

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

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Abstract

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

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

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

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

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

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

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

Keywords: keywords

Word count: X

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

Introduction

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

Methods

Ethical approval

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

Data Availability

Survey characteristics

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

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

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

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

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

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

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

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

Participants

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

questionnaire from 17.05.2021 to XX.XX.XXXX , whereas participants who filled out the questionnaire from YY.YY.YYYY to 03.09.2021 were included in the CFA analysis.

Participants indicated filling out the online survey from a diverse range of geographic locations. The ten most common geographic locations included:

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

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

Age among all participants ranged from 11 years to 84 years [EFA: *min* = 11, *max* = 84; CFA: *min* = 12, *max* = 74], with an overall mean of ~ 33 years of age [Overall: *M* = 32.95, *SD* = 14.57; EFA: *M* = 32.99, *SD* = 15.11; CFA: *M* = 32.89, *SD* = 13.66]. In total 325 (47%) of the participants indicated female sex [EFA: 189 (44%); CFA: 136 (52%)], 351 (51%) indicated male [EFA: 230 (54%); CFA: 121 (46%)] and 14 (2.0%) indicated other sex [EFA: 9 (2.1%), CFA: 5 (1.9%)]. Overall, 49 (7.2%) [EFA: 33 (7.8%); CFA: 16 (6.2%)] participants indicated a gender-variant identity. In a “Yes/No” question regarding native language, 320 (46%) of respondents [EFA: 191 (45%); CFA: 129 (49%)] indicated to be native English speakers. For their “Occupational Status,” more than half of the overall sample reported that they currently work [Overall: 396 (57%); EFA: 235 (55%); CFA: 161 (61%)], whereas 174 (25%) [EFA: 122 (29%); CFA: 52 (20%)] reported that

they go to school and 120 (17%) [EFA: 71 (17%); CFA: 49 (19%)] responded that they do “Neither.” With respect to the COVID-19 pandemic we asked participants to indicate their occupational setting during the last four weeks: In the overall sample 303 (44%) [EFA: 194 (45%); CFA: 109 (42%)] of the participants indicated that they were in a home office/home schooling setting, while 109 (16%) overall [EFA: 68 (16%) ; CFA: 41 (16%)] reported face-to-face work/schooling. Lastly, 147 (21%) overall [EFA: 94 (22%) ; CFA: 53 (20%)] reported a combination of home- and face-to-face work/schooling, whereas 131 (19%) overall [EFA: 72 (17%); CFA: 59 (23%)] filled in the “Neither (no work or school, or on vacation)” response option. We tested all demographic variables in Table 1 for significant group differences between the EFA and CFA sample, applying Wilcoxon rank sum test for the continuous variable “Age” and Pearson’s χ^2 test for all other categorical variables via the gtsummary R package’s “add_p” function (Sjoberg et al., 2021a) . The p-values were corrected for multiple testing applying false discovery rate (FDR) via the “add_q” function of the same package. After p-value (FDR) correction for multiple testing, none of the demographic variables were significantly different between the EFA sample and the CFA sample (all q-values $q \geq 0.2$, indicating equivalence).

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 established 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), χ^2 (1128) = 5042.86, $p < .001$ indicated the correlations between items are adequate for the EFA. However only 4.96% of the inter-item correlation coefficients were greater than .30. The inter item correlation ranged between .44 to .91.

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

With the initial 48 items we conducted three rounds of EFA and gradually discarded problematic items. (cross-loading items and poor factor loading ($<.30$) items). Finally, a five-factor EFA solution with 25 items was accepted with low RMSR = 0.08 (Brown, 2015), all factor-loading higher than .30 and no cross-loading greater than .30. We further confirmed this five-factor latent structure by another EFA using varimax rotation with a minimum residual extraction method (Table A1). Table 4 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 (Figure 5) showed 26% correlations greater than the absolute value of .05, indicating a possible under-factoring. (Desjardins & Bulut, 2018). Subsequently, we fitted a six-factor solution. However, a factor emerged with only one salient variable loading in the six-factor solution, thus disqualifying the six-factor solution (Table A2). Internal consistency reliability coefficient Cronbach's alpha assumes all the factor-loadings of the items under a factor are equal (Graham, 2006; Novick & Lewis, 1967) which is not the case in our sample. Additionally Cronbach's alpha coefficient has a tendency to deflate the estimates for Likert type data as the calculation is based on pearson-correlation matrix which requires that response data should be in continuous of nature (Gadermann, Guhn, & Zumbo, 2012; Zumbo, Gadermann, & Zeisser, 2007). Subsequently to get better estimates of reliability we reported ordinal alpha which used polychoric-correlation matrix and assumed that the responses data were ordered in nature instead of continuous (Zumbo et al., 2007). Ordinal alpha coefficient value ranges from 0 to 1 and higher value represents better reliability. In the five-factor solution, the first factor contained three items and explained 10.25% of the total variance with a internal reliability coefficient ordinal $\alpha = .94$. All the items in this factor stemmed from the individual's preference to use blue light filters in different light environments. The second factor contained six items and explained 9.93%

of the total variance with a internal reliability coefficient ordinal $\alpha = .76$. 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 χ^2 test statistics and

the standardized root mean square (SRMR). Parsimony fit indices including the root mean square error of approximation (RMSEA) considers the number of free parameters in the model to assess the parsimony of the model. Comparative fit indices evaluate the fit of the specified model solution in relation to a more restricted baseline model restricting all covariances among the indicators as zero. Comparative fit index (CFI) and the Tucker Lewis index (TLI) are such two comparative fit indices. Commonly used Model fit guidelines (Hu & Bentler, 1999; Schumacker & Lomax, 2004) includes (i) Reporting of χ^2 test statistics (A non-significant test statistics is required to reflect model fit) (ii) CFI and TLI (CFI/TLI close to .95 or above/ranging between 90-95 and above) (iii) RMSEA (close to .06 or below), (iv) SRMR (close to .08 or below) to estimate the model fit. Table 5 summarizes the fit indices of our fitted model. Our fitted model failed to attain an absolute fit estimated by the χ^2 test. However, the χ^2 test is sensitive to sample size and not recommended to be used as the sole index of absolute model fit (Brown, 2015). Another absolute fit index we obtained in our analysis was SRMR which does not work well with categorical data (C. Yu, 2002). We judged the model fit based on the comparative fit indices: CFI, TLI and parsimony fit index:RMSEA. Our fitted model attained acceptable fit (CFI = .94; TLI = .93; RMSEA = .06, [.05-.07, 90% CI]) with two imposed equity constrain on item pairs 32-33 [I dim my mobile phone screen within 1 hour before attempting to fall asleep.; I dim my computer screen within 1 hour before attempting to fall asleep.] and 16-17 [I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.; I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.]. Items pair 32-33 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 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 Bentler (1999). Internal consistency ordinal α for the five factors of LEBA were .96, .83, .70, .69, .52 respectively. We also estimated the internal consistency reliability of the total scale using McDonald's ω (total) coefficient which is a better reliability estimate for multidimensional constructs (Dunn, Baguley, & Brunsden, 2014; Sijtsma, 2009). McDonald's ω (total) coefficient for the total scale was .73.

