35	1.36	-1.09	-0.98	-0.75	-0.40
item38	0.40	-7.50	-5.58	-4.25	-0.91
item33	13.51	-0.66	-0.48	-0.24	0.13
item46	2.22	0.68	0.89	1.38	2.17
item45	1.51	0.30	0.55	1.17	1.91
item25	0.52	-1.37	-0.04	1.89	4.22
item4	0.84	2.44	2.80	3.18	3.67
item1	0.39	-0.91	1.52	3.25	5.53

Note. a = item discrimination parameter; b(1-4) = response category difficulty parameter

Table 8

Item fit statistics for the fitted models

Signed Chi-square	df	RMSEA	p	NA
item16	2.01	6.00	0.00	0.92
item36	39.06	13.00	0.05	0.00
item17	25.58	13.00	0.04	0.02
item11	24.42	21.00	0.02	0.27
item10	37.39	25.00	0.03	0.05
item12	36.60	34.00	0.01	0.35
item7	47.23	40.00	0.02	0.20
Ritem8	81.87	36.00	0.04	0.00
item27	16.41	11.00	0.03	0.13
item3	15.10	11.00	0.02	0.18
item40	9.91	9.00	0.01	0.36
item32	41.38	15.00	0.05	0.00
item35	41.68	14.00	0.05	0.00
item33	47.04	14.00	0.06	0.00
item46	49.04	33.00	0.03	0.04
item45	39.55	32.00	0.02	0.17
item25	51.56	36.00	0.03	0.04
item4	35.12	35.00	0.00	0.46
item1	32.85	39.00	0.00	0.75

