

¹ *Light Exposure Behaviour Assessment (LEBA): Development of a novel instrument to capture light exposure-related behaviours*

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51

Abstract

52 Light exposure is an important driver of health and well-being. Many aspects of light
53 exposure are modulated by our behaviour. How these light-related behaviours can be
54 shaped to optimise personal light exposure is currently unknown. Here, we present a
55 novel, self-reported and psychometrically validated instrument to capture light
56 exposure-related behaviour, the Light Exposure Behaviour Assessment (LEBA).

57 An expert panel prepared the initial 48 item pool spanning different light exposure
58 related behaviours. Responses, consisting rating the frequency of engaging in the
59 per-item behaviour on a 5-point Likert type scale were collected in an online survey
60 yielding responses from a geographically unconstrained sample (690 completed
61 responses, 74 countries, 28 time zones). Exploratory factor analysis (EFA) on an initial
62 subset of our sample ($n=428$) rendered a five-factor solution with 25 items (Wearing blue
63 light filters, spending time outdoors, using phone and smart-watch in bed, using light
64 before bedtime, using light in the morning and during daytime). In a confirmatory factor
65 analysis (CFA) performed on an independent subset of participants ($n=262$), we
66 removed two further items to attain the best fit for the five-factor solution ($CFI=0.95$,
67 $TLI=0.95$, $RMSEA=0.06$). The internal consistency reliability coefficient for the total
68 instrument was, McDonald's Omega(total)=0.68. Measurement model invariance
69 analysis between native and non-native English speakers showed our model attained
70 the highest level of invariance (residual invariance; $CFI=0.95$, $TLI=0.95$, $RMSEA=0.05$).
71 Lastly, a short form of LEBA ($n=18$) was developed using Item Response Theory on the
72 complete sample ($n=690$).

73 The psychometric properties of the LEBA instrument indicate the usability to
74 measure the light exposure-related behaviours across a variety of settings and may offer
75 a scalable solution to characterise light exposure-related behaviours in remote samples.
76 The LEBA instrument will be available under the open-access CC-BY-NC-ND license.

⁷⁷ *Keywords:* light exposure, light-related behaviours, non-visual effects of light,

⁷⁸ psychometrics

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81 *capture light exposure-related behaviours*

Introduction

- Light exposure is important
 - Light exposure Behaviour is important
 - Supplementary Table S1: Overview Existing Related Scales
 - Existing Scales: Review them in text
 - None of these do light exposure behaviour.

Methods

89 Data Collection

A quantitative cross-sectional fully anonymous geographically unconstrained online large-scale survey was conducted via REDCap (Harris et al., 2019, 2009) by way of the University of Basel sciCORE. Participants were recruited via the website (<https://enlightenyourclock.org/participate-in-research>) of the science-communication comic-book “Enlighten your clock” co-released with the survey (Weinzaepflein & 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 (F.lux Software LLC, 2021). The landing page of the online survey had the explanatory statements where we mentioned participation was voluntary and that respondents could withdraw from participation any time without being penalized. At the beginning of the survey, for the adult participants (>18 years) consent was recorded digitally. Under-aged participants (<18 years) were urged to obtain assent from their parents/legal guardians. The entire survey was estimated to take less than 30 minutes.

103 Participants were not compensated. As a part of the demographic information
104 participants provided information regarding age, sex, gender identity, occupational
105 status, COVID-19 related occupational setting, time zone/country of residence and
106 native language. The demographic characteristics of our sample are given in Table 1. To
107 ensure high data quality, five attention check items were included in the survey (e.g.,
108 “We want to make sure you are paying attention. What is 4+5?”). Participants were
109 asked to confirm that they were participating the survey for the first time. Questions
110 incorporating retrospective recall were all aligned to the period of “past four weeks”.

111 We conducted two rounds of data collection. At first, we collected data from 428
112 participants (EFA sample). In the second round we collected data from another 262
113 participants (CFA sample) making a total sample of 690. The data analysed in this study
114 was collected between 17 May 2021 and 3 September 2021.

115 Analytic Strategy

116 Figure 1 summarizes the steps we followed while developing LEBA. In our analysis
117 we used R statistical tool (R Core Team, 2021). First, we developed an item pool of 48
118 items with six-point Likert type response format (0-Does not apply/I don't know, 1-Never,
119 2-Rarely 3-Sometimes, 4-Often, 5-Always) for our initial scale. Our purpose was to
120 capture light exposure related behaviour. In that context, the first two response options:
121 “Does not apply/I don't know” and “Never” were providing similar information. As such
122 we collapsed them into one, making it a 5 point Likert type response format (1-Never,
123 2-Rarely 3-Sometimes, 4-Often, 5-Always).

124 Second, for data collection we conducted two rounds of large-scale survey. Third,
125 as a part of psychometric analysis, we conducted descriptive and item analysis and
126 proceeded to the exploratory factor analysis (EFA) using “psych” package (Revelle,
127 2021) on the data collected in the first round (EFA sample; n=428). Prior to the EFA,
128 necessary assumptions, 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, in EFA we used polychoric correlation matrix and employed principal axis (PA) as the factor extraction method (Desjardins & Bulut, 2018; Watkins, 2020). We used a combination of factor identification method including Scree plot (Cattell, 1966), minimum average partials method (Velicer, 1976), and Hull method (Lorenzo-Seva, Timmerman, & Kiers, 2011) to identify factor numbers. To determine the latent structure, we followed the common guidelines : (i) no factors with fewer than three items (ii) no factors with a factor loading <0.3 (iii) no items with cross-loading $> .3$ across factors (Bandalos & Finney, 2018).

For reliability estimation “psych” package was used (Revelle, 2021). Though Cronbach’s internal consistency coefficient alpha is widely used for estimating internal consistency, it has a tendency to deflate the estimates for Likert-type data since the calculation is based on Pearson-correlation matrix which requires response data to be continuous in nature (Gadermann, Guhn, & Zumbo, 2012; Zumbo, Gadermann, & Zeisser, 2007). Subsequently to get better estimates of reliability we reported ordinal alpha for each factors obtained in EFA (Zumbo et al., 2007). We also estimated the internal consistency reliability of the total scale using McDonald’s ω_t coefficient which is a better reliability estimate for multidimensional constructs (Dunn, Baguley, & Brunsden, 2014; Sijtsma, 2009). Both ordinal alpha and McDonald’s ω_t coefficient value range between 0 to 1 and higher value represents better reliability.

To validate the latent structure obtained in EFA, We conducted a categorical confirmatory factor analysis (CFA) with weighted least square with mean and variance adjusted (WLSMV) estimator (Desjardins & Bulut, 2018) using “lavaan” package (Rosseel, 2012) on the data collected in the second round (CFA sample; n=262). We assessed the model fit using common model fit guidelines: (i) χ^2 test statistics: a non-significant test statistics is required to accept the model (ii) comparative fit index

156 (CFI) and Tucker Lewis index (TLI): close to .95 or above/ between .90-.95 and above
157 (iii) root mean square error of approximation (RMSEA): close to .06 or below, (iv)
158 Standardized root mean square (SRMR): close to .08 or below (Hu & Bentle, 1999;
159 Schumacker & Lomax, 2004). However, the χ^2 test is sensitive to sample size (Brown,
160 2015) and SRMR does not work well with ordinal data (Yu, 2002) As such, we judged the
161 model fit using CFI, TLI and RMSEA.

162 We assessed the measurement invariance (MI) of our scale between native
163 English speakers (n=129) and non-native English speakers (n=133) in the CFA sample
164 (n=262). MI evaluates whether a construct has the psychometric equivalence and the
165 same meaning across groups (Kline, 2016; Putnick & Bornstein, 2016). We used
166 structural equation modelling framework using “lavaan” package (Rosseel, 2012) to
167 assess the measurement invariance. We successively compared four nested models:
168 configural, metric, scalar, and residual models using the χ^2 difference test ($\Delta\chi^2$).
169 Among MI models, the configural model is the least restrictive model and residual model
170 is the most restrictive model. A non-significant $\Delta\chi^2$ test between two nested
171 measurement invariance models indicates mode fit does not significantly decrease for
172 the superior model thus allowing the superior invariance model to be accepted (Dimitrov,
173 2010; Widaman & Reise, 1997).

174 Fourth, as secondary analysis we identified the educational grade level required to
175 understand the items in our scale using Flesch-Kincaid grade level identification method
176 (Flesch, 1948) using “koRpus” (Michalke, 2021) package. Also, we analysed possible
177 semantic overlap of our developed scale using “Semantic Scale Network” (SSN) engine
178 (Rosenbusch, Wanders, & Pit, 2020). The SSN detects semantically related scales and
179 provides cosine similarity index ranging between -.66 to 1 (Rosenbusch et al., 2020).
180 Pair of scales with a cosine similarity index value of 1 indicates they are perfectly
181 semantically similar scales indicating redundancy.

182 Lastly, we developed a short form of LEBA using Item Response Theory (IRT)
183 based analysis. We fitted each factor of LEBA using the graded response model
184 (Samejima, Liden, & Hambleton, 1997) to the combined EFA and CFA sample (n=690)
185 using "mirt" package (Chalmers, 2012). IRT assesses the item quality by estimating item
186 discrimination, item difficulty, item information curve, and test information curve (Baker &
187 Kim, 2017). Item discrimination indicates how well a particular item can differentiate
188 between participants across the given latent trait continuum (θ). Item difficulty
189 corresponds to the latent trait level at which the probability of endorsing a particular
190 response option is 50%. Item information curve (IIC) indicates the amount of information
191 an item carries along the latent trait continuum. Here, we reported the item difficulty and
192 discrimination parameter and categorize the items based on their item discrimination
193 index: none = 0; very low =0.01 to 0.34; low = 0.35 to 0.64; moderate = 0.65 to 1.34 ;
194 high = 1.35 to 1.69; very high >1.70 (Baker & Kim, 2017). We discarded the items with
195 relatively flat item information curve (information <.2) to develop the short form of LEBA.
196 We also assessed the precision of the short LEBA using Test information curve (TIC).
197 TIC indicates the amount of information a particular scale carries along the latent trait
198 continuum. Item fit and person fit of the fitted IRT models were also analysed to gather
199 more evidence on validity and meaningfulness of our scale (Desjardins & Bulut, 2018).
200 Item fit was evaluated using the RMSEA value obtained from Signed- χ^2 index
201 implementation, RMSEA value $\leq .06$ was considered adequate item fit. Person fit was
202 estimated using standardized fit index Zh statistics (Drasgow, Levine, & Williams, 1985).
203 Zh < -2 was considered as a misfit (Drasgow et al., 1985).

204 **Ethical Approval**

205 By reason of using fully anonymous online survey data, the present research
206 project does not fall under the scope of the Human Research Act, making an
207 authorisation from the ethics committee redundant. Nevertheless, the cantonal ethics

208 commission (Ethikkommission Nordwest- und Zentralschweiz, EKNZ) reviewed our
209 proposition (project ID Req-2021-00488) and issued an official clarification of
210 responsibility.

211 **Data Availability**

212 The present article is a fully reproducible open access “R Markdown” document. All
213 code and data underlying this article – along with two versions of the LEBA questionnaire
214 (full and short) and online survey implementation templates on common survey platforms
215 – will be available under open-access licence (CC-BY-NC-ND) on a public GitHub
216 repository.