Measurement Invariance

Measurement invariance (MI) evaluates whether a construct has the psychometric equivalence and same meaning across groups or measurement occasions (Kline, 2015; Putnick & Bornstein, 2016). We used structural equation modeling framework to assess the measurement invariance of our developed tool across two groups: **native English speakers** and **non-native English speakers**. Our measurement invariance testing involved successively comparing the nested models: configural, metric, scalar, and residual invariance models with each others (Widaman & Reise, 1997). Among these nested models configural model is the first and least restrictive model. The configural model assumes that the number of factors and item number under each factor will be equal across two groups. The metric invariance model assumes configural invariance of the fitted model and requires the factor-loadings of the items across the two groups to be equal. Having the factor-loadings equal across groups indicates each item contributes to the measured construct equivalently. Scalar invariance assumes the metric invariance of the fitted model demands the item intercepts to be equivalent across groups. This equity of item intercepts indicates the equivalence of response scale across the groups, i.e., persons with the same level of the underlying construct will score the same across the groups. The residual invariance model assumes metric invariance for the fitted model

and adds the assumption of equality in error variances and covariances across the groups. This model is the highest level of MI and assures the equivalence of precision of items across the groups in measuring the underlying constructs. The invariance model fit of our tool was assessed using the fit indices including χ^2 test, CFI and TLI (close to .95 or above), RMSEA (close to .06 or below) (Hu & Bentle, 1999). We excluded SRMR from our consideration as it does not behave optimally for categorical variables (C. Yu, 2002). Table 6 summarized the fit indices. The comparison among different measurement invariance models was made using the χ^2 difference test ($\Delta\chi^2$) to assess whether our obtained latent structure of “LEBA” attained the highest level of the MI. A non-significant $\Delta\chi^2$ test between two MI models fit indicates model fit does not significantly decrease for the superior model (Dimitrov, 2010) thus allowing the superior level of invariance model to be accepted. We started our analysis by comparing the model fit of the least restrictive model: configural model to metric MI model and continued successive comparisons. Table 6 indicates that our fitted model had acceptable fit indices for all of the fitted MI models. The model fit did not significantly decrease across the nested models up to the scalar MI model. The chi-square value difference between the scalar and residual model is zero, indicating model fit remained the same for both: scalar and residual MI model, indicating the acceptability of the residual MI model.

Semantic Analysis

To find out if our developed tool is overlapping with existing instruments, we subjected the items of LEBA to the “Semantic Scale Network”(SSN) analysis(Rosenbusch et al., 2020). The SSN detects semantically related scales and provides cosine similarity index ranging between -.66 to 1 (Rosenbusch et al., 2020). Pair of scales with a cosine similarity index value of 1 indicates they are perfectly semantically similar scales indicating redundancy. LEBA appeared most strongly related to scales about sleep: “Sleep Disturbance Scale For Children” (Bruni et al., 1996) and

“WHO-Composite International Diagnostic Interview (CIDI): Insomnia”(WHO, 1990).The cosine similarities lie between .47 to .51. Two factors of our LEBA tool: “Using phone and smart-watch in bed” and “Using light before bedtime” dealt with light exposure related behavior pertaining to sleep quality. As such the similarity index obtained is expected.

Developing Short form of LEBA

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

Test information curve (TIC) (Figure 9) indicate the amount of information an the full-scale carry along the latent trait continuum. As we treated each factor of short-LEBA

as an unidimensional construct we obtain 5 TICs (Figure 9). These information curves indicated except blue filter factor, the other factor's TICs are roughly centered on the center of the trait continuum (θ). Also the amount of information changed rather steadily with the change of (θ). Thus we conferred the LEBA 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- χ^2 index implementation. All of the items had RMSEA value $\leq .06$ 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

416 exposure related behavior. All-in-all we can recommend the short form of LEBA to be
417 used to capture light exposure related behavior.

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Discussion

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Table 1

Releated Scales

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

Table 1

Releated Scales (continued)

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

Table 1

Releated Scales (continued)

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

Table 2

Demographics

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

¹ Mean (SD); n (%)² Wilcoxon rank sum test; Pearson's Chi-squared test³ 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-Square | 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