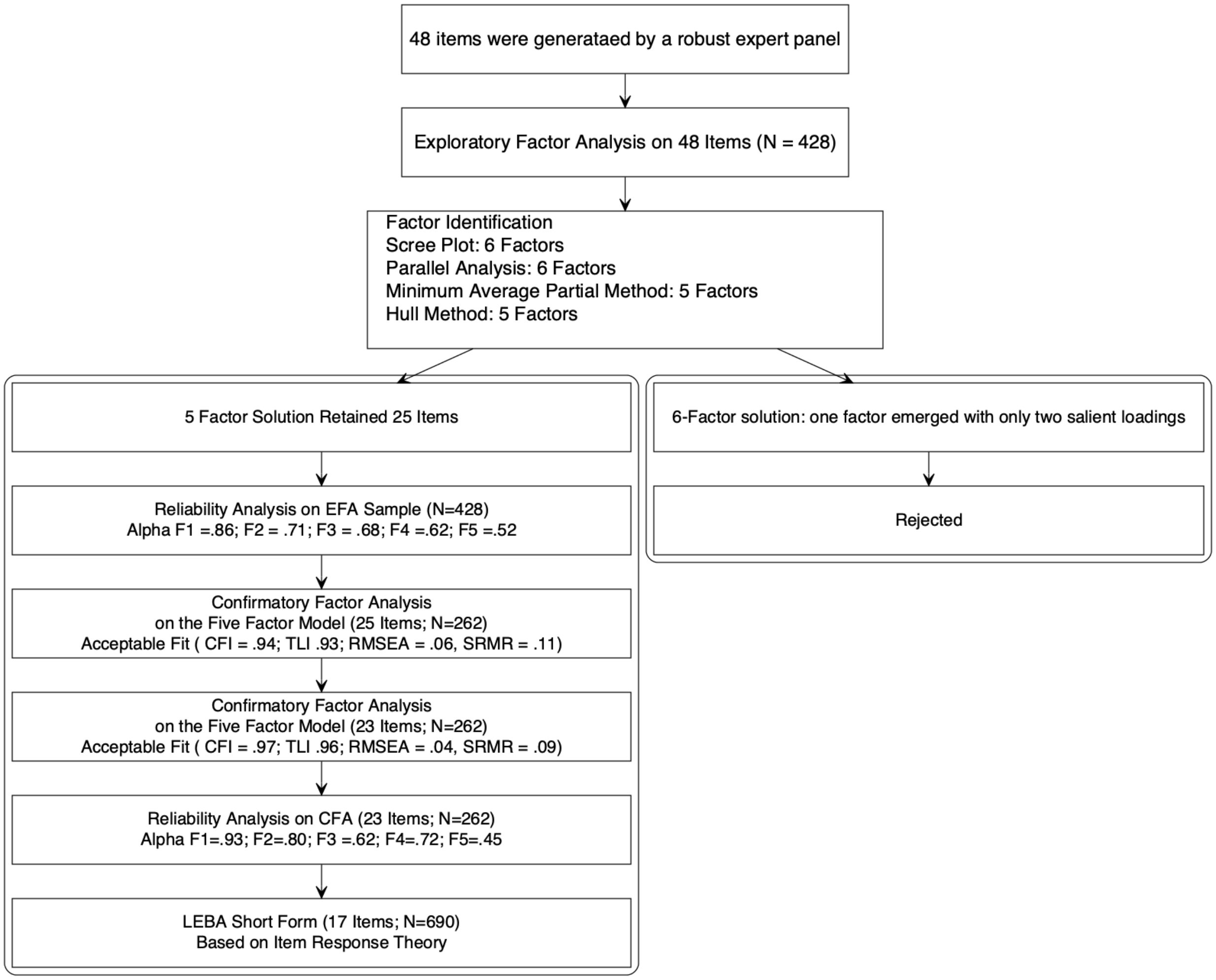

Figure 1. Development of long and short form of LEBA

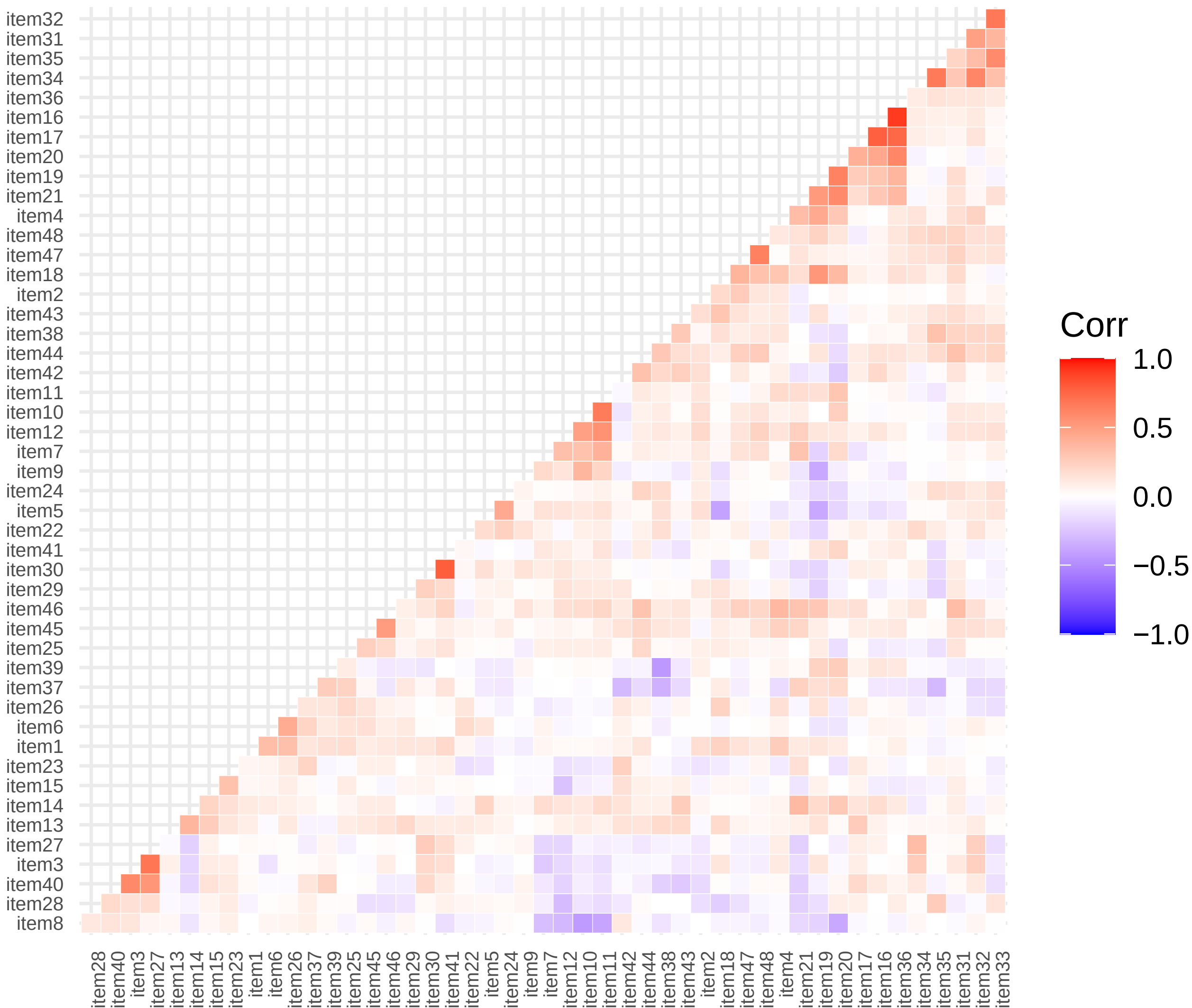

Figure 2. Correlation plot of the items

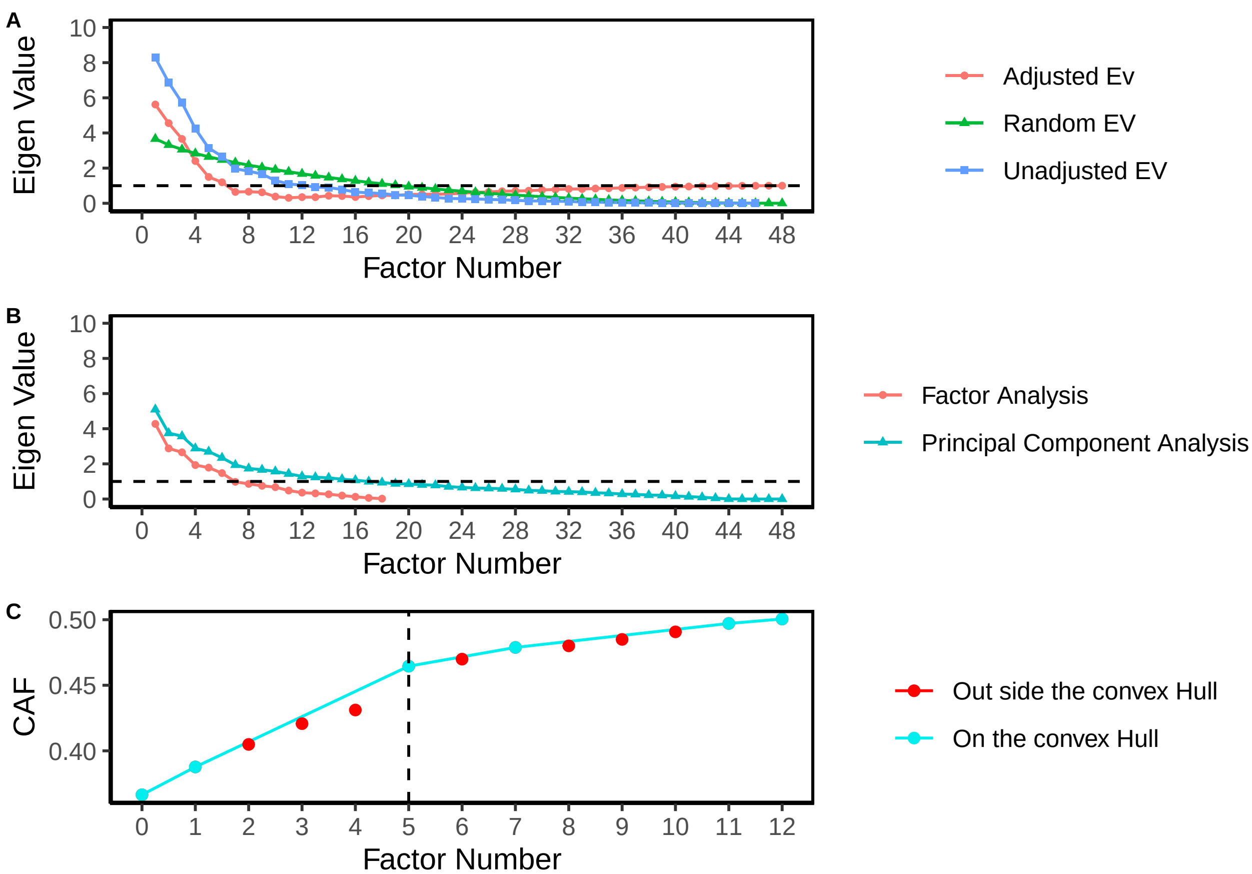

Figure 3. Factor Identification (A) Parallel analysis (B) Scree Plot (C) Hull Method