217 **Results**

218 **Development of the Initial Scale**

219 After reviewing the literature, we identified several light exposure related scales.
220 However, no scale specifically measuring the behavioural component of light exposure
221 were found (**Supplementary Table 1**). As such, an expert panel developed a
222 comprehensive item pool of 48 items. The expert panel composed of all authors and
223 researchers from the fields of chronobiology, light research, neuroscience and
224 psychology. The 48 items were then judged based on their relevance and
225 representativeness of the construct “Light Exposure Related Behaviour” by the expert
226 panel. The panel members independently judged each of the items in terms of their
227 relevance and representativeness and suggested required modification, if there is any.
228 The author team acknowledged the suggestions and amended the items as required
229 thus creating a 48-item scale.

230 **Large-scale Survey**

231 Table 1 summarizes the survey participants' demographic characteristics. Only
232 participants completing the full LEBA questionnaire were included, thus there are no
233 missing values in the item analyses. (XX??) participants were excluded from analysis
234 due to not passing at least one of the "attention check" items. For EFA, a sample of
235 250-300 is recommended (Comrey & Lee, 2013; Schönbrodt & Perugini, 2013). To
236 assess sampling adequacy for CFA, we followed the N:q rule (Bentler & Chou, 1987;
237 Jackson, 2003; Kline, 2016; Worthington & Whittaker, 2006), where ten participants per
238 item is required to earn trustworthiness of the result. Both our EFA and CFA sample size
239 exceeded these requirements. We collected data from 74 countries (28 time zones).
240 Participants reported a diverse range of geographic location Participants indicated filling
241 out the online survey from a diverse range of geographic locations. For a complete list of
242 geographic locations, see Supplementary Table 2.

243 Participants in our survey aged between 11 to 84 years [EFA sample: 11 to 84;
244 CFA sample: 12 to 74], with an overall mean of ~ 32.95 years of age [Overall:
245 32.95 ± 14.57 ; EFA: 32.99 ± 15.11 ; CFA: 32.89 ± 13.66]. In total 325 (47%) of the
246 participants indicated female sex [EFA: 189 (44%); CFA: 136 (52%)], 351 (51%)
247 indicated male [EFA: 230 (54%); CFA: 121 (46%)] and 14 (2.0%) indicated other sex
248 [EFA: 9 (2.1%), CFA: 5 (1.9%)]. Overall, 49 (7.2%) [EFA: 33 (7.8%); CFA: 16 (6.2%)]
249 participants indicated a gender-variant identity. In a "Yes/No" question regarding native
250 language, 320 (46%) of respondents [EFA: 191 (45%); CFA: 129 (49%)] indicated to be
251 native English speakers. For their "Occupational Status", more than half of the overall
252 sample reported that they currently work [Overall: 396 (57%); EFA: 235 (55%); CFA: 161
253 (61%)], whereas 174 (25%) [EFA: 122 (29%); CFA: 52 (20%)] reported that they go to
254 school and 120 (17%) [EFA: 71 (17%); CFA: 49 (19%)] responded that they do "Neither".
255 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.

Psychometric Analysis: Development of the Long Form

Descriptive Statistics and Item Analysis. Figure 2 and Figure 3 summarize the response pattern of our total sample (n=690) for all 48 items. Most of the items appeared skewed. The Shapiro–Wilk test of univariate normality (Shapiro & Wilk, 1965) and Mardia test of multivariate normality (Mardia, 1970) indicated our data violated both univariate and multivariate normality. Multivariate skew was 488.40 ($p < 0.001$) and multivariate kurtosis was 2,808.17 ($p < 0.001$).

Supplementary Figure 1 summarizes the univariate descriptive statistics for the 48 items in the EFA sample (n=428). Here also our data violated univariate (Shapiro & Wilk, 1965) and multivariate normality assumptions (Mardia, 1970). Multivariate skew was 583.80 ($p < 0.001$) and multivariate kurtosis was 2,749.15 ($p < 0.001$). The corrected item-total correlation ranges between .03 -.48. However, no item was discarded based on descriptive statistics or item analysis.

Exploratory Factor Analysis and Reliability Analysis. Sampling adequacy was checked using Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy using the EFA sample (n=428) (Kaiser, 1974) . The overall KMO vale for 48 items was 0.63 which was above the cut-off value (.50) indicating adequate sample size (Hutcheson, 1999). Bartlett's test of sphericity (Bartlett, 1954), χ^2 (1128)=5042.86, $p < .001$ indicated the correlations between items are adequate for conducting the EFA. However only 4.96% of

282 the inter-item correlation coefficients were greater than |.30|. The inter-item correlation
283 coefficients ranged between -.44 to .91. Figure 4-A depicts the correlation matrix.

284 Scree plot (Figure 4-B) suggested a six-factor solution. However, the minimum
285 average partial (MAP) (Velicer, 1976) method (**Supplementary Table 3**) and Hull method
286 (Lorenzo-Seva et al., 2011) (Figure 4-C) suggested a five-factor solution. As a result, we
287 tested both five-factor and six-factor solutions.

288 With the initial 48 items we conducted three rounds of EFA with varimax rotation
289 and gradually discarded problematic items (cross-loading items and items with factor
290 loading <.30). Finally, a five-factor EFA solution with 25 items was accepted with all
291 factor-loading higher than .30 and no cross-loading greater than .30. Table 2 displays the
292 factor-loading (structural coefficients) and communality of the items. The absolute value
293 of the factor-loading ranged from .32 to .99 indicating strong coefficients. The
294 commonalities ranged between .11 to .99. However, the histogram of the absolute
295 values of non-redundant residual-correlations (Figure 4-D) showed 26% correlations
296 were greater than the absolute value of .05, indicating a possible under-factoring.
297 (Desjardins & Bulut, 2018). Subsequently, we fitted a six-factor solution. However, a
298 factor emerged with only two salient variables, thus disqualifying the six-factor solution
299 (**Supplementary Table 4**).

300 In the five-factor solution, the first factor contained three items and explained
301 10.25% of the total variance with an internal reliability coefficient ordinal $\alpha = .94$. All the
302 items in this factor stemmed from the individual's preference of using blue light filters in
303 different light environments. The second factor contained six items and explained 9.93%
304 of the total variance with an internal reliability coefficient ordinal $\alpha = .76$. Items under this
305 factor investigated individuals' hours spent outdoor. The third factor contained five items
306 and explained 8.83% of the total variance. Items under this factor dealt with the specific
307 behaviours pertaining to using phone and smart-watch in bed. The internal consistency

308 reliability coefficient was, ordinal $\alpha = .75$. The fourth factor contained five items and
309 explained 8.44% of the total variance with an internal consistency coefficient, ordinal $\alpha =$
310 .72. These five items investigated the behaviours related to individual's light exposure
311 before bedtime. Lastly, the fifth factor contained six items and explained 6.14% of the
312 total variance. This factor captured individual's morning and daytime light exposure
313 related behaviour. The internal consistency reliability was, ordinal $\alpha = .62$. It is essential
314 to attain a balance between psychometric properties and interpretability of the common
315 themes when exploring the latent structure. As all of the emerged factors are highly
316 interpretable and relevant towards our aim to capture light exposure related behaviour,
317 regardless of the apparent low reliability of the fifth factor, we retain all the five-factors
318 with 25 items for our confirmatory factor analysis (CFA). Two items showed negative
319 factor-loading (items 44 and 21). Upon inspection, it was understood that these items
320 are negatively correlated to the respective common theme, and thus in the CFA analysis,
321 we reverse scored these two items. Internal consistency coefficient McDonald's ω_t for
322 the total scale was 0.77.

323 **Confirmatory Factor Analysis.** Table 3 summarizes the CFA fit indices of our fitted
324 model. Our fitted model attained acceptable fit ($CFI = .92$; $TLI = .91$; $RMSEA = .07$
325 [.06-.07, 90% CI]) with two imposed equity constrain on item pairs 32-33 [item 32: I dim
326 my mobile phone screen within 1 hour before attempting to fall asleep; item 33: I dim my
327 computer screen within 1 hour before attempting to fall asleep] and 16-17 [item 16: I
328 wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day; item
329 17: I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the
330 day]. Item pair 32-33 stemmed from the preference of dimming electric device's
331 brightness before bed time and item pair 16-17 stemmed from the preference of using
332 blue filtering or coloured glasses during the daytime. Given the similar nature of
333 behaviour these item pair were capturing, we accepted the equity constrain imposed.
334 Nevertheless, SRMR value was higher than the guideline ($SRMR = .12$).

To improve model fit we conducted a post-hoc model modification. Modification indices indicated the possibility of cross-loading of the item 37 and 26 [item 37: I purposely leave a light on in my sleep environment while sleeping; item 26: I turn on my ceiling room light when it is light outside] thus discarded. Also, item 30 and 41 [item 30: I look at my smart-watch within 1 hour before attempting to fall asleep; item 41: I look at my smart-watch when I wake up at night] showed a tendency to co-vary in their error variance ($MI = 141.127$, $p < .001$). By allowing this pair of items (30 & 41) to covary their error variance our model attained the best fit ($CFI = .95$; $TLI = .95$); $RMSEA = .06$ [.05-.06, 90% CI]; $SRMR = .11$). Internal consistency ordinal α for the five factors of LEBA were .96, .83, .70, .69, .52 respectively. As such, we accept this model thus finalizing the long Form of LEBA with 23 items. The items are provided in the **Supplementary File 1**.

Internal consistency McDonald's ω_t coefficient for the total scale was .68. Figure 5 depicts the obtained CFA structure. **Supplementary Figure 2** depicts the data distribution and endorsement pattern of the retained 23 items in our CFA sample.

Measurement Invariance. In our CFA sample we had 129 native English speakers and 133 non-native English speakers. **Supplementary Table 5** summarizes the demographic descriptions native and non-native English speakers. Table 4 indicates 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 indicating the acceptability of the highest measurement invariance model: residual model.

Secondary Analysis: Grade Level Identification and Semantic Scale Network Analysis

Flesch-Kincaid grade level (Flesch, 1948) analysis on the 23 items indicated required educational grade level was 3.33 and with a age above 8.33 years. This indicated our scale will be understandable to students of grade four and aged at least 8.33 years. Semantic Scale Network (SSN) analysis (Rosenbusch et al., 2020) indicated that LEBA (23 items) appeared most strongly related to scales about sleep: "Sleep

361 Disturbance Scale For Children" (Bruni et al., 1996) and "Composite International
362 Diagnostic Interview (CIDI): Insomnia"(Robins et al., 1988). The cosine similarities lie
363 between .47 to .51.

364 **Developing Short form of LEBA: IRT Based Analysis**

365 We fitted each factor of LEBA with the graded response model (Samejima et al.,
366 1997) to the combined EFA and CFA sample (n=690). Item discrimination parameters of
367 our scale fell in very high (10 items), high (4 items), moderate (4 items), and low (5
368 items) categorizes indicating a good range of discrimination along the latent trait level (θ)
369 (**Supplementary Table 6**). Examination of the item information curve (**Supplementary**
370 **Figure 3**) indicated five items (1, 25, 30, 38, & 41) had relatively flat information curves
371 ($I(\theta) < .20$). We discarded those items which yielded a short form of LEBA with 5 factors
372 and 18 items (**Supplementary File 2**).