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

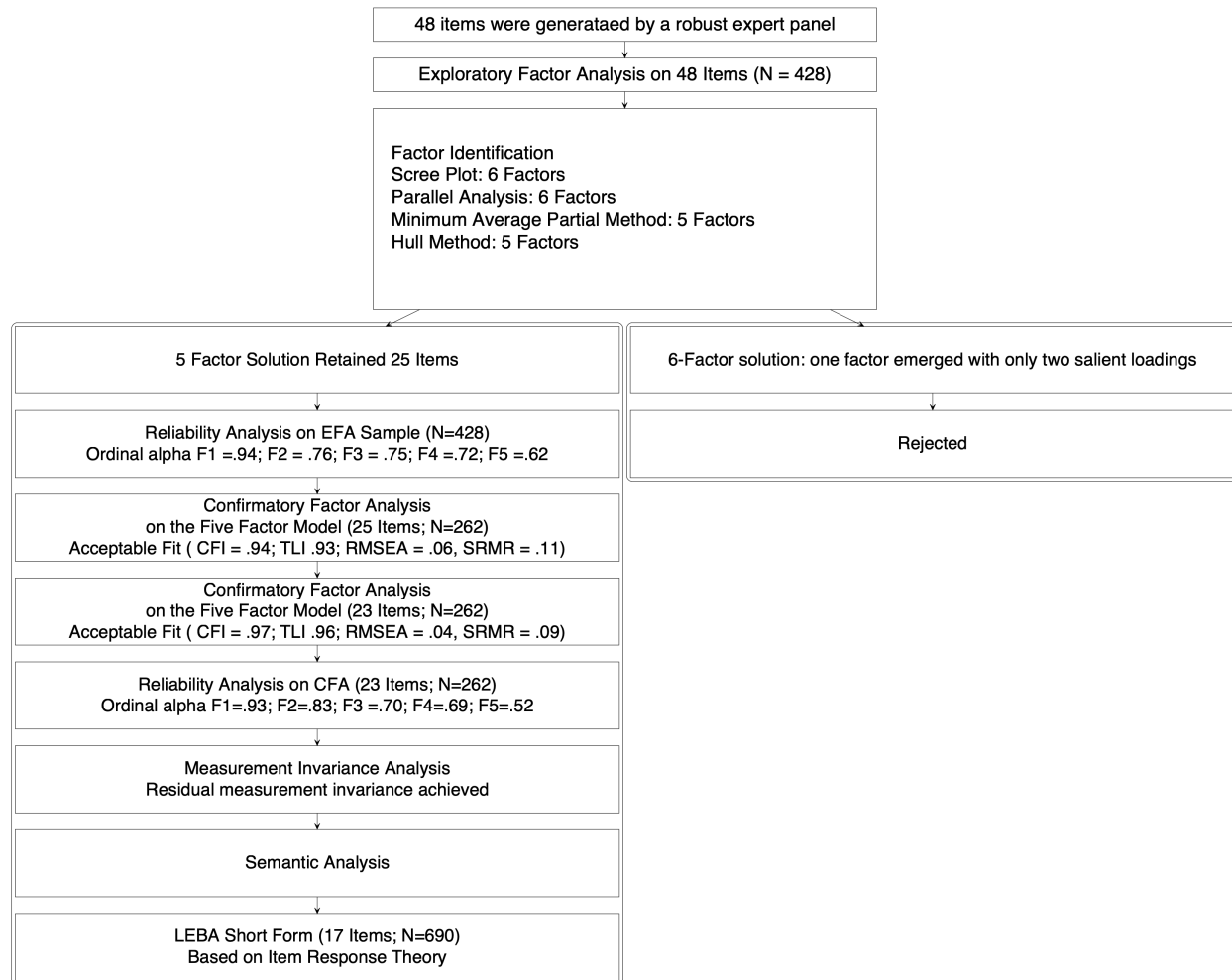


Figure 1. Development of long and short form of LEBA

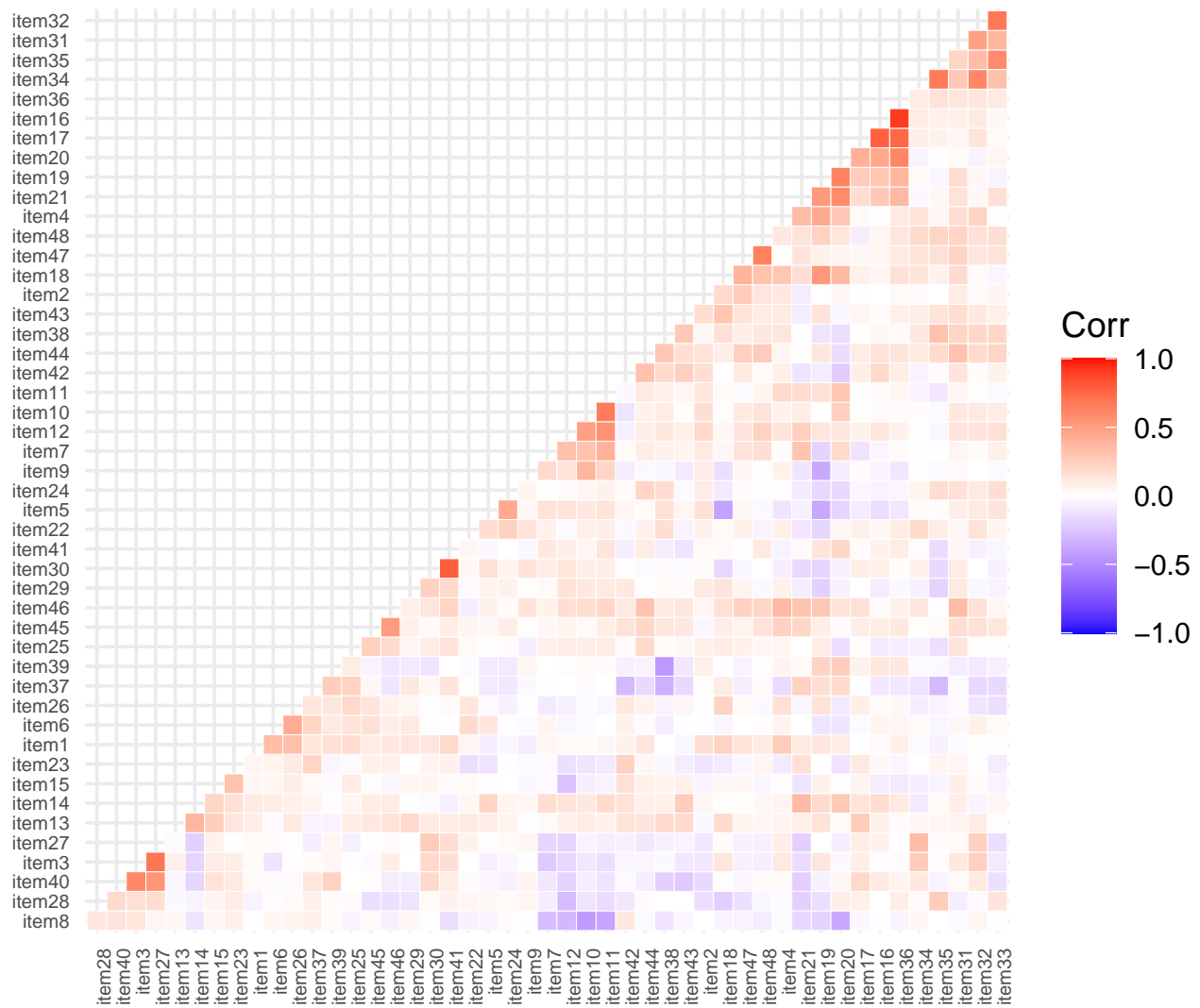


Figure 2. Correlation plot of the items

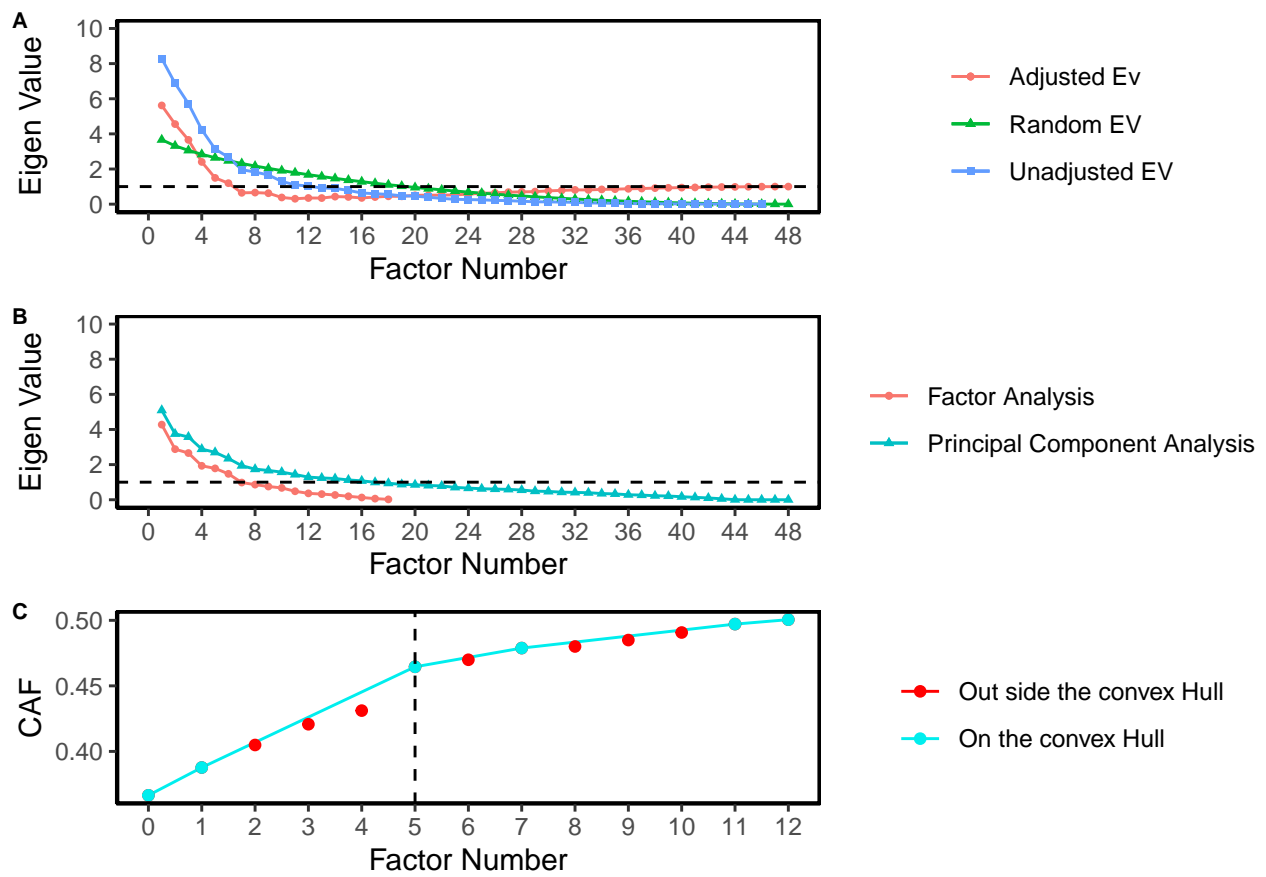


Figure 3. Factor Identification (A) Parallel analysis (B) Scree Plot (C) Hull Method

