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.

Name	Author
Visual Light Sensitivity Questionnaire-8	[@verriotto2017new]
Office Light Survey	[@eklund1996developme
Harvard Light Exposure Assessment Questionnaire	[@bajaj2011validation]
Hospital Lighting Survey	[@dianat2013objective]
Morningness-Eveningness Questionnaire	[@horne1976self]
Munich Chronotype Questionnaire (MCTQ)	[@roenneberg2003life]
Assessment of Sleep Environment	[@Olivier.2016] | 13
The Pittsburgh Sleep Quality Index (PSQI)	[@buysse1989pittsburgh]
Self-Rating of Biological Rhythm Disorder for Adolescents (SBRDA)	[@Xie.2021] | 29
Photosensitivity Assessment Questionnaire (PAQ)	[@Wu.2017] | 16

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; 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 four most common geographic locations included:

	x
United States - America/New_York (UTC -04:00)	63
United Kingdom - Europe/London (UTC)	57
Germany - Europe/Berlin (UTC +01:00)	53
India - Asia/Kolkata (UTC +05:30)	38

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 indication)" 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 Chi-squared 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).

1. Describe EFA and CFA sample separately.
2. Sampling technique: Convince sampling (non-probability sample)
3. Method: cross-sectional survey

4. How many missing data?
5. How incomplete data were addressed.
6. Why such sample was chosen?

Procedure

Development of the Scale.

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

Data Collection. Timeline of data collection, mode of data collection.

Analytic Strategies

We used R (version 4.1.0), including several R packages, for our analyses.Initially, our tool have six poin Likert type response scale(0:Does not apply/I don't know; 1:Never, 2:Rarely; 3:Sometimes; 4:Often; 5: Alsways). As our purpose was to capture light exposure related behavior, "Does not apply/I don't know" and "Never" were providing similar information. As such we decided to collapse "Does not apply/I don't know" and "Never" options 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 a polychoric correlation matrix (C. Desjardins & Bulut, 2018) for the EFA. We employed principal axis (PA) as a 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 method as well. We used a combination 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

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). Table2 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 (C. Desjardins & Bulut, 2018). Bartlett's test of sphericity (Bartlett, 1954), chi^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 .10 to .44.

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 initial 48 items we conducted three rounds of EFA 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 (Table**??**). Table3 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. (C. D. Desjardins, 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 (Table**??**).

In the five-factor solution, the first factor contained three items and explained 10.25% of the total variance with a satisfactory internal reliability coefficient ($alpha$ = .86). 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 satisfactory internal reliability coefficient ($alpha$ = .71). Items under this factor commonly investigate 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 sleep. The internal consistency reliability coefficient was, $alpha$ = .68. The fourth factor contained five items and explained 8.44% of the total variance with an internal consistency coefficient, $alpha$ = .62. These five items stemmed from the behavior related to an individual's cellphone usage during the sleep-wakeup time. Lastly, the fifth factor contained six items and explained 6.14% of the total variance. This factor tried to measure an individual's behavior lead by the awareness of light's influence on health. However, this factor showed unsatisfactory internal consistency reliability ($alpha$ = .53). 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 two factors, we retain the five-factor solution 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.

Confirmatory Factor Analysis

We conducted a categorical confirmatory factor analysis with robust weighted least square (WLSMV) estimator as our response data was in ordinary nature(C. Desjardins & Bulut, 2018). Several indices are suggested to measure model fit. These indices 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 chi-square 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 chi-square test statistics (A non-significant test statistics is required to reflect model fit) (i) CFI and TLI (CFI/TLI close to .95 or above/ranging between 90-95 and above) (ii) RMSEA (close to .06 or below), (iii) SRMR (close to .08 or below) to estimate the model fit. Table 4 summarizes the fit indices of our fitted model. Our fitted model failed to attain an absolute fit estimated by the chi-square test. However, the chi-square 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.-Y. Yu, 2002). Subsequently, 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 and 19-17 . However SRMR value was higher than the guideline (SRMR = .12). Further by allowing one pair of items (30-41) 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). Since reliability coefficient Cronbach's alpha tends to mis-measure reliability for multidimensional construct (Sijtsma, 2009) we report Mcdonald's omega(total) as the internal consistency reliability coefficient. Mcdonald's omega(total) is reported to be a satisfactory lower bound reliability coefficient that works for both unidimensional and multidimensional construct (Zinbarg, Revelle, Yovel, & Li, 2005). Mcdonald's omega(total) for the five factors were .90, .80, .61, .72, .45 respectively. Mcdonald's omega(total) coefficient for the total scale was .73.

Analysing the quality of items by Item Information Theory

We sought the IRT to gether information regarding the item quality. IRT complements the conventional classical test theory-based analysis by gathering information on item discrimination and item difficulty(Baker, 2017). Here, an item's quality is judged based on item information in relation to participants' latent trait level ($theta$). We gathered evidence on item quality by fitting each factor of LEBA with the graded response model (6 to the combined EFA sample and CFA sample (n =690). Item discrimination indicates the pattern of variation in the categorical responses with the changes in latent trait, 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. Item discrimination parameters of our scale fell in very high (10 items), high (4 items), moderate (4 items), low (5 items) indicating a good range of discrimination along the latent trait. Examination of the item information curve indicated 6 items (1, 25, 9, 38, 30, & 41) had relatively flat information curves thus discarded. We also gathered evidence of item fit and person fit to our fitted model.

Test information curve (TIC) indicate the amount of information an the full-scale carry along the latent trait continuum. As we treated each factor of LEBA as an unidmensional construct we obtain 5 TICs. These information curves indicated except blue filter factor, the other factor's TICs are roughly centered on the center of the trait continuum (($theta$)). Also the amount of information changed rather steadily with the change of ($theta$). 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.

Our result also indicated all the items fitted well to the respective models as assessed by assessed by RMSEA value obtained from Signed-X2 index implementation. All of the items had RMSEA value <.06 indicating adequate fit. Person fit indicates the validity and meaningfulness of the fitted model at the participants latent trait level (C. 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.

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

References

Anwar Siraji, M. (2021). *Tabledown: A companion pack for the book "basic & advanced psychometrics in r"*. Retrieved from https://github.com/masiraji/tabledown

Aust, F., & Barth, M. (2020). *papaja: Prepare reproducible APA journal articles with R Markdown*. Retrieved from https://github.com/crsh/papaja

Baker, F. B. (2017). *The Basics of Item Response Theory Using R* (1st ed. 2017.). Springer.

Bandalos, D. L., & Finney, S. J. (2018). Factor analysis: Exploratory and confirmatory. In *The reviewer's guide to quantitative methods in the social sciences* (pp. 98–122). Routledge.

Barnier, J., Briatte, F., & Larmarange, J. (2020). *Questionr: Functions to make surveys processing easier*. Retrieved from https://CRAN.R-project.org/package=questionr

Barth, M. (2021). *tinylabels: Lightweight variable labels*. Retrieved from https://github.com/mariusbarth/tinylabels

Bartlett, M. (1954). A Note on the Multiplying Factors for Various Chi-square Approximations. *Journal of the Royal Statistical Society. Series B, Methodological*, *16*(2), 296–298.

Bentler, P. M., & Chou, C.-P. (1987). Practical Issues in Structural Modeling. *Sociological Methods & Research*, *16*(1), 78–117. https://doi.org/10.1177/0049124187016001004

Bevans, K. B., Meltzer, L. J., La Motte, A. de, Kratchman, A., Viél, D., & Forrest, C. B. (2019). Qualitative development and content validation of the PROMIS pediatric sleep health items. *Behavioral Sleep Medicine*, *17*(5), 657–671. https://doi.org/10.1080/15402002.2018.1461102

Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.).

New York, NY, US: The Guilford Press.