373 We treated each factor of short-LEBA as a unidimensional construct and obtain 5
374 TICs (Figure 6). These information curves indicated except the first and fifth factors, the
375 other three factor's TICs are roughly centred on the centre of the trait continuum (θ). The
376 first and fifth factor had a peak to the right side of the centre of latent trait.Thus we
377 conferred the LEBA scale estimated the light exposure related behaviour with precision
378 near the centre of trait continuum for 2nd, 3rd and 4th factors and near the right side of
379 the centre of trait continuum for 1st and 5th factors (Baker & Kim, 2017).

380 **Supplementary Table 7** summarizes the item fit indexes of the 18 items. All items
381 had RMSEA value $\leq .06$ indicating adequate fit of the items to the fitted IRT model.
382 **Supplementary Figure 4** depicts the person fit Zh statistics histogram of our fitted
383 models. Zh statistics are larger than -2 for most participants, suggesting a good person
384 fit of the selected IRT models.

Discussion

Though there are lots of validated scale to measure light exposure, they don't tell us much about the behavioural aspects pertaining to the light exposure. In that vein we have developed a subjective self-reported scale that can capture light exposure related behaviour in different dimensions.

Authors along with an expert panel generated 48 items and evaluated their quality and relevance and made necessary amendments. A large-scale geographically unconstrained quantitative cross-sectional survey was conducted yielding responses from a large sample (n=690). Data collected on the first round was used to explore the latent structure (EFA sample; n=428). Exploratory factor analysis revealed a five factor solution with 25 items. ("Wearing blue light filters", "Spending time outdoors", "Using phone and smart-watch in bed", "Using light before bedtime", and "Using light in the morning and during daytime"). The internal consistency reliability coefficient ordinal alpha ranged between .62-.94. Except for the fifth factor the internal reliability coefficients were above .70. For the fifth factor it was .62. As a rule of thumb reliability coefficient higher than .70 is considered to be satisfactory. However for scales with less than 20 items and at the early developmental stage, a value of .50 is also acceptable (Dall'Oglio et al., 2010; Field, 2015; Nunnally, 1978). Also all of the factors were highly interpretable in terms of a common theme and contributed essentially towards our aim to capture light exposure related behaviour. This eventually led us to accept the obtained five-factor structure. The total scale exhibited satisfactory internal consistency (McDonald's $\omega_t=0.77$).

Our CFA analysis (CFA sample; n=262) confirmed the five factor structure we obtained in our EFA thus provided evidence of structural validity.(CFI=.95; TLI=.95); RMSEA=.06 [.05-.06, 90% CI]; SRMR=.11). However, in this model we discarded two items (item 26 & 37) for possible cross-loadings. Also, we accepted one pair of items

411 (item 30 & 41) to covary their error variance . This item-pair was capturing smart-watch
412 based light exposure behaviour. In retrospect, it seemed plausible that not having a
413 smart-watch may lead the respondent to answer in a similar fashion for these two items.
414 Thus, we decided to accept the modification to our model. The internal consistency
415 coefficients ordinal alpha for the five factors and the total scale were also satisfactory
416 (Ordinal alpha ranged between 0.52 to 0.96; McDonald's $\omega_t = .68$). On this same data set
417 our measurement invariance analysis indicated the underlying construct of our scale
418 "Light exposure related behaviour" was equivalent across native and non-native English
419 speakers. This indicated the applicability of LEBA on both native and non-native English
420 Speakers. However, this decisions brought up another question to be answered, what
421 was the required grade level to understand the items of our scale? To answer this
422 question we ran secondary analysis where we identified the grade level required using
423 Flesch-Kincaid grade level identification method. Our scale would appear
424 understandable to those who were at least a grade four student and had a age of at least
425 8.33 years. As a secondary analysis we also assessed the semantic similarity of our
426 scale to the scales recorded in the "Semantic Scale Network" database (Rosenbusch et
427 al., 2020). "LEBA" was related to "Sleep Disturbance Scale For Children" (SDSC) (Bruni
428 et al., 1996) and "Composite International Diagnostic Interview (CIDI): Insomnia"(Robins
429 et al., 1988). Upon inspecting the item contents we found items under "Using phone and
430 smart-watch in bed" and "Using light before bedtime" have semantic overlap with the
431 items of SDSC and CIDI. However, the aim of those scale and ours were different. Items
432 in those two scales were looking into behaviours related to sleep whereas our aim was to
433 capture light exposure related behaviour.

434 lastly, we developed a short-LEBA (18 items) using IRT analysis. We fitted a graded
435 response model model to the combined EFA and CFA sample (n=690). We discarded
436 five items (1, 25, 30, 38, & 41) with relatively flat item information curve [$I(\theta) < .20$]. Test
437 information curves indicated short form of LEBA is a psychometrically sound measure

438 with adequate coverage of underlying traits to capture different extents of light exposure
439 related behaviours with precision. Item fit index and person fit index for all five fitted
440 model were acceptable providing evidence of validity of our models. Items had diverse
441 item discrimination parameters indicating a good range of discrimination- the ability to
442 differentiate respondents with different levels of the light exposure related behaviour.

443 Based on all the gathered evidences, we can say LEBA can be used to profile
444 individuals based on their light exposure related behaviours, which can facilitate the
445 development process of individual interventions to promote health. All the five factors of
446 LEBA may identify ‘problematic’ behaviours that are opposed to good light hygiene.

447 Conclusion

448 We developed a novel self-reported subjective scale-“Light exposure behaviour
449 assessment”(LEBA) to capture light exposure related behaviour. We developed 48
450 items, judged the relevance and content of the items and conducted a large-scale
451 geographically unrestricted cross-sectional survey. Our EFA gave a five solution with 25
452 items. A CFA with this 25-item scale again offered a five-factor solution, but this time two
453 more item was discarded. The 23-item “LEBA” was found reliable (internal consistency)
454 and valid (structural validity). A short-form of LEBA was developed using IRT analysis.
455 IRT analysis gave a 18-item scale with a good coverage across the underlying trait
456 continuum. Hence, we could recommend that LEBA can be used to profile individuals
457 according to their light exposure related behaviours.

458 Future Direction

459 Since, LEBA is the first of its kind, estimating convergent validity with other
460 subjective scale was not possible. One way to establish the convergent validity of LEBA
461 is to administer this subjective scale along which some objective measurement scales

462 (e.g. personalised light dosimeter). Though such objective scales do not directly capture
463 light exposure related behaviour, potential insight can be drawn by understanding the
464 behaviour pattern and light exposure. Also, light exposure related behaviours can be
465 dependent upon the socio-economic status as behaviours can be modulated by
466 available scales individual have on their disposal. Our analysis did not consider
467 socio-economic status, as we didn't measure it. Investigating the properties of LEBA
468 while considering different socio-economic status would be a valuable addition.

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Table 1

Demographic Characteristics of Participants (n=690).

Variable	Overall, N = 690	1. EFA Sample, N = 428	2. CFA Sample, N = 262
Age	32.95 (14.57)	32.99 (15.11)	32.89 (13.66)
Sex			
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%)
Native English Speaker	320 (46%)	191 (45%)	129 (49%)
Occupational Status			
Work	396 (57%)	235 (55%)	161 (61%)
School	174 (25%)	122 (29%)	52 (20%)
Neither	120 (17%)	71 (17%)	49 (19%)
Occupational setting			
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 (%)

Table 2

Factor loadings and communality of the retained items in EFA using principal axis extraction method (n=482).

item	Stem	PA1	PA2	PA3	PA4	PA5	Communality
item16	I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.	0.99					0.99
item36	I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.	0.94					0.90
item17	I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.	0.8					0.66
item11	I spend more than 3 hours per day (in total) outside.		0.79				0.64
item10	I spend between 1 and 3 hours per day (in total) outside.		0.76				0.59
item12	I spend as much time outside as possible.		0.65				0.47
item07	I go for a walk or exercise outside within 2 hours after waking up.		0.5				0.27
item08	I spend 30 minutes or less per day (in total) outside.		-0.49				0.25
item09	I spend between 30 minutes and 1 hour per day (in total) outside.		0.32				0.11
item27	I use my mobile phone within 1 hour before attempting to fall asleep.		0.8				0.66
item03	I look at my mobile phone screen immediately after waking up.		0.8				0.68
item40	I check my phone when I wake up at night.		0.65				0.46
item30	I look at my smartwatch within 1 hour before attempting to fall asleep.		0.45				0.35
item41	I look at my smartwatch when I wake up at night.		0.36				0.33

Table 2 continued

item	Stem	PA1	PA2	PA3	PA4	PA5	Communality
item33	I dim my computer screen within 1 hour before attempting to fall asleep.				0.74		0.56
item32	I dim my mobile phone screen within 1 hour before attempting to fall asleep.				0.73		0.62
item35	I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.				0.66		0.45
item37	I purposely leave a light on in my sleep environment while sleeping.				-0.39		0.17
item38	I use as little light as possible when I get up during the night.				0.38		0.18
item46	I use tunable lights to create a healthy light environment.				0.6		0.42
item45	I use LEDs to create a healthy light environment.				0.59		0.37
item25	I use a desk lamp when I do focused work.				0.41		0.19
item04	I use an alarm with a dawn simulation light.				0.41		0.22
item01	I turn on the lights immediately after waking up.				0.4		0.17
item26	I turn on my ceiling room light when it is light outside.				0.35		0.16

Note. Only loading > .30 is reported.

Table 3

Confirmatory Factor Analysis model fit indices of the two model: (a) Model 1: five factor model with 25 items (b) Model 2: five factor model with 23 items. Model 2 attained the best fit.

Model	χ^2	df	CFI	TLI	RMSEA	RMSEA 90% Lower CI	RMSEA 90% Upper CI	SRMR
Model 1	566.80	267.00	.92	0.91	0.07	0.06	0.07	0.12
Model 2	415.45	231.00	.95	0.95	0.06	0.05	0.06	0.11

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 4

Measurment Invariance analysis on CFA sample (n=262) across native and non-native English speakers.

	χ^2	df	CFI	TLI	RMSEA	RMSEA 90% Lower CI	RMSEA 90% Upper	$\Delta \chi^2$	Δdf^*	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. 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; a = Metric vs Configural; b = Scalar vs Metric; c = Residual vs Scalar; d = Structural vs Residual; * = df of model comparison.