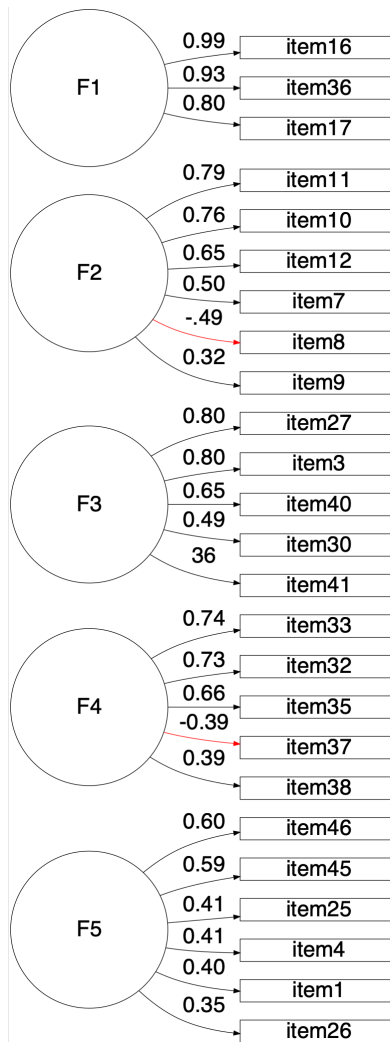


Figure 4. Five Factor Solution

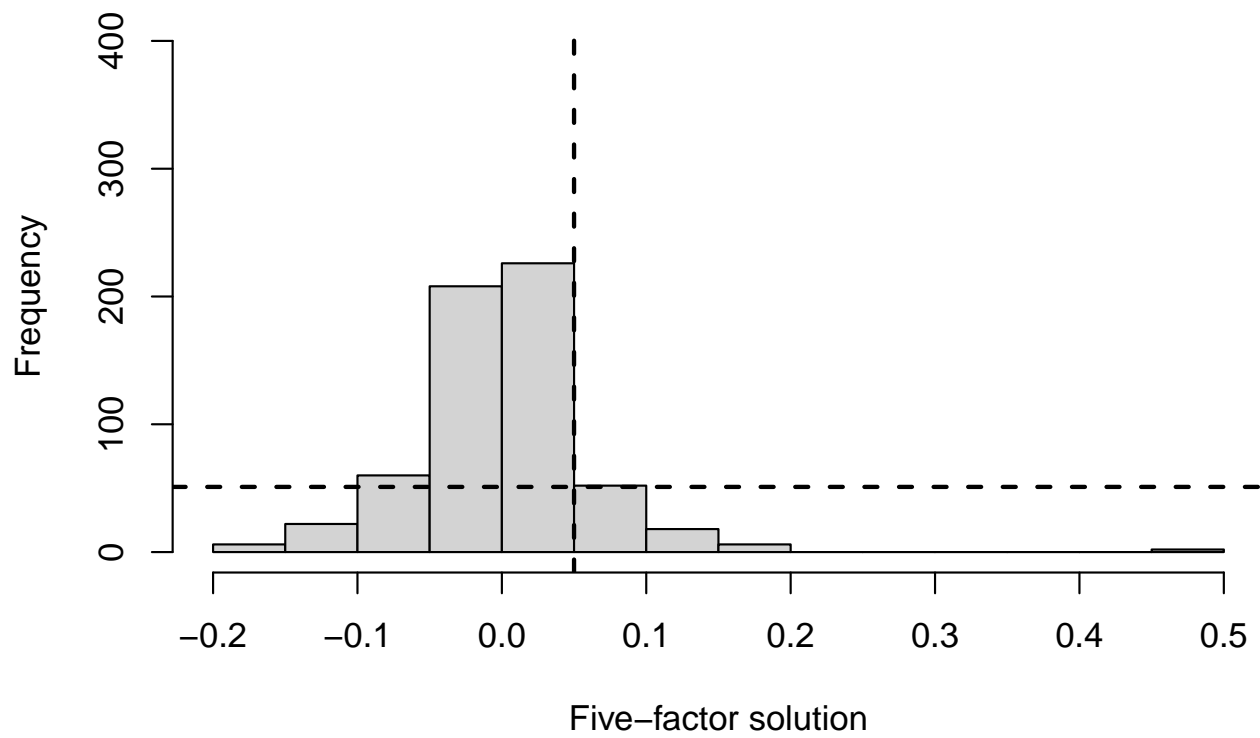


Figure 5. Histogram of residuals: five-factor solution

| LEBA | | | | | | | | | | | |
|---|--------------------|------|--------|-----|------------------------|----------------------|------------------|--------------|--------------|--------------|--------------|
| Summary Descriptives of CFA and EFA Sample (N =690) | | | | | | | | | | | |
| Items | Summary Statistics | | | | Graphics | | Response Pattern | | | | |
| LEBA Items | n | Mean | Median | SD | Histogram ¹ | Density ² | Never | Rarely | Sometimes | Often | Always |
| EFA (n = 428) | | | | | | | | | | | |
| ● item01 | 428 | 2.3 | 2.0 | 1.4 | | | 42.29% (181) | 22.20% (95) | 12.62% (54) | 12.38% (53) | 10.51% (45) |
| ● item03 | 428 | 3.4 | 4.0 | 1.4 | | | 15.89% (68) | 11.45% (49) | 17.29% (74) | 31.07% (133) | 24.30% (104) |
| ● item04 | 428 | 1.5 | 1.0 | 1.2 | | | 84.11% (360) | 3.50% (15) | 2.10% (9) | 2.10% (9) | 8.18% (35) |
| ● item07 | 428 | 2.3 | 2.0 | 1.2 | | | 35.98% (154) | 27.80% (119) | 17.29% (74) | 12.38% (53) | 6.54% (28) |
| ● item08 | 428 | 3.0 | 3.0 | 1.2 | | | 13.79% (59) | 22.20% (95) | 27.80% (119) | 25.93% (111) | 10.28% (44) |
| ● item09 | 428 | 2.9 | 3.0 | 1.0 | | | 10.28% (44) | 19.63% (84) | 41.82% (179) | 22.43% (96) | 5.84% (25) |
| ● item10 | 428 | 2.7 | 3.0 | 1.0 | | | 11.92% (51) | 31.31% (134) | 31.31% (134) | 21.96% (94) | 3.50% (15) |
| ● item11 | 428 | 2.2 | 2.0 | 0.9 | | | 22.43% (96) | 46.26% (198) | 23.13% (99) | 7.01% (30) | 1.17% (5) |
| ● item12 | 428 | 2.4 | 2.0 | 1.2 | | | 29.91% (128) | 29.67% (127) | 21.50% (92) | 12.15% (52) | 6.78% (29) |
| ● item16 | 428 | 1.6 | 1.0 | 1.2 | | | 79.67% (341) | 4.21% (18) | 3.97% (17) | 4.67% (20) | 7.48% (32) |
| ● item17 | 428 | 1.5 | 1.0 | 1.2 | | | 80.61% (345) | 3.27% (14) | 5.14% (22) | 3.27% (14) | 7.71% (33) |
| ● item25 | 428 | 2.6 | 3.0 | 1.4 | | | 34.35% (147) | 13.79% (59) | 22.20% (95) | 17.99% (77) | 11.68% (50) |
| ● item26 | 428 | 3.7 | 4.0 | 1.3 | | | 38.32% (164) | 23.36% (100) | 20.09% (86) | 10.98% (47) | 7.24% (31) |
| ● item27 | 428 | 3.8 | 4.0 | 1.3 | | | 8.41% (36) | 11.21% (48) | 11.21% (48) | 30.37% (130) | 38.79% (166) |
| ● item30 | 428 | 1.5 | 1.0 | 1.1 | | | 81.78% (350) | 3.27% (14) | 4.91% (21) | 5.37% (23) | 4.67% (20) |
| ● item32 | 428 | 3.6 | 4.0 | 1.6 | | | 23.13% (99) | 7.01% (30) | 8.18% (35) | 14.95% (64) | 46.73% (200) |
| ● item33 | 428 | 3.6 | 4.0 | 1.6 | | | 21.96% (94) | 7.01% (30) | 7.24% (31) | 14.49% (62) | 49.30% (211) |
| ● item35 | 428 | 3.9 | 5.0 | 1.7 | | | 22.90% (98) | 1.87% (8) | 3.74% (16) | 9.35% (40) | 62.15% (266) |
| ● item36 | 428 | 1.5 | 1.0 | 1.3 | | | 82.24% (352) | 3.04% (13) | 3.04% (13) | 2.34% (10) | 9.35% (40) |
| ● item37 | 428 | 2.3 | 2.0 | 1.3 | | | 38.32% (164) | 23.36% (100) | 20.09% (86) | 10.98% (47) | 7.24% (31) |
| ● item38 | 428 | 4.3 | 5.0 | 1.1 | | | 5.37% (23) | 3.50% (15) | 5.37% (23) | 27.57% (118) | 58.18% (249) |