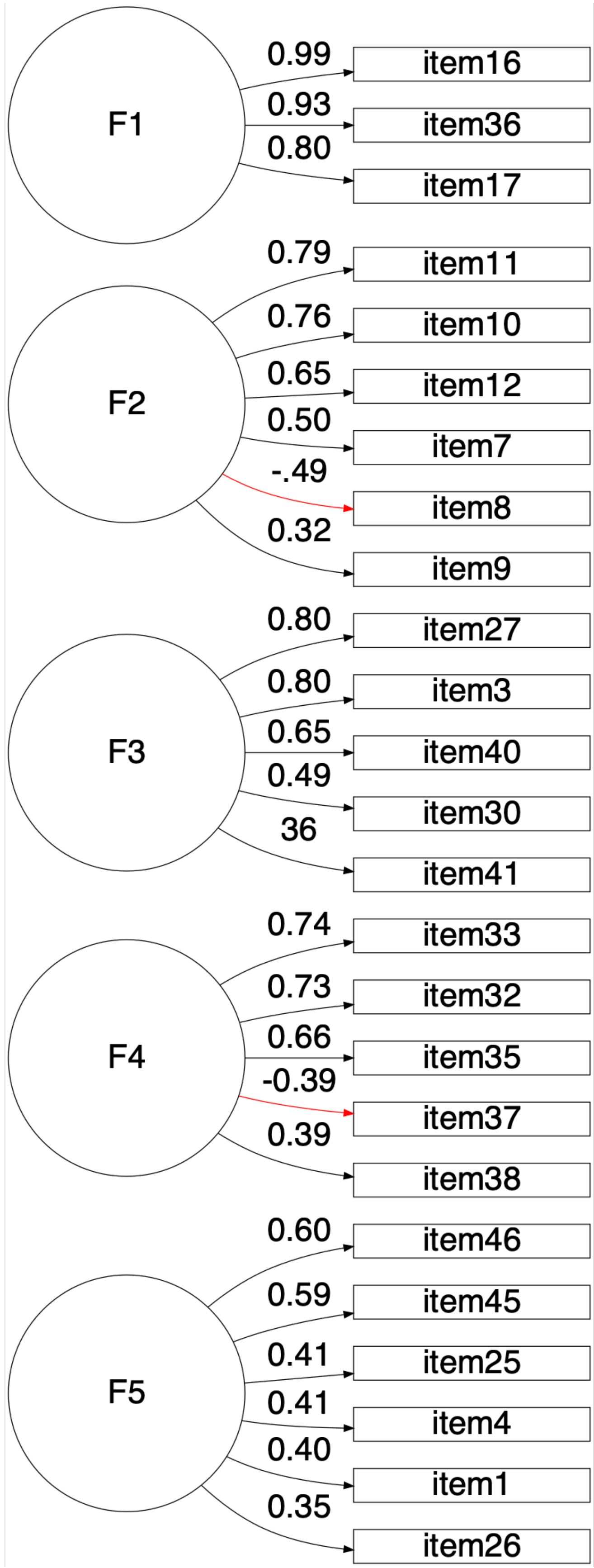

Figure 4. Five Factor Solution

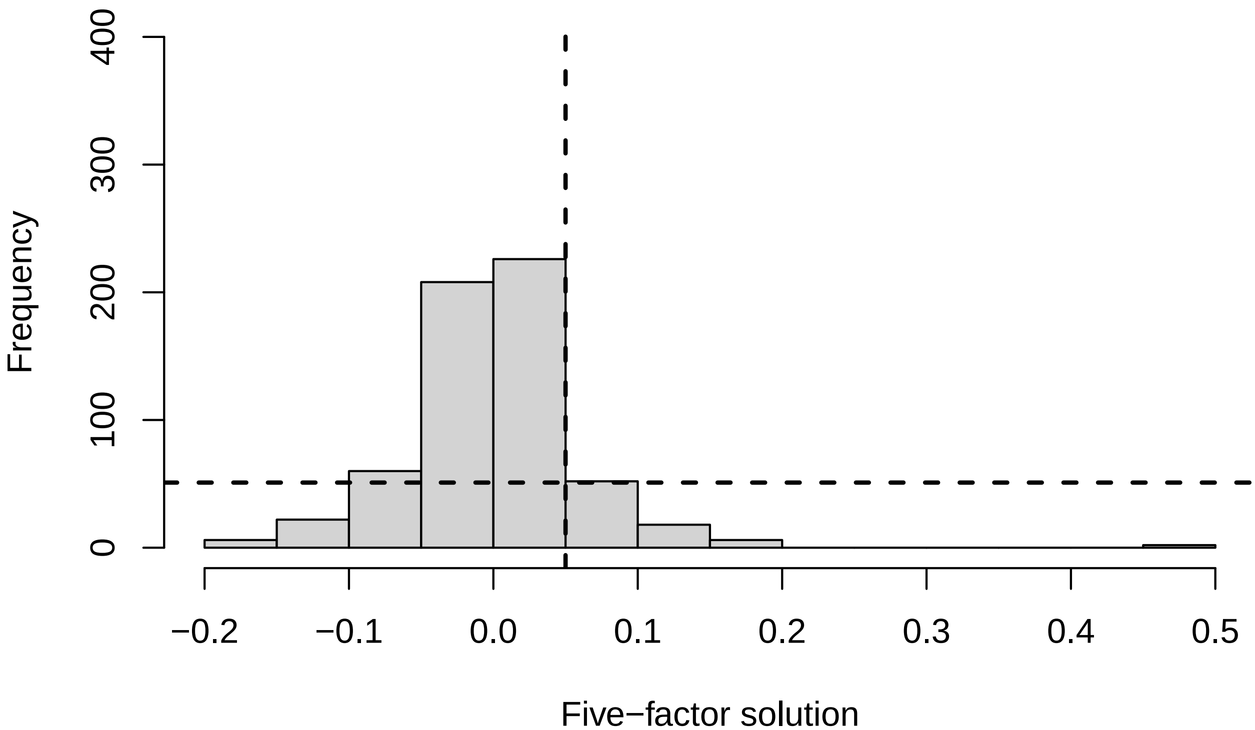

Figure 5. Histogram of residuals: five-factor solution

LEBA

Summary Descriptives of CFA and EFA Sample (N =690)

Items	Summary Statistics				Graphics		Response Pattern				
LEBA Items	n	Mean	Median	SD	Histogram[1]	Density[2]	Never	Rarely	Sometimes	Often	Always
EFA (n = 428)											
item01	428	2.3	2.0	1.4			42.29% (181)	22.20% (95)	12.62% (54)	12.38% (53)	10.51% (45)
item03	428	3.4	4.0	1.4			15.89% (68)	11.45% (49)	17.29% (74)	31.07% (133)	24.30% (104)
item04	428	1.5	1.0	1.2			84.11% (360)	3.50% (15)	2.10% (9)	2.10% (9)	8.18% (35)
item07	428	2.3	2.0	1.2			35.98% (154)	27.80% (119)	17.29% (74)	12.38% (53)	6.54% (28)
item08	428	3.0	3.0	1.2			13.79% (59)	22.20% (95)	27.80% (119)	25.93% (111)	10.28% (44)
item09	428	2.9	3.0	1.0			10.28% (44)	19.63% (84)	41.82% (179)	22.43% (96)	5.84% (25)
item10	428	2.7	3.0	1.0			11.92% (51)	31.31% (134)	31.31% (134)	21.96% (94)	3.50% (15)
item11	428	2.2	2.0	0.9			22.43% (96)	46.26% (198)	23.13% (99)	7.01% (30)	1.17% (5)
item12	428	2.4	2.0	1.2			29.91% (128)	29.67% (127)	21.50% (92)	12.15% (52)	6.78% (29)
item16	428	1.6	1.0	1.2			79.67% (341)	4.21% (18)	3.97% (17)	4.67% (20)	7.48% (32)
item17	428	1.5	1.0	1.2			80.61% (345)	3.27% (14)	5.14% (22)	3.27% (14)	7.71% (33)
item25	428	2.6	3.0	1.4			34.35% (147)	13.79% (59)	22.20% (95)	17.99% (77)	11.68% (50)
item26	428	3.7	4.0	1.3			38.32% (164)	23.36% (100)	20.09% (86)	10.98% (47)	7.24% (31)
item27	428	3.8	4.0	1.3			8.41% (36)	11.21% (48)	11.21% (48)	30.37% (130)	38.79% (166)
item30	428	1.5	1.0	1.1			81.78% (350)	3.27% (14)	4.91% (21)	5.37% (23)	4.67% (20)
item32	428	3.6	4.0	1.6			23.13% (99)	7.01% (30)	8.18% (35)	14.95% (64)	46.73% (200)
item33	428	3.6	4.0	1.6			21.96% (94)	7.01% (30)	7.24% (31)	14.49% (62)	49.30% (211)
item35	428	3.9	5.0	1.7			22.90% (98)	1.87% (8)	3.74% (16)	9.35% (40)	62.15% (266)
item36	428	1.5	1.0	1.3			82.24% (352)	3.04% (13)	3.04% (13)	2.34% (10)	9.35% (40)
item37	428	2.3	2.0	1.3			38.32% (164)	23.36% (100)	20.09% (86)	10.98% (47)	7.24% (31)
item38	428	4.3	5.0	1.1			5.37% (23)	3.50% (15)	5.37% (23)	27.57% (118)	58.18% (249)
item40	428	2.2	2.0	1.2			39.49% (169)	25.00% (107)	19.63% (84)	11.45% (49)	4.44% (19)
item41	428	1.3	1.0	0.8			85.05% (364)	4.67% (20)	6.07% (26)	3.04% (13)	1.17% (5)
item45	428	2.2	1.0	1.5			53.04% (227)	7.01% (30)	16.36% (70)	11.92% (51)	11.68% (50)
item46	428	1.8	1.0	1.2			67.06% (287)	7.71% (33)	11.68% (50)	8.88% (38)	4.67% (20)
CFA (n =262)											
item01	262	2.3	2.0	1.4			40.46% (106)	22.52% (59)	14.50% (38)	10.69% (28)	11.83% (31)
item03	262	3.7	4.0	1.3			11.83% (31)	7.25% (19)	17.56% (46)	28.24% (74)	35.11% (92)
item04	262	1.3	1.0	0.8			89.31% (234)	2.29% (6)	3.44% (9)	3.05% (8)	1.91% (5)
item07	262	2.1	2.0	1.2			43.13% (113)	23.66% (62)	14.50% (38)	14.12% (37)	4.58% (12)
item08	262	3.0	3.0	1.2			14.12% (37)	22.90% (60)	20.99% (55)	32.06% (84)	9.92% (26)
item09	262	2.9	3.0	1.1			12.98% (34)	22.14% (58)	34.35% (90)	26.34% (69)	4.20% (11)
item10	262	2.6	3.0	1.1			17.56% (46)	29.39% (77)	29.01% (76)	21.37% (56)	2.67% (7)
item11	262	2.1	2.0	0.9			25.95% (68)	46.56% (122)	20.23% (53)	5.34% (14)	1.91% (5)
item12	262	2.3	2.0	1.2			32.06% (84)	30.92% (81)	19.08% (50)	11.45% (30)	6.49% (17)
item16	262	1.6	1.0	1.3			78.24% (205)	3.44% (9)	4.20% (11)	5.73% (15)	8.40% (22)
item17	262	1.6	1.0	1.2			80.15% (210)	3.44% (9)	5.34% (14)	2.67% (7)	8.40% (22)
item25	262	2.5	2.0	1.4			32.82% (86)	18.32% (48)	21.76% (57)	16.79% (44)	10.31% (27)
item27	262	4.0	4.0	1.2			6.11% (16)	7.25% (19)	8.02% (21)	33.59% (88)	45.04% (118)
item30	262	1.4	1.0	1.1			83.59% (219)	2.67% (7)	4.20% (11)	6.11% (16)	3.44% (9)
item32	262	3.4	4.0	1.7			25.95% (68)	4.20% (11)	11.45% (30)	16.79% (44)	41.60% (109)
item33	262	3.1	3.0	1.7			32.44% (85)	6.11% (16)	11.83% (31)	14.12% (37)	35.50% (93)
item35	262	3.6	5.0	1.8			27.48% (72)	2.67% (7)	7.25% (19)	6.49% (17)	56.11% (147)
item36	262	1.6	1.0	1.3			80.53% (211)	3.44% (9)	3.05% (8)	3.44% (9)	9.54% (25)
item38	262	4.3	5.0	1.1			4.20% (11)	7.63% (20)	6.49% (17)	21.37% (56)	60.31% (158)
item40	262	2.5	2.0	1.3			30.92% (81)	27.10% (71)	18.70% (49)	12.21% (32)	11.07% (29)
item41	262	1.2	1.0	0.7			90.08% (236)	3.82% (10)	2.29% (6)	2.67% (7)	1.15% (3)
item45	262	2.0	1.0	1.4			64.12% (168)	5.34% (14)	9.54% (25)	11.83% (31)	9.16% (24)
item46	262	1.6	1.0	1.2			75.57% (198)	2.67% (7)	8.02% (21)	9.54% (25)	4.20% (11)