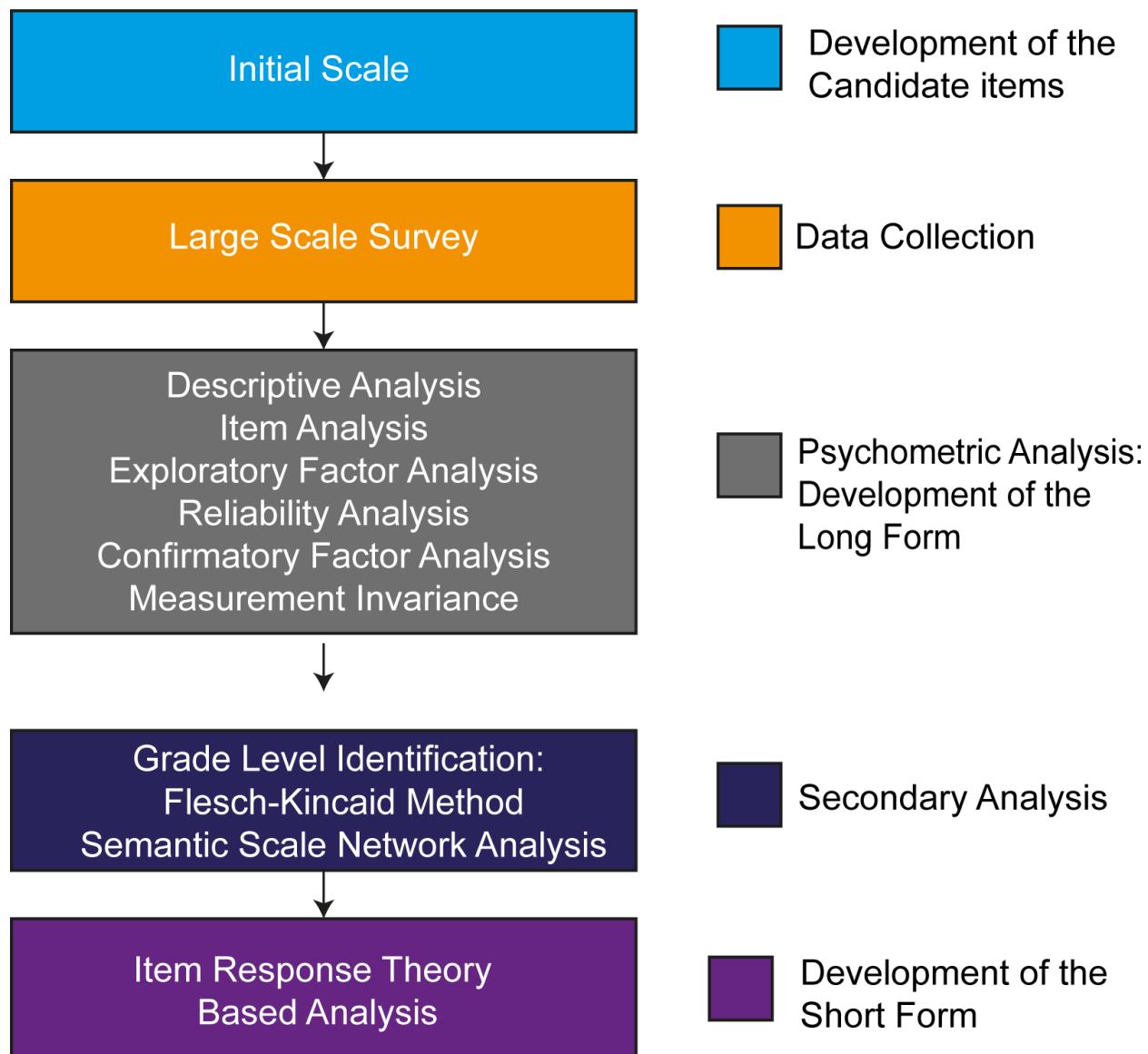


Figure 1. Flow chart of the LEBA (long and short form) development and evaluation.

Summary Descriptives (n=690)											
Items	Item	Summary Statistics			Graphics		Response Pattern				
		Mean	SD	SW ¹	Histogram	Density	Never	Rarely	Sometimes	Often	Always
●item01	I turn on the lights immediately after waking up.	2.3	1.4	0.82*			41.59% (287)	22.32% (154)	13.33% (92)	11.74% (81)	11.01% (76)
●item02	I open the curtains or blinds immediately after waking up.	2.8	1.6	0.84*			32.61% (225)	15.22% (105)	11.30% (78)	19.28% (133)	21.59% (149)
●item03	I look at my mobile phone screen immediately after waking up.	3.5	1.4	0.86*			14.35% (99)	9.86% (68)	17.39% (120)	30.00% (207)	28.41% (196)
●item04	I use an alarm with a dawn simulation light.	1.4	1.1	0.40*			86.09% (594)	3.04% (21)	2.61% (18)	2.46% (17)	5.80% (40)
●item05	I have breakfast within 3 meters from a window.	3.9	1.4	0.74*			14.35% (99)	4.78% (33)	11.01% (76)	18.26% (126)	51.59% (356)
●item06	I have breakfast in a brightly lit room (illuminated by electric light).	2.7	1.5	0.85*			33.19% (229)	15.36% (106)	16.38% (113)	16.09% (111)	18.99% (131)
●item07	I go for a walk or exercise outside within 2 hours after waking up.	2.2	1.2	0.84*			38.70% (267)	26.23% (181)	16.23% (112)	13.04% (90)	5.80% (40)
●item08	I spend 30 minutes or less per day (in total) outside.	3.0	1.2	0.91*			13.91% (96)	22.46% (155)	25.22% (174)	28.26% (195)	10.14% (70)
●item09	I spend between 30 minutes and 1 hour per day (in total) outside.	2.9	1.0	0.91*			11.30% (78)	20.58% (142)	38.99% (269)	23.91% (165)	5.22% (36)
●item10	I spend between 1 and 3 hours per day (in total) outside.	2.7	1.1	0.91*			14.06% (97)	30.58% (211)	30.43% (210)	21.74% (150)	3.19% (22)
●item11	I spend more than 3 hours per day (in total) outside.	2.2	0.9	0.86*			23.77% (164)	46.38% (320)	22.03% (152)	6.38% (44)	1.45% (10)
●item12	I spend as much time outside as possible.	2.3	1.2	0.87*			30.72% (212)	30.14% (208)	20.58% (142)	11.88% (82)	6.67% (46)
●item13	I use sunglasses when I go outside in bright daylight.	2.7	1.5	0.87*			30.14% (208)	17.54% (121)	17.83% (123)	18.70% (129)	15.80% (109)
●item14	I wear a visor or cap when I go outside in bright daylight.	2.1	1.3	0.79*			47.54% (328)	18.84% (130)	12.90% (89)	15.22% (105)	5.51% (38)
●item15	I seek shade when I am outside in bright daylight.	3.3	1.1	0.91*			7.97% (55)	13.91% (96)	35.36% (244)	27.97% (193)	14.78% (102)
●item16	I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.	1.6	1.3	0.51*			79.13% (546)	3.91% (27)	4.06% (28)	5.07% (35)	7.83% (54)
●item17	I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.	1.5	1.2	0.49*			80.43% (555)	3.33% (23)	5.22% (36)	3.04% (21)	7.97% (55)
●item18	I use light therapy applying a white light box.	1.1	0.5	0.27*			92.90% (641)	3.48% (24)	2.75% (19)	0.58% (4)	0.29% (2)
●item19	I use light therapy applying a blue light box.	1.0	0.3	0.12*			97.68% (674)	0.87% (6)	0.72% (5)	0.72% (5)	0.00% (0)
●item20	I use light therapy applying a light visor.	1.0	0.3	0.08*			98.70% (681)	0.14% (1)	0.58% (4)	0.43% (3)	0.14% (1)
●item21	I use light therapy applying another form of light device.	1.1	0.6	0.24*			94.06% (649)	1.45% (10)	3.04% (21)	0.58% (4)	0.87% (6)
●item22	I spend most of my daytime in a brightly lit environment.	3.5	1.1	0.88*			5.36% (37)	13.33% (92)	21.74% (150)	41.59% (287)	17.97% (124)
●item23	I close the curtains or blinds during the day if the light from outside is bright.	2.6	1.3	0.89*			26.38% (182)	24.93% (172)	23.33% (161)	17.25% (119)	8.12% (56)
●item24	I spend most of my indoor time within 3 meters from a window.	4.1	1.0	0.79*			2.90% (20)	5.65% (39)	11.45% (79)	37.83% (261)	42.17% (291)

¹ Shapiro-Wilk test

Figure 2. Summary descriptives and response pattern observed in the large-scale survey for item 01-24. All items violated normality assumption.

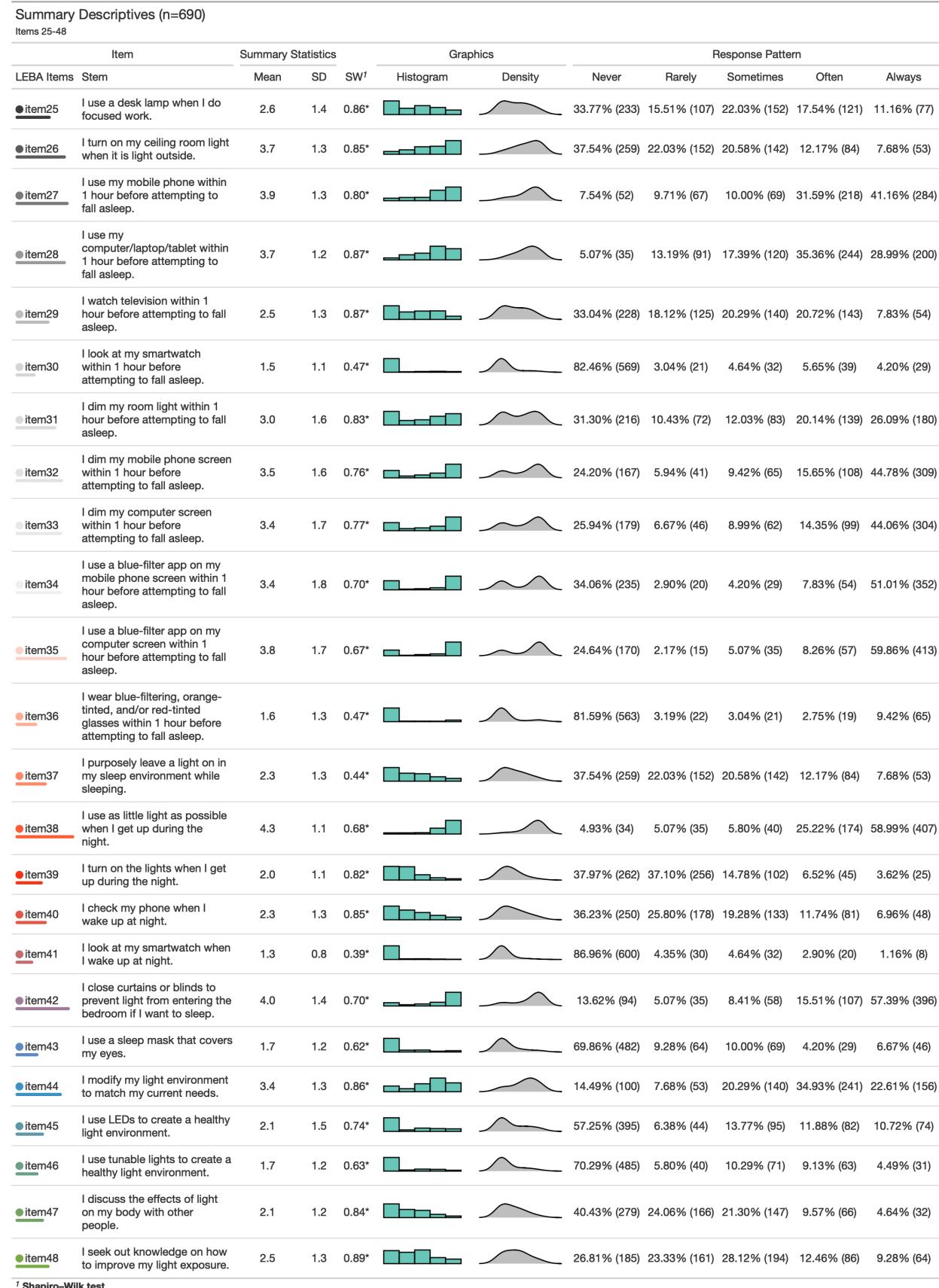
¹ Shapiro-Wilk test

Figure 3. Summary descriptives and response pattern observed in the large-scale survey for item 25-48. All items violated normality assumption.