| ● item40 | 428 | 2.2 | 2.0 | 1.2 | | | 39.49% (169) | 25.00% (107) | 19.63% (84) | 11.45% (49) | 4.44% (19) |
| ● item41 | 428 | 1.3 | 1.0 | 0.8 | | | 85.05% (364) | 4.67% (20) | 6.07% (26) | 3.04% (13) | 1.17% (5) |
| ● item45 | 428 | 2.2 | 1.0 | 1.5 | | | 53.04% (227) | 7.01% (30) | 16.36% (70) | 11.92% (51) | 11.68% (50) |
| ● item46 | 428 | 1.8 | 1.0 | 1.2 | | | 67.06% (287) | 7.71% (33) | 11.68% (50) | 8.88% (38) | 4.67% (20) |
| CFA (n =262) | | | | | | | | | | | |
| ● item01 | 262 | 2.3 | 2.0 | 1.4 | | | 40.46% (106) | 22.52% (59) | 14.50% (38) | 10.69% (28) | 11.83% (31) |
| ● item03 | 262 | 3.7 | 4.0 | 1.3 | | | 11.83% (31) | 7.25% (19) | 17.56% (46) | 28.24% (74) | 35.11% (92) |
| ● item04 | 262 | 1.3 | 1.0 | 0.8 | | | 89.31% (234) | 2.29% (6) | 3.44% (9) | 3.05% (8) | 1.91% (5) |
| ● item07 | 262 | 2.1 | 2.0 | 1.2 | | | 43.13% (113) | 23.66% (62) | 14.50% (38) | 14.12% (37) | 4.58% (12) |
| ● item08 | 262 | 3.0 | 3.0 | 1.2 | | | 14.12% (37) | 22.90% (60) | 20.99% (55) | 32.06% (84) | 9.92% (26) |
| ● item09 | 262 | 2.9 | 3.0 | 1.1 | | | 12.98% (34) | 22.14% (58) | 34.35% (90) | 26.34% (69) | 4.20% (11) |
| ● item10 | 262 | 2.6 | 3.0 | 1.1 | | | 17.56% (46) | 29.39% (77) | 29.01% (76) | 21.37% (56) | 2.67% (7) |
| ● item11 | 262 | 2.1 | 2.0 | 0.9 | | | 25.95% (68) | 46.56% (122) | 20.23% (53) | 5.34% (14) | 1.91% (5) |
| ● item12 | 262 | 2.3 | 2.0 | 1.2 | | | 32.06% (84) | 30.92% (81) | 19.08% (50) | 11.45% (30) | 6.49% (17) |
| ● item16 | 262 | 1.6 | 1.0 | 1.3 | | | 78.24% (205) | 3.44% (9) | 4.20% (11) | 5.73% (15) | 8.40% (22) |
| ● item17 | 262 | 1.6 | 1.0 | 1.2 | | | 80.15% (210) | 3.44% (9) | 5.34% (14) | 2.67% (7) | 8.40% (22) |
| ● item25 | 262 | 2.5 | 2.0 | 1.4 | | | 32.82% (86) | 18.32% (48) | 21.76% (57) | 16.79% (44) | 10.31% (27) |
| ● item27 | 262 | 4.0 | 4.0 | 1.2 | | | 6.11% (16) | 7.25% (19) | 8.02% (21) | 33.59% (88) | 45.04% (118) |
| ● item30 | 262 | 1.4 | 1.0 | 1.1 | | | 83.59% (219) | 2.67% (7) | 4.20% (11) | 6.11% (16) | 3.44% (9) |
| ● item32 | 262 | 3.4 | 4.0 | 1.7 | | | 25.95% (68) | 4.20% (11) | 11.45% (30) | 16.79% (44) | 41.60% (109) |
| ● item33 | 262 | 3.1 | 3.0 | 1.7 | | | 32.44% (85) | 6.11% (16) | 11.83% (31) | 14.12% (37) | 35.50% (93) |
| ● item35 | 262 | 3.6 | 5.0 | 1.8 | | | 27.48% (72) | 2.67% (7) | 7.25% (19) | 6.49% (17) | 56.11% (147) |
| ● item36 | 262 | 1.6 | 1.0 | 1.3 | | | 80.53% (211) | 3.44% (9) | 3.05% (8) | 3.44% (9) | 9.54% (25) |
| ● item38 | 262 | 4.3 | 5.0 | 1.1 | | | 4.20% (11) | 7.63% (20) | 6.49% (17) | 21.37% (56) | 60.31% (158) |
| ● item40 | 262 | 2.5 | 2.0 | 1.3 | | | 30.92% (81) | 27.10% (71) | 18.70% (49) | 12.21% (32) | 11.07% (29) |
| ● item41 | 262 | 1.2 | 1.0 | 0.7 | | | 90.08% (236) | 3.82% (10) | 2.29% (6) | 2.67% (7) | 1.15% (3) |
| ● item45 | 262 | 2.0 | 1.0 | 1.4 | | | 64.12% (168) | 5.34% (14) | 9.54% (25) | 11.83% (31) | 9.16% (24) |
| ● item46 | 262 | 1.6 | 1.0 | 1.2 | | | 75.57% (198) | 2.67% (7) | 8.02% (21) | 9.54% (25) | 4.20% (11) |
| ¹ Histogram | | | | | | | | | | | |
| ² Density | | | | | | | | | | | |