[1] **Histogram**
[2] **Density**

Figure 6. Summary Descriptives of CFA and EFA Sample

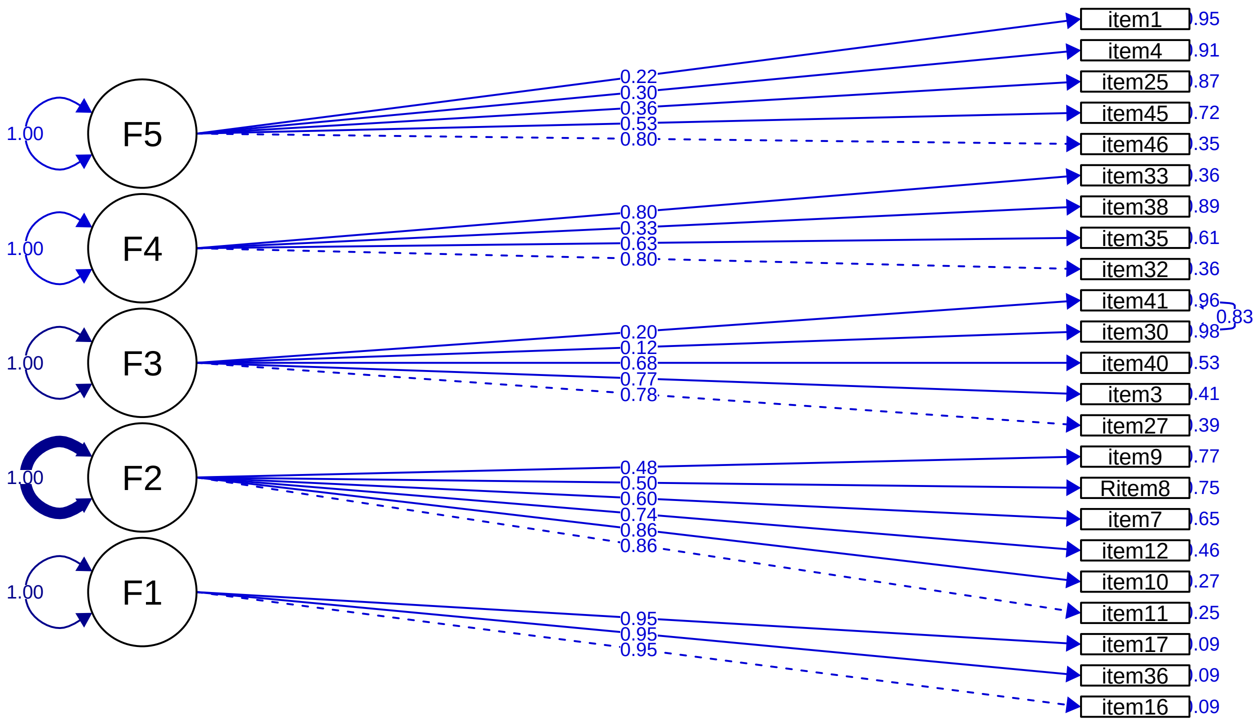

Figure 7. Five Factor CFA Model of LEBA

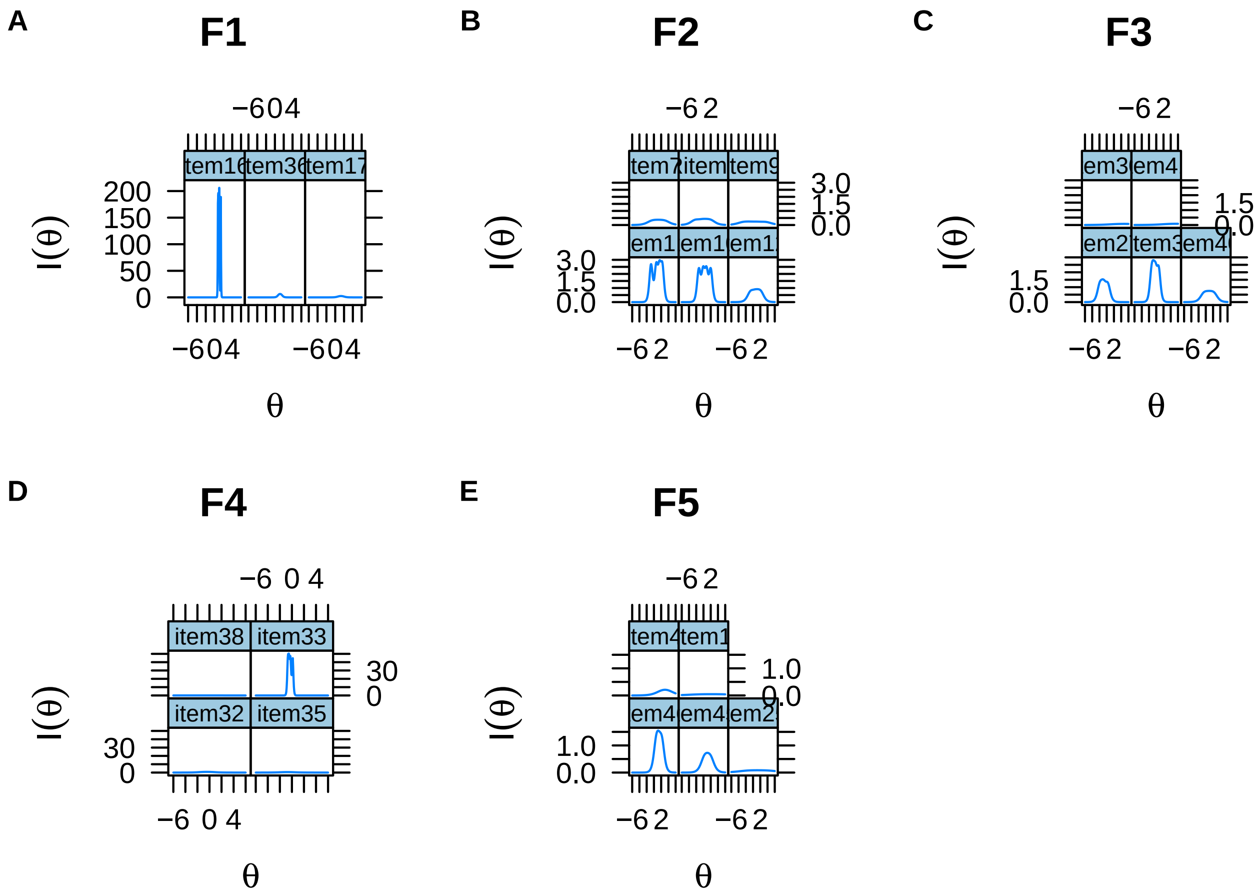

Figure 8. Item information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

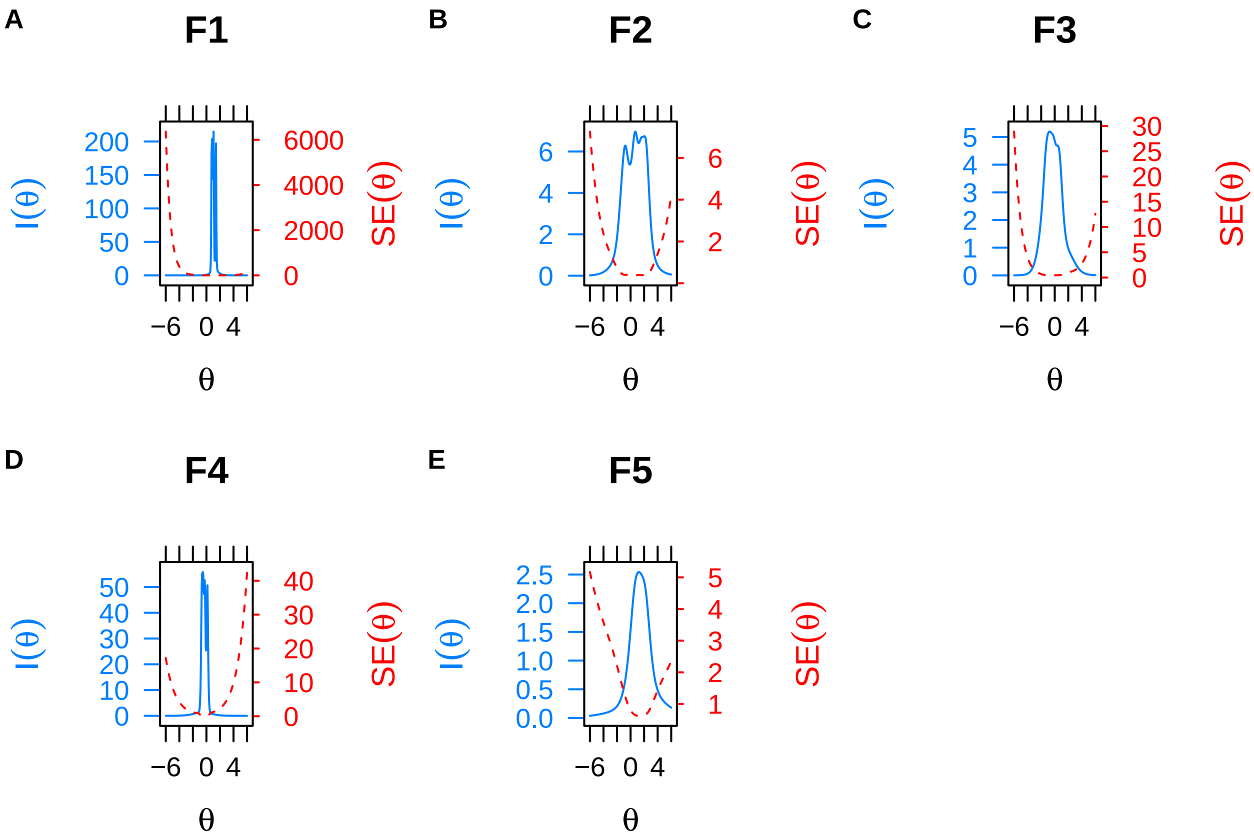

Figure 9. Test information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

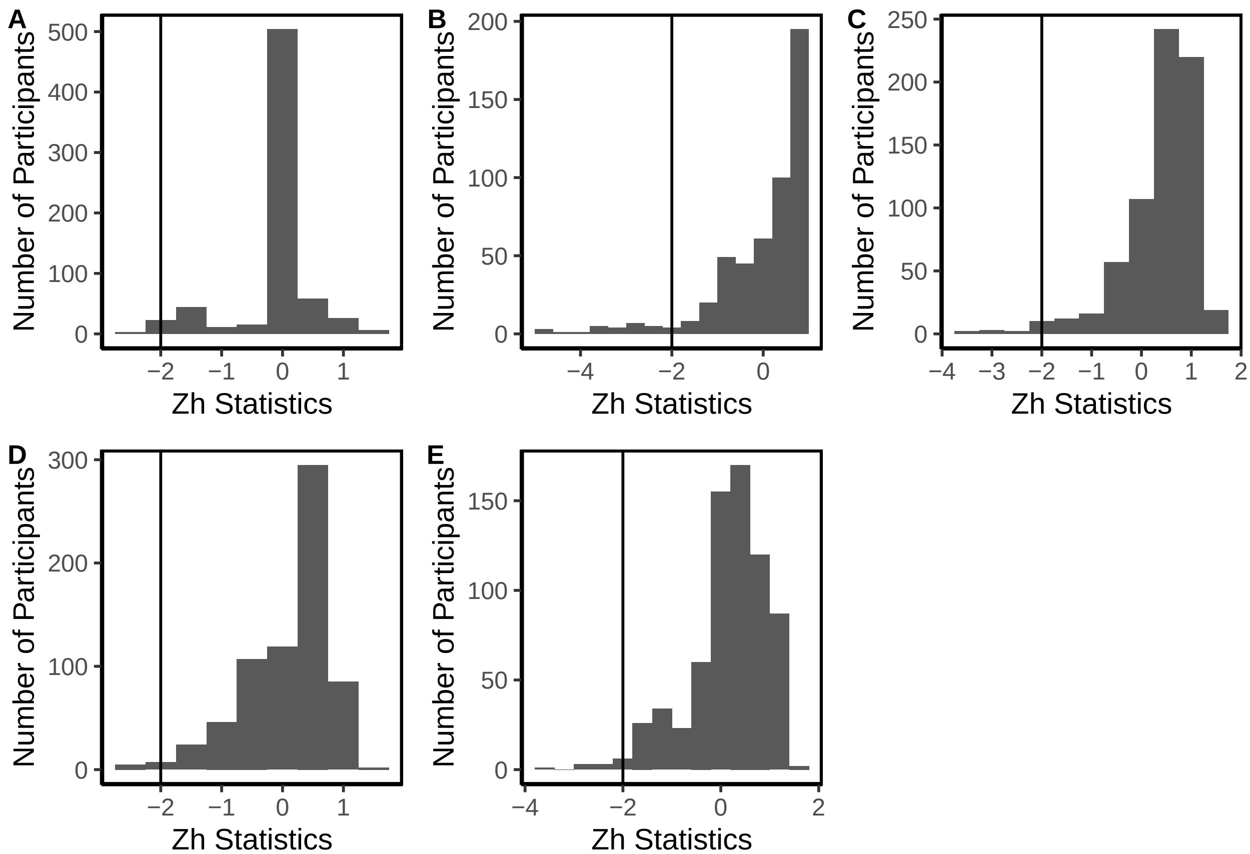

Figure 10. Person fit of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

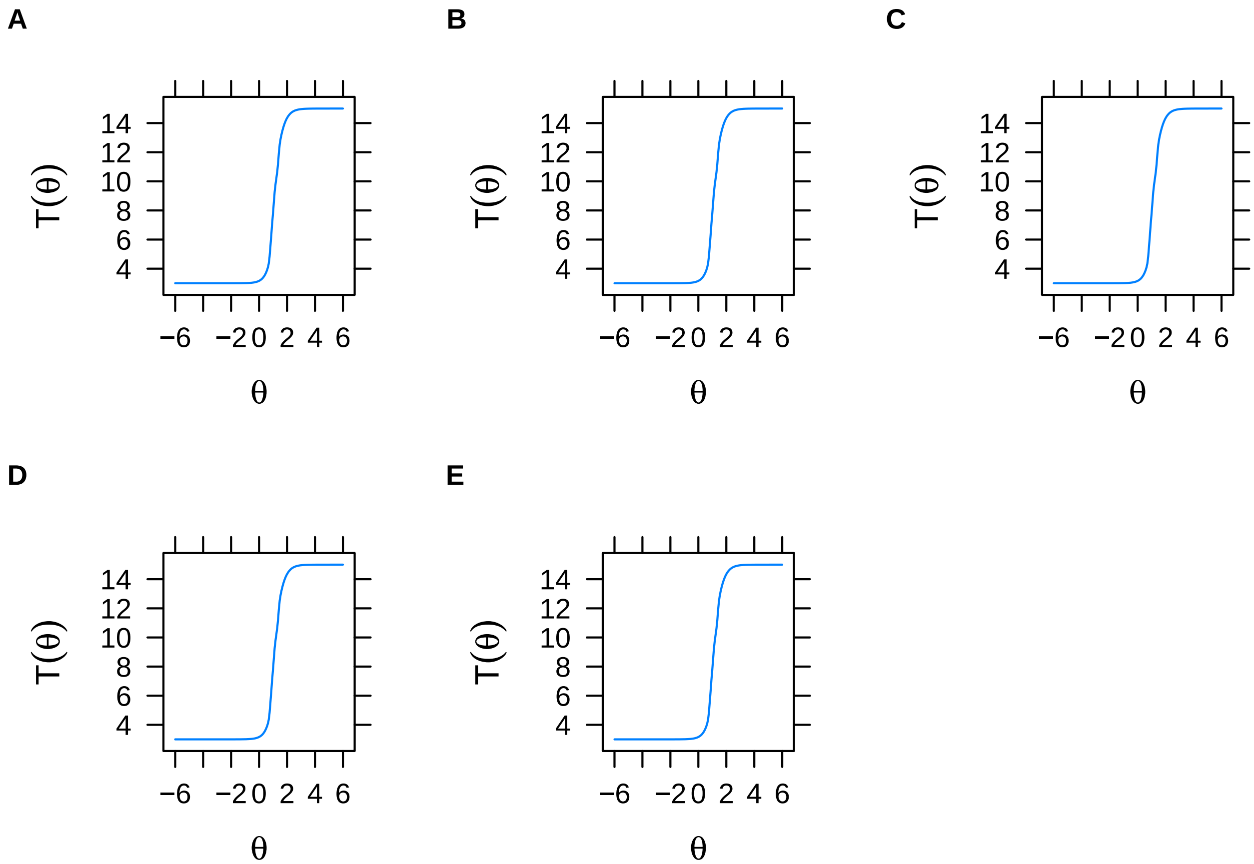

Figure 11. Scale characteristic curve of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

Appendix A

Table A1

Factor loadings and communality of the retained items(Minmum Residual)

item	MR1	MR2	MR3	MR4	MR5	Communality	Uniqueness
item16	1					0.996	0.004
item36	0.94					0.897	0.103
item17	0.8					0.658	0.342
item11		0.79				0.642	0.358
item10		0.76				0.592	0.408
item12		0.65				0.465	0.535
item7		0.5				0.267	0.733
item8		-0.49				0.252	0.748
item9		0.32				0.113	0.887
item27			0.8			0.659	0.341
item3			0.8			0.683	0.317
item40			0.65			0.464	0.536
item30			0.45			0.353	0.647
item41			0.36			0.329	0.671
item33				0.74		0.555	0.445
item32				0.73		0.623	0.377
item35				0.66		0.455	0.545
item37				-0.39		0.175	0.825
item38				0.38		0.178	0.822
item46					0.6	0.422	0.578
item45					0.59	0.374	0.626

Table A1 continued

item	MR1	MR2	MR3	MR4	MR5	Communality	Uniqueness
item25					0.41	0.193	0.807
item4					0.41	0.219	0.781
item1					0.4	0.17	0.83
item26					0.35	0.165	0.835