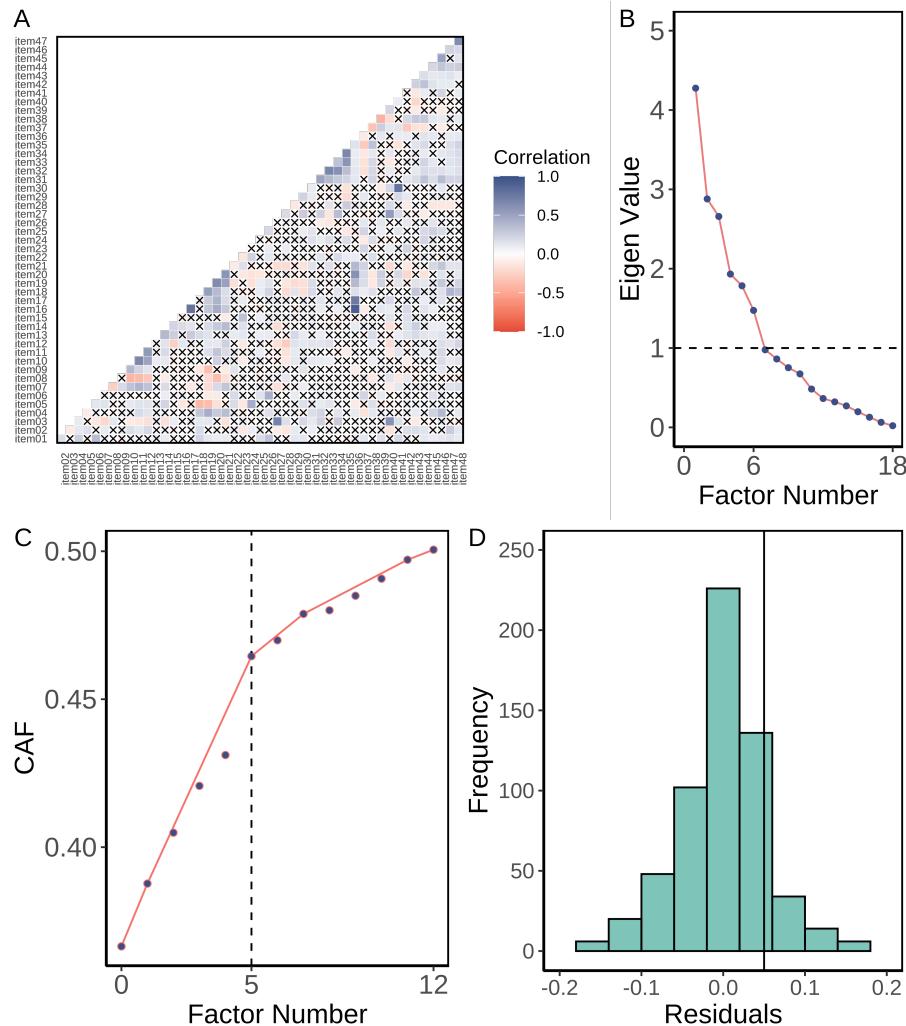
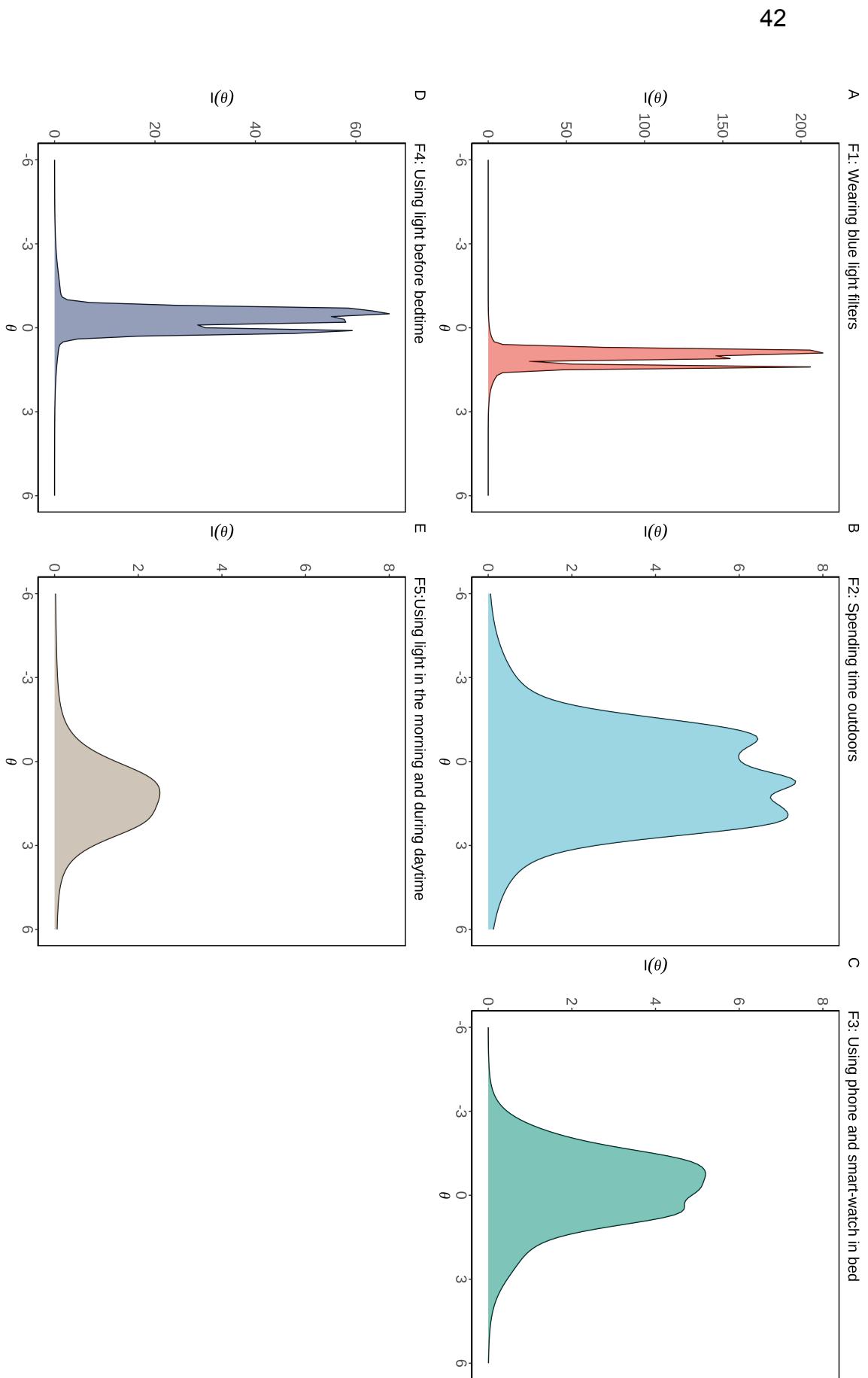


Figure 4. (A) Inter-item polychoric correlation coefficients for the 48 items. 4.9 % inter-item correlation coefficients were higher than $|.30|$. 'x' denotes non-significant item-total correlation. (B) Scree plot suggested six factors. (C) Hull method indicated 5 factors were required to balance the model fit and number of parameters. (D) Histogram of nonredundant residual correlations indicated 26% of inter-item correlations were higher than .05, hinting a possible under factoring.



Figure 5. Five factor model of LEBA obtained by confirmatory factor analysis. By allowing item pair 41 and 30 to covary their error variance our model attained the best fit.



LEBA

Figure 6. Test information curves for the five factors of LEBA: (a) wearing blue light filters (b) spending time outdoors (c) using phone and smart-watch in bed (d) using light before bedtime (e) using light in the morning and during daytime. Along x-axis we plotted the underlying latent trait continuum for each factor. Along y-axis we plotted how much information a particular factor is caring across its latent trait continuum

Supplementary File 1
Light Exposure Behaviour Assessment (LEBA): Long Form

Participant's Instruction

Please indicate how often you performed the following behaviours in the **past four weeks**

	Items	Never	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. <i>(Reverse-scored)</i>					
05	I spend between 30 minutes and 1 hour per day (in total) outside.					
06	I spend between 1 and 3 hours per day (in total) outside.					
07	I spend more than 3 hours per day (in total) outside.					
08	I spend as much time outside as possible.					
09	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.					
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.					
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.					

LEBA: Supplementary Materials

Scoring

(Note: R = reverse-scored item)

LEBA captures light exposure-related behaviours on a 5-point Likert type scale ranging from 1 to 5 (1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always; for reversed-scored item: 1 = always; 2 = often; 3 = sometimes; 4 = rarely; 5 = never). The score of each factor is calculated by the summation of scores of items belonging to the corresponding factor.

Factor Name	Score
F1: Wearing blue light filters	01+02+03
F2: Spending time outdoors	04(R)+05+06+07+08+09
F3: Using phone and smartwatch in bed	10+11+12+13+14
F4: Using light before bedtime	15+16+17+18
F5: Using light in the morning and during daytime	19+20+21+22+23

Supplementary File 2
Light Exposure Behaviour Assessment (LEBA): Short Form

Participant's Instruction

Please indicate how often you performed the following behaviours in the **past four weeks**.

	Items	Never	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. <i>(Reverse-scored)</i>					
05	I spend between 30 minutes and 1 hour per day (in total) outside.					
06	I spend between 1 and 3 hours per day (in total) outside.					
07	I spend more than 3 hours per day (in total) outside.					
08	I spend as much time outside as possible.					
09	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.					
11	I look at my mobile phone screen immediately after waking up.					
12	I check my phone 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.					
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.					
22	I use an alarm with a dawn simulation light.					

Scoring

(Note: R = reverse-scored item)

LEBA captures light exposure-related behaviours on a 5-point Likert type scale ranging from 1 to 5 (1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always; for reversed-scored item: 1 = always; 2 = often; 3 = sometimes; 4 = rarely; 5 = never). The score of each factor is calculated by the summation of scores of items belonging to the corresponding factor.

Factor Name	Score
F1: Wearing blue light filters	01+02+03
F2: Spending time outdoors	04(R)+05+06+07+08+09
F3: Using phone and smartwatch in bed	10+11+12
F4: Using light before bedtime	15+16+18
F5: Using light in the morning and during daytime	19+20+22

Supplementary Tables

Supplementary Table 1

List of instruments measuring related constructs to LEBA.

Name	Number of items	Description	Relevant items	Scale type
Visual Light Sensitivity Questionnaire-8 (Verriotto et al., 2017)	Eight-item	To assess the presence and severity of photosensitivity symptoms	None	5-point Likert scale
Office Light Survey (Eklund & Boyce, 1996)	30-item	To assess electrical lighting environment in office	Item 29	Mixed response format
Harvard Light Exposure Assessment Questionnaire (Bajaj et al., 2011)	One-item	To assess an individual's daily light exposure	None	Semi-quantitative
Hospital Lighting Survey (Dianat et al., 2013)	23-item	To assess light environment in a hospital	Item 16,17	5-point Likert scale
Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976)	19-item	To assess an individual's chronotype	item 1,2,8,13,14	Mixed response format
Munich Chronotype Questionnaire (Roenneberg et al., 2003)	17-item	To understand an individual's phase of entrainment	Time spent outdoors	Mixed response format
Sleep Practices and Attitudes Questionnaire (Grandner et al., 2014)	16-subscale	To assess practice, behaviour and attitude related to sleep	Activities in bed and sleep environment subscales	5-point Likert scale
The Pittsburgh Sleep Quality Index (Buysse et al., 1989)	Nine-item	To assess sleep quality and sleeping pattern	item 1-4	Mixed response format
Self-Rating of Biological Rhythm Disorder for Adolescents (Xie et al., 2022)	29-item	To assess four dimensions of biological rhythm disorder in adolescents	Item 3,6,22-25 and 29	5-point Likert scale
Photosensitivity Assessment Questionnaire (PAQ) (Bossini et al., 2006)	16-item	To assess "photophobia" and "photophilia"	All items	Binary response option

Supplementary Table 2

Geographical location of the participants (n =690).

	Time zone and country name	Number of Participants
1	Africa/Ceuta (UTC +01:00)	2
2	Africa/Douala (UTC +01:00)	1
3	Africa/Johannesburg (UTC +02:00)	5
4	Africa/Khartoum (UTC +02:00)	2
5	Africa/Lagos (UTC +01:00)	1
6	America/Adak (UTC -09:00)	2
7	America/Anchorage (UTC -08:00)	3
8	America/Araguaina (UTC -03:00)	2
9	America/Argentina/Buenos_Aires (UTC -03:00)	5
10	America/Argentina/Cordoba (UTC -03:00)	2
11	America/Argentina/Jujuy (UTC -03:00)	1
12	America/Bahia (UTC -03:00)	2
13	America/Blanc-Sablon (UTC -04:00)	1
14	America/Bogota (UTC -05:00)	2
15	America/Boise (UTC -06:00)	4
16	America/Cayman (UTC -05:00)	1
17	America/Chicago (UTC -05:00)	30
18	America/Costa_Rica (UTC -06:00)	2
19	America/Cuiaba (UTC -04:00)	1
20	America/Denver (UTC -06:00)	6
21	America/Detroit (UTC -04:00)	6
22	America/Edmonton (UTC -06:00)	14
23	America/Fortaleza (UTC -03:00)	1
24	America/Guatemala (UTC -06:00)	1
25	America/Guayaquil (UTC -05:00)	2
26	America/Halifax (UTC -03:00)	1
27	America/Indiana/Indianapolis (UTC -04:00)	3
28	America/Indiana/Tell_City (UTC -05:00)	1
29	America/Kentucky/Louisville (UTC -04:00)	3
30	America/Los_Angeles (UTC -07:00)	37
31	America/Martinique (UTC -04:00)	1
32	America/Mexico_City (UTC -06:00)	2
33	America/Moncton (UTC -03:00)	2
34	America/Monterrey (UTC -06:00)	1
35	America/New_York (UTC -04:00)	63
36	America/North_Dakota/Center (UTC -05:00)	1

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37	America/North_Dakota/New_Salem (UTC -05:00)	1
38	America/Panama (UTC -05:00)	1
39	America/Phoenix (UTC -07:00)	7
40	America/Resolute (UTC -05:00)	1
41	America/Santiago (UTC -03:00)	8
42	America/Sao_Paulo (UTC -03:00)	19
43	America/Toronto (UTC -04:00)	16
44	America/Vancouver (UTC -07:00)	6
45	Antarctica/Macquarie (UTC +11:00)	1
46	Asia /Taipei City (UTC +08:00)	3
47	Asia/Amman (UTC +03:00)	2
48	Asia/Barnaul (UTC +07:00)	1
49	Asia/Dhaka (UTC +06:00)	1
50	Asia/Famagusta (UTC +02:00)	1
51	Asia/Ho_Chi_Minh (UTC +07:00),British - America/Tortola (UTC -04:00)	2
52	Asia/Hong_Kong (UTC +08:00)	2
53	Asia/Jakarta (UTC +07:00)	9
54	Asia/Jerusalem (UTC +02:00)	4
55	Asia/Karachi (UTC +05:00)	1
56	Asia/Kathmandu (UTC +05:45)	2
57	Asia/Kolkata (UTC +05:30)	38
58	Asia/Kuala_Lumpur (UTC +08:00)	7
59	Asia/Kuching (UTC +08:00)	2
60	Asia/Manila (UTC +08:00)	6
61	Asia/Novosibirsk (UTC +07:00)	1
62	Asia/Riyadh (UTC +03:00)	1
63	Asia/Seoul (UTC +09:00)	1
64	Asia/Shanghai (UTC +08:00)	7
65	Asia/Singapore (UTC +08:00)	1
66	Asia/Tokyo (UTC +09:00)	3
67	Asia/Tomsk (UTC +07:00)	1
68	Asia/Ulaanbaatar (UTC +08:00)	1
69	Asia/Vladivostok (UTC +10:00)	1
70	Asia/Yangon (UTC +06:30)	1
71	Asia/Yekaterinburg (UTC +05:00)	1
72	Atlantic/Canary (UTC)	1
73	Australia/Adelaide (UTC +10:30)	2
74	Australia/Brisbane (UTC +10:00)	4
75	Australia/Darwin (UTC +09:30)	1
76	Australia/Melbourne (UTC +11:00)	5
77	Australia/Perth (UTC +08:00)	2
78	Australia/Sydney (UTC +11:00)	2

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79	East Africa/Dodoma (UTC +03:00)	1
80	Europe/Amsterdam (UTC +01:00)	19
81	Europe/Athens (UTC +02:00)	3
82	Europe/Belgrade (UTC +01:00)	3
83	Europe/Berlin (UTC +01:00)	53
84	Europe/Bratislava (UTC +01:00)	2
85	Europe/Brussels (UTC +01:00)	4
86	Europe/Bucharest (UTC +02:00)	3
87	Europe/Budapest (UTC +01:00)	2
88	Europe/Busingen (UTC +01:00)	3
89	Europe/Copenhagen (UTC +01:00)	3
90	Europe/Dublin (UTC)	5
91	Europe/Helsinki (UTC +02:00)	9
92	Europe/Istanbul (UTC +03:00)	6
93	Europe/Kiev (UTC +02:00)	1
94	Europe/Lisbon (UTC)	2
95	Europe/Ljubljana (UTC +01:00)	3
96	Europe/London (UTC)	57
97	Europe/Madrid (UTC +01:00)	7
98	Europe/Moscow (UTC +03:00)	8
99	Europe/Oslo (UTC +01:00)	3
100	Europe/Paris (UTC +01:00)	22
101	Europe/Prague (UTC +01:00)	3
102	Europe/Riga (UTC +02:00)	2
103	Europe/Rome (UTC +01:00)	9
104	Europe/Sofia (UTC +02:00)	1
105	Europe/Stockholm (UTC +01:00)	4
106	Europe/Tallinn (UTC +02:00)	2
107	Europe/Tirane (UTC +01:00)	1
108	Europe/Vienna (UTC +01:00)	1
109	Europe/Vilnius (UTC +02:00)	5
110	Europe/Warsaw (UTC +01:00)	15
111	Europe/Zagreb (UTC +01:00)	2
112	Europe/Zurich (UTC +01:00)	21
113	European /Skopje (UTC +01:00)	1
114	Iran /Tehran (UTC +0:30)	3
115	Pacific/Auckland (UTC +13:00)	6
116	Pacific/Chatham (UTC +13:45)	1
117	Pacific/Easter (UTC -05:00)	1
118	Pacific/Honolulu (UTC -10:00)	2

Supplementary Table 3.

Minimum average partial (MAP) method of factor number determination. MAP Statistics is the lowest in the 5th row indicating five factors are required.

MAP Statistic ¹	df	χ^2	RMSEA	BIC	SRMR
0.01125	1080	4344.31	0.08	-2199.54	0.09
0.01062	1033	3735.35	0.08	-2523.72	0.08
0.01077	987	3065.44	0.07	-2914.91	0.07
0.01042	942	2661.78	0.07	-3045.92	0.06
0.0093	898	2237.56	0.06	-3203.53	0.06
0.0094	855	2040.02	0.06	-3140.53	0.05
0.0097	813	1861.69	0.05	-3064.37	0.04
0.0100	772	1620.64	0.05	-3057.00	0.04

Note. ¹ Minimum average partial.

Supplementary Table 4

Factor loadings and communality of the retained in EFA with six factors. One factor emerged with only two items (n=428).

Items	PA1	PA2	PA3	PA4	PA5	PA6	Communality
Item 16	.99						.01
Item 36	.94						.10
Item 17	.80						.33
Item 11		.82					.30
Item 10		.81					.34
Item 12		.64					.53
Item 08		-.48					.75
Item 07		.47					.74
Item 09		.33					.88
Item 33			.97				.02
Item 32			.77				.31
Item 35			.54				.59
Item 31			.49				.67
Item 03				.84			.27
Item 27				.81			.33
Item 40				.69			.47
Item 46					.65		.48
Item 45					.57		.65
Item 04					.48		.67
Item 25					.40		.76
Item 01					.35		.87
Item 26					.35		.84
Item 37						-.8	.32
Item 38						.39	.76
% Of Variance	11	10	9	9	6	5	-

Note. Only loading higher than .30 is reported.

Supplementary Table 5

Demographics Characteristics of the native and non-native English Speakers (n=262).

Variable	Overall ¹ (n= 262)	Native English Speakers ¹ (n=129)	Non-native English Speakers ¹ (n=133)
Age	32.89 (13.66)	34.08 (15.32)	31.74 (11.77)
Sex			
Female	136 (52%)	80 (62%)	56 (42%)
Male	121 (46%)	48 (37%)	73 (55%)
Other	5 (1.9%)	1 (.08%)	4 (3.0%)
Occupational Status			
Work	161 (61%)	76 (59%)	85 (64%)
School	52 (20%)	27 (21%)	25 (19%)
Neither	49 (19%)	26 (20%)	23 (17%)
Occupational Setting			
Home Office/Home schooling	109 (42%)	50 (39%)	59 (44%)
Face-to-face work/Face-to-face schooling	41 (16%)	22 (17%)	19 (14%)
Combination of home and face-to-face work/schooling	53 (20%)	23 (18%)	30 (23%)
Neither (no work or school, or in vacation)	59 (23%)	34 (26%)	25 (19%)

¹ Mean (SD); n (%).

Supplementary Table 6

Items discrimination and response category difficulty thresholds of 23 items in LEBA (n=690).

Items	a	b ₁	b ₂	b ₃	b ₄	Item Discrimination Category
F1: Wearing blue light filters						
Item 16	28.13	0.78	0.90	1.06	1.40	Very High
Item 36	4.49	0.94	1.08	1.23	1.40	Very High
Item 17	2.81	0.97	1.11	1.38	1.62	Very High
F2: Spending time outdoors						
Item 11	3.27	-0.79	0.65	1.54	2.31	Very High
Item 10	3.07	-1.27	-0.09	0.82	2.00	Very High
Item 12	1.72	-0.67	0.44	1.28	2.11	Very High
Item 07	1.09	-0.50	0.73	1.63	2.97	Moderate
Item 08	1.19	-2.26	-0.48	0.64	1.91	Moderate
Item 09	0.91	-2.63	-0.96	1.11	3.49	Moderate
F3: Using phone and smartwatch in bed						
Item 27	2.21	-1.88	-1.19	-0.73	0.30	Very High
Item 03	3.03	-1.24	-0.77	-0.20	0.66	Very High
Item 40	1.55	-0.51	0.46	1.32	2.22	High
Item 30	0.49	3.27	3.74	4.64	6.52	Low
Item 41	0.51	3.87	4.78	6.39	8.91	Low
F4: Using light before bedtime						
Item 32	1.62	-1.03	-0.78	-0.42	0.16	High
Item 35	1.37	-1.09	-0.98	-0.75	-0.40	High
Item 38	0.40	-7.48	-5.56	-4.23	-0.90	Low
Item 33	12.31	-0.66	-0.48	-0.24	0.13	Very High
F5: Using light in the morning and during daytime						
Item 46	2.22	0.68	0.89	1.38	2.17	Very High
Item 45	1.51	0.30	0.55	1.17	1.91	High
Item 25	0.52	-1.37	-0.04	1.89	4.22	Low
Item 04	0.84	2.44	2.80	3.18	3.67	Moderate
Item 01	0.39	-0.91	1.52	3.25	5.53	Low

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

Supplementary Table 7

Item discrimination, response category difficulty thresholds and fit statistics of the 18 items in short LEBA (n=690).

Items	a	b ₁	b ₂	b ₃	b ₄	Signed χ^2	df	RMSEA	p	Item Discrimination Category
F1: Wearing blue light filters										
Item 16	28.13	0.78	0.90	1.06	1.40	2.02	6	0.00	0.92	Very High
Item 36	4.49	0.94	1.08	1.23	1.40	39.07	13	0.05	0.00	Very High
Item 17	2.81	0.97	1.11	1.38	1.62	25.58	13	0.04	0.02	Very High
F2: Spending time outdoors										
Item 11	3.27	-0.79	0.65	1.54	2.31	55.03	27	0.04	0.00	Very High
Item 10	3.07	-1.27	-0.09	0.82	2.00	53.19	30	0.03	0.01	Very High
Item 12	1.72	-0.67	0.44	1.28	2.11	34.39	42	0.00	0.79	Very High
Item 07	1.09	-0.50	0.73	1.63	2.97	67.45	46	0.03	0.02	Moderate
Item 08	1.19	-2.26	-0.48	0.64	1.91	140.90	46	0.05	0.00	Moderate
Item 09	0.91	-2.63	-0.96	1.11	3.49	131.19	45	0.05	0.00	Moderate
F3: Using phone and smartwatch in bed										
Item 27	2.12	-1.91	-1.21	-0.74	0.31	16.41	11	0.03	0.13	Very High
Item 03	3.24	-1.22	-0.76	-0.20	0.65	15.09	11	0.02	0.18	Very High
Item 40	1.57	-0.50	0.45	1.30	2.20	9.92	9	0.01	0.36	High
F4: Using light before bedtime										
Item 32	1.60	-1.04	-0.79	-0.42	0.16	41.33	15	0.05	0.00	High
Item 35	1.34	-1.10	-0.99	-0.76	-0.41	41.71	14	0.05	0.00	High
Item 33	15.66	-0.66	-0.48	-0.24	0.13	46.89	14	0.06	0.00	Very High
F5: Using light in the morning and during daytime										
Item 46	2.34	0.66	0.88	1.36	2.12	19.00	15	0.02	0.21	Very High
Item 45	1.51	0.30	0.55	1.17	1.91	15.05	15	0.00	0.45	High
Item 25	0.49	-1.45	-0.04	1.99	4.46	31.60	15	0.04	0.01	Low

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

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Supplementary Figures

Light Exposure Behavior Assessment

Summary Descriptives EFA Sample (n =428)

Items	Summary Statistics					Item Total Correlation	Graphics		Response Pattern				
	Mean	SD	Skew	Kurtosis	SW ^a		Histogram	Density	Never	Rarely	Sometimes	Often	Always
● item01	2.27	1.39	0.74	-0.81	0.81*	0.19			42.29% (181)	22.20% (95)	12.62% (54)	12.38% (53)	10.51% (45)
● item02	2.87	1.59	0.08	-1.60	0.83*	0.28			31.78% (136)	15.65% (67)	9.35% (40)	20.09% (86)	23.13% (99)
● item03	3.36	1.38	-0.48	-1.03	0.87*	0.23			15.89% (68)	11.45% (49)	17.29% (74)	31.07% (133)	24.30% (104)
● item04	1.47	1.18	2.38	4.00	0.43*	0.24			84.11% (360)	3.50% (15)	2.10% (9)	2.10% (9)	8.18% (35)
● item05	4.01	1.40	-1.22	0.07	0.70*	0.17			12.85% (55)	3.50% (15)	9.58% (41)	17.52% (75)	56.54% (242)
● item06	2.79	1.55	0.19	-1.48	0.85*	0.13			32.01% (137)	15.42% (66)	15.89% (68)	15.42% (66)	21.26% (91)
● item07	2.26	1.25	0.70	-0.60	0.85*	0.32			35.98% (154)	27.80% (119)	17.29% (74)	12.38% (53)	6.54% (28)
● item08	2.97	1.20	-0.06	-0.94	0.91*	0.25			13.79% (59)	22.20% (95)	27.80% (119)	25.93% (111)	10.28% (44)
● item09	2.94	1.03	-0.12	-0.40	0.91*	0.08			10.28% (44)	19.63% (84)	41.82% (179)	22.43% (96)	5.84% (25)
● item10	2.74	1.04	0.09	-0.74	0.91*	0.42			11.92% (51)	31.31% (134)	31.31% (134)	21.96% (94)	3.50% (15)
● item11	2.18	0.90	0.60	0.12	0.86*	0.41			22.43% (96)	46.26% (198)	23.13% (99)	7.01% (30)	1.17% (5)
● item12	2.36	1.22	0.59	-0.62	0.87*	0.48			29.91% (128)	29.67% (127)	21.50% (92)	12.15% (52)	6.78% (29)
● item13	2.73	1.46	0.20	-1.36	0.87*	0.25			30.14% (129)	17.52% (75)	17.76% (76)	18.69% (80)	15.89% (68)
● item14	2.14	1.31	0.77	-0.78	0.80*	0.28			47.20% (202)	18.93% (81)	12.62% (54)	15.65% (67)	5.61% (24)
● item15	3.26	1.09	-0.26	-0.45	0.91*	0.03			7.48% (32)	13.79% (59)	37.15% (159)	28.04% (120)	13.55% (58)
● item16	1.56	1.23	2.00	2.45	0.50*	0.28			79.67% (341)	4.21% (18)	3.97% (17)	4.67% (20)	7.48% (32)
● item17	1.54	1.21	2.07	2.75	0.49*	0.21			80.61% (345)	3.27% (14)	5.14% (22)	3.27% (14)	7.71% (33)
● item18	1.12	0.49	5.02	27.80	0.25*	0.18			93.22% (399)	3.50% (15)	2.10% (9)	0.70% (3)	0.47% (2)
● item19	1.05	0.36	7.23	52.98	0.13*	0.17			97.43% (417)	0.93% (4)	0.47% (2)	1.17% (5)	0.00% (0)
● item20	1.04	0.33	8.99	85.28	0.10*	0.16			98.36% (421)	0.23% (1)	0.70% (3)	0.47% (2)	0.23% (1)
● item21	1.14	0.59	4.79	24.05	0.25*	0.21			93.69% (401)	1.64% (7)	3.04% (13)	0.47% (2)	1.17% (5)
● item22	3.57	1.07	-0.65	-0.17	0.88*	0.20			4.91% (21)	11.92% (51)	21.96% (94)	43.22% (185)	17.99% (77)
● item23	2.56	1.27	0.33	-1.00	0.89*	0.08			26.40% (113)	25.23% (108)	22.66% (97)	17.76% (76)	7.94% (34)
● item24	4.14	0.99	-1.23	1.14	0.79*	0.22			2.34% (10)	5.84% (25)	10.98% (47)	37.38% (160)	43.46% (186)
● item25	2.59	1.41	0.27	-1.27	0.86*	0.15			34.35% (147)	13.79% (59)	22.20% (95)	17.99% (77)	11.68% (50)
● item26	2.25	1.27	0.69	-0.64	0.84*	0.08			38.32% (164)	23.36% (100)	20.09% (86)	10.98% (47)	7.24% (31)
● item27	3.80	1.29	-0.87	-0.42	0.82*	0.17			8.41% (36)	11.21% (48)	11.21% (48)	30.37% (130)	38.79% (166)
● item28	3.76	1.14	-0.68	-0.45	0.86*	0.18			3.97% (17)	13.08% (56)	17.06% (73)	34.81% (149)	31.07% (133)
● item29	2.44	1.31	0.38	-1.14	0.86*	0.13			34.35% (147)	20.33% (87)	19.39% (83)	19.16% (82)	6.78% (29)
● item30	1.48	1.11	2.18	3.35	0.48*	0.13			81.78% (350)	3.27% (14)	4.91% (21)	5.37% (23)	4.67% (20)
● item31	3.00	1.62	-0.08	-1.61	0.83*	0.39			31.31% (134)	10.05% (43)	11.68% (50)	20.79% (89)	26.17% (112)
● item32	3.55	1.65	-0.60	-1.34	0.76*	0.33			23.13% (99)	7.01% (30)	8.18% (35)	14.95% (64)	46.73% (200)
● item33	3.62	1.64	-0.68	-1.25	0.74*	0.37			21.96% (94)	7.01% (30)	7.24% (31)	14.49% (62)	49.30% (211)
● item34	3.42	1.83	-0.45	-1.69	0.69*	0.20			33.64% (144)	3.04% (13)	3.04% (13)	8.64% (37)	51.64% (221)
● item35	3.86	1.67	-0.99	-0.85	0.65*	0.20			22.90% (98)	1.87% (8)	3.74% (16)	9.35% (40)	62.15% (266)
● item36	1.54	1.25	2.13	2.86	0.46*	0.35			82.24% (352)	3.04% (13)	3.04% (13)	2.34% (10)	9.35% (40)
● item37	1.33	0.91	3.03	8.43	0.41*	0.09			84.58% (362)	7.01% (30)	3.04% (13)	1.64% (7)	3.74% (16)
● item38	4.30	1.08	-1.79	2.53	0.67*	0.32			5.37% (23)	3.50% (15)	5.37% (23)	27.57% (118)	58.18% (249)
● item39	1.96	0.98	1.02	0.69	0.82*	0.07			37.62% (161)	38.79% (166)	15.65% (67)	5.61% (24)	2.34% (10)
● item40	2.16	1.19	0.71	-0.54	0.84*	0.25			39.49% (169)	25.00% (107)	19.63% (84)	11.45% (49)	4.44% (19)
● item41	1.31	0.81	2.75	6.92	0.43*	0.14			85.05% (364)	4.67% (20)	6.07% (26)	3.04% (13)	1.17% (5)
● item42	3.93	1.48	-1.06	-0.44	0.71*	0.15			14.72% (63)	5.84% (25)	7.94% (34)	14.95% (64)	56.54% (242)
● item43	1.64	1.18	1.79	2.02	0.60*	0.22			71.26% (305)	9.35% (40)	10.05% (43)	2.80% (12)	6.54% (28)
● item44	3.51	1.30	-0.70	-0.59	0.85*	0.40			13.55% (58)	7.24% (31)	18.69% (80)	35.98% (154)	24.53% (105)
● item45	2.22	1.48	0.71	-1.02	0.76*	0.29			53.04% (227)	7.01% (30)	16.36% (70)	11.92% (51)	11.68% (50)
● item46	1.76	1.23	1.35	0.44	0.66*	0.39			67.06% (287)	7.71% (33)	11.68% (50)	8.88% (38)	4.67% (20)
● item47	2.11	1.17	0.77	-0.39	0.83*	0.37			41.12% (176)	24.77% (106)	20.09% (86)	9.81% (42)	4.21% (18)
● item48	2.60	1.25	0.29	-0.86	0.89*	0.36			25.00% (107)	21.50% (92)	30.84% (132)	13.79% (59)	8.88% (38)

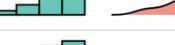
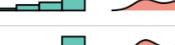
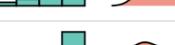
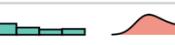
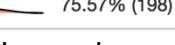
^aShapiro-Wilk test

Sup.Fig. 1. Summary descriptive statistics and response pattern of EFA sample (n=428). All items violated normality assumptions

LEBA: Supplementary Materials

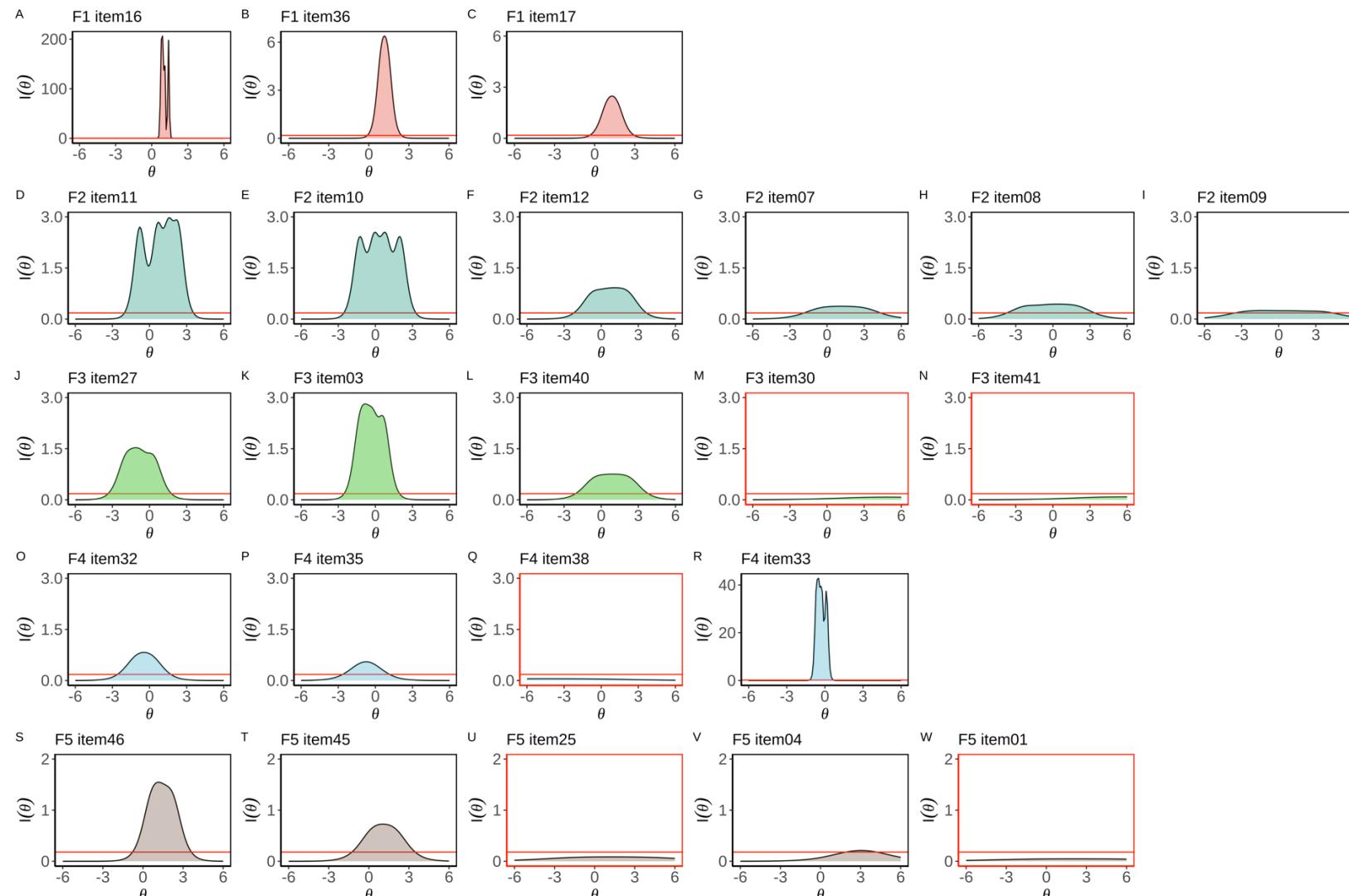
Light Exposure Behavior Assessment

Summary Descriptives CFA Sample (n=262)

Items	Summary Statistics			Graphics		Response Pattern					
	n	Mean	Median	SD	Histogram	Density	Never	Rarely	Sometimes	Often	Always
F1: Wearing blue light filters											
● 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)
● item36	262	1.6	1.0	1.3			80.53% (211)	3.44% (9)	3.05% (8)	3.44% (9)	9.54% (25)
F2: Spending time outdoors											
● 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)
F3: Using phone and smart-watch in bed											
● item03	262	3.7	4.0	1.3			11.83% (31)	7.25% (19)	17.56% (46)	28.24% (74)	35.11% (92)
● 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)
● 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)
F4: Using light before bedtime											
● 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)
● item38	262	4.3	5.0	1.1			4.20% (11)	7.63% (20)	6.49% (17)	21.37% (56)	60.31% (158)
F5: Using light in the morning and during daytime											
● item01	262	2.3	2.0	1.4			40.46% (106)	22.52% (59)	14.50% (38)	10.69% (28)	11.83% (31)
● item04	262	1.3	1.0	0.8			89.31% (234)	2.29% (6)	3.44% (9)	3.05% (8)	1.91% (5)
● item25	262	2.5	2.0	1.4			32.82% (86)	18.32% (48)	21.76% (57)	16.79% (44)	10.31% (27)
● 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)

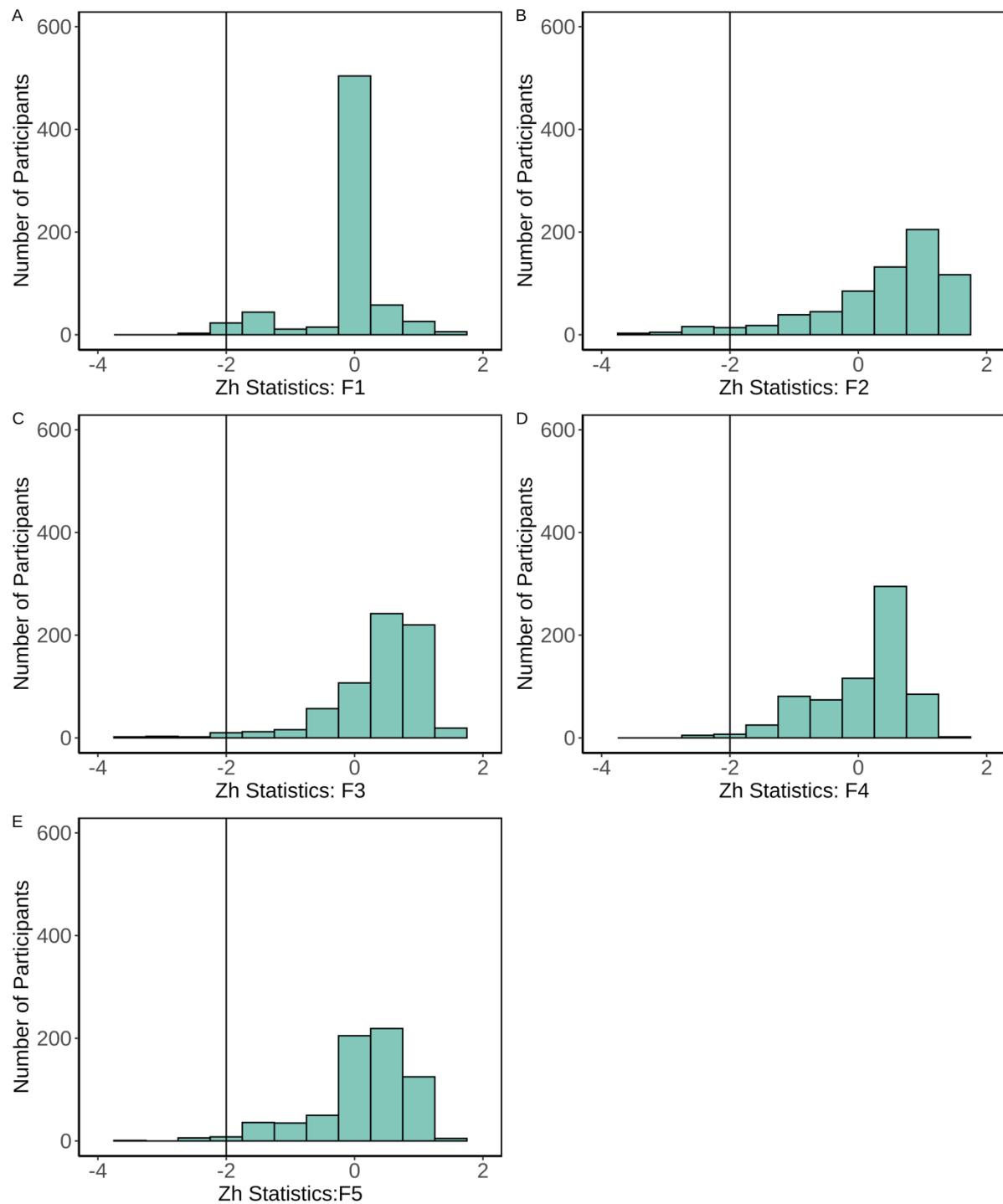
Sup.Fig.2. Summary descriptive statistics and response pattern of CFA sample (n=262).

LEBA: Supplementary Materials



Sup. Fig.3. Item information curves for all items of LEBA. The red boxed five items (1, 25, 30, 38, 41) had relatively flat information curves.

LEBA: Supplementary Materials



Sup. Fig. 4. Person fit of the five fitted IRT models (a) wearing blue light filters (b) spending time outdoors (c) using phone and smart-watch in bed (d) using light before bedtime (e) using light in the morning and during daytime. Most of the Zh values are higher than -2.