Figure 6. Summary Descriptives of CFA and EFA Sample

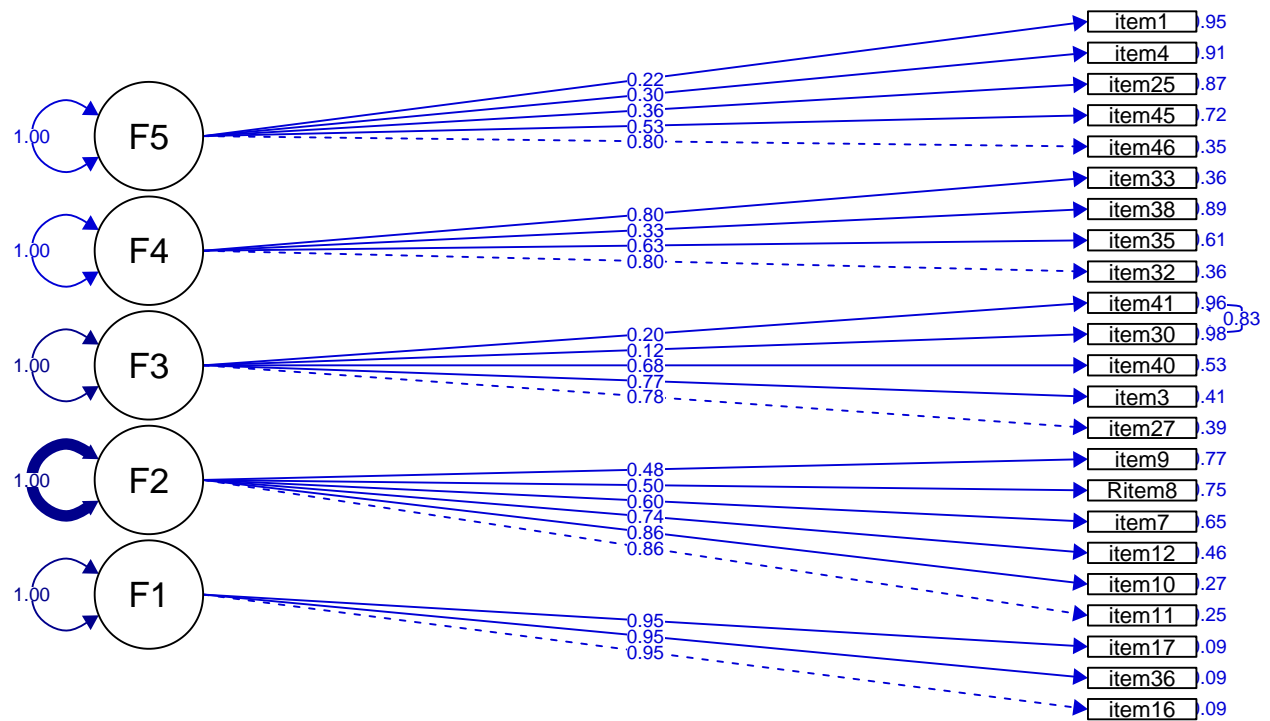


Figure 7. Five Factor CFA Model of LEBA

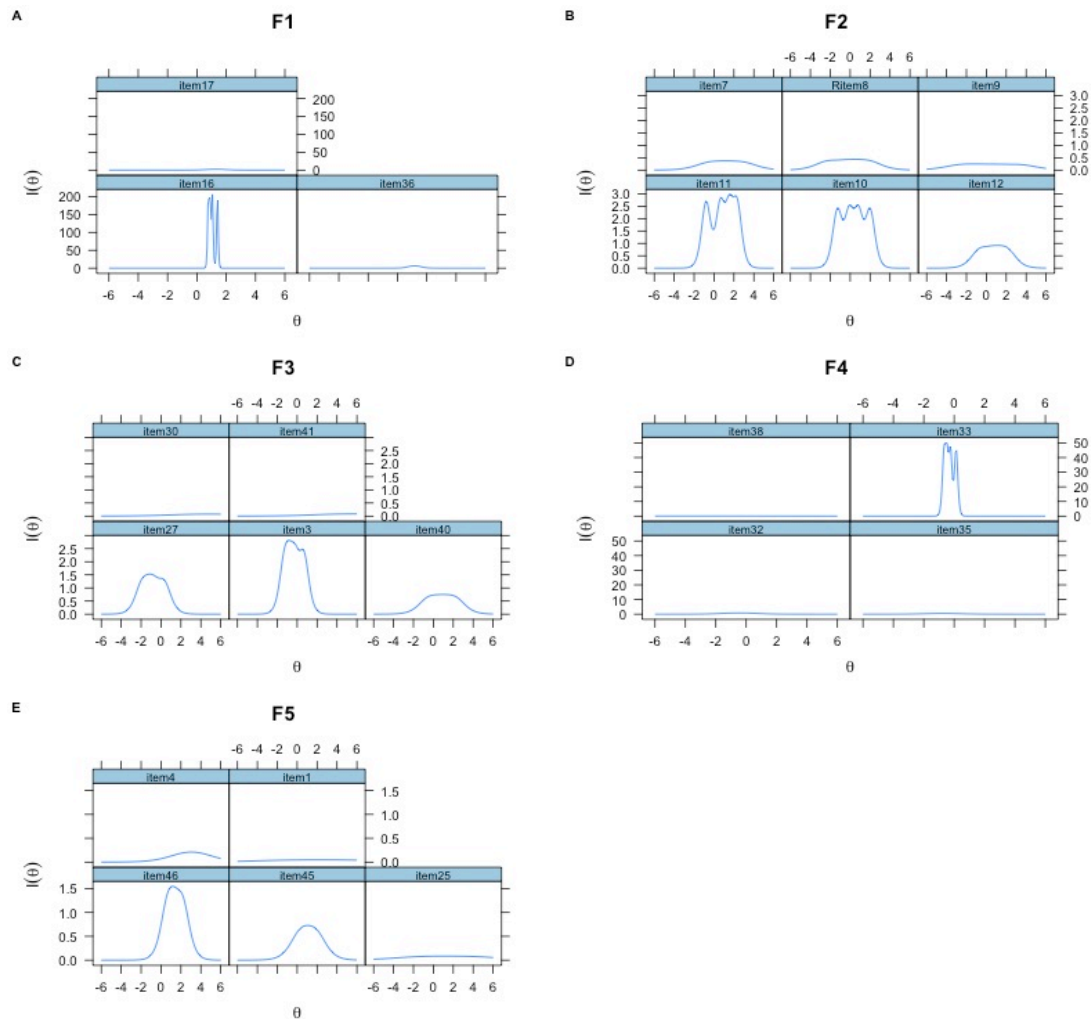


Figure 8. Item information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatch in bed (d) Using light before bedtime (e) Using light in the morning and during daytime

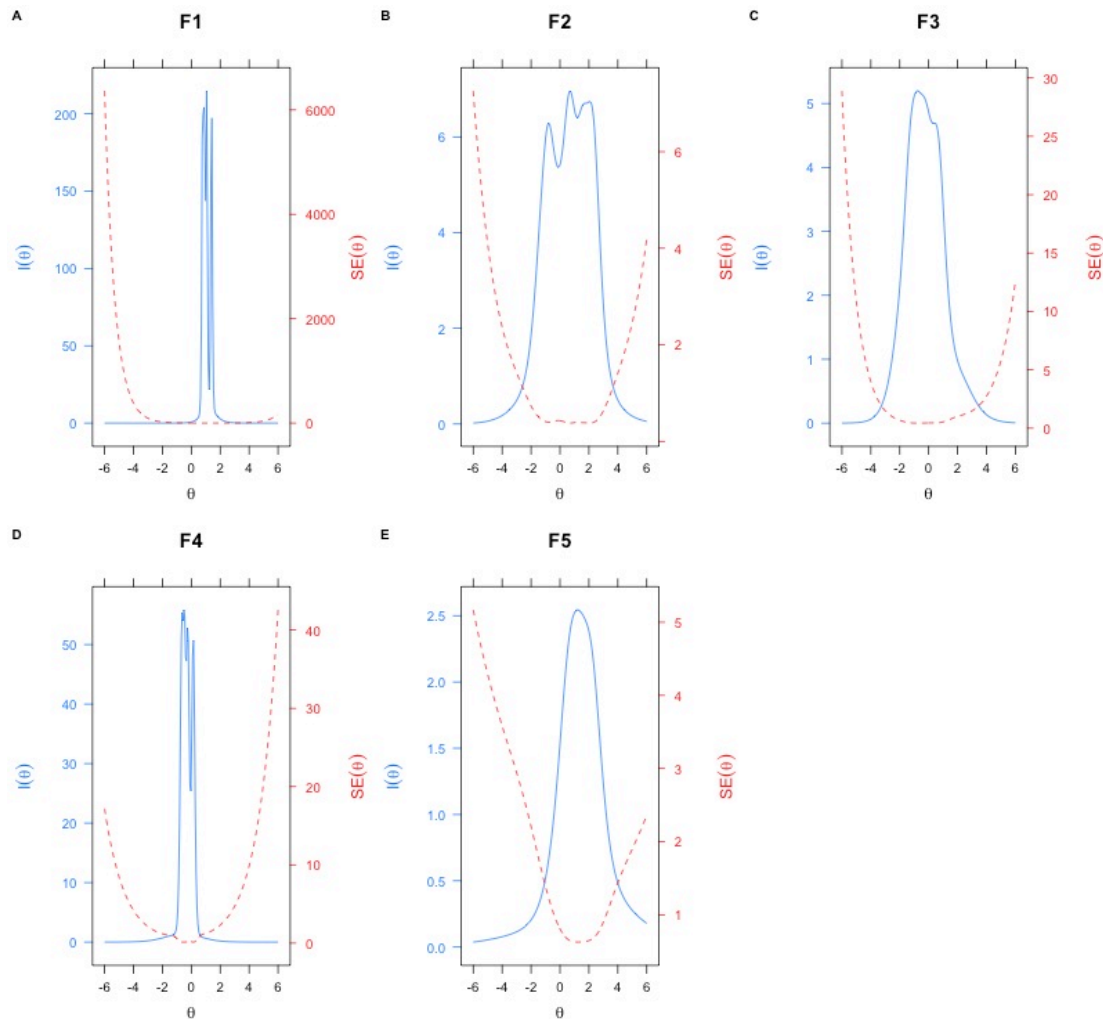


Figure 9. Test information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatch in bed (d) Using light before bedtime (e) Using light in the morning and during daytime

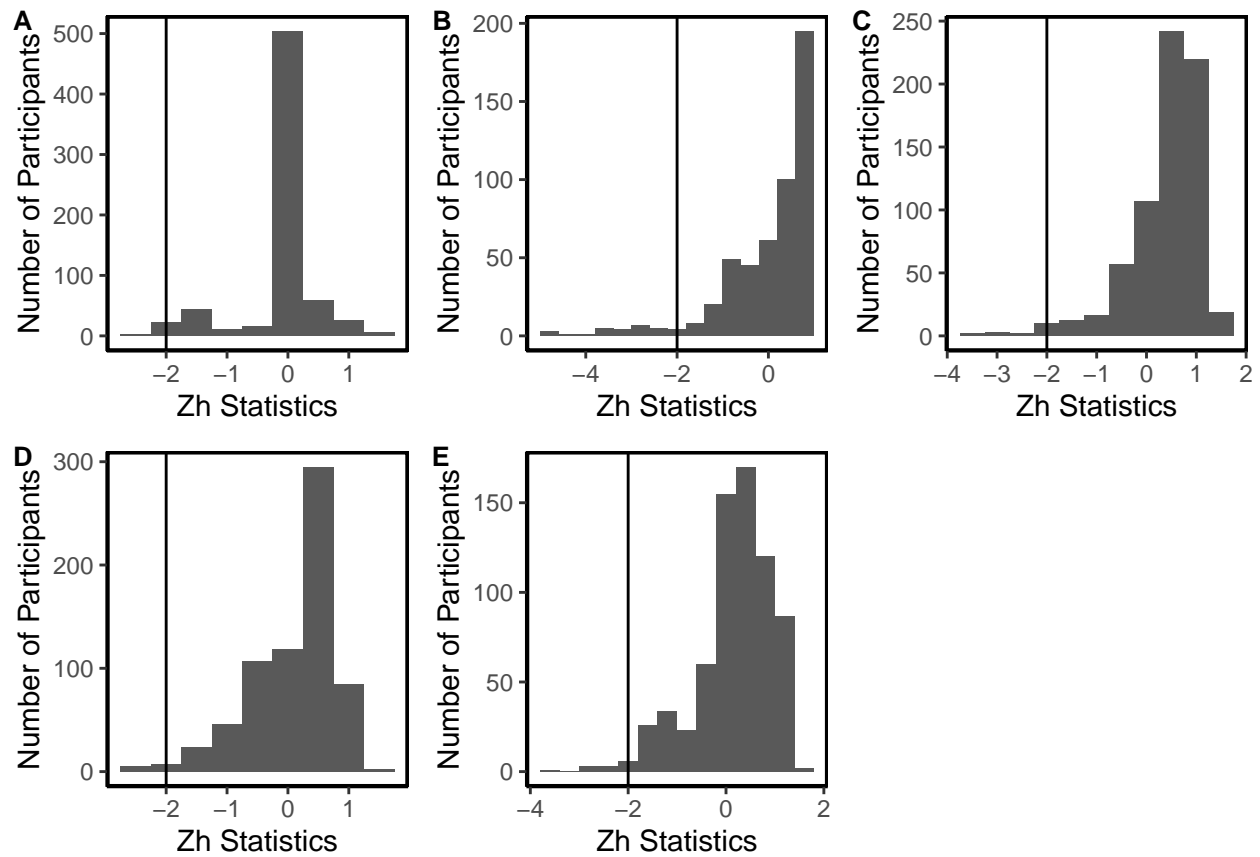


Figure 10. Person fit of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatch in bed (d) Using light before bedtime (e) Using light in the morning and during daytime

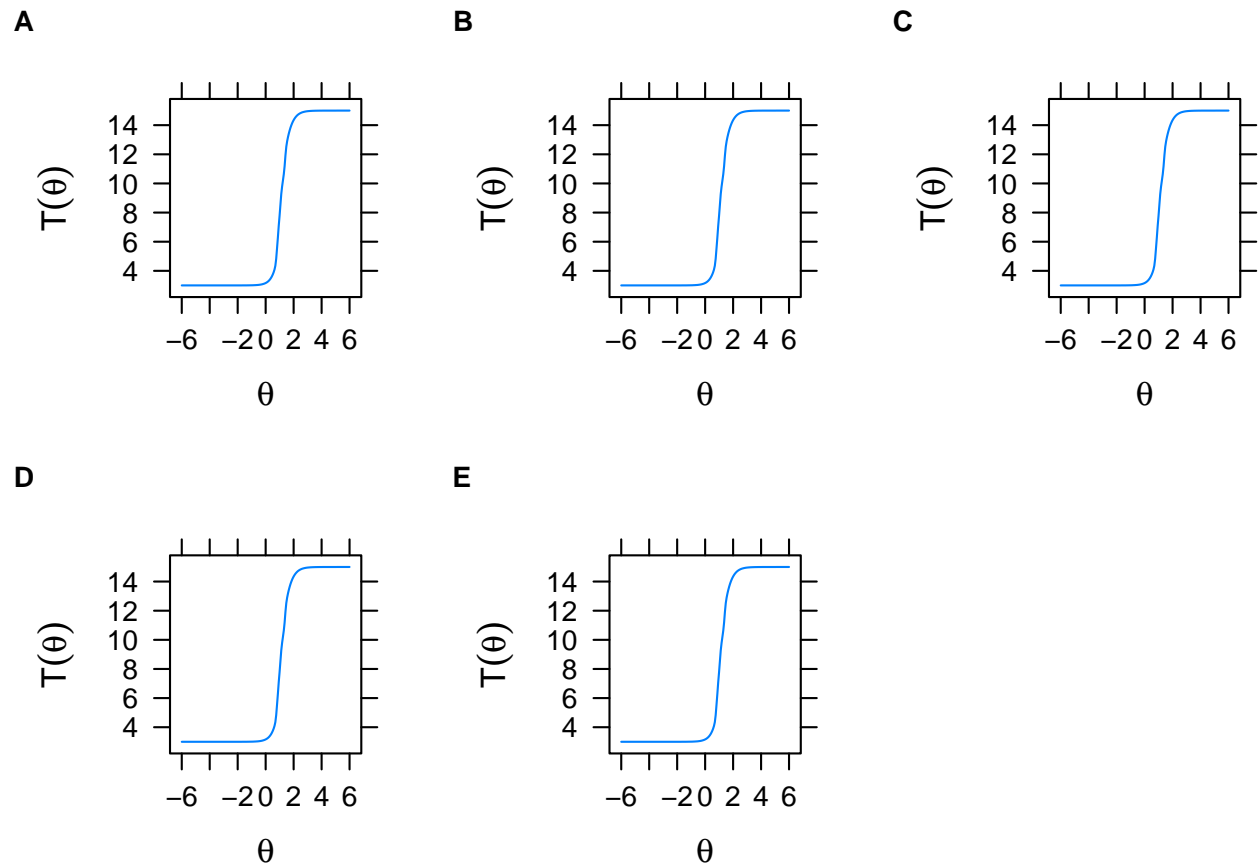


Figure 11. Scale characteristic curve of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatch in bed (d) Using light before bedtime (e) Using light in the morning and during daytime

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

743

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

745

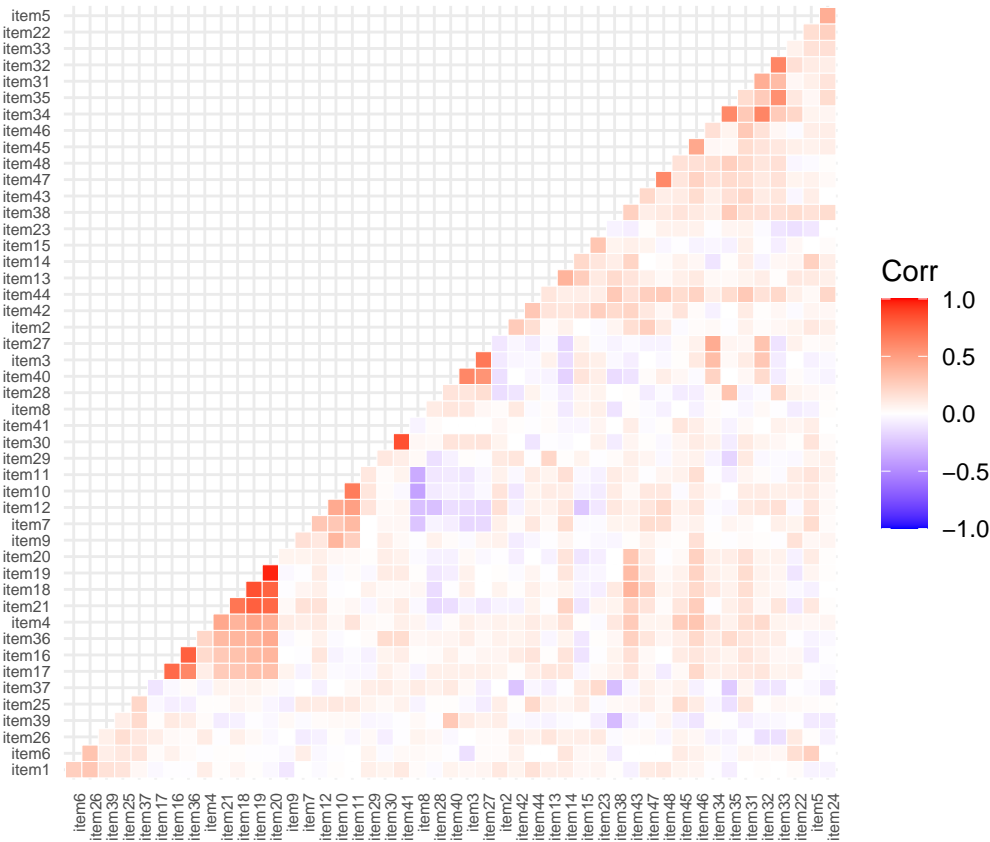


Figure B1. Correlation plot of the items

746

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

747

Scree plot and the MAP method suggested 6-factor solution. five-factor solution . As a

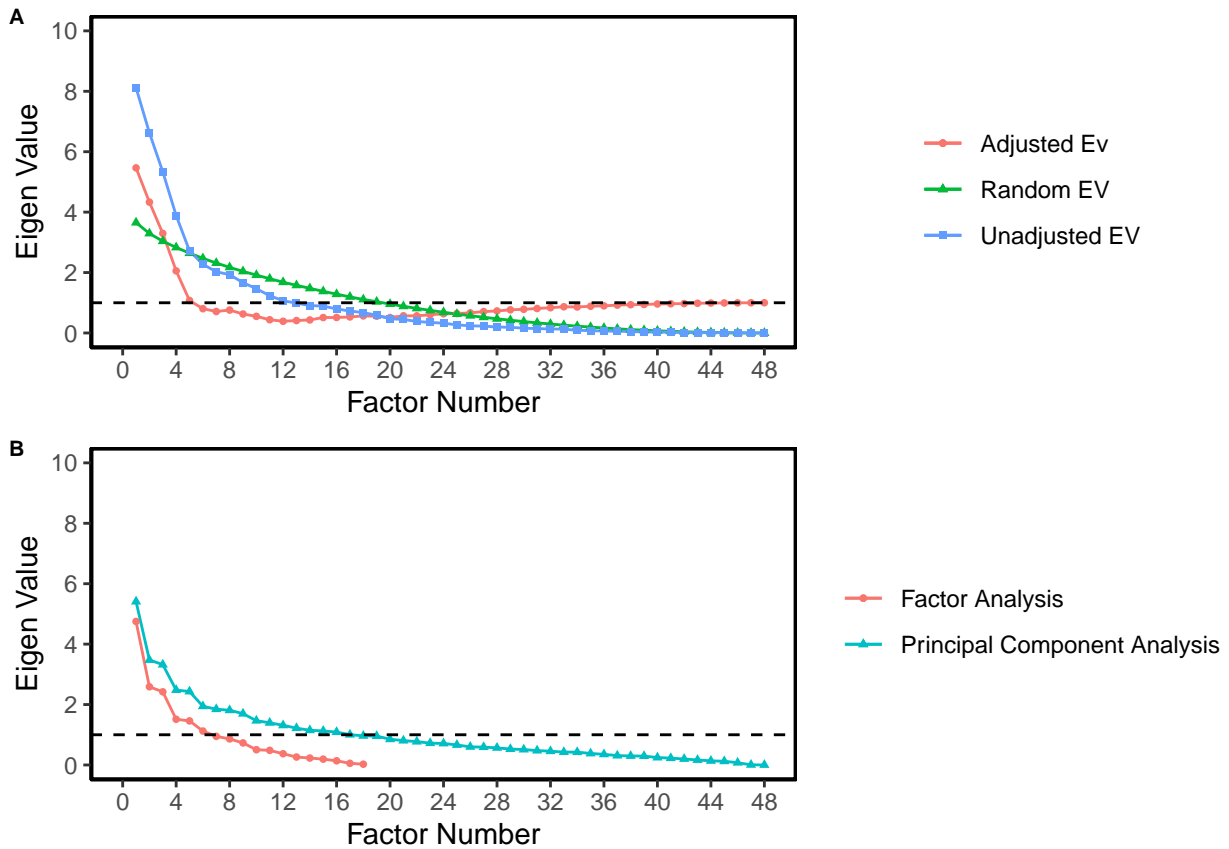


Figure B2. Factor Identification (A) Parallel analysis (B) Scree Plot

748 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

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

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

Appendix D
LEBA Long Form (23 Items)

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

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

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

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

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

759 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) |

760 LEBA -long form showed satisfactory structural validity (CFI =.97; TLI = .96; RMSEA = .05[.04-.06, 90% CI]; SRMR =
761 .09).

762 **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. | | | | | |

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

764 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 |

765 **How to cite:**