% of Variance	0.1	0.1	0.09	0.08	0.06		

Note. Only loading higher than .30 is reported

Table A2

Factor loadings and communality of the retained items(six factor)

item	PA1	PA4	PA2	PA3	PA5	PA6	Communality	Uniqueness
item19	1.78						3.318	-2.318
item5							0.11	0.89
item16		1					1.004	-0.004
item36		0.91					0.86	0.14
item17		0.81					0.691	0.309
item11			0.83				0.71	0.29
item10			0.79				0.638	0.362
item12			0.63				0.465	0.535
item8			-0.5				0.269	0.731
item7			0.47				0.268	0.732
item9			0.32				0.163	0.837

Table A2 continued

item	PA1	PA4	PA2	PA3	PA5	PA6	Communality	Uniqueness
item33				0.83			0.698	0.302
item32				0.75			0.666	0.334
item35				0.64			0.446	0.554
item31				0.48			0.331	0.669
item38				0.39			0.191	0.809
item37				-0.35			0.153	0.847
item3					0.85		0.748	0.252
item27					0.8		0.644	0.356
item40					0.68		0.507	0.493
item46						0.6	0.431	0.569
item45						0.56	0.341	0.659
item4						0.43	0.265	0.735
item25						0.4	0.178	0.822
item1						0.36	0.142	0.858
item26						0.36	0.173	0.827
item13							0.087	0.913
item29							0.108	0.892
% of Variance	0.12	0.09	0.09	0.08	0.07	0.06		

Note. Only loading higher than .30 is reported

Appendix B

Factor Analysis with Unmerged Response Option

Table B1

Descriptive Statistics for Unmerged response options

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item1	2.16	1.51	0.49	-0.86	0.90*	.21
Item2	2.76	1.75	-0.10	-1.42	0.88*	.20
Item3	3.34	1.43	-0.58	-0.77	0.88*	.18
Item4	1.30	1.31	1.93	2.92	0.62*	.32
Item5	3.95	1.56	-1.42	0.75	0.70*	.19
Item6	2.70	1.66	0.02	-1.33	0.90*	.18
Item7	2.23	1.28	0.60	-0.59	0.89*	.18
Item8	2.95	1.24	-0.19	-0.70	0.93*	-.07
Item9	2.92	1.09	-0.37	0.11	0.91*	.14
Item10	2.73	1.07	-0.03	-0.52	0.92*	.27
Item11	2.17	0.93	0.44	0.20	0.89*	.25
Item12	2.34	1.26	0.46	-0.58	0.91*	.24
Item13	2.71	1.49	0.14	-1.29	0.89*	.28
Item14	2.11	1.34	0.68	-0.78	0.84*	.24
Item15	3.26	1.11	-0.34	-0.21	0.91*	.11
Item16	1.46	1.31	1.71	1.90	0.65*	.33
Item17	1.43	1.30	1.76	2.12	0.64*	.30
Item18	0.92	0.67	2.00	9.41	0.62*	.32
Item19	0.85	0.56	1.71	10.74	0.55*	.34
Item20	0.83	0.54	1.76	13.92	0.53*	.31
Item21	0.94	0.75	2.46	10.66	0.58*	.27

Table B1 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item22	3.57	1.08	-0.72	0.08	0.88*	.19
Item23	2.53	1.31	0.22	-0.91	0.92*	.11
Item24	4.13	1.01	-1.39	2.01	0.78*	.19
Item25	2.57	1.43	0.22	-1.23	0.88*	.17
Item26	2.23	1.30	0.59	-0.63	0.88*	.16
Item27	3.78	1.34	-1.01	0.08	0.82*	.18
Item28	3.75	1.16	-0.78	-0.10	0.86*	.01
Item29	2.38	1.40	0.20	-1.04	0.92*	.11
Item30	0.94	1.42	1.66	1.69	0.68*	.24
Item31	2.91	1.76	-0.24	-1.41	0.87*	.45
Item32	3.49	1.76	-0.71	-1.06	0.78*	.43
Item33	3.56	1.75	-0.79	-0.95	0.77*	.32
Item34	3.30	2.00	-0.54	-1.50	0.74*	.34
Item35	3.80	1.79	-1.07	-0.59	0.67*	.24
Item36	1.36	1.38	1.75	2.05	0.65*	.38
Item37	1.30	0.94	2.79	7.65	0.48*	-.01
Item38	4.27	1.18	-2.07	4.01	0.65*	.23
Item39	1.94	1.01	0.85	0.61	0.86*	.05
Item40	2.13	1.24	0.56	-0.54	0.89*	.16
Item41	0.87	1.08	1.68	2.74	0.73*	.21
Item42	3.90	1.55	-1.15	-0.12	0.72*	.17
Item43	1.59	1.23	1.59	1.70	0.69*	.22
Item44	3.46	1.41	-0.92	-0.01	0.86*	.38
Item45	2.04	1.66	0.46	-1.12	0.87*	.29

Table B1 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item46	1.57	1.40	0.97	-0.07	0.82*	.38
Item47	2.07	1.23	0.59	-0.42	0.89*	.34
Item48	2.57	1.30	0.14	-0.74	0.93*	.31

Note. *p<.001

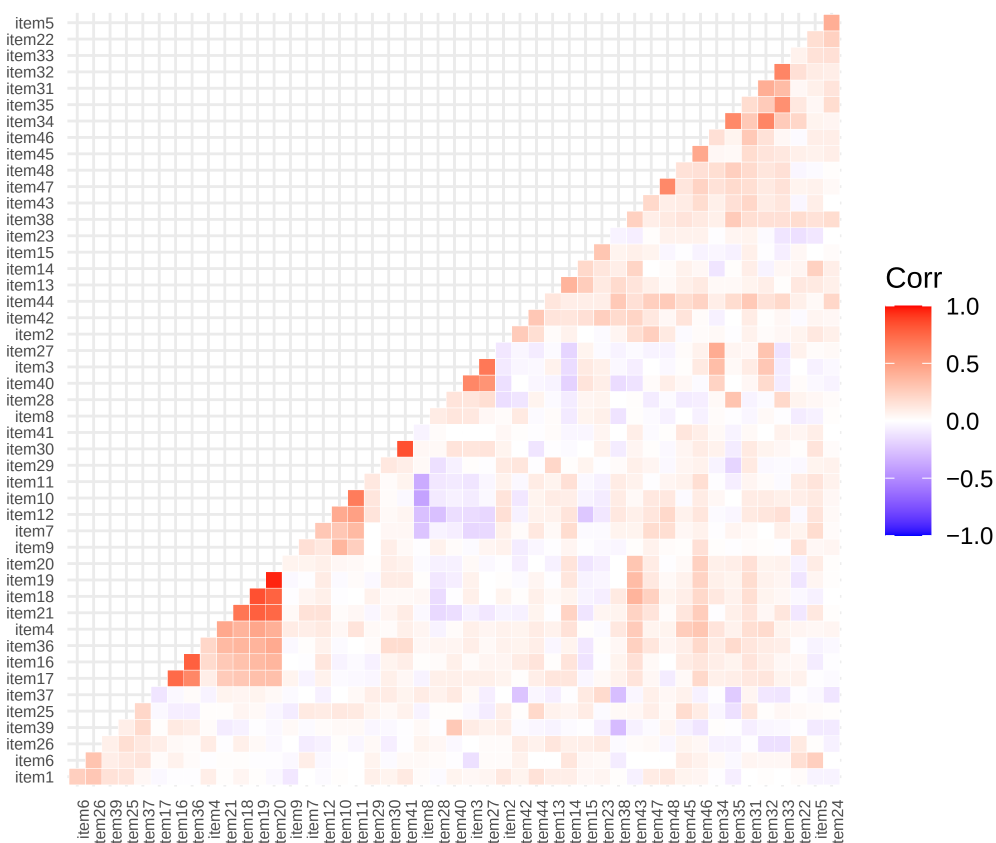

Figure B1. Correlation plot of the items

Horn’s parallel analysis with 500 iterations indicated a five-factor solution. However, Scree plot and the MAP method suggested 6-factor solution. five-factor solution . As a

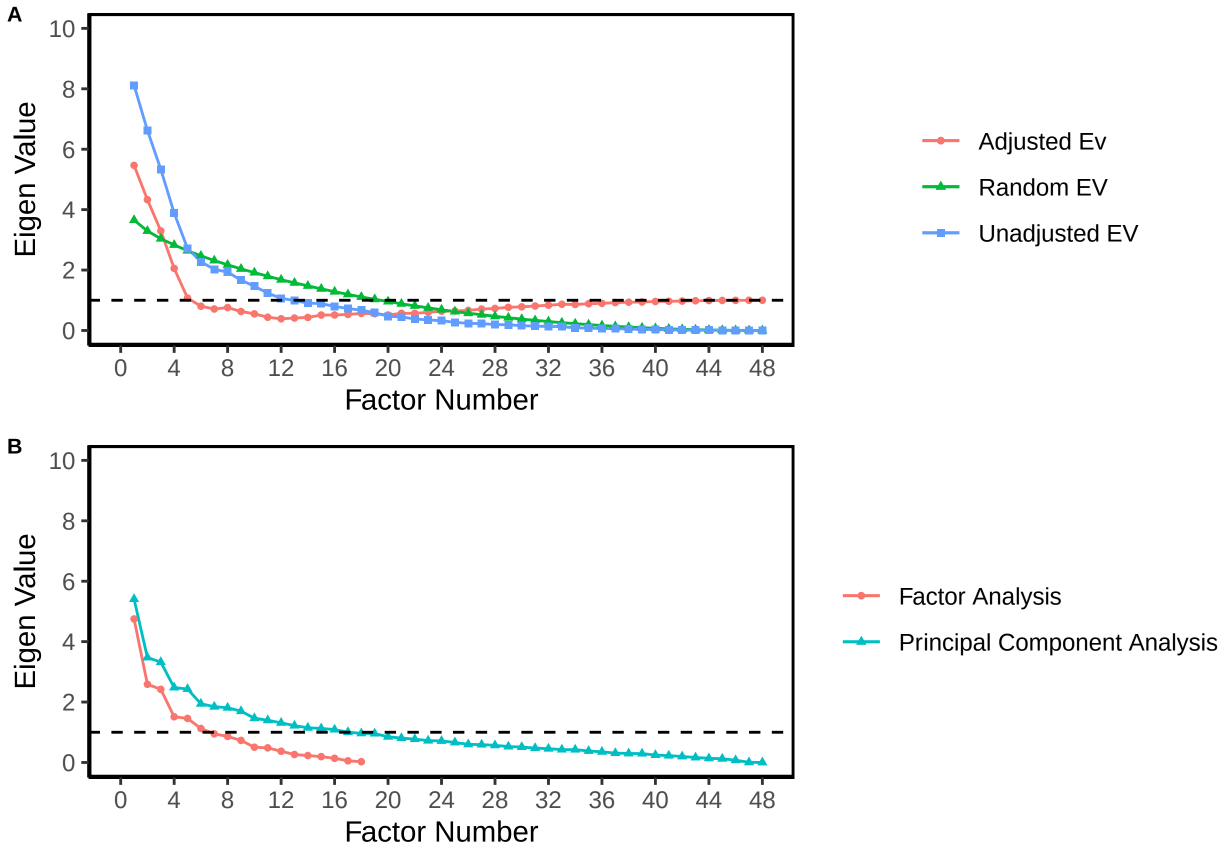

Figure B2. Factor Identification (A) Parallel analysis (B) Scree Plot

result, we tested both five-factor and six-factor solutions.

Table B2

Factor loadings and communality of the retained items [Unmerged Responses]

item	PA1	PA2	PA5	PA3	PA4	Communality	Uniqueness	Complexity
item19	0.99					1.007	-0.007	1.058
item20	0.91					0.874	0.126	1.114
item18	0.82					0.711	0.289	1.123
item21	0.8					0.683	0.317	1.163
item4	0.47					0.25	0.75	1.298
item11		0.83				0.687	0.313	1.007

Table B2 continued

item	PA1	PA2	PA5	PA3	PA4	Communality	Uniqueness	Complexity
item10		0.81				0.67	0.33	1.031
item12		0.56				0.371	0.629	1.374
item8		-0.44				0.206	0.794	1.106
item7		0.42				0.226	0.774	1.614
item9		0.33				0.115	0.885	1.1
item16			0.95			0.946	0.054	1.097
item17			0.74			0.595	0.405	1.168
item36	0.3		0.73			0.653	0.347	1.431
item3				0.85		0.746	0.254	1.048
item27				0.78		0.624	0.376	1.028
item40				0.71		0.512	0.488	1.05
item35					0.58	0.351	0.649	1.091
item48					0.57	0.354	0.646	1.144
item33					0.55	0.32	0.68	1.085
item47					0.52	0.294	0.706	1.186
item44					0.45	0.216	0.784	1.145
item31					0.41	0.206	0.794	1.477
item38					0.33	0.129	0.871	1.317
% of Variance	0.15	0.09	0.09	0.08	0.08			

Note. Only loading higher than .30 is reported

Five Factor Solution[Unmerged Responses] (24 Items)

F1

I use light therapy applying a blue light box.

I use light therapy applying a light visor.

I use light therapy applying a white light box.

I use light therapy applying another form of light device.

I use an alarm with a dawn simulation light.

F2

I spend more than 3 hours per day (in total) outside.

I spend between 1 and 3 hours per day (in total) outside.

I spend as much time outside as possible.

I spend 30 minutes or less per day (in total) outside.

I go for a walk or exercise outside within 2 hours after waking up.

I spend between 30 minutes and 1 hour per day (in total) outside.

F3

I look at my mobile phone screen immediately after waking up.

I use my mobile phone within 1 hour before attempting to fall asleep.

I check my phone when I wake up at night.

F4

I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.

I seek out knowledge on how to improve my light exposure.

I dim my computer screen within 1 hour before attempting to fall asleep.

I discuss the effects of light on my body with other people.

I modify my light environment to match my current needs.

I dim my room light within 1 hour before attempting to fall asleep.

Five Factor Solution[Unmerged Responses] (24 Items)
I use as little light as possible when I get up during the night.
F5
I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.
I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.
I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.

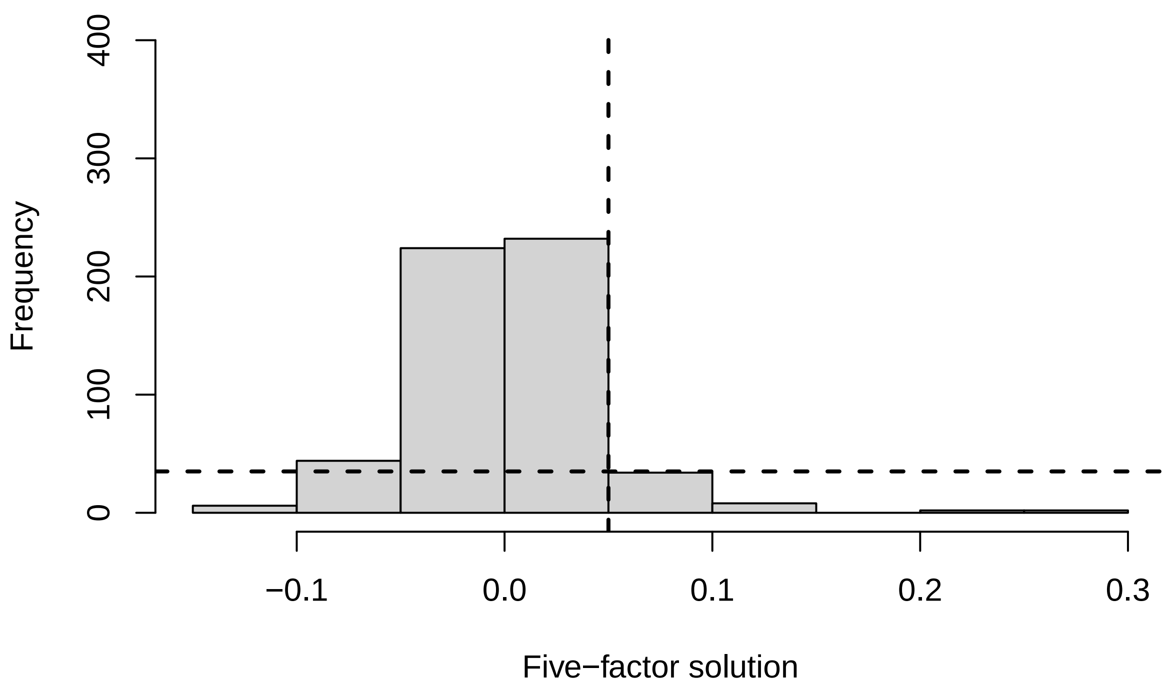

Figure B3. Histogram of residulas: five-factor solution

Appendix C

Disclaimer: This is a non-public version of LEBA (dated November 15, 2021) and still a work in progress. Please do not distribute!

LEBA captures light exposure-related behaviours on a 5 point Likert type scale ranging from 1 to 5 (Never/Does not apply/I don't know = 1; Rarely = 2; Sometimes = 3; Often = 4; Always = 5). The score of each factor is calculated by the summation of scores of items belonging to the corresponding factor. The following instruction is given before displaying the items: "Please indicate how often you performed the following behaviours in the past 4 weeks."

Appendix D

LEBA Long Form (23 Items)

	Items	Never/Does not apply/I don't know	Rarely	Sometimes	Often	Always
1	I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.					
2	I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.					
3	I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.					
4	I spend 30 minutes or less per day (in total) outside.					

	Items	Never/Does not apply/I don’t know	Rarely	Sometimes	Often	Always
5	I spend between 1 and 3 hours per day (in total) outside.					
6	I spend between 30 minutes and 1 hour per day (in total) outside.					
7	I spend more than 3 hours per day (in total) outside.					
8	I spend as much time outside as possible.					
9	I go for a walk or exercise outside within 2 hours after waking up.					
10	I use my mobile phone within 1 hour before attempting to fall asleep.					

	Items	Never/Does not apply/I don't know	Rarely	Sometimes	Often	Always
11	I look at my mobile phone screen immediately after waking up.					
12	I check my phone when I wake up at night.					
13	I look at my smartwatch within 1 hour before attempting to fall asleep.					
14	I look at my smartwatch when I wake up at night.					
15	I dim my mobile phone screen within 1 hour before attempting to fall asleep.					
16	I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.					

	Items	Never/Does not apply/I don’t know	Rarely	Sometimes	Often	Always
17	I use as little light as possible when I get up during the night.					
18	I dim my computer screen within 1 hour before attempting to fall asleep.					
19	I use tunable lights to create a healthy light environment.					
20	I use LEDs to create a healthy light environment.					
21	I use a desk lamp when I do focused work.					
22	I use an alarm with a dawn simulation light.					
23	I turn on the lights immediately after waking up.					

Latent Structure, Reliability and Structural Validity

The long form of LEBA consists 23 items with five factors.

Factor names	Items	Reliability Coefficients: ordinal alpha
F1: Wearing blue light filters	1-3	.96
F2: Spending time outdoors	4-9 (Item 4 is reversed)	.83
F3: Using phone and smartwatch in bed	10-14	.70
F4: Using light before bedtime	15-18	.69
F5: Using light in the morning and during daytime	19-23	.52
McDonald's Omega coefficient for the total scale		.73(Total scale)

LEBA -long form showed satisfactory structural validity (CFI =.97; TLI = .96; RMSEA = .05[.04-.06, 90% CI]; SRMR = .09).

How to cite:

Appendix E

LEBA Short Form (17 Items)

	Short Form (17 Items)	Never/Does not apply/I don't know	Rarely	Sometimes	Often	Always
01	I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.					
02	I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.					
03	I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.					
04	I spend 30 minutes or less per day (in total) outside.					

	Short Form (17 Items)	Never/Does not apply/I don't know	Rarely	Sometimes	Often	Always
05	I spend between 1 and 3 hours per day (in total) outside.					
06	I spend more than 3 hours per day (in total) outside.					
07	I spend as much time outside as possible.					
08	I go for a walk or exercise outside within 2 hours after waking up.					
09	I use my mobile phone within 1 hour before attempting to fall asleep.					
10	I look at my mobile phone screen immediately after waking up.					
11	I check my phone when I wake up at night.					

	Short Form (17 Items)	Never/Does not apply/I don't know	Rarely	Sometimes	Often	Always
12	I dim my mobile phone screen within 1 hour before attempting to fall asleep.					
13	I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.					
14	I dim my computer screen within 1 hour before attempting to fall asleep.					
15	I use tunable lights to create a healthy light environment.					
16	I use LEDs to create a healthy light environment.					
17	I use an alarm with a dawn simulation light.					

Latent Structure, Reliability and Structural Validity

The short form of LEBA consists 23 items with five factors.

Factor names	Items
F1: Wearing blue light filters	1-3
F2: Spending time outdoors	4-8 (Item 4 is reversed)
F3: Using phone and smart-watch in bed	9-11
F4: Using light before bedtime	12-14
F5: Using light in the morning and during daytime	15-17

How to cite: