1    *Light Exposure Behavior Assessment (LEBA)*: Development of a novel instrument to

2                        capture light exposure-related behaviours

3      Mushfiqul Anwar Siraji[1, *], Rafael Robert Lazar[2, 3, *], Juliëtte van Duijnhoven[4], Luc

4    Schlangen[5], Shamsul Haque[1], Vineetha Kalavally[6], Céline Vetter[7, 8], Gena Glickman[9],

5                        Karin Smolders[10], & Manuel Spitschan[11, 2, 3]


6    [1] Monash University, Department of Psychology, Jeffrey Cheah School of Medicine and

7                              Health Sciences, Malaysia

8    [2] Psychiatric Hospital of the University of Basel (UPK), Centre for Chronobiology, Basel,

9                                    Switzerland

10      [3] University of Basel, Transfaculty Research Platform Molecular and Cognitive

11                            Neurosciences, Basel, Switzerland

12    [4] Eindhoven University of Technology, Department of the Built Environment, Building

13                          Lighting, Eindhoven, Netherlands

14      [5] Eindhoven University of Technology, Department of Industrial Engineering and

15        Innovation Sciences, Intelligent Lighting Institute, Eindhoven, Netherlands

16    [6] Monash University, Department of Electrical and Computer Systems Engineering,

17                          Malaysia, Selangor, Malaysia

18    [7] University of Colorado Boulder, Department of Integrative Physiology, Boulder, USA

19                        [8] Ximes GmbH, Frankfurt, Germany

20      [9] Uniformed Services University of the Health Sciences, Department of Psychiatry,

21          Bethesda, USA

22      [10] Eindhoven University of Technology, Human-Technology Interaction Group,

23          Eindhoven, Netherlands

24      [11] University of Oxford, Department of Experimental Psychology, Oxford, UK

25          [*] Joint first author

**Author Note**

26

## Abstract

44 One or two sentences providing a **basic introduction** to the field, comprehensible to a

45 scientist in any discipline.

46 Two to three sentences of **more detailed background**, comprehensible to

47 scientists in related disciplines.

48 One sentence clearly stating the **general problem** being addressed by this

49 particular study.

50 One sentence summarizing the main result (with the words "**here we show**" or their

51 equivalent).

52 Two or three sentences explaining what the **main result** reveals in direct

53 comparison to what was thought to be the case previously, or how the main result adds

54 to previous knowledge.

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

56 Two or three sentences to provide a **broader perspective**, readily comprehensible

57 to a scientist in any discipline.

58 *Keywords:* keywords

59 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)

107    • Meal timing & caffeine consumption [custom items]

108    • Light sensitivity (photophobia vs. photophilia) (Wu & Hallett, 2017)

109    • Self-reported pubertal stage (only if younger than 18 years old) (Petersen,

110       Crockett, Richards, & Boxer, 1988)

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

112    • Age

113    • Sex

114    • Gender identity

115    • Occupational Status

116    • COVID-19 related Occupational setting during the past four weeks

117    • Time zone & country of residence

118    • English as native language

**Participants**

119

120    Table 1 summarizes the survey participants' demographic characteristics. Only

121    participants completing the full LEBA questionnaire were included, thus there are no

122    missing values in the item analyses. XX participants were excluded from analysis due to

123    not passing at least one of the "attention check" items. For exploring initial factor

124    structure (EFA) , a sample of 250-300 is recommended (Comrey & Lee, 1992;

125    Schönbrodt & Perugini, 2013). For estimating the sample size for the confirmatory factor

126    analysis (CFA) we followed the N:q rule (Bentler & Chou, 1987; Jackson, 2003; Kline,

127    2015; Worthington & Whittaker, 2006), where ten participants per parameter is required

128    to earn trustworthiness of the result. Our sample size exceeds these requirements:

129    Anonymous responses from a total of $n$ = 690 participants were included in the analysis

130    of the current study, split into samples for exploratory (EFA: $n$ = 428) and confirmatory

131    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 $\chi^2$ 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).

**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 format (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 format. 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 confirmed the latent structure obtained in the EFA by conducting a "Confirmatory Factor Analysis" (CFA) using "robust weighted least square estimator" (WLSMV). We estiablished the measurement invariance of our tool across native and non-native English speakers using structural equation model framework. To assess the possible semantic overlap of our tool with the existing tools, we sought to "Semantic Scale Network" (Rosenbusch, Wanders, & Pit, 2020). Lastly, we sought "Item Response Theory" (IRT) based analysis on developing a short form of LEBA. We also conducted psychometric analysis on non-merged response options data (Supp. Table B2) 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. However, 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), $\chi^2$ (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 .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.

232    With the initial 48 items we conducted three rounds of EFA and gradually discarded

233 problematic items. (cross-loading items and poor factor loading (<.30) items). Finally, a

234 five-factor EFA solution with 25 items was accepted with low RMSR = 0.08 (Brown,

235 2015), all factor-loading higher than .30 and no cross-loading greater than .30. We

236 further confirmed this five-factor latent structure by another EFA using varimax rotation

237 with a minimum residual extraction method (TableA1). Table 4 displays the factor-loading

238 (structural coefficients) and communality of the items. The absolute value of the

239 factor-loading ranged from .49 to .99 indicating strong coefficients. The commonalities

240 ranged between .11 to .99. However, the histogram of the absolute values of

241 non-redundant residual-correlations Fig5 showed 26% correlations greater than the

242 absolute value of .05, indicating a possible under-factoring. (Desjardins & Bulut, 2018).

243 Subsequently, we fitted a six-factor solution. However, a factor emerged with only one

244 salient variable loading in the six-factor solution, thus disqualifying the six-factor solution

245 (TableA2). Internal consistency reliability coefficient Cronbach's alpha assumes all the

246 factor-loadings of the items under a factor are equal (Graham, 2006; Novick & Lewis,

247 1967) which is not the case in our sample. Additionally Cronbach's alpha coefficient has

248 a tendency to deflate the estimates for Likert type data as the calculation is based on

249 pearson-correlation matrix which requires that response data should be in continuous of

250 nature (Gadermann, Guhn, & Zumbo, 2012; Zumbo, Gadermann, & Zeisser, 2007).

251 Subsequently to get better estimates of reliability we reported ordinal alpha which used

252 polychoric-correlation matrix and assumed that the responses data were ordered in

253 nature instead of continuous (Zumbo et al., 2007). Ordinal alpha coefficient value ranges

254 from 0 to 1 and higher value represents better reliability. In the five-factor solution, the

255 first factor contained three items and explained 10.25% of the total variance with a

256 internal reliability coefficient ordinal $\alpha$ = .94. All the items in this factor stemmed from the

257 individual's preference to use blue light filters in different light environments. The second

258 factor contained six items and explained 9.93% of the total variance with a internal

reliability coefficient ordinal $\alpha$ = .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 $\alpha$ = .75. The fourth factor contained five items and explained

8.44% of the total variance with an internal consistency coefficient, ordinal $\alpha$ = .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 $\alpha$ = .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 tool 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 $\chi^2$ 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 $\chi^2$ 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 $\chi^2$ test. However, the $\chi^2$ 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 stemmed from the

preference of dimming electric device's brightness before bed time and items pair 16 and

19 stemmed 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

312 value, our model attained best fit (CFI =.97; TLI = .96); RMSEA = .05[.04-.06, 90% CI])

313 and SRMR value (SRMR = .09) was also close to the suggestions of Hu and Bentle

314 (1999). Internal consistency ordinal $\alpha$ for the five factors of LEBA were .96, .83, .70, .69,

315 .52 respectively. We also estimated the internal consistency reliability of the total scale

316 using Mcdonald's $\omega$ (total) coefficient which is a better reliability estimate for

317 multidimensional constructs (Dunn, Baguley, & Brunsden, 2014; Sijtsma, 2009).

318 McDonald's omega(total) coefficient for the total scale was .73.

**Measurement Invariance**

320    Measurement invariance (MI) evaluates whether a construct has the psychometric

321 equivalence and same meaning across groups or measurement occasions (Kline, 2015;

322 Putnick & Bornstein, 2016). We used structural equation modeling framework to assess

323 the measurement invariance of our developed tool across two groups: **native English**

324 **speakers** and **non-native English speakers**. Our measurement invariance testing

325 involved successively comparing the nested models: configural, metric, scalar, and

326 residual invariance models with each others (Widaman & Reise, 1997). Among these

327 nested models configural model is the first and least restrictive model. The configural

328 model assumes that the number of factors and item number under each factor will be

329 equal across two groups. The metric invariance model assumes configural invariance of

330 the fitted model and requires the factor-loadings of the items across the two groups to be

331 equal. Having the factor-loadings equal across groups indicates each item contributes to

332 the measured construct equivalently. Scalar invariance assumes the metric invariance of

333 the fitted model demands the item intercepts to be equivalent across groups. This equity

334 of item intercepts indicates the equivalence of response scale across the groups, i.e.,

335 persons with the same level of the underlying construct will score the same across the

336 groups. The residual invariance model assumes metric invariance for the fitted model

337 and adds the assumption of equality in error variances and covariances across the

338  groups. This model is the highest level of MI and assures the equivalence of precision of

339  items across the groups in measuring the underlying constructs. The invariance model fit

340  of our tool was assessed using the fit indices including $\chi^2$ test, CFI and TLI (close to .95

341  or above), RMSEA (close to .06 or below) (Hu & Bentle, 1999). We excluded SRMR

342  from our consideration as it does not behave optimally for categorical variables (C. Yu,

343  2002). Table 6 summarized the fit indices. The comparison among different

344  measurement invariance models was made using the $\chi^2$ difference test ($\Delta\chi^2$) to

345  assess whether our obtained latent structure of "LEBA" attained the highest level of the

346  MI. A non-significant $\Delta\chi^2$ test between two MI models fit indicates mode fit does not

347  significantly decrease for the superior model (Dimitrov, 2010) thus allowing the superior

348  level of invariance model to be accepted. We started our analysis by comparing the

349  model fit of the least restrictive model:configural model to metric MI model and continued

350  successive comparisons. Table 6 indicates that our fitted model had acceptable fit

351  indices for all of the fitted MI models. The model fit did not significantly decrease across

352  the nested models up to the scalar MI model. The chi-square value difference between

353  the scalar and residual model is zero, indicating model fit remained the same for both:

354  scalar and residual MI model, indicating the acceptability of the residual MI model.

355  **Semantic Analysis**

356      To find out if our developed tool is overlapping with existing instruments, we

357  subjected the items of LEBA to the "Semantic Scale Network"(SSN)

358  analysis(Rosenbusch et al., 2020). The SSN detects semantically related scales and

359  provides cosine similarity index ranging between -.66 to 1 (Rosenbusch et al., 2020).

360  Pair of scales with a cosine similarity index value of 1 indicates they are perfectly

361  semantically similar scales indicating redundancy. LEBA appeared most strongly related

362  to scales about sleep: "Sleep Disturbance Scale For Children" (Bruni et al., 1996) and

363  "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 ($\theta$). 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 ($\theta$), 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 tool. Item discrimination parameters of our tool 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 ($\theta$). 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 ($(\theta)$). Also the amount of information changed rather steadily with the change of $(\theta)$. Thus we conferred the LEBA tool (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-$\chi^2$ 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 short form of 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 short form of LEBA to be

416  used to capture light exposure related behavior.

417                                        **Discussion**

## References

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

Bajaj, A., Rosner, B., Lockley, S. W., & Schernhammer, E. S. (2011). Validation of a light questionnaire with real-life photopic illuminance measurements: The harvard light exposure assessment questionnaire. *Cancer Epidemiology and Prevention Biomarkers*, *20*(7), 1341–1349.

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.

Bruni, O., Ottaviano, S., Guidetti, V., Romoli, M., Innocenzi, M., Cortesi, F., & Giannotti, F. (1996). The sleep disturbance scale for children (SDSC) construct ion and validation of an instrument to evaluate sleep disturbances in childhood and adolescence. *Journal of Sleep Research*, *5*(4), 251–261.

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, Daniel J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213.

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

Dianat, I., Sedghi, A., Bagherzade, J., Jafarabadi, M. A., & Stedmon, A. W. (2013). Objective and subjective assessments of lighting in a hospital setting: Implications for health, safety and performance. *Ergonomics*, *56*(10), 1535–1545.

Dimitrov, D. M. (2010). Testing for factorial invariance in the context of construct validation. *Measurement and Evaluation in Counseling and Development*, *43*(2), 121–149.

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.

Dunn, T. J., Baguley, T., & Brunsden, V. (2014). From alpha to omega: A practical solution to the pervasive problem of internal consistency estimation. *British Journal of Psychology*, *105*(3), 399–412.

Eklund, N., & Boyce, P. (1996). The development of a reliable, valid, and simple office lighting survey. *Journal of the Illuminating Engineering Society*, *25*(2),

25–40.

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

Gadermann, A. M., Guhn, M., & Zumbo, B. D. (2012). Estimating ordinal reliability for likert-type and ordinal item response data: A conceptual, empirical, and practical guide. *Practical Assessment, Research, and Evaluation*, *17*(1), 3.

Graham, J. M. (2006). Congeneric and (essentially) tau-equivalent estimates of score reliability: What they are and how to use them. *Educational and Psychological Measurement*, *66*(6), 930–944.

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

Horne, J. A., & Östberg, O. (1976). A self-assessment questionnaire to determine
morningness-eveningness in human circadian rhythms. *International Journal
of Chronobiology*.

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

Novick, M. R., & Lewis, C. (1967). Coefficient alpha and the reliability of composite measurements. *Psychometrika*, *32*(1), 1–13.

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

Peters, G.-J. (2021). *Ufs: Quantitative analysis made accessible*. Retrieved from https://CRAN.R-project.org/package=ufs

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

Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, *41*, 71–90.

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.

Rosenbusch, H., Wanders, F., & Pit, I. L. (2020). The semantic scale network: An online tool to detect semantic overlap of psychological scales and prevent scale redundancies. *Psychological Methods*, *25*(3), 380.

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

Samejima, F., Liden, W. van der, & Hambleton, R. (1997). Handbook of modern item response theory. New York, NY: Springer.

Sarkar, D. (2008). *Lattice: Multivariate data visualization with r*. New York:

634    Springer. Retrieved from http://lmdvr.r-forge.r-project.org

635    Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations

636    stabilize? *Journal of Research in Personality*, *47*(5), 609–612.

637    https://doi.org/10.1016/j.jrp.2013.05.009

638    Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural*

639    *equation modeling*. psychology press.

640    Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality

641    (complete samples). *Biometrika*, *52*(3-4), 591–611.

642    https://doi.org/10.1093/biomet/52.3-4.591

643    Sijtsma, K. (2009). On the use, the misuse, and the very limited usefulness of

644    cronbach's alpha. *Psychometrika*, *74*(1), 107.

645    Siraji, M. A. (2021). *Tabledown: A companion pack for the book "basic &*

646    *advanced psychometrics in r"*. Retrieved from

647    https://github.com/masiraji/tabledown

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

649    (2021b). *Gtsummary: Presentation-ready data summary and analytic result*

650    *tables*. Retrieved from https://CRAN.R-project.org/package=gtsummary

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

652    (2021a). *Gtsummary: Presentation-ready data summary and analytic result*

653    *tables*. Retrieved from https://CRAN.R-project.org/package=gtsummary

654    Stauffer, R., Mayr, G. J., Dabernig, M., & Zeileis, A. (2009). Somewhere over the

655    rainbow: How to make effective use of colors in meteorological visualizations.

656    *Bulletin of the American Meteorological Society*, *96*(2), 203–216.

657    https://doi.org/10.1175/BAMS-D-13-00155.1

658    Terry M. Therneau, & Patricia M. Grambsch. (2000). *Modeling survival data:*

659    *Extending the Cox model*. New York: Springer.

660    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/

Verriotto, J. D., Gonzalez, A., Aguilar, M. C., Parel, J.-M. A., Feuer, W. J., Smith, A. R., & Lam, B. L. (2017). New methods for quantification of visual photosensitivity threshold and symptoms. *Translational Vision Science & Technology*, *6*(4), 18–18.

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

WHO. (1990). Composite international diagnostic interview.

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

Widaman, K. F., & Reise, S. P. (1997). Exploring the measurement invariance of
        psychological instruments: Applications in the substance use domain.

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

Xie, Y., Wu, X., Tao, S., Wan, Y., & Tao, F. (2021). Development and validation of
        the self-rating of biological rhythm disorder for chinese adolescents.
        *Chronobiology International*, 1–7.
        https://doi.org/10.1080/07420528.2021.1989450

Yu, C. (2002). *Evaluating cutoff criteria of model fit indices for latent variable*

715 *models with binary and continuous outcomes* (Thesis). ProQuest

716 Dissertations Publishing.

717 Yu, L., Buysse, D. J., Germain, A., Moul, D. E., Stover, A., Dodds, N. E., …

718 Pilkonis, P. A. (2011). Development of short forms from the PROMIS™ sleep

719 disturbance and sleep-related impairment item banks. *Behavioral Sleep*

720 *Medicine*, *10*(1), 6–24. https://doi.org/10.1080/15402002.2012.636266

721 Yuan, K.-H., & Zhang, Z. (2020). *Rsem: Robust structural equation modeling with*

722 *missing data and auxiliary variables*. Retrieved from

723 https://CRAN.R-project.org/package=rsem

724 Zeileis, A., & Croissant, Y. (2010). Extended model formulas in R: Multiple parts

725 and multiple responses. *Journal of Statistical Software*, *34*(1), 1–13.

726 https://doi.org/10.18637/jss.v034.i01

727 Zeileis, A., Fisher, J. C., Hornik, K., Ihaka, R., McWhite, C. D., Murrell, P., …

728 Wilke, C. O. (2020). colorspace: A toolbox for manipulating and assessing

729 colors and palettes. *Journal of Statistical Software*, *96*(1), 1–49.

730 https://doi.org/10.18637/jss.v096.i01

731 Zeileis, A., Hornik, K., & Murrell, P. (2009). Escaping RGBland: Selecting colors

732 for statistical graphics. *Computational Statistics & Data Analysis*, *53*(9),

733 3259–3270. https://doi.org/10.1016/j.csda.2008.11.033

734 Zhang, Z., & Yuan, K.-H. (2020). *Coefficientalpha: Robust coefficient alpha and*

735 *omega with missing and non-normal data*. Retrieved from

736 https://CRAN.R-project.org/package=coefficientalpha

737 Zhu, H. (2021). *kableExtra: Construct complex table with 'kable' and pipe syntax*.

738 Retrieved from https://CRAN.R-project.org/package=kableExtra

739 Zumbo, B. D., Gadermann, A. M., & Zeisser, C. (2007). Ordinal versions of

740 coefficients alpha and theta for likert rating scales. *Journal of Modern Applied*

741 *Statistical Methods*, *6*(1), 4.

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 |
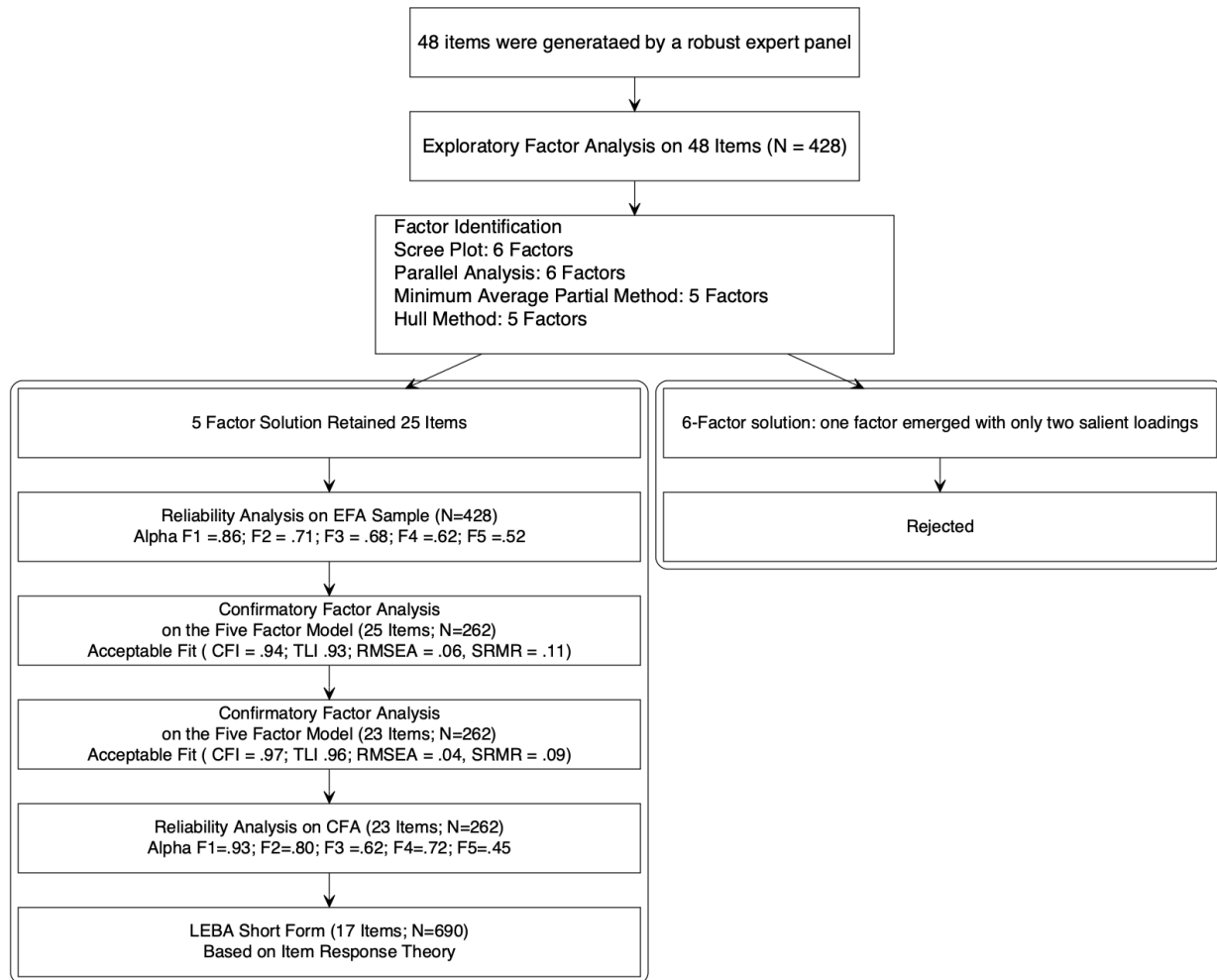
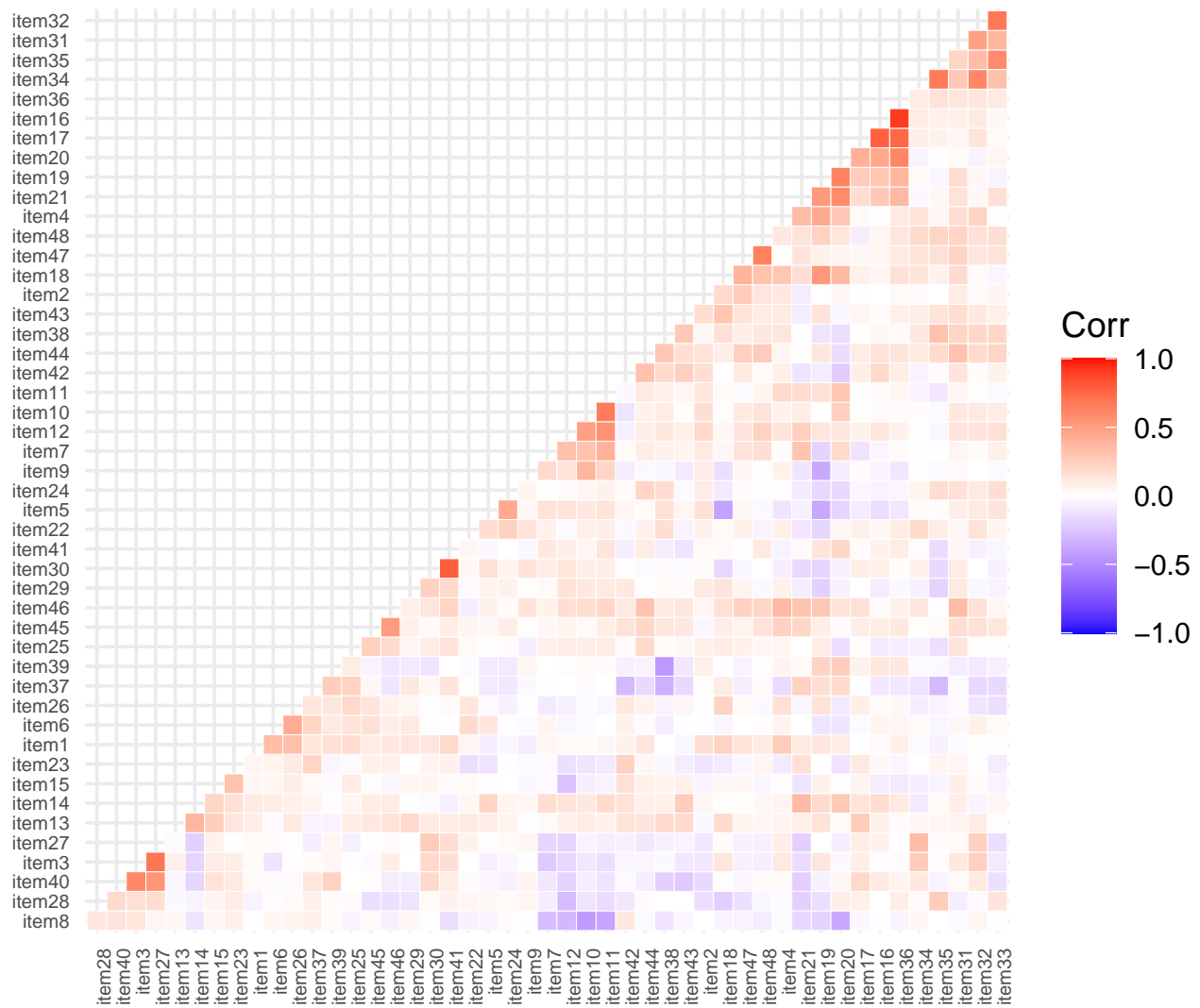*Figure 1*. Development of long and short form of LEBA

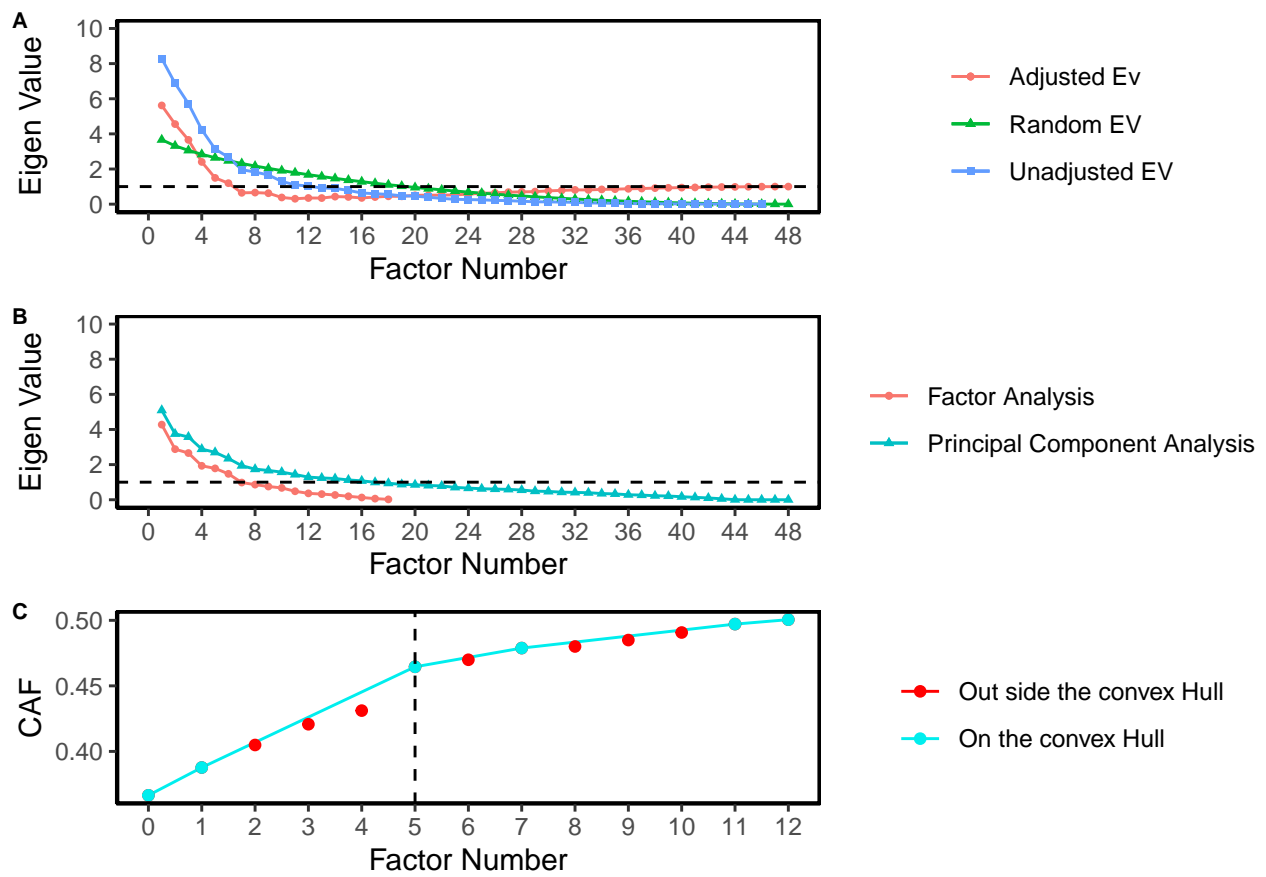*Figure 2*. Correlation plot of the items

*Figure 3.* Factor Identification (A) Parallel analysis (B) Scree Plot (C) Hull Method
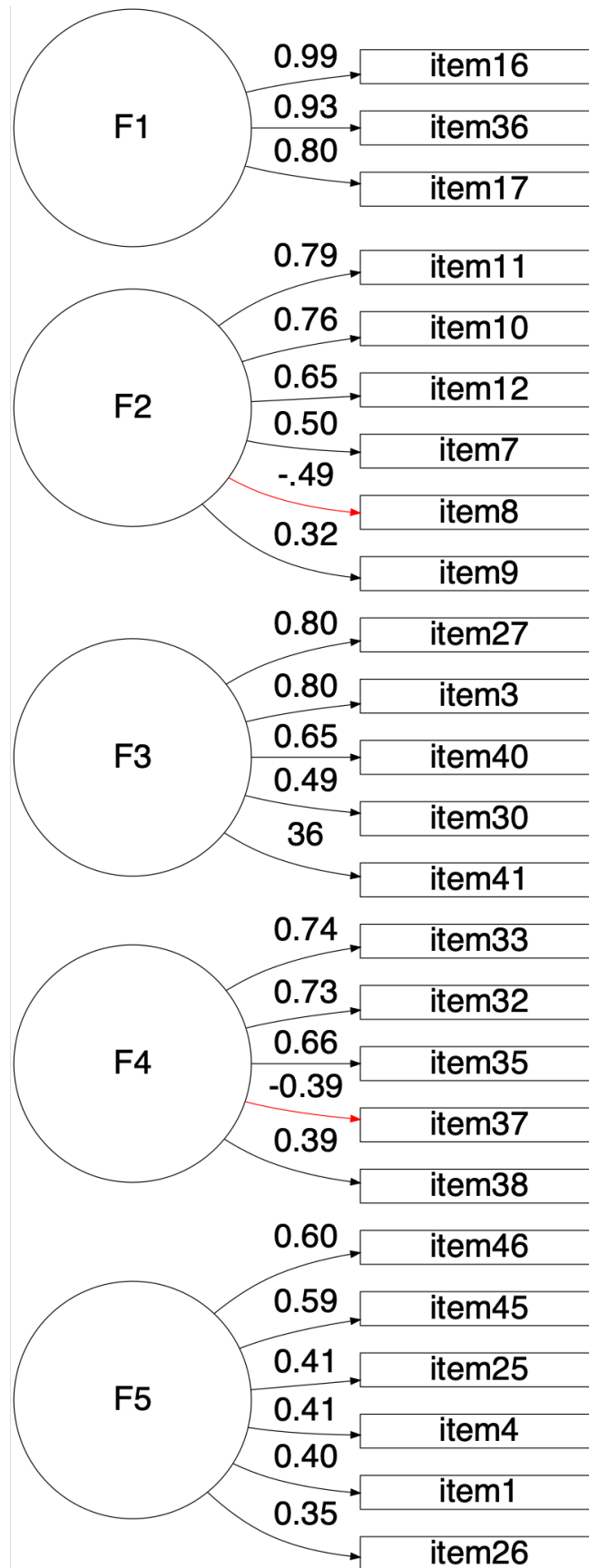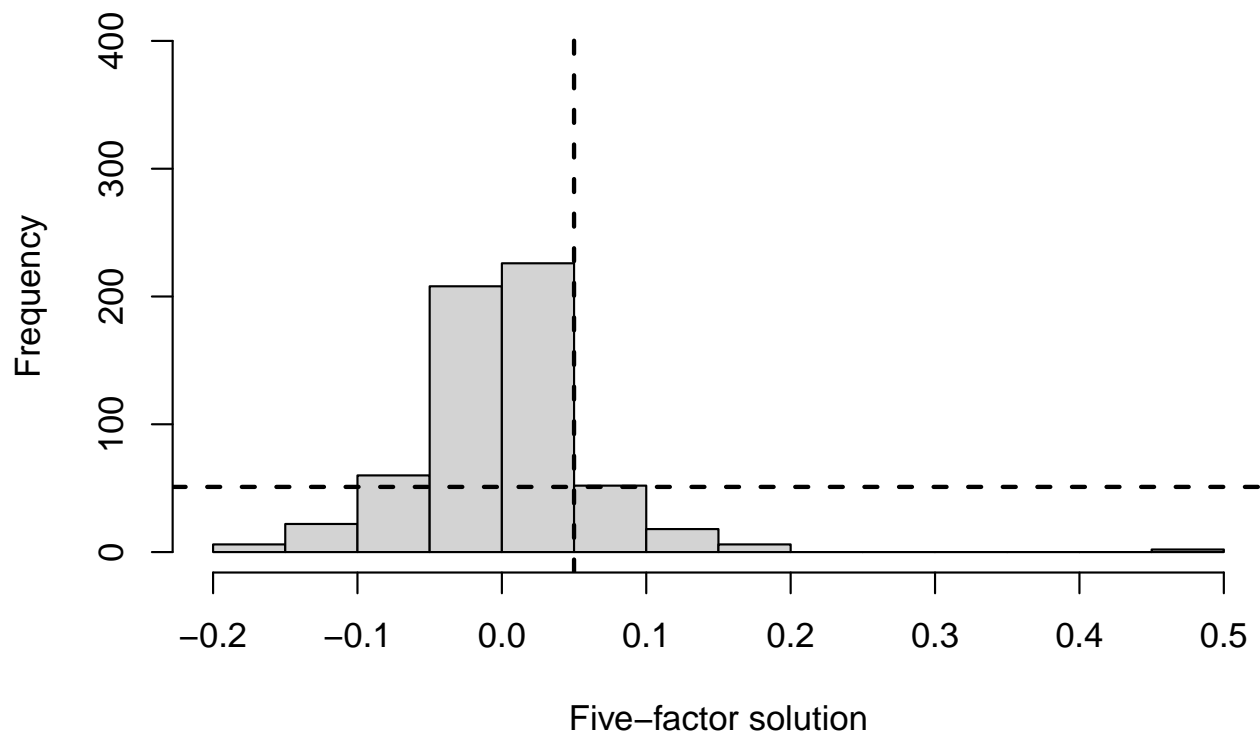
*Figure 4*. Five Factor Solution

*Figure 5*. Histogram of residuals: five-factor solution

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

| 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
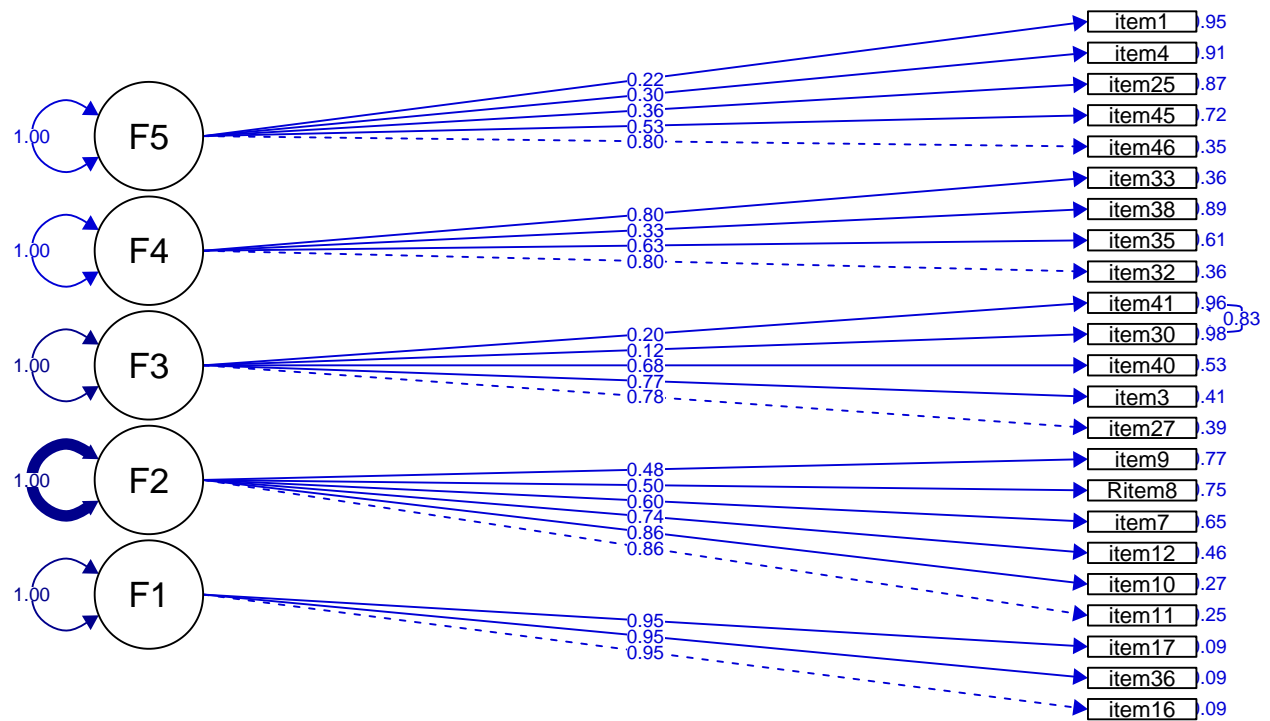
*Figure 7.* Five Factor CFA Model of LEBA

*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
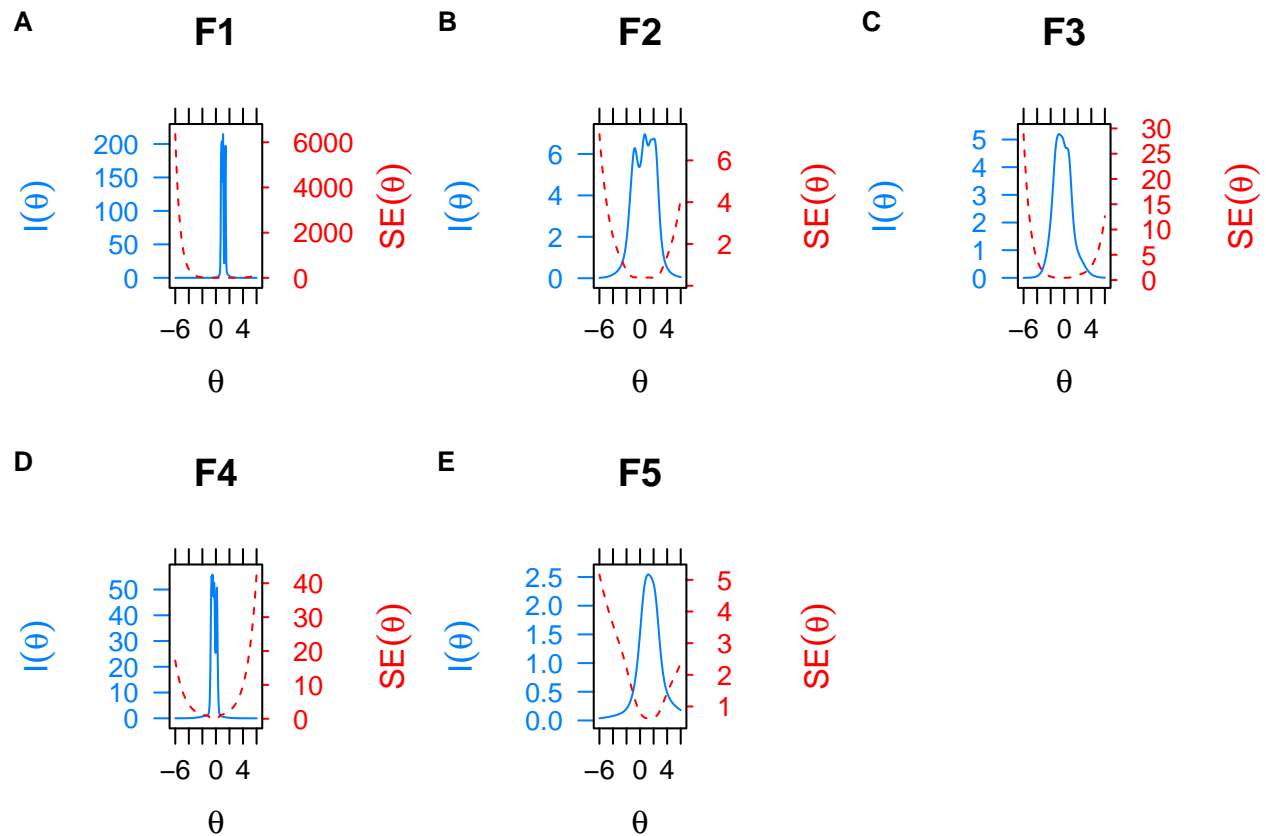
*Figure 9*. Test information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime
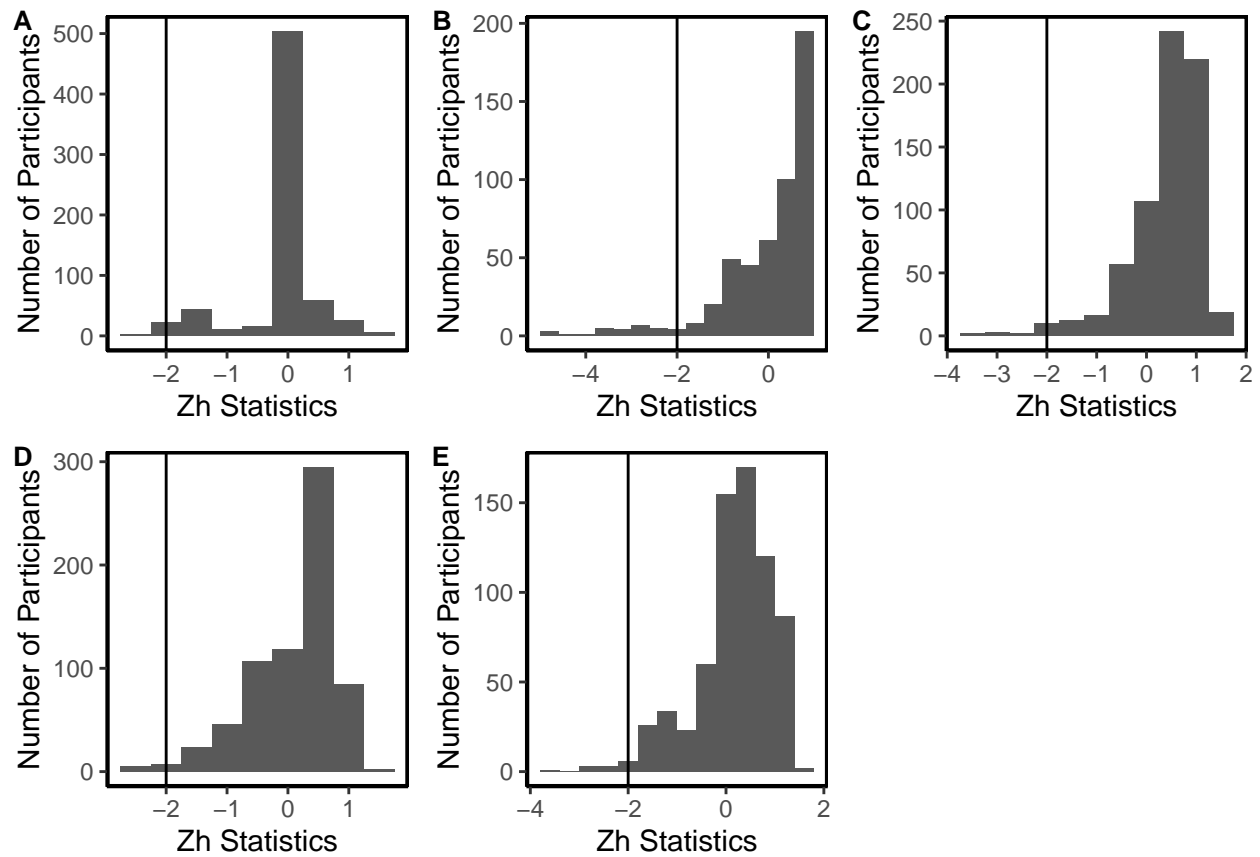
*Figure 10*. Person fit of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

**A**

**B**

**C**

**D**

**E**

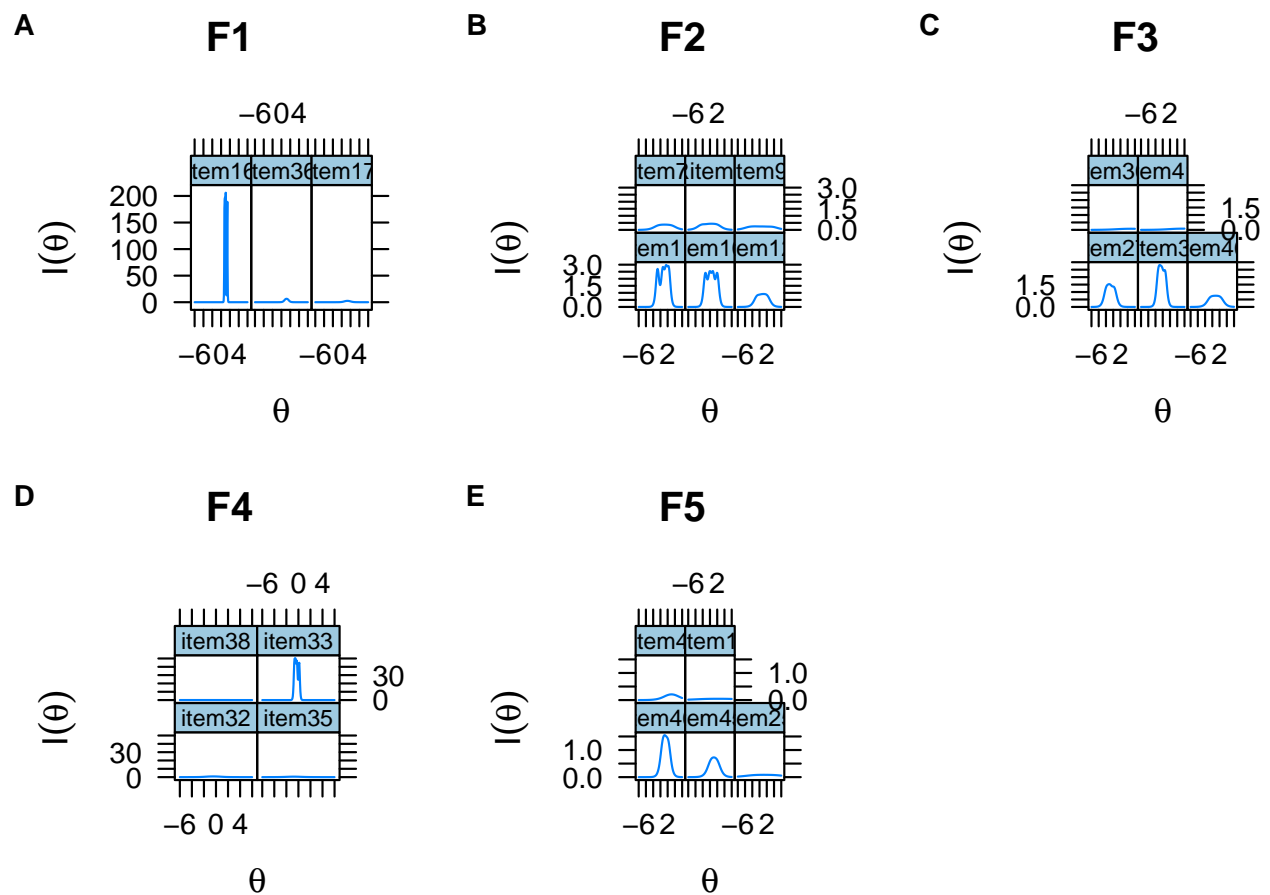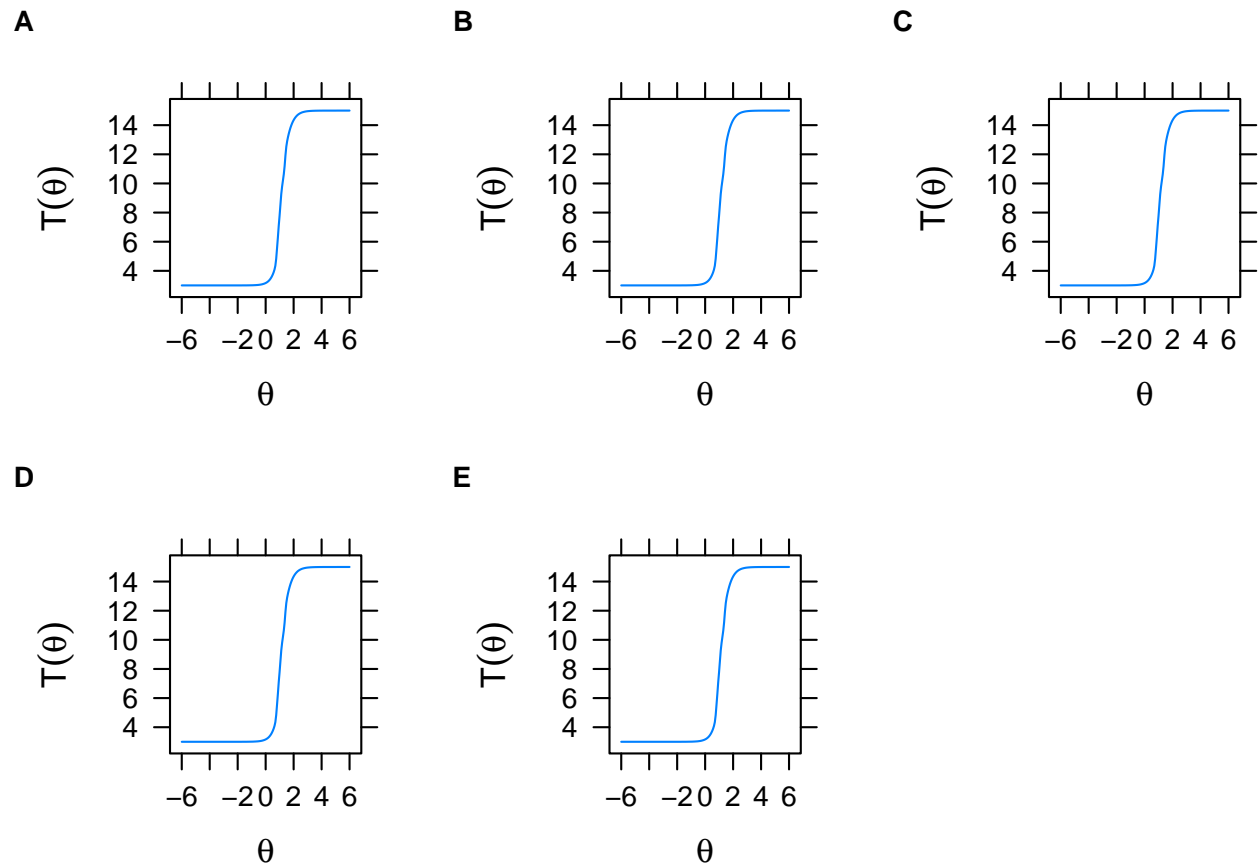*Figure 11*.  Scale characteristic curve of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

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

742

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

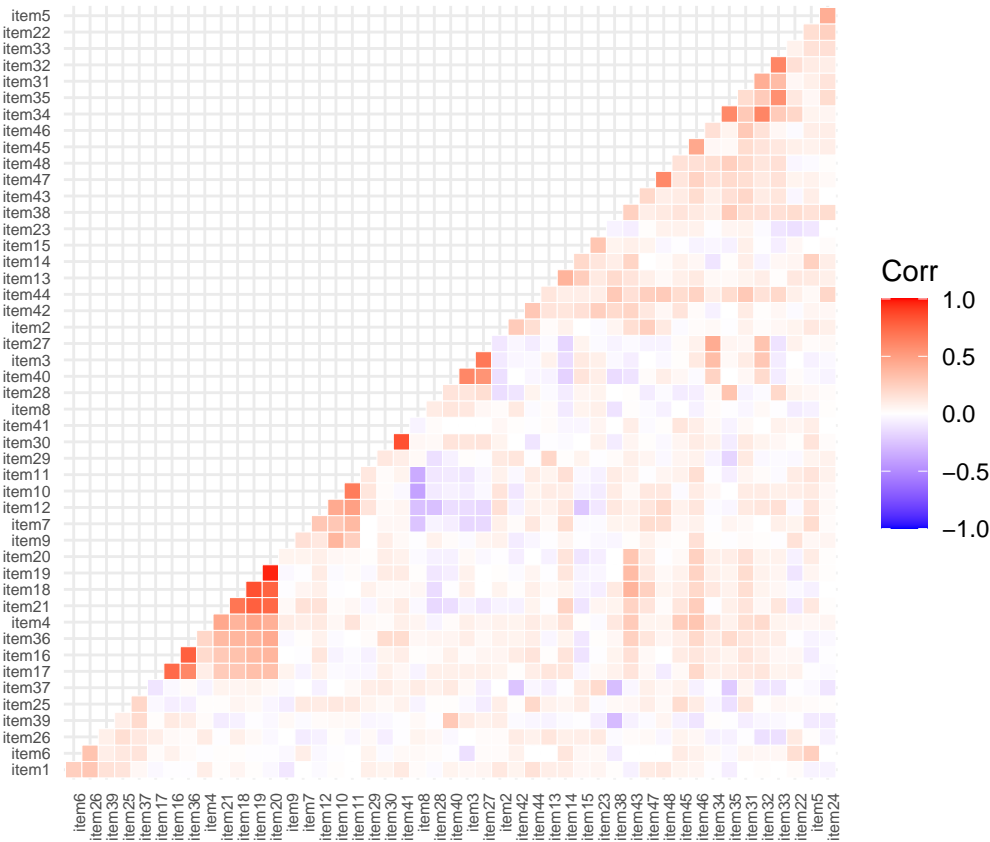|        | Mean | SD   | Skew | Kurtosis | Shapiro-Wilk Statistics | Item-Total Correlation |
|--------|------|------|------|----------|-------------------------|------------------------|
| Item46 | 1.57 | 1.40 | 0.97 | -0.07    | 0.82*                   | .38                    |
| Item47 | 2.07 | 1.23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

*Note.* *p<.001

744



*Figure B1*. Correlation plot of the items

745    Horn's parallel analysis with 500 iterations indicated a five-factor solution. However,

746    Scree plot and the MAP method suggested 6-factor solution. five-factor solution . As a
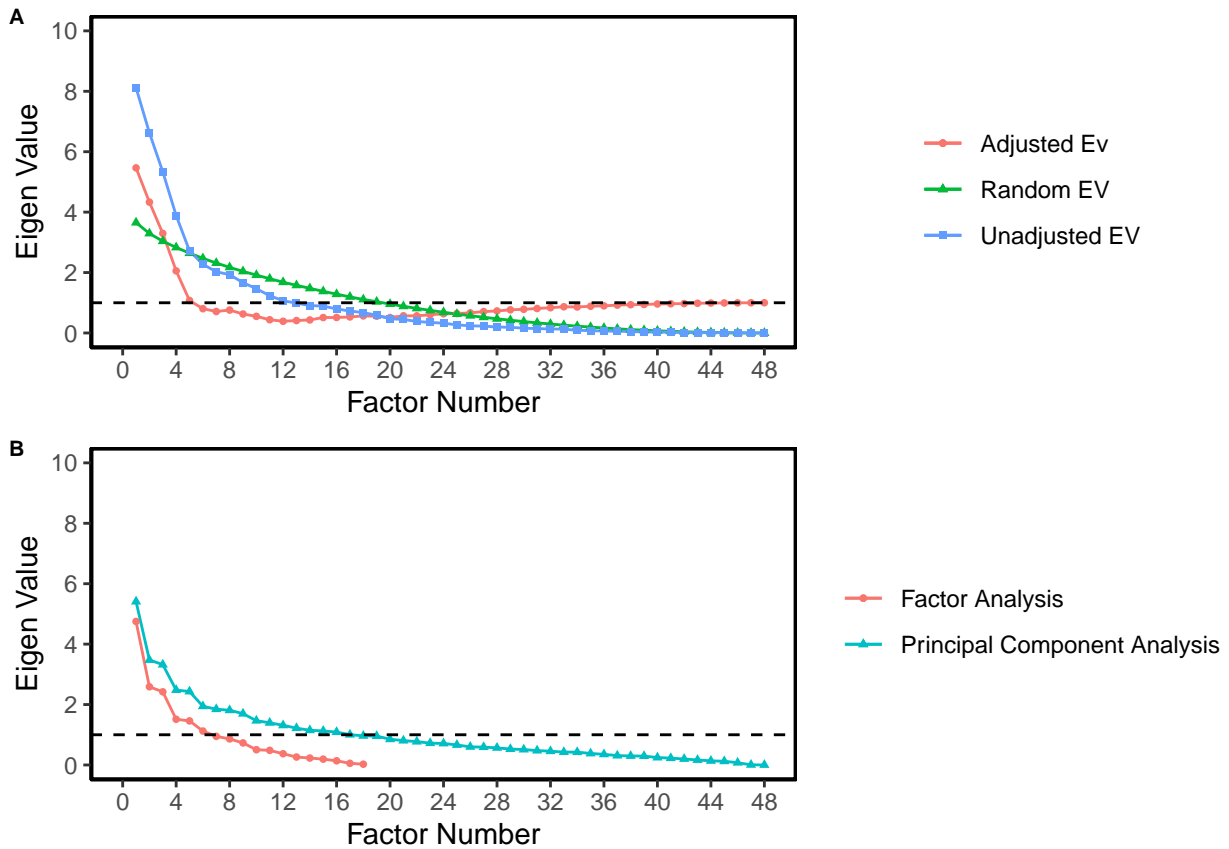
*Figure B2*. Factor Identification (A) Parallel analysis (B) Scree Plot

747 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.

Appendix C

749 **Disclaimer**: This is a non-public version of LEBA (dated November 15, 2021) and still a

750 work in progress. Please do not distribute!

751        LEBA captures light exposure-related behaviours on a 5 point Likert type scale

752 ranging from 1 to 5 (Never/Does not apply/I don't know = 1; Rarely = 2; Sometimes = 3;

753 Often = 4; Always = 5). The score of each factor is calculated by the summation of

754 scores of items belonging to the corresponding factor. The following instruction is given

755 before displaying the items: "Please indicate how often you performed the following

756 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. | | | | | |

757 **Latent Structure, Reliability and Structural Validity**

758    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) |

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

760    .09).

761    **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:**