Bryer, J., & Speerschneider, K. (2016). *Likert: Analysis and visualization likert items*. Retrieved from https://CRAN.R-project.org/package=likert

Buchanan, E. M., Gillenwaters, A., Scofield, J. E., & Valentine, K. D. (2019). *MOTE: Measure of the Effect: Package to assist in effect size calculations and their confidence intervals*. Retrieved from http://github.com/doomlab/MOTE

Buysse, D. J., Yu, L., Moul, D. E., Germain, A., Stover, A., Dodds, N. E., … Pilkonis, P. A. (2010). Development and validation of patient-reported outcome measures for sleep disturbance and sleep-related impairments. *Sleep*, *33*(6), 781–792. https://doi.org/10.1093/sleep/33.6.781

Cattell, R. B. (1966). The Scree Test For The Number Of Factors. *Multivariate Behavioral Research*, *1*(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Chalmers, R. P. (2012). mirt: A multidimensional item response theory package for the R environment. *Journal of Statistical Software*, *48*(6), 1–29. https://doi.org/10.18637/jss.v048.i06

Chang, W., Cheng, J., Allaire, J., Sievert, C., Schloerke, B., Xie, Y., … Borges, B. (2021). *Shiny: Web application framework for r*. Retrieved from https://CRAN.R-project.org/package=shiny

Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis, 2nd ed*. Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc.

Conigrave, J. (2020). *Corx: Create and format correlation matrices*. Retrieved from https://CRAN.R-project.org/package=corx

Dahl, D. B., Scott, D., Roosen, C., Magnusson, A., & Swinton, J. (2019). *Xtable: Export tables to LaTeX or HTML*. Retrieved from https://CRAN.R-project.org/package=xtable

Desjardins, C. D. (2018). *Handbook of educational measurement and* *psychometrics using R*. (O. Bulut & ProQuest (Firm), Eds.). Boca Raton, FL : CRC Press.

Desjardins, C., & Bulut, O. (2018). *Handbook of Educational Measurement and Psychometrics Using R*. https://doi.org/10.1201/b20498

Dinno, A. (2018). *Paran: Horn's test of principal components/factors*. Retrieved from https://CRAN.R-project.org/package=paran

Drasgow, F., Levine, M. V., & Williams, E. A. (1985). Appropriateness measurement with polychotomous item response models and standardized indices. *British Journal of Mathematical and Statistical Psychology*, *38*(1), 67–86.

Epskamp, S. (2019). *semPlot: Path diagrams and visual analysis of various SEM packages' output*. Retrieved from https://CRAN.R-project.org/package=semPlot

Epskamp, S., Cramer, A. O. J., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). qgraph: Network visualizations of relationships in psychometric data. *Journal of Statistical Software*, *48*(4), 1–18.

F.lux Software LLC. (2021). F.lux (Version 4.120). Retrieved from https://justgetflux.com/

Forrest, C. B., Meltzer, L. J., Marcus, C. L., La Motte, A. de, Kratchman, A., Buysse, D. J., … Bevans, K. B. (2018). Development and validation of the PROMIS pediatric sleep disturbance and sleep-related impairment item banks. *Sleep*, *41*(6). https://doi.org/10.1093/sleep/zsy054

Fox, J., & Weisberg, S. (2019). *An R companion to applied regression* (Third). Thousand Oaks CA: Sage. Retrieved from https://socialsciences.mcmaster.ca/jfox/Books/Companion/

Fox, J., Weisberg, S., & Price, B. (2020). *carData: Companion to applied regression data sets*. Retrieved from https://CRAN.R-project.org/package=carData

Harb, F., Hidalgo, M. P., & Martau, B. (2015). Lack of exposure to natural light in the workspace is associated with physiological, sleep and depressive symptoms. *Chronobiology International*, *32*(3), 368–375. https://doi.org/10.3109/07420528.2014.982757

Harrell Jr, F. E., Charles Dupont, with contributions from, & others., many. (2021). *Hmisc: Harrell miscellaneous*. Retrieved from https://CRAN.R-project.org/package=Hmisc

Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., … others. (2019). The REDCap consortium: Building an international community of software platform partners. *Journal of Biomedical Informatics*, *95*, 103208.

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics*, *42*(2), 377–381.

Henry, L., & Wickham, H. (2020). *Purrr: Functional programming tools*. Retrieved from https://CRAN.R-project.org/package=purrr

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika*, *30*(2), 179–185. https://doi.org/10.1007/BF02289447

Hu, L., & Bentle, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hutcheson, G. D. (1999). *The multivariate social scientist : Introductory statistics using generalized linear models*. London : SAGE.

Iannone, R. (2016). *DiagrammeRsvg: Export DiagrammeR graphviz graphs as SVG*. Retrieved from https://CRAN.R-project.org/package=DiagrammeRsvg

Iannone, R. (2021). *DiagrammeR: Graph/network visualization*. Retrieved from https://github.com/rich-iannone/DiagrammeR

Jackson, D. L. (2003). Revisiting Sample Size and Number of Parameter Estimates: Some Support for the N:q Hypothesis. *Structural Equation Modeling*, *10*(1), 128–141. https://doi.org/10.1207/S15328007SEM1001_6

Johnson, P., & Kite, B. (2020). *semTable: Structural equation modeling tables*. Retrieved from https://CRAN.R-project.org/package=semTable

Johnson, P., Kite, B., & Redmon, C. (2020). *Kutils: Project management tools*. Retrieved from https://CRAN.R-project.org/package=kutils

Jorgensen, T. D., Pornprasertmanit, S., Schoemann, A. M., & Rosseel, Y. (2021). *semTools: Useful tools for structural equation modeling*. Retrieved from https://CRAN.R-project.org/package=semTools

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, *39*(1), 31–36. https://doi.org/10.1007/bf02291575

Kassambara, A. (2019). *Ggcorrplot: Visualization of a correlation matrix using 'ggplot2'*. Retrieved from https://CRAN.R-project.org/package=ggcorrplot

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. The Guilford Press.

Kowarik, A., & Templ, M. (2016). Imputation with the R package VIM. *Journal of Statistical Software*, *74*(7), 1–16. https://doi.org/10.18637/jss.v074.i07

Lishinski, A. (2021). *lavaanPlot: Path diagrams for 'lavaan' models via 'DiagrammeR'*. Retrieved from https://CRAN.R-project.org/package=lavaanPlot

Lorenzo-Seva, U., Timmerman, M., & Kiers, H. (2011). The Hull Method for Selecting the Number of Common Factors. *Multivariate Behavioral Research*, *46*, 340–364. https://doi.org/10.1080/00273171.2011.564527

Makowski, D., Ben-Shachar, M. S., Patil, I., & Lüdecke, D. (2020). Methods and algorithms for correlation analysis in r. *Journal of Open Source Software*, *5*(51), 2306. https://doi.org/10.21105/joss.02306

Mardia, K. V. (1970). Measures of multivariate skewness and kurtosis with applications. *Biometrika*, *57*(3), 519–530. https://doi.org/10.1093/biomet/57.3.519

Mock, T. (2021). *gtExtras: A collection of helper functions for the gt package*. Retrieved from https://github.com/jthomasmock/gtExtras

Müller, K., & Wickham, H. (2021). *Tibble: Simple data frames*. Retrieved from https://CRAN.R-project.org/package=tibble

Navarro-Gonzalez, D., & Lorenzo-Seva, U. (2021). *EFA.MRFA: Dimensionality assessment using minimum rank factor analysis*. Retrieved from https://CRAN.R-project.org/package=EFA.MRFA

Olivier, K., Gallagher, R. A., Killgore, W. D. S., Carrazco, N., Alfonso-Miller, P., … Grandner, M. A. (2016). Development and initial validation of the assessment of sleep environment: A novel inventory for describing and quantifying the impact of environmental factors on sleep. *Sleep*, *39*(Abstract Supplement: A367).

Ooms, J. (2021a). *Magick: Advanced graphics and image-processing in r*. Retrieved from https://CRAN.R-project.org/package=magick

Ooms, J. (2021b). *Rsvg: Render SVG images into PDF, PNG, PostScript, or bitmap arrays*. Retrieved from https://CRAN.R-project.org/package=rsvg

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence*, *17*(2), 117–133. https://doi.org/10.1007/BF01537962

Pornprasertmanit, S., Miller, P., Schoemann, A., & Jorgensen, T. D. (2021). *Simsem: SIMulated structural equation modeling*. Retrieved from https://CRAN.R-project.org/package=simsem

R Core Team. (2021). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Revelle, W. (2021). *Psych: Procedures for psychological, psychometric, and personality research*. Evanston, Illinois: Northwestern University. Retrieved from https://CRAN.R-project.org/package=psych

Roenneberg, T., Wirz-Justice, A., & Merrow, M. (2003). Life between clocks: Daily temporal patterns of human chronotypes. *Journal of Biological Rhythms*, *18*(1), 80–90.

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2), 1–36. Retrieved from https://www.jstatsoft.org/v48/i02/

Ryu, C. (2021). *Dlookr: Tools for data diagnosis, exploration, transformation*. Retrieved from https://CRAN.R-project.org/package=dlookr

Sarkar, D. (2008). *Lattice: Multivariate data visualization with r*. New York: Springer. Retrieved from http://lmdvr.r-forge.r-project.org

Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize? *Journal of Research in Personality*, *47*(5), 609–612. https://doi.org/10.1016/j.jrp.2013.05.009

Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural equation modeling*. psychology press.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, *52*(3-4), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Sijtsma, K. (2009). On the use, the misuse, and the very limited usefulness of cronbach's alpha. *Psychometrika*, *74*(1), 107.

Sjoberg, D. D., Curry, M., Hannum, M., Larmarange, J., Whiting, K., & Zabor, E. C.

(2021b). *Gtsummary: Presentation-ready data summary and analytic result tables*. Retrieved from https://CRAN.R-project.org/package=gtsummary

Sjoberg, D. D., Curry, M., Hannum, M., Larmarange, J., Whiting, K., & Zabor, E. C. (2021a). *Gtsummary: Presentation-ready data summary and analytic result tables*. Retrieved from https://CRAN.R-project.org/package=gtsummary

Stauffer, R., Mayr, G. J., Dabernig, M., & Zeileis, A. (2009). Somewhere over the rainbow: How to make effective use of colors in meteorological visualizations. *Bulletin of the American Meteorological Society*, *96*(2), 203–216. https://doi.org/10.1175/BAMS-D-13-00155.1

Terry M. Therneau, & Patricia M. Grambsch. (2000). *Modeling survival data: Extending the Cox model*. New York: Springer.

Ushey, K., McPherson, J., Cheng, J., Atkins, A., & Allaire, J. (2021). *Packrat: A dependency management system for projects and their r package dependencies*. Retrieved from https://CRAN.R-project.org/package=packrat

van Lissa, C. J. (2021). *tidySEM: Tidy structural equation modeling*. Retrieved from https://CRAN.R-project.org/package=tidySEM

Velicer, W. (1976). Determining the Number of Components from the Matrix of Partial Correlations. *Psychometrika*, *41*, 321–327. https://doi.org/10.1007/BF02293557

Venables, W. N., & Ripley, B. D. (2002). *Modern applied statistics with s* (Fourth). New York: Springer. Retrieved from https://www.stats.ox.ac.uk/pub/MASS4/

Watkins, M. (2020). *A Step-by-Step Guide to Exploratory Factor Analysis with R and RStudio*. https://doi.org/10.4324/9781003120001

Weinzaepflen, C., & Spitschan, M. (2021). Enlighten your clock: How your body tells time. Open Science Framework. https://doi.org/10.17605/OSF.IO/ZQXVH

Wickham, H. (2011). The split-apply-combine strategy for data analysis. *Journal of Statistical Software*, *40*(1), 1–29. Retrieved from http://www.jstatsoft.org/v40/i01/

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York. Retrieved from https://ggplot2.tidyverse.org

Wickham, H. (2019). *Stringr: Simple, consistent wrappers for common string operations*. Retrieved from https://CRAN.R-project.org/package=stringr

Wickham, H. (2021a). *Forcats: Tools for working with categorical variables (factors)*. Retrieved from https://CRAN.R-project.org/package=forcats

Wickham, H. (2021b). *Tidyr: Tidy messy data*. Retrieved from https://CRAN.R-project.org/package=tidyr

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., … Yutani, H. (2019). Welcome to the tidyverse. *Journal of Open Source Software*, *4*(43), 1686. https://doi.org/10.21105/joss.01686

Wickham, H., & Bryan, J. (2019). *Readxl: Read excel files*. Retrieved from https://CRAN.R-project.org/package=readxl

Wickham, H., François, R., Henry, L., & Müller, K. (2021). *Dplyr: A grammar of data manipulation*. Retrieved from https://CRAN.R-project.org/package=dplyr

Wickham, H., & Hester, J. (2021). *Readr: Read rectangular text data*. Retrieved from https://CRAN.R-project.org/package=readr

Wilke, C. O. (2020). *Cowplot: Streamlined plot theme and plot annotations for 'ggplot2'*. Retrieved from https://CRAN.R-project.org/package=cowplot

Winston Chang. (2014). *Extrafont: Tools for using fonts*. Retrieved from https://CRAN.R-project.org/package=extrafont

Worthington, R. L., & Whittaker, T. A. (2006). Scale Development Research: A Content Analysis and Recommendations for Best Practices. *The Counseling Psychologist*, *34*(6), 806–838. https://doi.org/10.1177/0011000006288127

Wu, Y., & Hallett, M. (2017). Photophobia in neurologic disorders. *Translational Neurodegeneration*, *6*(1), 26. https://doi.org/10.1186/s40035-017-0095-3

Yu, C.-Y. (2002). *Evaluating cutoff criteria of model fit indices for latent variable models with binary and continuous outcomes* (Thesis). ProQuest Dissertations Publishing.

Yu, L., Buysse, D. J., Germain, A., Moul, D. E., Stover, A., Dodds, N. E., … Pilkonis, P. A. (2011). Development of short forms from the PROMIS™ sleep disturbance and sleep-related impairment item banks. *Behavioral Sleep Medicine*, *10*(1), 6–24. https://doi.org/10.1080/15402002.2012.636266

Zeileis, A., & Croissant, Y. (2010). Extended model formulas in R: Multiple parts and multiple responses. *Journal of Statistical Software*, *34*(1), 1–13. https://doi.org/10.18637/jss.v034.i01

Zeileis, A., Fisher, J. C., Hornik, K., Ihaka, R., McWhite, C. D., Murrell, P., … Wilke, C. O. (2020). colorspace: A toolbox for manipulating and assessing colors and palettes. *Journal of Statistical Software*, *96*(1), 1–49. https://doi.org/10.18637/jss.v096.i01

Zeileis, A., Hornik, K., & Murrell, P. (2009). Escaping RGBland: Selecting colors for statistical graphics. *Computational Statistics & Data Analysis*, *53*(9), 3259–3270. https://doi.org/10.1016/j.csda.2008.11.033

Zhu, H. (2021). *kableExtra: Construct complex table with ’kable’ and pipe syntax*. Retrieved from https://CRAN.R-project.org/package=kableExtra

Zinbarg, R. E., Revelle, W., Yovel, I., & Li, W. (2005). Cronbach’s α, revelle’s β, and McDonald’s ω h: Their relations with each other and two alternative conceptualizations of reliability. *Psychometrika*, *70*(1), 123–133.

Table 1

Dempgraphics

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 2

Descriptive Statistics

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item1	2.27	1.39	0.74	-0.81	0.81*	.25
Item2	2.87	1.59	0.08	-1.60	0.83*	.19
Item3	3.36	1.38	-0.48	-1.03	0.87*	.16
Item4	1.47	1.18	2.38	4.00	0.43*	.28
Item5	4.01	1.40	-1.22	0.07	0.70*	.13
Item6	2.79	1.55	0.19	-1.48	0.85*	.20
Item7	2.26	1.25	0.70	-0.60	0.85*	.19
Item8	2.97	1.20	-0.06	-0.94	0.91*	-.10
Item9	2.94	1.03	-0.12	-0.40	0.91*	.10
Item10	2.74	1.04	0.09	-0.74	0.91*	.28
Item11	2.18	0.90	0.60	0.12	0.86*	.26
Item12	2.36	1.22	0.59	-0.62	0.87*	.25
Item13	2.73	1.46	0.20	-1.36	0.87*	.33
Item14	2.14	1.31	0.77	-0.78	0.80*	.26
Item15	3.26	1.09	-0.26	-0.45	0.91*	.14
Item16	1.56	1.23	2.00	2.45	0.50*	.32
Item17	1.54	1.21	2.07	2.75	0.49*	.31
Item18	1.12	0.49	5.02	27.80	0.25*	.16
Item19	1.05	0.36	7.23	52.98	0.13*	.18
Item20	1.04	0.33	8.99	85.28	0.10*	.16
Item21	1.14	0.59	4.79	24.05	0.25*	.16
Item22	3.57	1.07	-0.65	-0.17	0.88*	.21
Item23	2.56	1.27	0.33	-1.00	0.89*	.11

Table 2 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item24	4.14	0.99	-1.23	1.14	0.79*	.19
Item25	2.59	1.41	0.27	-1.27	0.86*	.19
Item26	2.25	1.27	0.69	-0.64	0.84*	.18
Item27	3.80	1.29	-0.87	-0.42	0.82*	.17
Item28	3.76	1.14	-0.68	-0.45	0.86*	.00
Item29	2.44	1.31	0.38	-1.14	0.86*	.11
Item30	1.48	1.11	2.18	3.35	0.48*	.24
Item31	3.00	1.62	-0.08	-1.61	0.83*	.44
Item32	3.55	1.65	-0.60	-1.34	0.76*	.43
Item33	3.62	1.64	-0.68	-1.25	0.74*	.32
Item34	3.42	1.83	-0.45	-1.69	0.69*	.33
Item35	3.86	1.67	-0.99	-0.85	0.65*	.23
Item36	1.54	1.25	2.13	2.86	0.46*	.36
Item37	1.33	0.91	3.03	8.43	0.41*	.01
Item38	4.30	1.08	-1.79	2.53	0.67*	.22
Item39	1.96	0.98	1.02	0.69	0.82*	.05
Item40	2.16	1.19	0.71	-0.54	0.84*	.14
Item41	1.31	0.81	2.75	6.92	0.43*	.21
Item42	3.93	1.48	-1.06	-0.44	0.71*	.18
Item43	1.64	1.18	1.79	2.02	0.60*	.15
Item44	3.51	1.30	-0.70	-0.59	0.85*	.39
Item45	2.22	1.48	0.71	-1.02	0.76*	.30
Item46	1.76	1.23	1.35	0.44	0.66*	.38
Item47	2.11	1.17	0.77	-0.39	0.83*	.32

Table 2 continued

	Mean	SD	Skew	Kurtosis	Shapiro-Wilk Statistics	Item-Total Correlation
Item48	2.60	1.25	0.29	-0.86	0.89*	.35

Note. *p<.001

Table 3

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 4

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 5

Invariance Analysis

	Chi-Square	df	CFI	TLI	RMSEA	RMSEA 90% Lower CI	RMSEA 90% Upper	SRMR	Chi-Sqr comparison	df*	p
Configural	632.20	442.00	0.95	0.94	0.06	0.05	0.07	0.13	-	-	-
Metric	644.58	458.00	0.95	0.95	0.06	0.05	0.07	0.13	18.019a	16	0.323
Scalar	714.19	522.00	0.95	0.95	0.05	0.04	0.06	0.13	67.961b	64	0.344
Residual	714.19	522.00	0.95	0.95	0.05	0.04	0.06	0.13	0c	0	NA
Structural	691.49	542.00	0.96	0.96	0.05	0.04	0.06	0.13	12.617d	20	0.893

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

Table 6

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

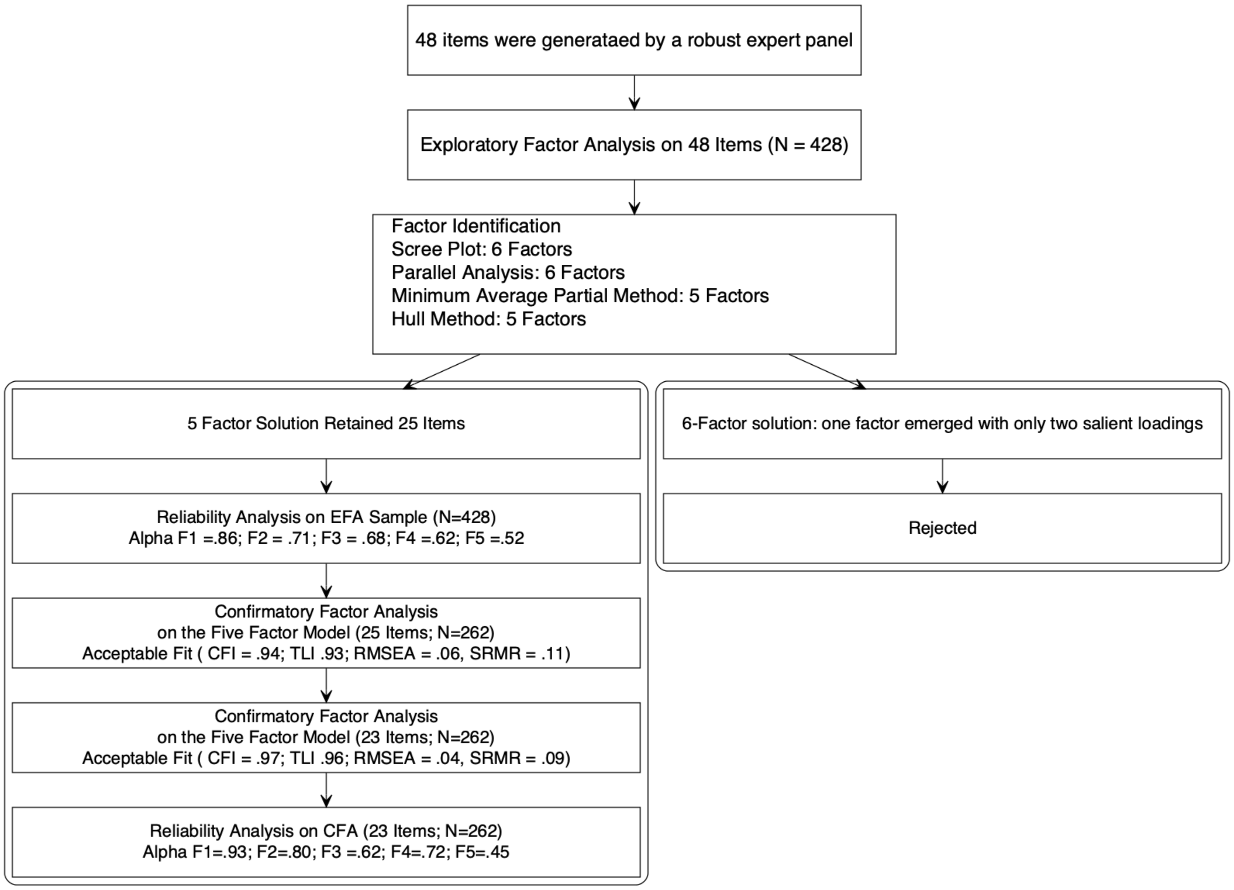

Figure 1. Development

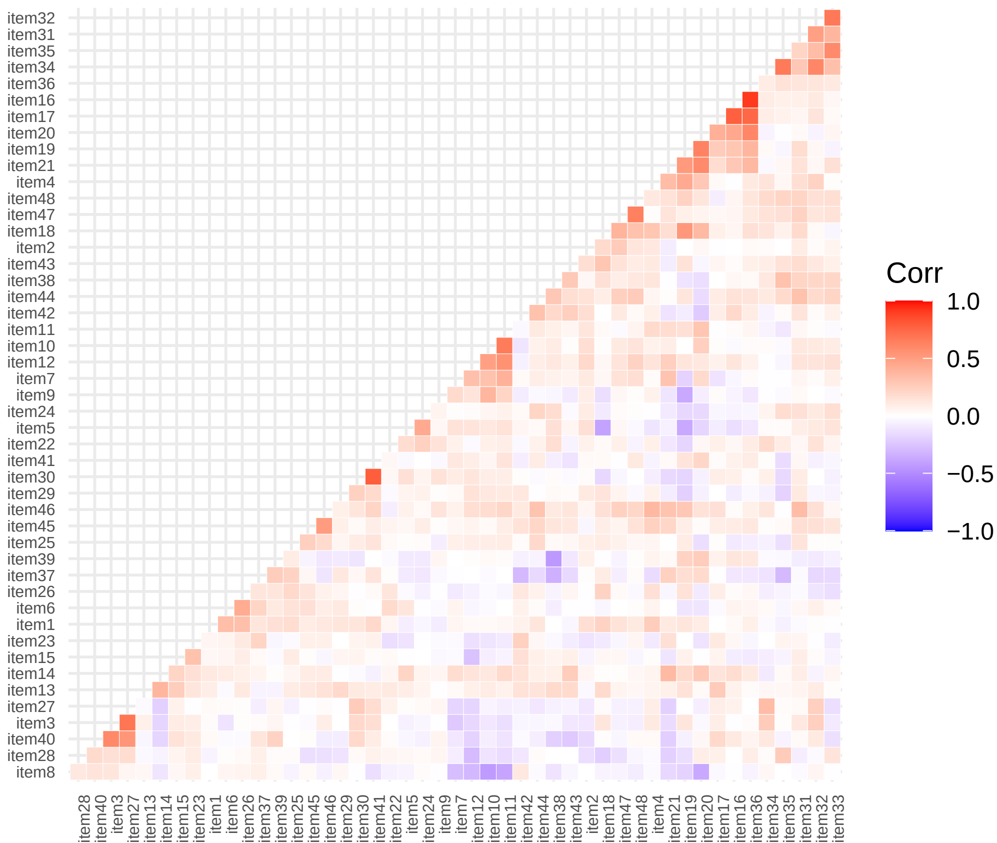

Figure 2. Correlation plot of the items

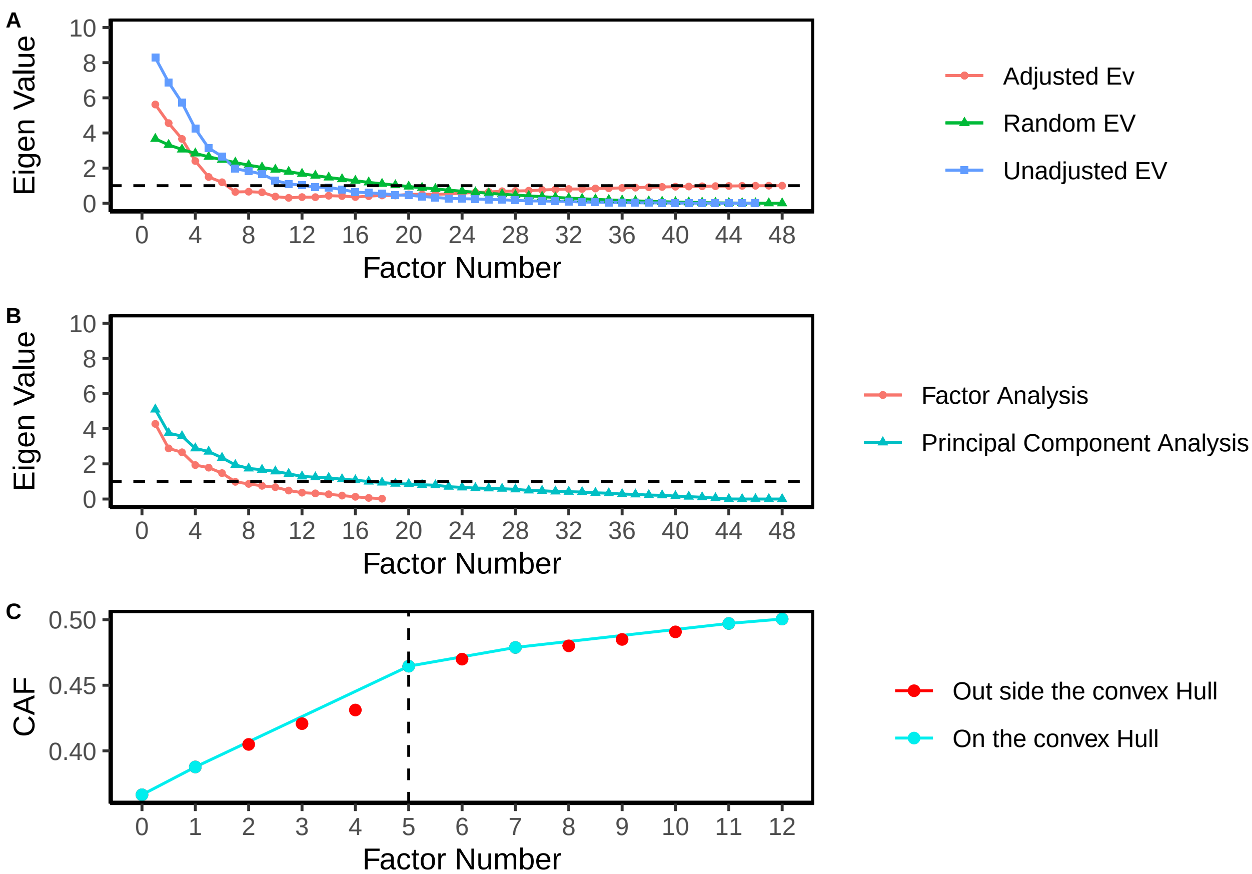

Figure 3. Factor Identification (A) Parallel analysis (B) Scree Plot (C) Hull Method

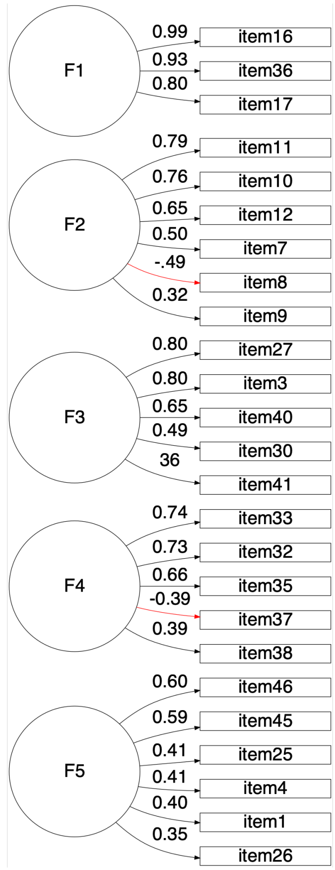

Figure 4. Five Factor Solution

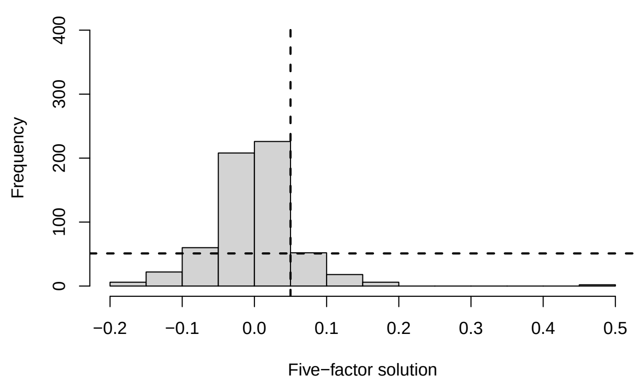

Figure 5. Histogram of residulas: five-factor solution

LEBA

Summary results of LEBA (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			22.20% (95)	12.38% (53)	10.51% (45)	12.62% (54)	42.29% (181)
item03	428	3.4	4.0	1.4			11.45% (49)	31.07% (133)	24.30% (104)	17.29% (74)	15.89% (68)
item04	428	1.5	1.0	1.2			3.50% (15)	2.10% (9)	8.18% (35)	2.10% (9)	84.11% (360)
item07	428	2.3	2.0	1.2			27.80% (119)	12.38% (53)	6.54% (28)	17.29% (74)	35.98% (154)
item08	428	3.0	3.0	1.2			25.93% (111)	22.20% (95)	13.79% (59)	27.80% (119)	10.28% (44)
item09	428	2.9	3.0	1.0			19.63% (84)	22.43% (96)	5.84% (25)	41.82% (179)	10.28% (44)
item10	428	2.7	3.0	1.0			31.31% (134)	21.96% (94)	3.50% (15)	31.31% (134)	11.92% (51)
item11	428	2.2	2.0	0.9			46.26% (198)	7.01% (30)	1.17% (5)	23.13% (99)	22.43% (96)
item12	428	2.4	2.0	1.2			29.67% (127)	12.15% (52)	6.78% (29)	21.50% (92)	29.91% (128)
item16	428	1.6	1.0	1.2			4.21% (18)	4.67% (20)	7.48% (32)	3.97% (17)	79.67% (341)
item17	428	1.5	1.0	1.2			3.27% (14)	3.27% (14)	7.71% (33)	5.14% (22)	80.61% (345)
item25	428	2.6	3.0	1.4			13.79% (59)	17.99% (77)	11.68% (50)	22.20% (95)	34.35% (147)
item26	428	3.7	4.0	1.3			10.98% (47)	23.36% (100)	38.32% (164)	20.09% (86)	7.24% (31)
item27	428	3.8	4.0	1.3			11.21% (48)	30.37% (130)	38.79% (166)	11.21% (48)	8.41% (36)
item30	428	1.5	1.0	1.1			3.27% (14)	5.37% (23)	4.67% (20)	4.91% (21)	81.78% (350)
item32	428	3.6	4.0	1.6			7.01% (30)	14.95% (64)	46.73% (200)	8.18% (35)	23.13% (99)
item33	428	3.6	4.0	1.6			7.01% (30)	14.49% (62)	49.30% (211)	7.24% (31)	21.96% (94)
item35	428	3.9	5.0	1.7			1.87% (8)	9.35% (40)	62.15% (266)	3.74% (16)	22.90% (98)
item36	428	1.5	1.0	1.3			3.04% (13)	2.34% (10)	9.35% (40)	3.04% (13)	82.24% (352)
item37	428	2.3	2.0	1.3			23.36% (100)	10.98% (47)	7.24% (31)	20.09% (86)	38.32% (164)
item38	428	4.3	5.0	1.1			3.50% (15)	27.57% (118)	58.18% (249)	5.37% (23)	5.37% (23)
item40	428	2.2	2.0	1.2			25.00% (107)	11.45% (49)	4.44% (19)	19.63% (84)	39.49% (169)
item41	428	1.3	1.0	0.8			4.67% (20)	3.04% (13)	1.17% (5)	6.07% (26)	85.05% (364)
item45	428	2.2	1.0	1.5			7.01% (30)	11.92% (51)	11.68% (50)	16.36% (70)	53.04% (227)
item46	428	1.8	1.0	1.2			7.71% (33)	8.88% (38)	4.67% (20)	11.68% (50)	67.06% (287)
CFA (n =262)											
item01	262	2.3	2.0	1.4			22.52% (59)	10.69% (28)	11.83% (31)	14.50% (38)	40.46% (106)
item03	262	3.7	4.0	1.3			7.25% (19)	28.24% (74)	35.11% (92)	17.56% (46)	11.83% (31)
item04	262	1.3	1.0	0.8			2.29% (6)	3.05% (8)	1.91% (5)	3.44% (9)	89.31% (234)
item07	262	2.1	2.0	1.2			23.66% (62)	14.12% (37)	4.58% (12)	14.50% (38)	43.13% (113)
item08	262	3.0	3.0	1.2			32.06% (84)	22.90% (60)	14.12% (37)	20.99% (55)	9.92% (26)
item09	262	2.9	3.0	1.1			22.14% (58)	26.34% (69)	4.20% (11)	34.35% (90)	12.98% (34)
item10	262	2.6	3.0	1.1			29.39% (77)	21.37% (56)	2.67% (7)	29.01% (76)	17.56% (46)
item11	262	2.1	2.0	0.9			46.56% (122)	5.34% (14)	1.91% (5)	20.23% (53)	25.95% (68)
item12	262	2.3	2.0	1.2			30.92% (81)	11.45% (30)	6.49% (17)	19.08% (50)	32.06% (84)
item16	262	1.6	1.0	1.3			3.44% (9)	5.73% (15)	8.40% (22)	4.20% (11)	78.24% (205)
item17	262	1.6	1.0	1.2			3.44% (9)	2.67% (7)	8.40% (22)	5.34% (14)	80.15% (210)
item25	262	2.5	2.0	1.4			18.32% (48)	16.79% (44)	10.31% (27)	21.76% (57)	32.82% (86)
item27	262	4.0	4.0	1.2			7.25% (19)	33.59% (88)	45.04% (118)	8.02% (21)	6.11% (16)
item30	262	1.4	1.0	1.1			2.67% (7)	6.11% (16)	3.44% (9)	4.20% (11)	83.59% (219)
item32	262	3.4	4.0	1.7			4.20% (11)	16.79% (44)	41.60% (109)	11.45% (30)	25.95% (68)
item33	262	3.1	3.0	1.7			6.11% (16)	14.12% (37)	35.50% (93)	11.83% (31)	32.44% (85)
item35	262	3.6	5.0	1.8			2.67% (7)	6.49% (17)	56.11% (147)	7.25% (19)	27.48% (72)
item36	262	1.6	1.0	1.3			3.44% (9)	3.44% (9)	9.54% (25)	3.05% (8)	80.53% (211)
item38	262	4.3	5.0	1.1			7.63% (20)	21.37% (56)	60.31% (158)	6.49% (17)	4.20% (11)
item40	262	2.5	2.0	1.3			27.10% (71)	12.21% (32)	11.07% (29)	18.70% (49)	30.92% (81)
item41	262	1.2	1.0	0.7			3.82% (10)	2.67% (7)	1.15% (3)	2.29% (6)	90.08% (236)
item45	262	2.0	1.0	1.4			5.34% (14)	11.83% (31)	9.16% (24)	9.54% (25)	64.12% (168)
item46	262	1.6	1.0	1.2			2.67% (7)	9.54% (25)	4.20% (11)	8.02% (21)	75.57% (198)

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

Figure 6

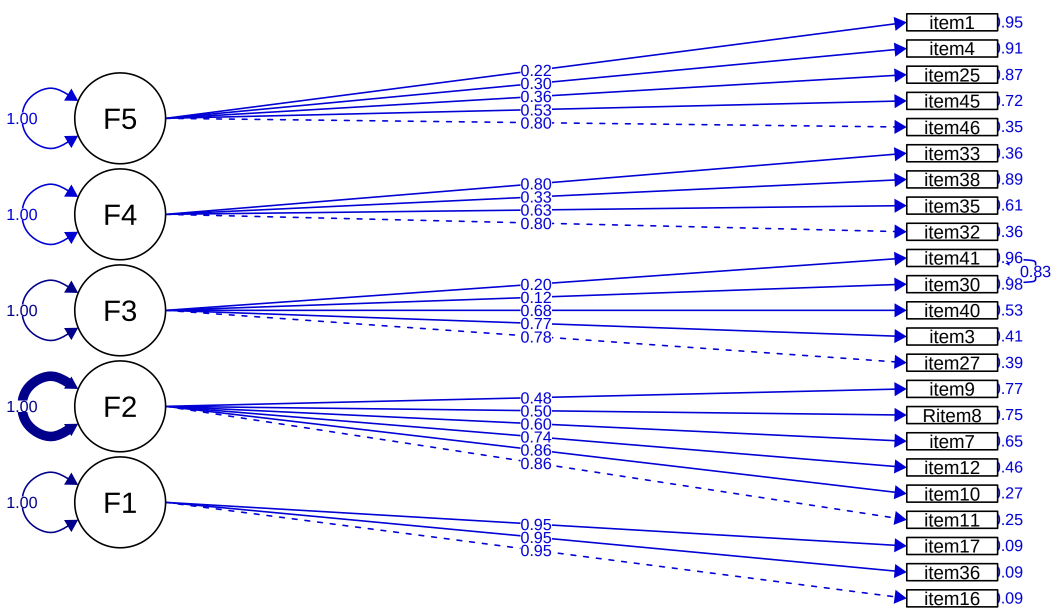

Figure 7. (A) Five Factor Model of LEBA

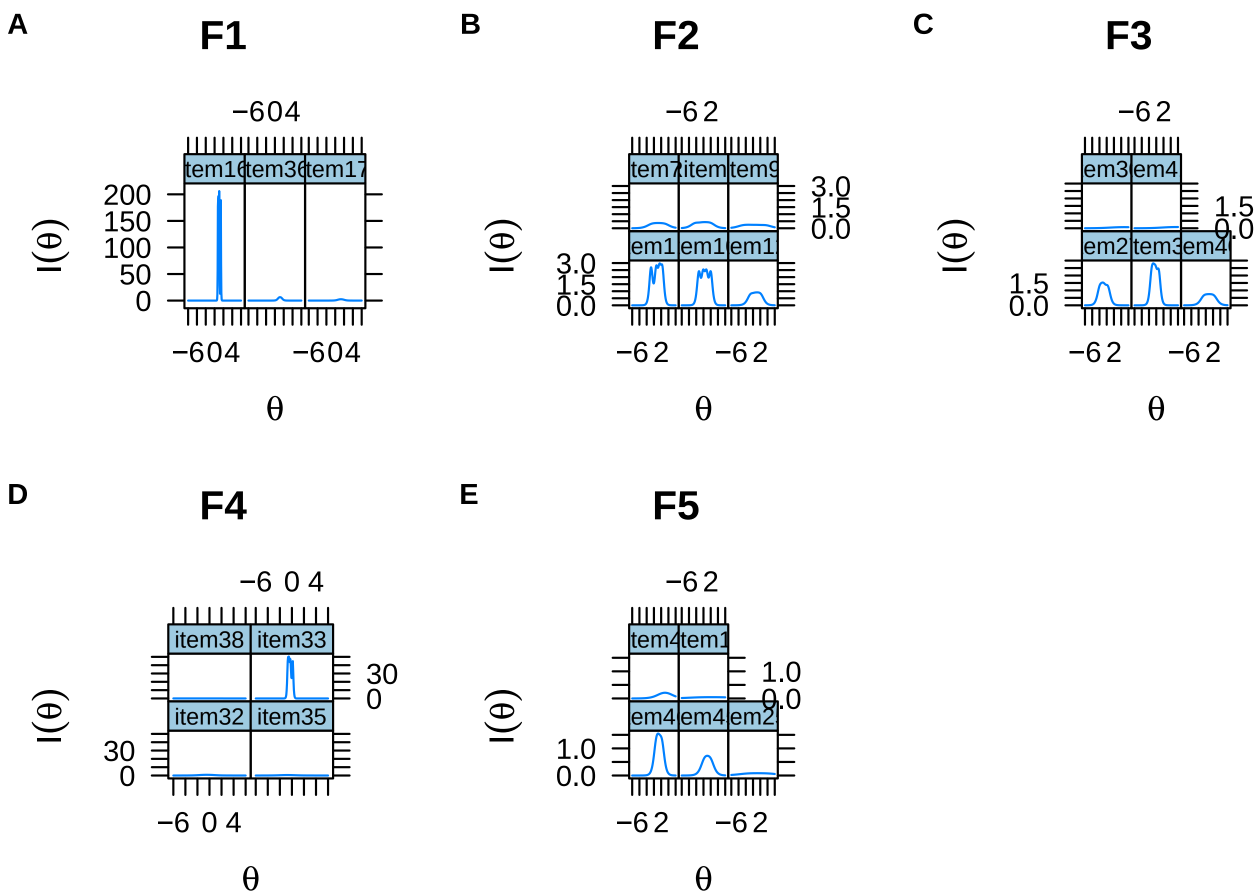

Figure 8. Item information curves (A) blue filter (B) natural light (C)smart device (D)sleep environment (E)electic light

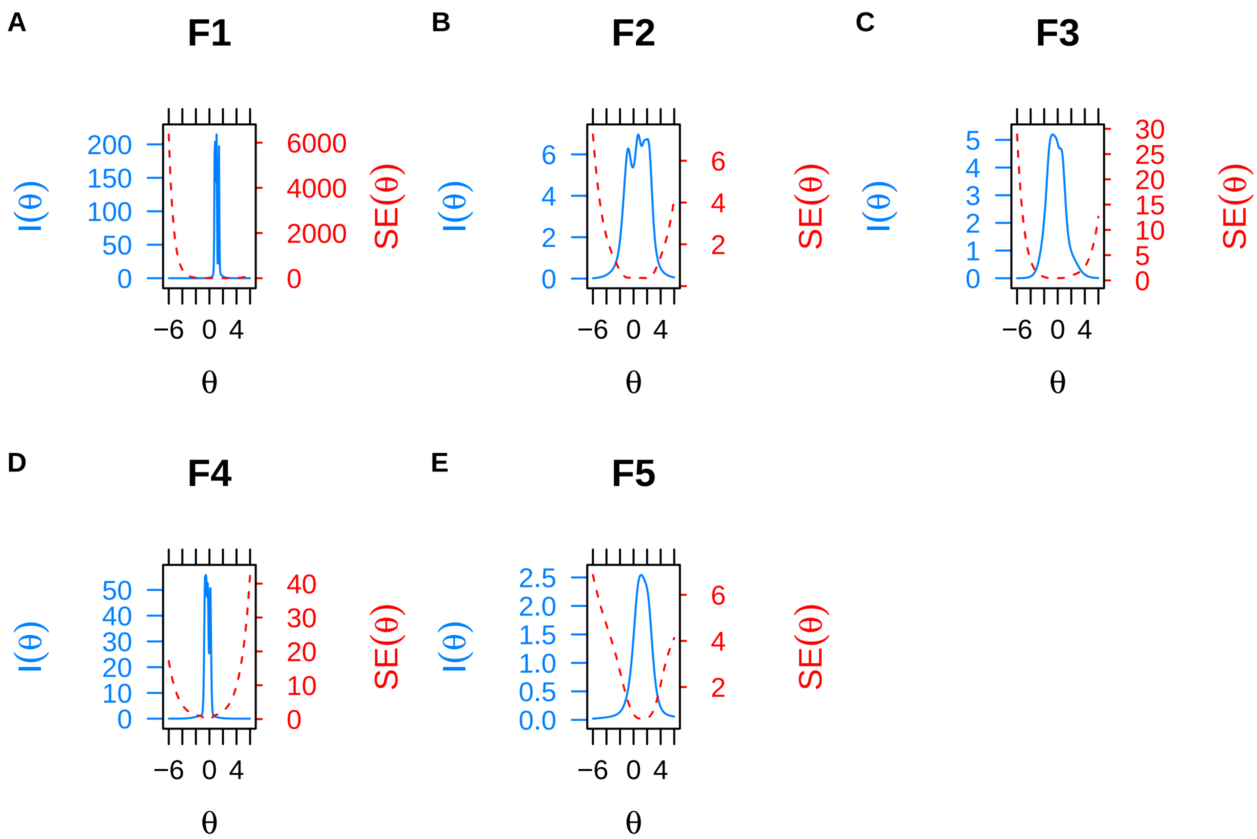

Figure 9. Test information curves (A) blue filter (B) natural light (C)smart device (D)sleep environment (E)electic light

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
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
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

Appendix B

Factor Analysis with Unmerged Response Option

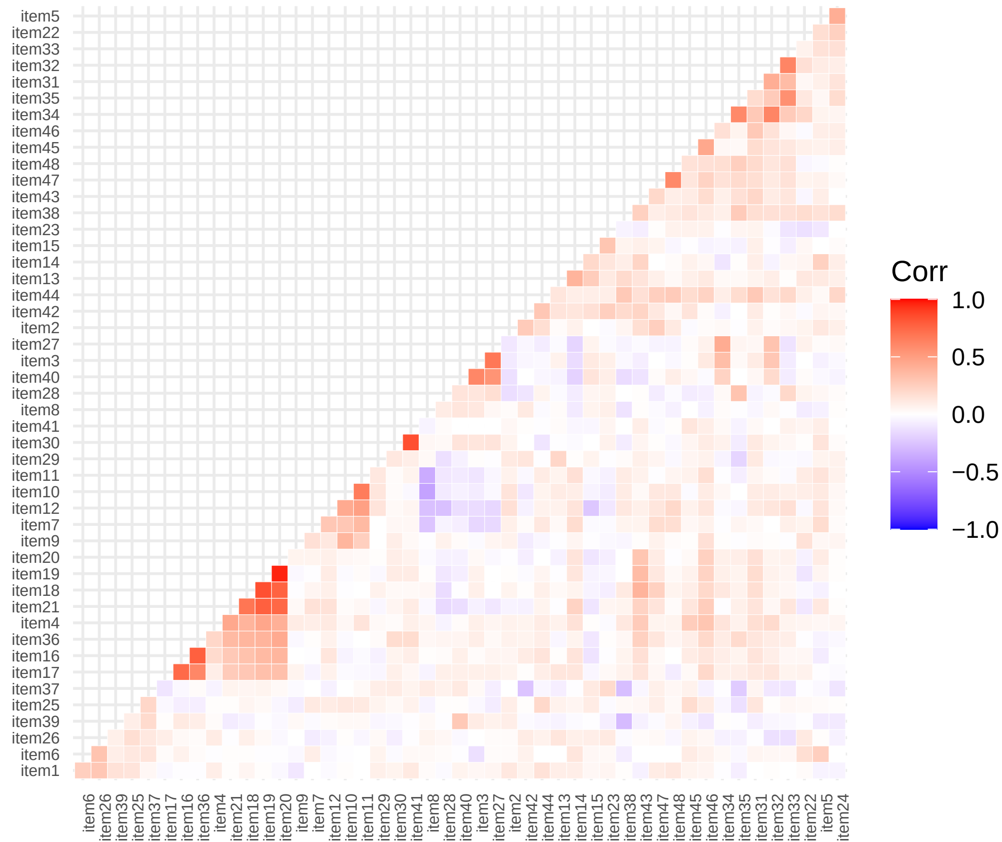

Figure B1. Correlation plot of the items

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

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.

Five Factor Solution[Unmerged Responses] (24 Items)
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.
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.

Five Factor Solution[Unmerged Responses] (24 Items)
I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.

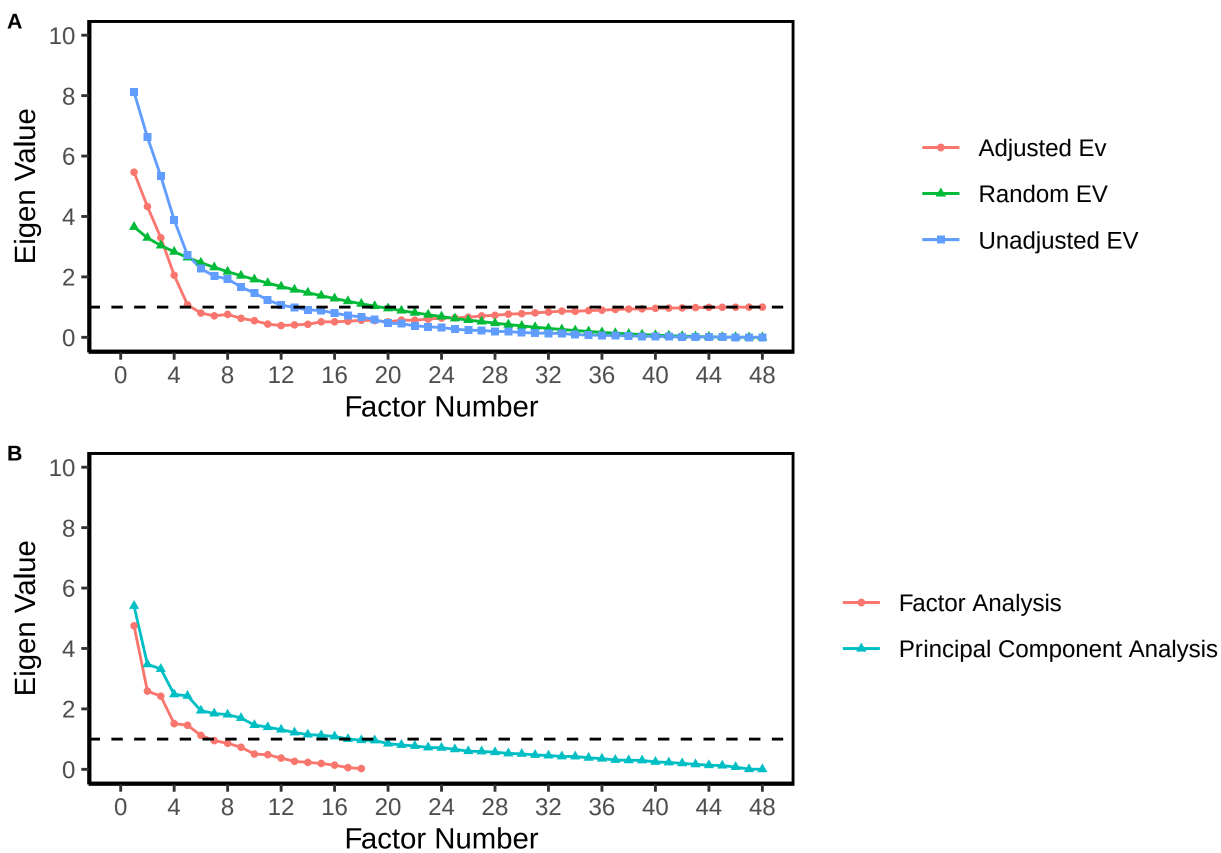

Figure B2. Factor Identification (A) Parallel analysis (B) Scree Plot

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
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	[illegible]	[illegible]	[illegible]	[illegible]	0.88*	.16

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
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

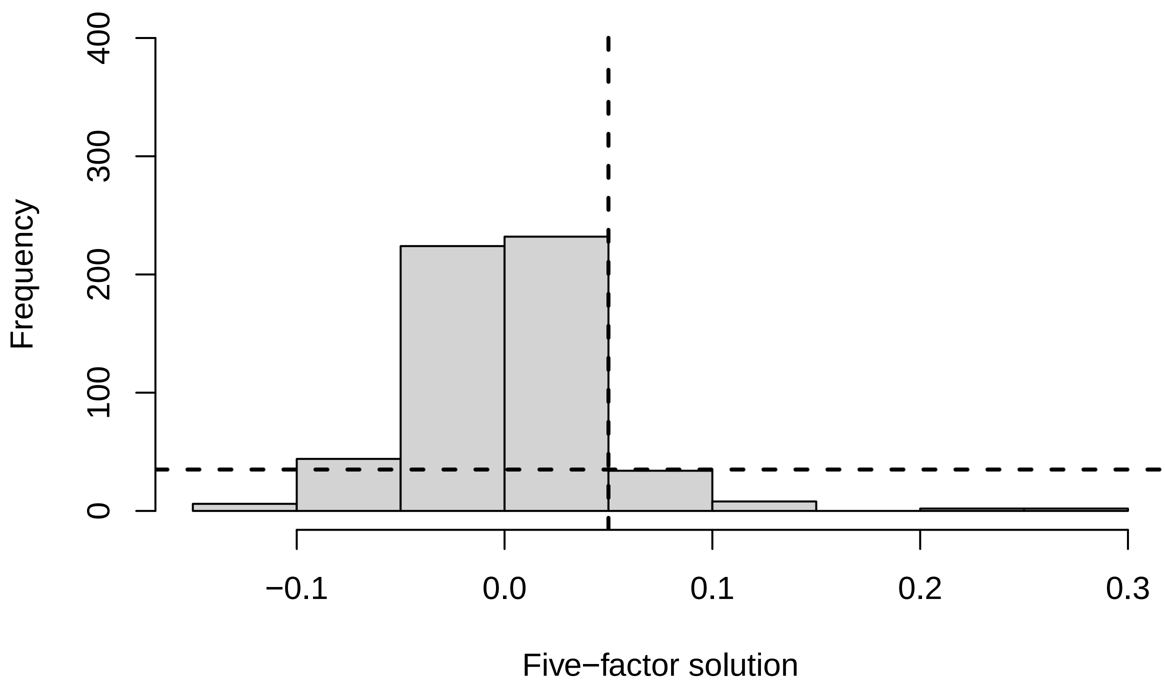

Figure B3. Histogram of residulas: five-factor solution

Appendix C

Disclaimer: This is a non-public version of LEBA (dated November 12, 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: McDonald's Omega	Reliability Coefficients: Cronbach's alpha
F1: Wearing blue light filters	1-3	.93	.90
F2: Spending time outdoors	4-9 (Item 4 is reversed)	.80	.78
F3: Using phone and smartwatch in bed	10-14	.61	.62
F4: Using light before bedtime	15-18	.72	.62
F5: Using light in the morning and during daytime	19-23	.45	.41
		.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: