

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

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50

Abstract

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

56 An expert panel prepared the initial 48 item pool. Responses, consisting rating the
57 frequency of engaging in the per-item behavior on a 5-point Likert type scale were
58 collected in an online survey producing responses from an international sample (690
59 completed responses, 74 countries, 28 time zones). Exploratory factor analysis (EFA) on
60 an initial subset of our sample (n=428) rendered a five-factor solution with 25 items
61 (Wearing blue light filters, spending time outdoors, using phone and smart-watch in bed,
62 using light before bedtime, using light in the morning and during daytime). In a
63 confirmatory factor analysis (CFA) performed on an independent subset of participants
64 (n=262), we removed two further items to attain the best fit for the five-factor solution
65 (CFI=0.97, TLI=0.96, RMSEA=0.05, SRMR=0.09). The internal consistency reliability
66 coefficient for the total instrument was McDonald's omega_total=0.73. Measurement
67 model invariance analysis between native and non-native English speakers showed our
68 model attained the highest level of invariance (residual invariance; CFI=0.95, TLI =0.95,
69 RMSEA=0.05). Lastly, a short form of LEBA (n=18) was developed using Item Response
70 Theory on the complete sample (n=690).

71

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

⁷⁵ *Keywords:* light exposure, light-related behaviours, non-visual effects of light,

⁷⁶ psychometrics

⁷⁷ 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

88 Item Generation

To ensure construct adequacy we thoroughly assessed the current status of literature and identified a variety of light exposure related scales. However, no scales specifically measuring the behavioural component of light exposure were found (see Table 1). Consequentially we pursued to introduce a new openly available scale to address this research gap. For this purpose, an expert researcher panel from the fields of chronobiology, light research, neuroscience, and psychology – comprising all authors of the present manuscript – generated and collected preliminary item ideas. Special attention was paid to design items circumscribed to assess light exposure *behaviour* as opposed to subjective measurements of the light environment (Dianat, Sedghi, Bagherzade, Jafarabadi, & Stedmon, 2013; Eklund & Boyce, 1996) and semi-quantitative assessments of light sources' illuminance (Bajaj, Rosner, Lockley, & Schernhammer, 2011) in order to maintain content validity. In a collective effort the

101 generated items were then peer-reviewed, amended, unified, and complemented with a
102 suitable response scale (5-point Likert-scale ranging from 1 “Never/Does not apply/I
103 don’t know” to 5 “Always”). This process was finalized when all experts were in
104 agreement, resulting in 48 items to implement in the data collection.

105 **Survey characteristics**

106 Data was collected in a quantitative cross-sectional approach via a fully
107 anonymous online survey hosted on REDCap (Harris et al., 2019, 2009) by way of the
108 University of Basel sciCORE. Participants were recruited via the website of a Comic
109 co-released with the survey(Weinzaepflen & Spitschan, 2021), social media (i.e.,
110 LinkedIn, Twitter, Facebook), mailing lists, word of mouth, the investigators’ personal
111 contacts, and supported by distribution of the survey link via f.lux (F.lux Software LLC,
112 2021). Completing the online survey took approx. 15 to 20 minutes and was not
113 compensated. The first page of the survey comprised a participant information sheet,
114 where participants’ informed consent to participate was obtained before any of the
115 questions were displayed. Underaged participants (<18 years) were urged to obtain
116 assent from their parents/legal guardians, before filling in the survey. Information on the
117 first page included the objectives of the study, inclusion criteria, estimated duration, the
118 use, storage and sharing of the data, compensation (none), and information about the
119 type of questions in the survey. Moreover, participants needed to confirm that they were
120 participating the survey for the first time. To ensure high data quality, five attention check
121 items were included in the survey (e.g., “We want to make sure you are paying attention.
122 What is 4+5?”). The data analysed in this study was collected between 17 May 2021 and
123 3 September 2021. Questions incorporating retrospective recall were all aligned to the
124 period of “past four weeks,” matching the presented LEBA instrument.

125 In addition to the LEBA questionnaire, which is subject of the current study, we
126 assessed other variables and items which were not included in the present analysis.

127 This comprised various sleep-related measures, i.e., sleep disturbances and
128 sleep-related impairment (adult and pediatric versions) (Bevans et al., 2019; Daniel J.
129 Buysse et al., 2010; Forrest et al., 2018; Harb, Hidalgo, & Martau, 2015; L. Yu et al.,
130 2011), sleep duration, timing, and latency, chronotype, social jetlag, time in bed,
131 work/sleep schedule and outdoor light exposure duration (MCTQ version for adults and
132 adolescents Roenneberg, Wirz-Justice, & Merrow, 2003) plus sleep environment (Olivier
133 et al., 2016). Furthermore, we included a light sensitivity questionnaire (photophobia
134 vs. photophilia) (Wu & Hallett, 2017) and self-reported pubertal stage assessment
135 (Petersen, Crockett, Richards, & Boxer, 1988) for participants younger than 18 years of
136 age. Moreover, we incorporated custom items on meal timing and caffeine consumption
137 in the “workday vs. free day” structure of the MCTQ sleep-wake regulation. Example
138 items are: “On workdays I usually have my first meal at :” “On free days I usually have
139 my last meal at :” and “On workdays I usually drink my first caffeinated drink at :”

140 Finally, we assessed age, sex, gender identity, occupational status, COVID-19
141 related occupational setting, time zone/country of residence and native language as
142 single-item demographic variables. The demographic characteristics of our sample are
143 given in Table ??.

144 Analytic Strategies

145 Figure 1 summarizes the steps of our psychometric analysis. In our analysis we
146 used R (version 4.1.0), with several R packages. Initially, our tool had six point Likert
147 type response format (0:Does not apply/I don't know; 1:Never, 2:Rarely; 3:Sometimes;
148 4:Often; 5:Always). Our purpose was to capture light exposure related behavior and
149 these two response options: “Does not apply/I don't know” and “Never” were providing
150 similar information. As such we decided to collapse them into one, making it a 5 point
151 Likert type response format. Necessary assumptions of EFA, including sample
152 adequacy, normality assumptions, quality of correlation matrix, were assessed. Our data

153 violated both the univariate and multivariate normality assumptions. Due to these
154 violations and the ordinal nature of our response data, we used polychoric correlation
155 matrix (Desjardins & Bulut, 2018) for the EFA. We employed principal axis (PA) as factor
156 extraction method with varimax rotation. PA is robust to the normality assumption
157 violations (Watkins, 2020). The obtained latent structure was confirmed by another factor
158 extraction method: “the minimum residuals extraction” as well. We used a combination
159 of factor identification method including scree plot (Cattell, 1966), Horn’s parallel analysis
160 (Horn, 1965), minimum average partials method (Velicer, 1976), and hull method
161 (Lorenzo-Seva, Timmerman, & Kiers, 2011) to identify factor numbers. Additionally, to
162 determine the simple structure, we followed the guidelines recommended by
163 psychometricians: (i) no factors with fewer than three items (ii) no factors with a factor
164 loading <0.3 (iii) no items with cross-loading greater than .3 across factors (Bandalos &
165 Finney, 2018). We confirmed the latent structure obtained in the EFA by conducting a
166 categorical “Confirmatory Factor Analysis” (CFA) using “robust weighted least square
167 estimator” (WLSMV). We established the measurement invariance of our tool across the
168 native and non-native English speakers using structural equation model framework. To
169 assess the possible semantic overlap of our tool with the existing tools, we sought to
170 “Semantic Scale Network” (Rosenbusch, Wanders, & Pit, 2020). To assess the possible
171 semantic overlap of our tool with the existing tools, we sought to “Semantic Scale
172 Network” (Rosenbusch et al., 2020). Lastly, we sought “Item Response Theory” (IRT)
173 based analysis on developing a short form of LEBA. We also conducted psychometric
174 analysis on non-merged response options data (Supp. Table A9) and rejected the latent
175 structure obtained as the factors were less interpretable.

176 **Ethical approval**

177 By reason of using fully anonymous online survey data, the present research
178 project does not fall under the scope of the Human Research Act, making an

179 authorisation from the ethics committee redundant. Nevertheless, the cantonal ethics
180 commission (Ethikkommission Nordwest- und Zentralschweiz, EKNZ) reviewed our
181 proposition (project ID Req-2021-00488) and issued an official clarification of
182 responsibility (full document see Suppl. X in appendix).

183 **Data Availability**

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

189 **Results**

190 **Participants**

191 Table ?? summarizes the survey participants’ demographic characteristics. Only
192 participants completing the full LEBA questionnaire were included, thus there are no
193 missing values in the item analyses. XX participants were excluded from analysis due to
194 not passing at least one of the “attention check” items. For exploring initial factor
195 structure (EFA), a sample of 250-300 is recommended (Comrey & Lee, 1992; Schönbrodt
196 & Perugini, 2013). For estimating the sample size for the confirmatory factor analysis
197 (CFA) we followed the N:q rule (Bentler & Chou, 1987; Jackson, 2003; Kline, 2015;
198 Worthington & Whittaker, 2006), where ten participants per parameter is required to earn
199 trustworthiness of the result. Our sample size exceeds these requirements: Anonymous
200 responses from a total of $n = 690$ participants were included in the analysis of the current
201 study, split into samples for exploratory (EFA: $n = 428$) and confirmatory factor analysis
202 (CFA: $n = 262$). The EFA sample included participants filling out the questionnaire from
203 17 May 2021 to XX XXX 2021, whereas participants who filled out the questionnaire from

204 YY YYY 2021 to 3 September 2021 were included in the CFA analysis. Participants
205 indicated filling out the online survey from a diverse range of geographic locations. The
206 ten most common country and time zone combinations included:

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

217 For a complete list of geographic locations, see Suppl. Table A11.

218 Age among all participants ranged from 11 years to 84 years [EFA: *min* = 11, *max* =

219 84; CFA: *min* = 12, *max* = 74], with an overall mean of ~ 33 years of age [Overall: *M* =
220 32.95, *SD* = 14.57; EFA: *M* = 32.99, *SD* = 15.11; CFA: *M* = 32.89, *SD* = 13.66]. In total
221 325 (47%) of the participants indicated female sex [EFA: 189 (44%); CFA: 136 (52%)],
222 351 (51%) indicated male [EFA: 230 (54%); CFA: 121 (46%)] and 14 (2.0%) indicated
223 other sex [EFA: 9 (2.1%), CFA: 5 (1.9%)]. Overall, 49 (7.2%) [EFA: 33 (7.8%); CFA: 16
224 (6.2%)] participants indicated a gender-variant identity. In a “Yes/No” question regarding
225 native language, 320 (46%) of respondents [EFA: 191 (45%); CFA: 129 (49%)] indicated
226 to be native English speakers. For their “Occupational Status,” more than half of the
227 overall sample reported that they currently work [Overall: 396 (57%); EFA: 235 (55%);
228 CFA: 161 (61%)], whereas 174 (25%) [EFA: 122 (29%); CFA: 52 (20%)] reported that
229 they go to school and 120 (17%) [EFA: 71 (17%); CFA: 49 (19%)] responded that they do

230 "Neither." With respect to the COVID-19 pandemic we asked participants to indicate their
231 occupational setting during the last four weeks: In the overall sample 303 (44%) [EFA:
232 194 (45%); CFA: 109 (42%)] of the participants indicated that they were in a home office/
233 home schooling setting, while 109 (16%) overall [EFA: 68 (16%) ; CFA: 41 (16%)]
234 reported face-to-face work/schooling. Lastly, 147 (21%) overall [EFA: 94 (22%) ; CFA: 53
235 (20%)] reported a combination of home- and face-to-face work/schooling, whereas 131
236 (19%) overall [EFA: 72 (17%); CFA: 59 (23%)] filled in the "Neither (no work or school, or
237 on vacation)" response option. We tested all demographic variables in Table 1 for
238 significant group differences between the EFA and CFA sample, applying Wilcoxon rank
239 sum test for the continuous variable "Age" and Pearson's χ^2 test for all other categorical
240 variables via the gtsummary R package's "add_p" function (Sjoberg et al., 2021a) . The
241 p-values were corrected for multiple testing applying false discovery rate (FDR) via the
242 "add_q" function of the same package. After p-value (FDR) correction for multiple testing,
243 none of the demographic variables were significantly different between the EFA sample
244 and the CFA sample (all q-values $q \geq 0.2$).

245 Item Analysis

246 Table 3 summarizes the univariate descriptive statistics for the 48 items. Some of
247 the items were skewed with high Kurtosis values. Our data violated both univariate
248 normality (Shapiro-Wilk statistics; (Shapiro & Wilk, 1965)) and multivariate normality
249 assumptions [Marida's test;(Mardia, 1970)]. Multivariate skew was = 583.80 ($p <0.001$)
250 and multivariate kurtosis was = 2,749.15 ($p <0.001$). Due to these violations and ordinal
251 nature of the response data polychoric correlations over Pearson's correlations was
252 chosen (Desjardins & Bulut, 2018). The corrected item-total correlation ranges between
253 .03 -.48. However, no item was discarded based on descriptive statistics or item analysis.

254 Exploratory Factor Analysis

255 Sampling adequacy was checked using Kaiser-Meyer-Olkin (KMO) measures of
256 sampling adequacy (Kaiser, 1974). The overall KMO vale for 48 items was 0.63 which
257 was above the cutoff value (.50) indicating a mediocre sample (Hutcheson, 1999).

258 Bartlett's test of sphericity (Bartlett, 1954), χ^2 (1128) = 5042.86, p < .001 indicated the
259 correlations between items are adequate for the EFA. However only 4.96% of the
260 inter-item correlation coefficients were greater than .30. The absolute value of inter-item
261 correlation ranged between .00 to .91. Figure 2 depicts the correlation matrix.

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

267 With the initial 48 items we conducted three rounds of EFA and gradually discarded
268 problematic items. (cross-loading items and poor factor loading (<.30) items). Finally, a
269 five-factor EFA solution with 25 items was accepted with low RMSR = 0.08 (Brown,
270 2015), all factor-loading higher than .30 and no cross-loading greater than .30. We
271 further confirmed this five-factor latent structure by another EFA using varimax rotation
272 with a minimum residual extraction method (Sup.Table A7). Table 4 displays the
273 factor-loading (structural coefficients) and communality of the items. The absolute value
274 of the factor-loading ranged from .49 to .99 indicating strong coefficients. The
275 commonalities ranged between .11 to .99. Figure 4(A) depicts the obtained five factor
276 structure. However, the histogram of the absolute values of non-redundant
277 residual-correlations (Figure 4(B)) showed 26% correlations were greater than the
278 absolute value of .05, indicating a possible under-factoring. (Desjardins & Bulut, 2018).
279 Subsequently, we fitted a six-factor solution. However, a factor emerged with only two

280 salient variables, thus disqualifying the six-factor solution (Sup.Table A8). Internal
281 consistency reliability coefficient Cronbach's alpha assumes all the factor-loadings of the
282 items under a factor are equal (Graham, 2006; Novick & Lewis, 1967) which is not the
283 case in our sample. Additionally Cronbach's alpha coefficient has a tendency to deflate
284 the estimates for Likert type data as the calculation is based on pearson-correlation
285 matrix which requires that response data should be in continuous of nature (Gadermann,
286 Guhn, & Zumbo, 2012; Zumbo, Gadermann, & Zeisser, 2007). Subsequently to get
287 better estimates of reliability we reported ordinal alpha which used polychoric-correlation
288 matrix and assumed that the responses data were ordered in nature instead of
289 continuous (Zumbo et al., 2007). Ordinal alpha coefficient value ranges from 0 to 1 and
290 higher value represents better reliability. In the five-factor solution, the first factor
291 contained three items and explained 10.25% of the total variance with a internal reliability
292 coefficient ordinal $\alpha = .94$. All the items in this factor stemmed from the individual's
293 preference to use blue light filters in different light environments. The second factor
294 contained six items and explained 9.93% of the total variance with a internal reliability
295 coefficient ordinal $\alpha = .76$. Items under this factor commonly investigated an individual's
296 hours spent outdoor. The third factor contained five items and explained 8.83% of the
297 total variance. Items under this factor dealt with the specific behaviors pertaining to using
298 phone and smart-watch in bed. The internal consistency reliability coefficient was,
299 ordinal $\alpha = .75$. The fourth factor contained five items and explained 8.44% of the total
300 variance with an internal consistency coefficient, ordinal $\alpha = .72$. These five items
301 investigated the behaviors related to individual's light exposure before bedtime. Lastly,
302 the fifth factor contained six items and explained 6.14% of the total variance. This factor
303 captured individual's morning and daytime light exposure related behavior. The internal
304 consistency reliability was, ordinal $\alpha = .62$. It is essential to attain a balance between
305 psychometric properties and interpretability of the common themes when exploring the
306 latent structure. As all of the emerged factors are highly interpretable and relevant

307 towards our aim to capture light exposure related behavior, regardless of the apparent
308 low reliability of the fifth factor, we retain all the five-factors with 23 items for our
309 confirmatory factor analysis (CFA). Two items showed negative factor-loading (items 44
310 and 21). Upon inspection, it was understood that these items are negatively correlated to
311 the common theme, and thus in the CFA analysis, we reversed the response code for
312 these two items. Figure ?? depicts the data distribution and endorsement pattern for the
313 included items in our LEBA tool for both the EFA and CFA sample.

314 **Confirmatory Factor Analysis**

315 We conducted categorical confirmatory factor analysis with robust weighted least
316 square (WLSMV) estimator since our response data was of ordinary nature (Desjardins
317 & Bulut, 2018). Several indices are suggested to measure model fit which can be
318 categorized as absolute, comparative and parsimony fit indices (Brown, 2015). Absolute
319 fit assess the model fit at an absolute level using indices including χ^2 test statistics and
320 the standardized root mean square (SRMR). Parsimony fit indices including the root
321 mean square error of approximation (RMSEA) considers the number of free parameters
322 in the model to assesses the parsimony of the model. Comparative fit indices evaluate
323 the fit of the specified model solution in relation to a more restricted baseline model
324 restricting all covariances among the indicators as zero. Comparative fit index (CFI) and
325 the Tucker Lewis index (TLI) are such two comparative fit indices. Commonly used
326 Model fit guidelines (Hu & Bentle, 1999; Schumacker & Lomax, 2004) includes (i)
327 Reporting of χ^2 test statistics (A non-significant test statistics is required to reflect model
328 fit) (ii) CFI and TLI (CFI/TLI close to .95 or above/ranging between 90-95 and above) (iii)
329 RMSEA (close to .06 or below), (iv) SRMR (close to .08 or below) to estimate the model
330 fit. Table 5 summarizes the fit indices of our fitted model. Our fitted model failed to attain
331 an absolute fit estimated by the χ^2 test. However, the χ^2 test is sensitive to sample size
332 and not recommended to be used as the sole index of absolute model fit (Brown, 2015).

333 Another absolute fit index we obtained in our analysis was SRMR which does not work
334 well with categorical data (C. Yu, 2002). We judged the model fit based on the
335 comparative fit indices: CFI, TLI and parsimony fit index:RMSEA. Our fitted model
336 attained acceptable fit (CFI = .94; TLI = .93); RMSEA = .06,[.05-.07, 90% CI]) with two
337 imposed equity constrain on item pairs 32-33 [I dim my mobile phone screen within 1
338 hour before attempting to fall asleep.;I dim my computer screen within 1 hour before
339 attempting to fall asleep.] and 16-17 [I wear blue-filtering, orange-tinted, and/or
340 red-tinted glasses indoors during the day.;I wear blue-filtering, orange-tinted, and/or
341 red-tinted glasses outdoors during the day.]. Items pair 32-33 stemmed from the
342 preference of dimming electric device's brightness before bed time and items pair 16 and
343 19 stemmed from the preference of using blue filtering or colored glasses during the
344 daytime. Nevertheless, SRMR value was higher than the guideline (SRMR = .12).
345 Further by allowing one pair of items (30-41) [I look at my smartwatch within 1 hour
346 before attempting to fall asleep.;I look at my smartwatch when I wake up at night.] to
347 covary their error variance and discarding two item (item 37 & 26) for very low r-square
348 value, our model attained best fit (CFI = .95; TLI = .95); RMSEA = .06[.05-.06, 90% CI])
349 and SRMR value (SRMR = .11) was also close to the suggestions of Hu and Bentle
350 (1999). Internal consistency ordinal α for the five factors of LEBA were .96, .83, .70, .69,
351 .52 respectively. We also estimated the internal consistency reliability of the total scale
352 using McDonald's ω_t coefficient which is a better reliability estimate for multidimensional
353 constructs (Dunn, Baguley, & Brunsden, 2014; Sijtsma, 2009). McDonald's ω_t coefficient
354 for the total scale was .68. Figure 7 depicts the obtained CFA structure.

355 Measurement Invariance

356 Measurement invariance (MI) evaluates whether a construct has the psychometric
357 equivalence and same meaning across groups or measurement occasions (Kline, 2015;
358 Putnick & Bornstein, 2016). We used structural equation modeling framework to assess

359 the measurement invariance of our developed tool across two groups: native English
360 speakers(n= 129) and non-native English speakers (n = 133). For a detailed description
361 these two groups please see Sup. Table ???. Our measurement invariance testing
362 involved successively comparing the nested models: configural, metric, scalar, and
363 residual invariance models with each others (Widaman & Reise, 1997). Among these
364 nested models configural model is the first and least restrictive model. The configural
365 model assumes that the number of factors and item number under each factor will be
366 equal across two groups. The metric invariance model assumes configural invariance of
367 the fitted model and requires the factor-loadings of the items across the two groups to be
368 equal. Having the factor-loadings equal across groups indicates each item contributes to
369 the measured construct equivalently. Scalar invariance assumes the metric invariance of
370 the fitted model demands the item intercepts to be equivalent across groups. This equity
371 of item intercepts indicates the equivalence of response scale across the groups, i.e.,
372 persons with the same level of the underlying construct will score the same across the
373 groups. The residual invariance model assumes metric invariance for the fitted model
374 and adds the assumption of equality in error variances and covariances across the
375 groups. This model is the highest level of MI and assures the equivalence of precision of
376 items across the groups in measuring the underlying constructs. The invariance model fit
377 of our tool was assessed using the fit indices including χ^2 test, CFI and TLI (close to .95
378 or above), RMSEA (close to .06 or below) (Hu & Bentle, 1999). We excluded SRMR
379 from our consideration as it does not behave optimally for categorical variables (C. Yu,
380 2002). Table 6 summarized the fit indices. The comparison among different
381 measurement invariance models was made using the χ^2 difference test ($\Delta\chi^2$) to
382 assess whether our obtained latent structure of “LEBA” attained the highest level of the
383 MI. A non-significant $\Delta\chi^2$ test between two MI models fit indicates mode fit does not
384 significantly decrease for the superior model (Dimitrov, 2010) thus allowing the superior
385 level of invariance model to be accepted. We started our analysis by comparing the

386 model fit of the least restrictive model:configural model to metric MI model and continued
387 successive comparisons. Table 6 indicates that our fitted model had acceptable fit
388 indices for all of the fitted MI models. The model fit did not significantly decrease across
389 the nested models up to the scalar MI model. The chi-square value difference between
390 the scalar and residual model is zero, indicating model fit remained the same for both:
391 scalar and residual MI model, indicating the acceptability of the residual MI model.

392 **Semantic Analysis**

393 To find out if our developed tool (23 items) is overlapping with existing instruments,
394 we subjected the items of LEBA to the “Semantic Scale Network”(SSN) analysis
395 (Rosenbusch et al., 2020). The SSN detects semantically related scales and provides
396 cosine similarity index ranging between -.66 to 1 (Rosenbusch et al., 2020). Pair of
397 scales with a cosine similarity index value of 1 indicates they are perfectly semantically
398 similar scales indicating redundancy. LEBA appeared most strongly related to scales
399 about sleep: “Sleep Disturbance Scale For Children” (Bruni et al., 1996) and
400 “WHO-Composite International Diagnostic Interview (CIDI): Insomnia”(WHO, 1990).The
401 cosine similarities lie between .47 to .51. Flesch-Kincaid Grade Level (Flesch, 1948)
402 analysis on the the 23 items of our scale indicated required educational grade level was
403 3.33 and with a age above 8.33.

404 ## |

405 **Developing Short form of LEBA**

406 We sought the Item Response Theory (IRT) to develop the short form of LEBA. IRT
407 the conventional classical test theory-based analysis by gathering information on item
408 quality by indices like item difficulty, item discrimination, and item information (Baker,
409 2017). Item is judged based on item information in relation to participants' latent trait level
410 (θ). We fitted each factor of LEBA with the graded response model (Samejima, Liden, &

411 Hambleton, 1997) to the combined EFA and CFA sample (n =690). Item discrimination
412 indicates the pattern of variation in the categorical responses with the changes in latent
413 trait level (θ), and item information curve (IIC) indicates the amount of information an
414 item carries along the latent trait continuum. Here, we reported the item discrimination
415 parameter and only discarded the items with relatively flat item information curve
416 (information <.2) to develop the short form of LEBA. Baker (2017) categorized the item
417 discrimination in as none = 0; very low =0.01 to 0.34; low = 0.35 to 0.64; moderate = 0.65
418 to 1.34 ; high = 1.35 to 1.69; very high >1.70. Table 7 summarizes the IRT parameters of
419 our tool. Item discrimination parameters of our tool fell in very high (10 items), high (4
420 items), moderate (4 items), and low (5 items) categorizes indicating a good range of
421 discrimination along the latent trait level (θ). Examination of the item information curve
422 (Sup.fig A1) indicated 5 items (1, 25, 38, 30, & 41) had relatively flat information curves
423 ($I(\theta) < .20$) thus discarded creating a short form of LEBA with 5 factors and 18 items.

424 Test information curve (TIC) (Figure 8) indicate the amount of information an the
425 full-scale carry along the latent trait continuum. As we treated each factor of short-LEBA
426 as an unidimensional construct we obtain 5 TICs (Figure 8). These information curves
427 indicated except the first and fifth factors, the other three factor's TICs are roughly
428 centered on the center of the trait continuum (θ).The first and fifth factor had a peak to
429 the right side of the center of latent trait.Thus we conferred the LEBA tool estimated the
430 light exposure related behavior with precision near the center of trait continuum for 2nd,
431 3rd and 4th factors and near the right side of the center of trait continuum for 1st and 5th
432 factors (Baker, 2017).

433 Table 8 summarizes the item fit indexes of the items. All the items fitted well to the
434 respective models as assessed by RMSEA value obtained from Signed- χ^2 index
435 implementation. All of the items had RMSEA value $\leq .06$ indicating adequate fit.
436 Sup.Figure A2 depicts the person fit of out fitted models. Person fit indicates the validity

437 and meaningfulness of the fitted model at the participants latent trait level (Desjardins &
438 Bulut, 2018). We estimated the person fit statistics using standardized fit index Z_h
439 statistics (Drasgow, Levine, & Williams, 1985). $Z_h < -2$ should be considered as a misfit.
440 Fig indicates that Z_h is larger than -2 for most participants, suggesting a good fit of the
441 selected IRT models.

442 **Discussion**

443 We developed a self-reported tool to capture different light exposure related
444 behavior and evaluated its psychometric properties using classical test theory and Item
445 Response Theory based analysis.

446 48 items were generated by an expert panel and administered to a large sample (n
447 = 428 to explore the latent structure. Exploratory Factor Analysis revealed a five factor
448 solution with 25 items. (“Wearing blue light filters,” “Spending time outdoors,” “Using
449 phone and smart-watch in bed,” “Using light before bedtime,” and “Using light in the
450 morning and during daytime”). The internal consistency reliability coefficient ordinal
451 alpha ranged between .62-.94. As all the retained factors were meaningful and
452 contributed essentially towards our aim we retained all five factors.

453 A CFA on a separate sample (($n = 262$ gave a five-factor solution (CFI = .95; TLI =
454 .95); RMSEA = .06[.05-.06, 90% CI]) and SRMR = .11) after discarding two item. The
455 internal consistency McDonald’s ω_t of the five factors were satisfactory (.96, .83, .70,
456 .69, .52) Internal consistency reliability of the total scale (23 items) was also satisfactory,
457 McDonald’s $\omega_t = .68$. In the same sample, our measurement invariance analysis
458 revealed that the latent structure attained the residual measurement invariance across
459 subgroups: male and female (CFI: .98, TLI: .98, SRMR: .98).

460 The “Semantic Scale Network”(SSN) analysis (Rosenbusch et al., 2020) on the
461 retained 23 items showed “LEBA” was related to “Sleep Disturbance Scale For Children”

462 (SDSC) (Bruni et al., 1996) and “WHO-Composite International Diagnostic Interview
463 (CIDI): Insomnia”(WHO, 1990). Upon inspecting the item contents we found items under
464 “Using phone and smart-watch in bed” and “Using light before bedtime” have semantic
465 overlap with the items of SDSC ans CIDI. Items in those two scales were looking into
466 behaviors related to sleep. As such the similarity index obtained is expected.
467 Flesch-Kincaid Grade Level (Flesch, 1948) analysis on the the 23 items of our scale
468 indicated required educational grade level was 3.33 and with a age above 8.33.

469 Lastly, we developed a short-LEBA (n=23) using IRT analysis. We fitted a graded
470 response model model to the combined EFA and CFA sample (n =690). We discarded 5
471 items with relatively flat item information curve [$I(\theta) < .20$]. IRT analysis indicated short
472 form of LEBA is a psychometrically sound measure. Item fit indexes and person fit index
473 for all five fitted model were acceptable. Items had diverse slope parameters indicating a
474 good range of discrimination- the ability to differentiate respondents with different levels
475 of the light exposure related behavior. Test information curve also indicated a good
476 coverage of underlying trait continuum with precision.

477 **Conclusion**

478 “The Light exposure behavior assessment”(LEBA) gave a five solution with 25
479 items in an EFA. A CFA with this 25-item scale again offered a five-factor solution, but
480 this time two more item was discarded. The 23-item “LEBA” was found reliable and valid.
481 A short-form of LEBA was developed using IRT analysis. IRT analysis gave a 18-item
482 scale with a good range of coverage across the underlying trait continuum. All-in-all, we
483 can recommend both forms to be used to capture individual’s light exposure related
484 behavior

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Table 1

List of instruments measuring related constructs to LEBA

Name	Author	Description	Relevant Items	Scale type	Validity evidences
Visual Light Sensitivity Questionnaire-8	Verriotto et al., 2017	Eight-question survey to assess the presence and severity of photosensitivity symptoms	None	5-point Likert scale	Not available
Office Light Survey	Eklundet al., 1996	30 items survey to assess electrical lighting environment in office	Item 29	Mixed response format	Not available
Harvard Exposure Assessment Questionnaire	Bajaj et al., 2011	1 item semi-quantitative questionnaire	None light	Semi-quantitative	Correlation with physical measurement
Hospital Lighting Survey	Dianat et el., 2013	23 items questionnaire to assess light environment in a hospital	Item 16,17	5-point Likert scale	Face and Content validity
Morningness-Eveningness Questionnaire	Horne et al., 1976	19 items questionnaire to understand your body clock	item 1,2,8,13,14	Mixed response format	Correlation with oral temperature

Table 1 continued

Name	Author	Description	Relevant Items	Scale type	Validity evidences
Munich Chrono-type Questionnaire (MCTQ)	Roenneberg et al., 2003	17 items questionnaire to understand individuals phase of entrainment	Time spent outdoors	Mixed response format	Correlation with sleep-logs, actimetry, and physiological parameters
Sleep Practices and Attitudes Questionnaire (SPAQ)	Olivier et.al., 2016	16 Factor questionnaire measuring practice, behavior and attitude related sleep	Subscale 8&9	5-point Likert scale	Face and Construct validity
The Pittsburgh Sleep Quality Index (PSQI)	Buysse et al., 1989	9 items inventory to measure sleep quality and sleeping pattern	item 1-4	Mixed response format	Correlation with clinical measurements
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 3,6,22-25 and 29	5-point Likert scale	Construct validity
Photosensitivity Assessment Questionnaire (PAQ)	Bossini et al.,2006	16 dichotomous items questionnaire to assess "photophobia" and "photophilia"	All items	Binary response option	Not available

Table 2

Demographic Characteristics

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 False discovery rate correction for multiple testing³ Wilcoxon rank sum test⁴ Pearson's Chi-squared test

Table 3

Descriptive Statistics

Item	Stem	Mean	SD	Skew	Kurtosis	SW Statistics	Item-total corelation
item01	I turn on the lights immediately after waking up.	2.27	1.39	0.74	-0.81	0.81*	0.19
item02	I open the curtains or blinds immediately after waking up.	2.87	1.59	0.08	-1.60	0.83*	0.28
item03	I look at my mobile phone screen immediately after waking up.	3.36	1.38	-0.48	-1.03	0.87*	0.23
item04	I use an alarm with a dawn simulation light.	1.47	1.18	2.38	4.00	0.43*	0.24
item05	I have breakfast within 3 meters from a window.	4.01	1.40	-1.22	0.07	0.70*	0.17
item06	I have breakfast in a brightly lit room (illuminated by electric light).	2.79	1.55	0.19	-1.48	0.85*	0.13
item07	I go for a walk or exercise outside within 2 hours after waking up.	2.26	1.25	0.70	-0.60	0.85*	0.32
item08	I spend 30 minutes or less per day (in total) outside.	2.97	1.20	-0.06	-0.94	0.91*	0.25
item09	I spend between 30 minutes and 1 hour per day (in total) outside.	2.94	1.03	-0.12	-0.40	0.91*	0.08
item10	I spend between 1 and 3 hours per day (in total) outside.	2.74	1.04	0.09	-0.74	0.91*	0.42
item11	I spend more than 3 hours per day (in total) outside.	2.18	0.90	0.60	0.12	0.86*	0.41
item12	I spend as much time outside as possible.	2.36	1.22	0.59	-0.62	0.87*	0.48
item13	I use sunglasses when I go outside in bright daylight.	2.73	1.46	0.20	-1.36	0.87*	0.25
item14	I wear a visor or cap when I go outside in bright daylight.	2.14	1.31	0.77	-0.78	0.80*	0.28
item15	I seek shade when I am outside in bright daylight.	3.26	1.09	-0.26	-0.45	0.91*	0.03
item16	I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.	1.56	1.23	2.00	2.45	0.50*	0.28
item17	I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.	1.54	1.21	2.07	2.75	0.49*	0.21
item18	I use light therapy applying a white light box.	1.12	0.49	5.02	27.80	0.25*	0.18

Table 3 continued

Item	Stem	Mean	SD	Skew	Kurtosis	SW Statistics	Item-total corelation
item19	I use light therapy applying a blue light box.	1.05	0.36	7.23	52.98	0.13*	0.17
item20	I use light therapy applying a light visor.	1.04	0.33	8.99	85.28	0.10*	0.16
item21	I use light therapy applying another form of light device.	1.14	0.59	4.79	24.05	0.25*	0.21
item22	I spend most of my daytime in a brightly lit environment.	3.57	1.07	-0.65	-0.17	0.88*	0.20
item23	I close the curtains or blinds during the day if the light from outside is bright.	2.56	1.27	0.33	-1.00	0.89*	0.08
item24	I spend most of my indoor time within 3 meters from a window.	4.14	0.99	-1.23	1.14	0.79*	0.22
item25	I use a desk lamp when I do focused work.	2.59	1.41	0.27	-1.27	0.86*	0.15
item26	I turn on my ceiling room light when it is light outside.	2.25	1.27	0.69	-0.64	0.84*	0.08
item27	I use my mobile phone within 1 hour before attempting to fall asleep.	3.80	1.29	-0.87	-0.42	0.82*	0.17
item28	I use my computer/laptop/tablet within 1 hour before attempting to fall asleep.	3.76	1.14	-0.68	-0.45	0.86*	0.18
item29	I watch television within 1 hour before attempting to fall asleep.	2.44	1.31	0.38	-1.14	0.86*	0.13
item30	I look at my smartwatch within 1 hour before attempting to fall asleep.	1.48	1.11	2.18	3.35	0.48*	0.13
item31	I dim my room light within 1 hour before attempting to fall asleep.	3.00	1.62	-0.08	-1.61	0.83*	0.39
item32	I dim my mobile phone screen within 1 hour before attempting to fall asleep.	3.55	1.65	-0.60	-1.34	0.76*	0.33

Table 3 continued

Item	Stem	Mean	SD	Skew	Kurtosis	SW Statistics	Item-total corelation
item33	I dim my computer screen within 1 hour before attempting to fall asleep.	3.62	1.64	-0.68	-1.25	0.74*	0.37
item34	I use a blue-filter app on my mobile phone screen within 1 hour before attempting to fall asleep.	3.42	1.83	-0.45	-1.69	0.69*	0.20
item35	I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.	3.86	1.67	-0.99	-0.85	0.65*	0.20
item36	I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.	1.54	1.25	2.13	2.86	0.46*	0.35
item37	I purposely leave a light on in my sleep environment while sleeping.	1.33	0.91	3.03	8.43	0.41*	0.09
item38	I use as little light as possible when I get up during the night.	4.30	1.08	-1.79	2.53	0.67*	0.32
item39	I turn on the lights when I get up during the night.	1.96	0.98	1.02	0.69	0.82*	0.07
item40	I check my phone when I wake up at night.	2.16	1.19	0.71	-0.54	0.84*	0.25
item41	I look at my smartwatch when I wake up at night.	1.31	0.81	2.75	6.92	0.43*	0.14
item42	I close curtains or blinds to prevent light from entering the bedroom if I want to sleep.	3.93	1.48	-1.06	-0.44	0.71*	0.15
item43	I use a sleep mask that covers my eyes.	1.64	1.18	1.79	2.02	0.60*	0.22
item44	I modify my light environment to match my current needs.	3.51	1.30	-0.70	-0.59	0.85*	0.40
item45	I use LEDs to create a healthy light environment.	2.22	1.48	0.71	-1.02	0.76*	0.29
item46	I use tunable lights to create a healthy light environment.	1.76	1.23	1.35	0.44	0.66*	0.39

Table 3 continued

Item	Stem	Mean	SD	Skew	Kurtosis	SW Statistics	Item-total corelation
item47	I discuss the effects of light on my body with other people.	2.11	1.17	0.77	-0.39	0.83*	0.37
item48	I seek out knowledge on how to improve my light exposure.	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
item07		0.5				0.267	0.733
item08		-0.49				0.252	0.748
item09		0.32				0.113	0.887
item27			0.8			0.658	0.342
item03			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
item04					0.41	0.219	0.781
item01					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

Confirmatory Factor Analysis model fit indices of the two model: five factor model with 25 items and five factor model with 23 items. The second model attained the best fit.

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	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 6

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

	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

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

	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
item07	1.09	-0.50	0.73	1.63	2.97
Ritem08	1.19	-2.26	-0.48	0.64	1.91
item09	0.91	-2.63	-0.96	1.11	3.49
item27	2.21	-1.88	-1.19	-0.73	0.30
item03	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
item04	0.84	2.44	2.80	3.18	3.67
item01	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 discrimination, response category difficulty thresholds and fit statistics of the 18 items in short LEBA (n=690)

Items	a	b1	b2	b3	b4	Signed Chi-square	df	RMSEA	p
item16	28.55	0.78	0.90	1.06	1.40	2.01	6.00	0.00	0.92
item36	4.49	0.94	1.08	1.23	1.40	39.06	13.00	0.05	0.00
item17	2.81	0.97	1.11	1.38	1.62	25.58	13.00	0.04	0.02
item11	3.27	-0.79	0.65	1.54	2.31	55.03	27.00	0.04	0.00
item10	3.07	-1.27	-0.09	0.82	2.00	53.19	30.00	0.03	0.01
item12	1.72	-0.67	0.44	1.28	2.11	34.39	42.00	0.00	0.79
item07	1.09	-0.50	0.73	1.63	2.97	67.45	46.00	0.03	0.02
Ritem08	1.19	-2.26	-0.48	0.64	1.91	140.90	46.00	0.05	0.00
item09	0.91	-2.63	-0.96	1.11	3.49	131.19	45.00	0.05	0.00
item27	2.12	-1.91	-1.21	-0.74	0.31	16.41	11.00	0.03	0.13
item03	3.24	-1.22	-0.76	-0.20	0.65	15.10	11.00	0.02	0.18
item40	1.57	-0.50	0.45	1.30	2.20	9.91	9.00	0.01	0.36
item32	1.60	-1.04	-0.78	-0.42	0.16	41.38	15.00	0.05	0.00
item35	1.35	-1.10	-0.99	-0.76	-0.41	41.68	14.00	0.05	0.00
item33	14.17	-0.66	-0.48	-0.24	0.13	47.04	14.00	0.06	0.00
item46	2.36	0.66	0.87	1.35	2.12	19.01	15.00	0.02	0.21
item45	1.51	0.30	0.56	1.17	1.91	15.04	15.00	0.00	0.45
item25	0.48	-1.45	-0.04	2.00	4.47	31.61	15.00	0.04	0.01

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

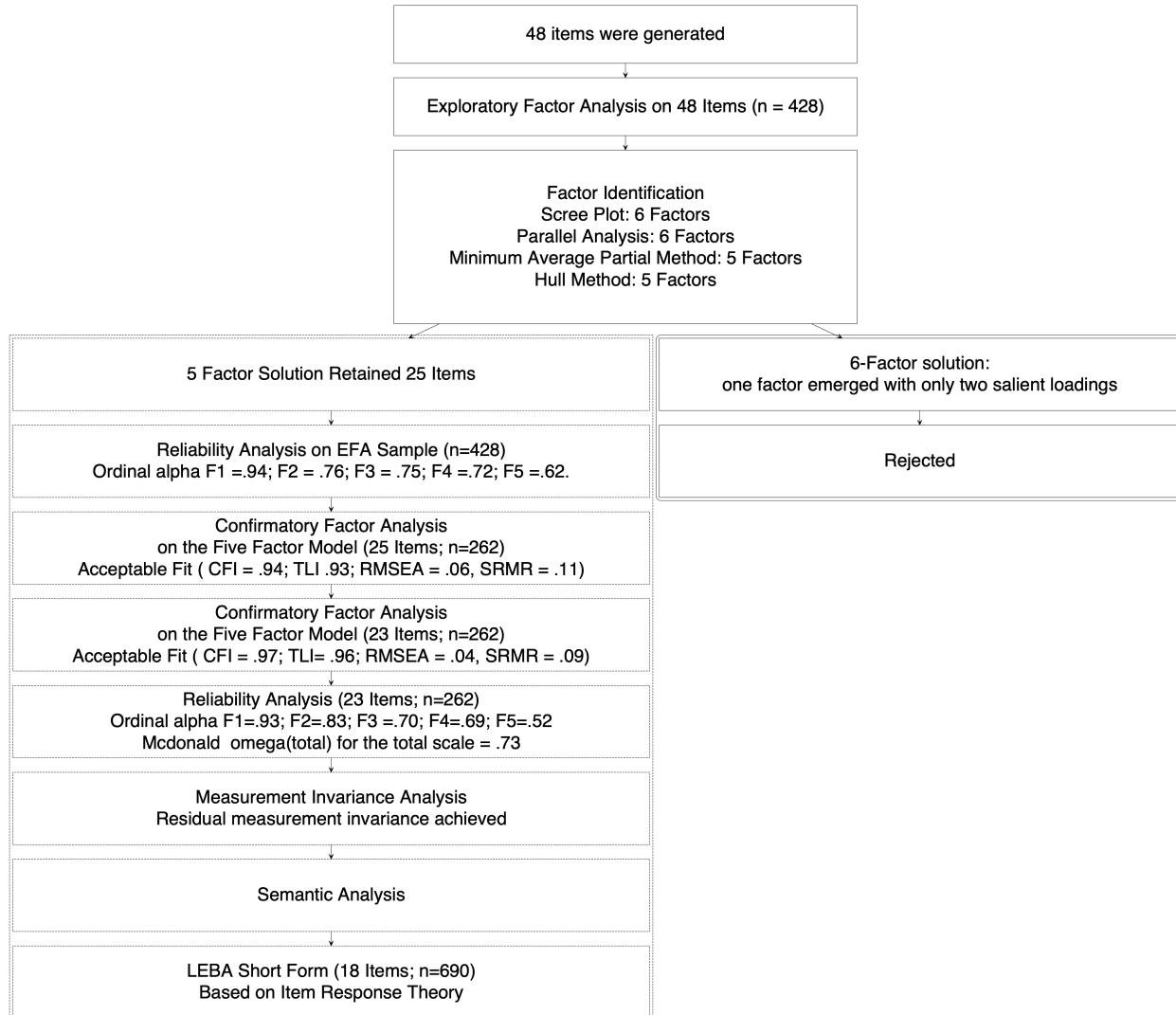


Figure 1. Development of long and short form of LEBA

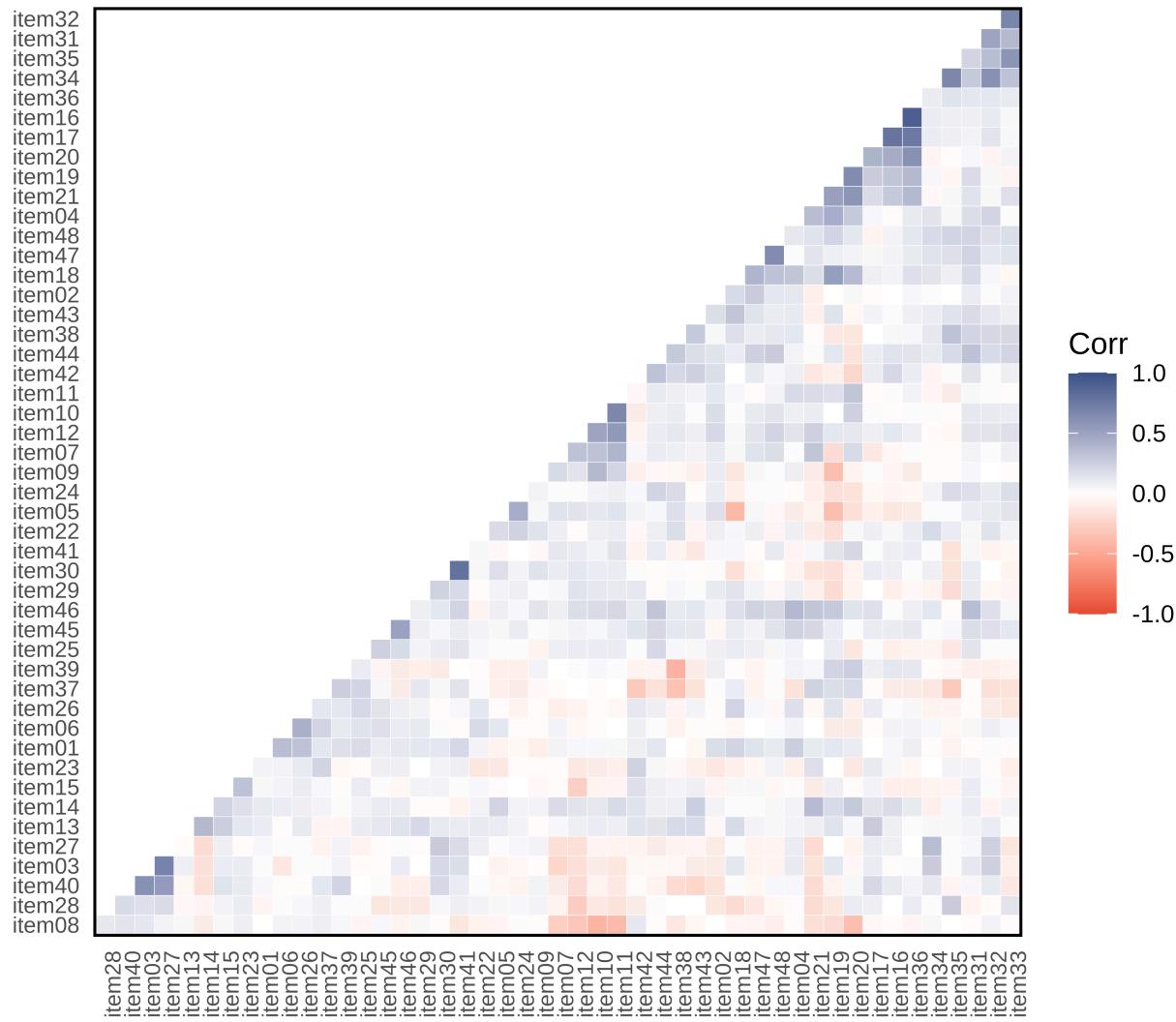


Figure 2. Inter item polychoric correlation coefficients for the 48 items. 4.9 % inter-item correlation coefficients were higher than .30

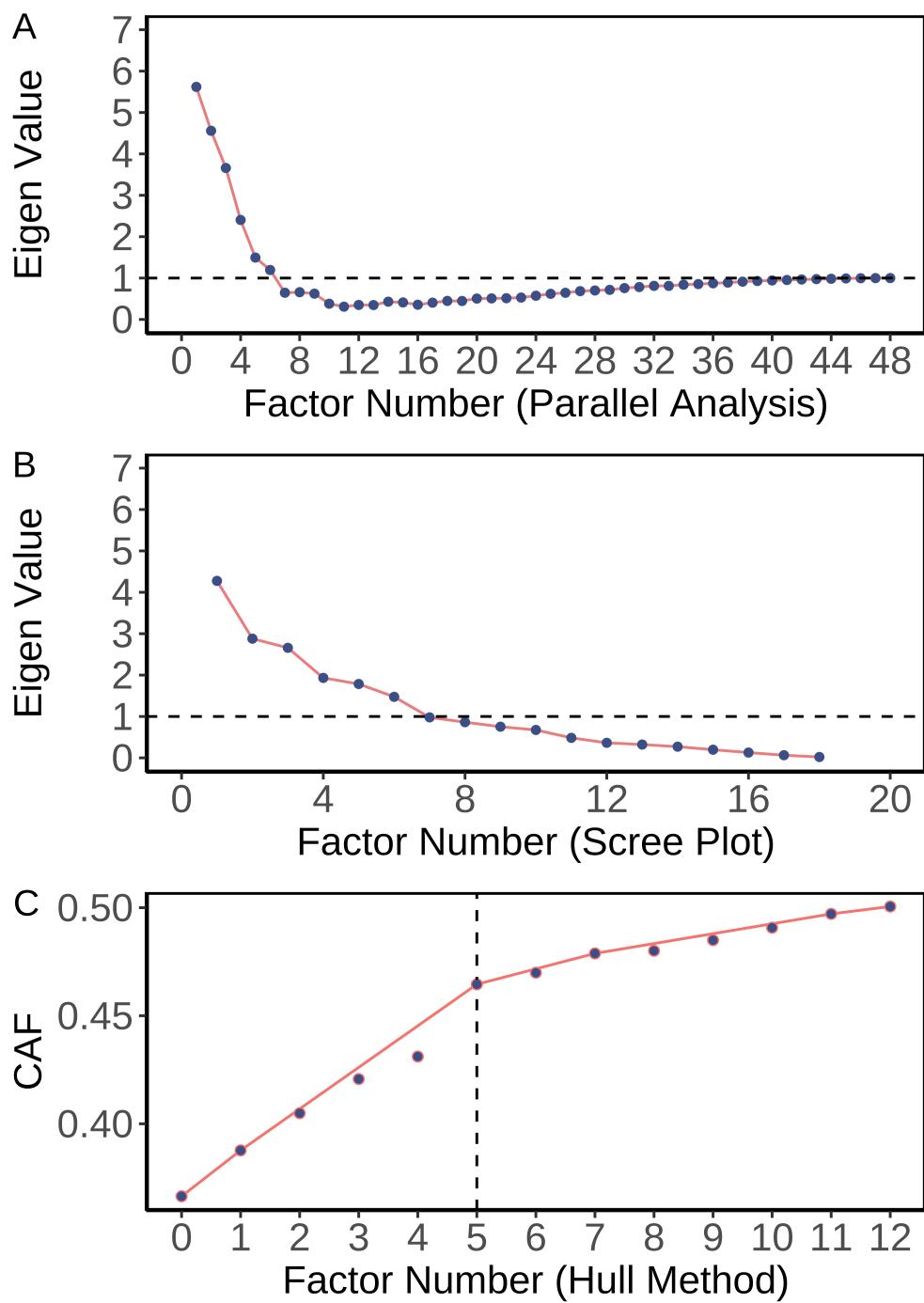


Figure 3. Factor Identification Methods (A) Parallel analysis indicated the optimal number of factors were six. (B) Scree plot suggested six factors. (C) Hull method indicated 5 factors were required to balance the model fit and number of parameters.

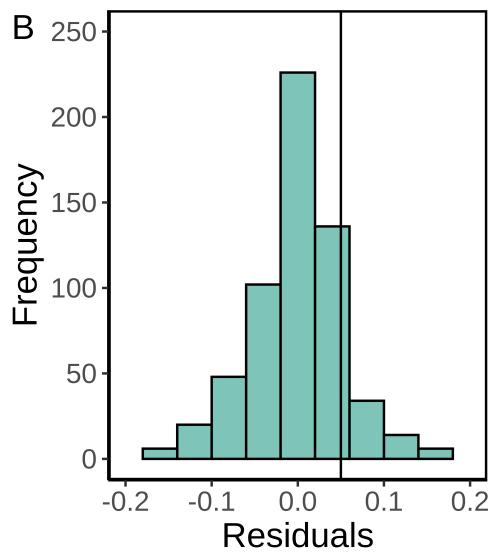
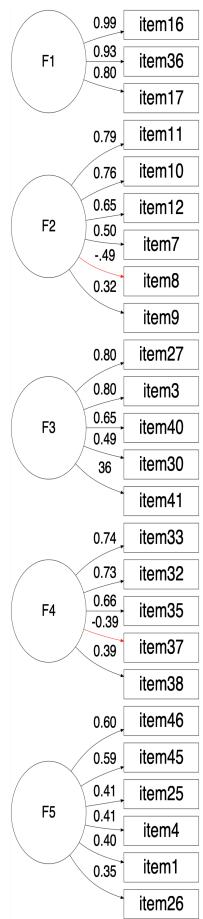
A

Figure 4. (A) Five Factor Solution obtained in Exploratory Factor Analysis (B) Histogram of nonredundant residula correlations

LEBA

Summary Descriptives EFA Sample (n =428)

Items	Summary Statistics				Histogram ¹	Density ²	Response Pattern				
	n	Mean	Median	SD			Never	Rarely	Sometimes	Often	Always
LEBA Items											
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)
item36	428	1.5	1.0	1.3			82.24% (352)	3.04% (13)	3.04% (13)	2.34% (10)	9.35% (40)
F1:Wearing blue light filters											
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)
F2:Spending time outdoors											
item03	428	3.4	4.0	1.4			15.89% (68)	11.45% (49)	17.29% (74)	31.07% (133)	24.30% (104)
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)
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)
F3:Using phone and smart-watch in bed											
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)
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)
F4:Using light before bedtime											
item01	428	2.3	2.0	1.4			42.29% (181)	22.20% (95)	12.62% (54)	12.38% (53)	10.51% (45)
item04	428	1.5	1.0	1.2			84.11% (360)	3.50% (15)	2.10% (9)	2.10% (9)	8.18% (35)
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)
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)

¹Histogram²Density

Figure 5. Summary Descriptives EFA Sample

LEBA

Summary Descriptives CFA Sample (Nn=262)

Items	Summary Statistics				Graphics		Response Pattern					
	LEBA Items	n	Mean	Median	SD	Histogram ¹	Density ²	Never	Rarely	Sometimes	Often	Always
F1:Wearing blue light filters												
item16	262	1.6	1.0	1.3	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	1.2			75.57% (198)	2.67% (7)	8.02% (21)	9.54% (25)	4.20% (11)

¹ Histogram² Density

Figure 6. Summary Descriptives of CFA Sample

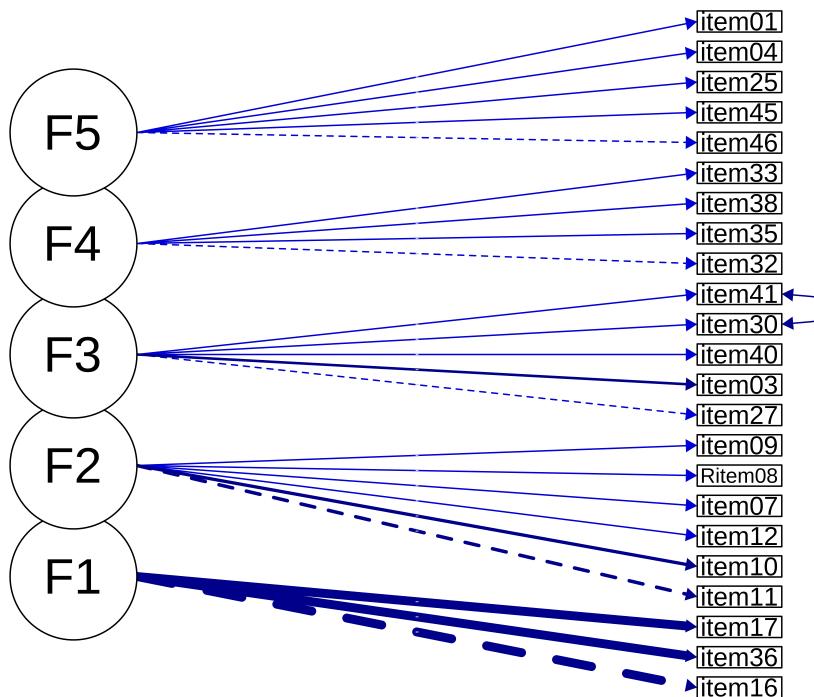


Figure 7. Five Factor Model of LEBA obtained by Confirmatory Factor Analysis. By allowing item pair 41 and 30 to covary their error variance our model attained the best fit.

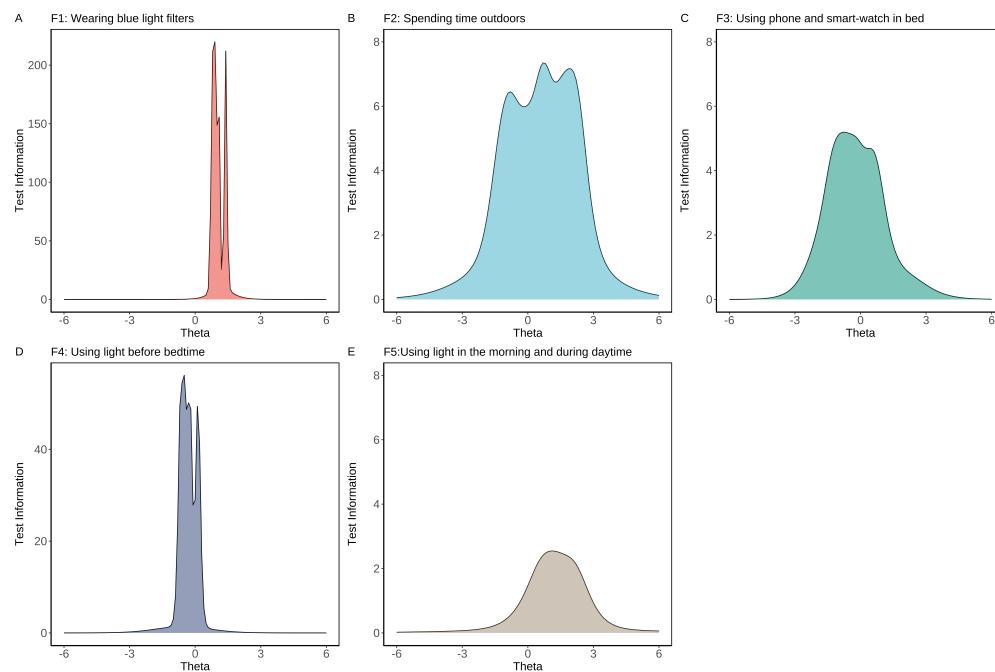


Figure 8. Test information curves (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatchin bed (d) Using light before bedtime (e) Using light in the morning andduring daytime

Appendix

845 **Disclaimer:** This is a non-public version of LEBA (dated January 30, 2022) and still a
846 work in progress. Please do not distribute!

847 LEBA captures light exposure-related behaviours on a 5 point Likert type scale
848 ranging from 1 to 5 (Never = 1; Rarely = 2; Sometimes = 3; Often = 4; Always = 5). The
849 score of each factor is calculated by the summation of scores of items belonging to the
850 corresponding factor.

851 **Instruction:**

852 “Please indicate how often you performed the following behaviours in the past 4
853 weeks.”

Table A1

LEBA Long Form (23 Items)

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.					
05. I spend between 1 and 3 hours per day (in total) outside.					
06. I spend between 30 minutes and 1 hour 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.					

Table A1 continued

Items	Never	Rarely	Sometimes	Often	Always
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.					

Table A2

LEBA Long Form (23 Items):Latent Structure and Reliability

Factor names	Items	Reliability Coefficients
F1: Wearing blue light filters	01-03	0.96
F2: Spending time outdoors	4-9 (Item 4 is reversed)	0.83
F3: Using phone and smartwatch in bed	10-14	0.7
F4: Using light before bedtime	15-18	0.69
F5: Using light in the morning and during daytime	19-23	0.52
McDonald's Omega coefficient for the total scale		0.73

Table A3

LEBA Short Form (18 Items)

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.					
05. I spend between 1 and 3 hours per day (in total) outside.					
06. I spend between 30 minutes and 1 hour 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 dim my mobile phone screen within 1 hour before attempting to fall asleep.					
14.I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.					
15. I dim my computer screen within 1 hour before attempting to fall asleep.					
16. I use tunable lights to create a healthy light environment.					
17. I use LEDs to create a healthy light environment.					
18. I use an alarm with a dawn simulation light.					

Table A4

LEBA Short Form (18 Items): Latent Structure

Factor names	Items	Reliability Coefficients
F1: Wearing blue light filters	01-03	0.96
F2: Spending time outdoors	4-9 (Item 4 is reversed)	0.83
F3: Using phone and smartwatch in bed	10-14	0.7
F4: Using light before bedtime	15-18	0.69
F5: Using light in the morning and during daytime	19-23	0.52
McDonald's Omega coefficient for the total scale		0.73

Table A5

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

MAP Statistics	dof	chisq	fit	RMSEA	BIC	eChisq	SRMR
.01125	1,080.00	4,344.31	0.18	0.08	-2,199.54	8,678.73	0.09
.01062	1,033.00	3,735.35	0.30	0.08	-2,523.72	6,414.94	0.08
.01077	987.00	3,065.44	0.38	0.07	-2,914.91	5,022.94	0.07
.01042	942.00	2,661.78	0.45	0.07	-3,045.92	3,969.03	0.06
.00938	898.00	2,237.56	0.51	0.06	-3,203.53	2,971.15	0.06
.00943	855.00	2,040.02	0.56	0.06	-3,140.53	2,441.92	0.05
.00973	813.00	1,861.69	0.59	0.05	-3,064.37	2,063.72	0.05
.00999	772.00	1,620.64	0.62	0.05	-3,057.00	1,707.87	0.04

Table A6

Demographic Characteristics: Native English Speakers

Variable	Overall, N = 262	Yes, N = 129	No, N = 133	p-value	q-value
Age	32.89 (13.66)	34.08 (15.32)	31.74 (11.77)	0.5	0.6
Sex				0.002	0.009
Female	136 (52%)	80 (62%)	56 (42%)		
Male	121 (46%)	48 (37%)	73 (55%)		
Other	5 (1.9%)	1 (0.8%)	4 (3.0%)		
Occupational Status				0.7	0.7
Work	161 (61%)	76 (59%)	85 (64%)		
School	52 (20%)	27 (21%)	25 (19%)		
Neither	49 (19%)	26 (20%)	23 (17%)		
Occupational setting				0.4	0.6
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 (%)² False discovery rate correction for multiple testing³ Wilcoxon rank sum test⁴ Fisher's exact test⁵ Pearson's Chi-squared test

Table A7

Factor loadings and communality of the retained items (Minimum 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
item07		0.5				0.267	0.733
item08		-0.49				0.252	0.748
item09		0.32				0.113	0.887
item27			0.8			0.659	0.341
item03			0.8			0.683	0.317
item40			0.65			0.464	0.536
item30			0.45			0.353	0.647
item41			0.36			0.329	0.671
item33				0.74		0.555	0.445
item32				0.73		0.623	0.377
item35				0.66		0.455	0.545
item37				-0.39		0.175	0.825
item38				0.38		0.178	0.822
item46					0.6	0.422	0.578
item45					0.59	0.374	0.626
item25					0.41	0.193	0.807
item04					0.41	0.219	0.781
item01					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 A8

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

item	PA1	PA2	PA3	PA4	PA5	PA6	Communality	Uniqueness
item16	0.99						0.987	0.013
item36	0.94						0.896	0.104
item17	0.8						0.674	0.326
item11		0.82					0.698	0.302
item10		0.81					0.656	0.344
item12		0.64					0.467	0.533
item08		-0.48					0.254	0.746
item07		0.47					0.257	0.743
item09		0.33					0.122	0.878
item33			0.97				0.978	0.022
item32			0.77				0.69	0.31
item35			0.54		0.3	0.408	0.592	
item31			0.49				0.332	0.668
item03				0.84			0.728	0.272
item27				0.81			0.666	0.334
item40				0.69			0.535	0.465
item46					0.65		0.525	0.475
item45					0.57		0.355	0.645
item04					0.48		0.332	0.668
item25					0.4		0.238	0.762
item01					0.35		0.134	0.866
item26					0.35		0.161	0.839
item37						-0.8	0.682	0.318
item38						0.39	0.245	0.755
% of Variance	0.11	0.1	0.09	0.09	0.06	0.05		

Note. Only loading higher than .30 is reported; Sixth factor has only two salient loadings

Table A9

Factor loadings and communality of the retained items in five factor solution [Unmerged Responses]

item	PA1	PA2	PA5	PA3	PA4	Communality	Uniqueness
item19	0.99					1.007	-0.007
item20	0.91					0.874	0.126
item18	0.82					0.711	0.289
item21	0.8					0.683	0.317
item04	0.47					0.25	0.75
item11		0.83				0.687	0.313
item10		0.81				0.67	0.33
item12		0.56				0.371	0.629
item08		-0.44				0.206	0.794
item07		0.42				0.226	0.774
item09		0.33				0.115	0.885
item16			0.95			0.946	0.054
item17			0.74			0.595	0.405
item36	0.3		0.73			0.653	0.347
item03				0.85		0.746	0.254
item27				0.78		0.624	0.376
item40				0.71		0.512	0.488
item35					0.58	0.351	0.649
item48					0.57	0.354	0.646
item33					0.55	0.32	0.68
item47					0.52	0.294	0.706
item44					0.45	0.216	0.784
item31					0.41	0.206	0.794
item38					0.33	0.129	0.871
% of Variance	0.15	0.09	0.09	0.08	0.08		

Note. Only loading higher than .30 is reported

Table A10

*Factor loadings and communality of the retained items in six factor solution
[Unmerged Responses]*

item	PA1	PA2	PA3	PA4	PA6	PA5	Communality	Uniqueness
item19	0.98						0.995	0.005
item20	0.92						0.904	0.096
item21	0.79						0.666	0.334
item04	0.49						0.296	0.704
item43	0.32					0.31	0.282	0.718
item10		0.81					0.67	0.33
item11		0.81					0.668	0.332
item12		0.58					0.408	0.592
item08		-0.45					0.218	0.782
item07		0.42					0.229	0.771
item09		0.33					0.115	0.885
item03			0.85				0.731	0.269
item27			0.77				0.606	0.394
item40			0.72				0.533	0.467
item35				0.64			0.426	0.574
item33				0.62			0.413	0.587
item48				0.52			0.305	0.695
item47				0.48			0.259	0.741
item31				0.39			0.206	0.794
item38				0.32			0.18	0.82
item17					0.85		0.786	0.214
item16					0.78		0.681	0.319
item13						0.57	0.336	0.664
item14						0.5	0.356	0.644
item15						0.48	0.277	0.723
item42						0.37	0.168	0.832

Table A10 continued

item	PA1	PA2	PA3	PA4	PA6	PA5	Communality	Uniqueness
item26							0.064	0.936
% of Variance	0.11	0.08	0.07	0.06	0.06	0.05		

Note. Only loading higher than .30 is reported

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Table A11

Geographical Location of the participants (n =690)

Timezone	Number of Participants
Africa/Ceuta (UTC +01:00)	2.00
Africa/Douala (UTC +01:00)	1.00
Africa/Johannesburg (UTC +02:00)	5.00
Africa/Khartoum (UTC +02:00)	2.00
Africa/Lagos (UTC +01:00)	1.00
America/Adak (UTC -09:00)	2.00
America/Anchorage (UTC -08:00)	3.00
America/Araguaina (UTC -03:00)	2.00
America/Argentina/Buenos_Aires (UTC -03:00)	5.00
America/Argentina/Cordoba (UTC -03:00)	2.00
America/Argentina/Jujuy (UTC -03:00)	1.00
America/Bahia (UTC -03:00)	2.00
America/Blanc-Sablon (UTC -04:00)	1.00
America/Bogota (UTC -05:00)	2.00
America/Boise (UTC -06:00)	4.00
America/Cayman (UTC -05:00)	1.00
America/Chicago (UTC -05:00)	30.00
America/Costa_Rica (UTC -06:00)	2.00
America/Cuiaba (UTC -04:00)	1.00

Table A11 continued

Timezone	Number of Participants
America/Denver (UTC -06:00)	6.00
America/Detroit (UTC -04:00)	6.00
America/Edmonton (UTC -06:00)	14.00
America/Fortaleza (UTC -03:00)	1.00
America/Guatemala (UTC -06:00)	1.00
America/Guayaquil (UTC -05:00)	2.00
America/Halifax (UTC -03:00)	1.00
America/Indiana/Indianapolis (UTC -04:00)	3.00
America/Indiana/Tell_City (UTC -05:00)	1.00
America/Kentucky/Louisville (UTC -04:00)	3.00
America/Los_Angeles (UTC -07:00)	37.00
America/Martinique (UTC -04:00)	1.00
America/Mexico_City (UTC -06:00)	2.00
America/Moncton (UTC -03:00)	2.00
America/Monterrey (UTC -06:00)	1.00
America/New_York (UTC -04:00)	63.00
America/North_Dakota/Center (UTC -05:00)	1.00
America/North_Dakota/New_Salem (UTC -05:00)	1.00
America/Panama (UTC -05:00)	1.00
America/Phoenix (UTC -07:00)	7.00
America/Resolute (UTC -05:00)	1.00
America/Santiago (UTC -03:00)	8.00
America/Sao_Paulo (UTC -03:00)	19.00
America/Toronto (UTC -04:00)	16.00
America/Vancouver (UTC -07:00)	6.00
Antarctica/Macquarie (UTC +11:00)	1.00
Asia /Taipei City (UTC +08:00)	3.00
Asia/Amman (UTC +03:00)	2.00
Asia/Barnaul (UTC +07:00)	1.00

Table A11 continued

Timezone	Number of Participants
Asia/Dhaka (UTC +06:00)	1.00
Asia/Famagusta (UTC +02:00)	1.00
Asia/Ho_Chi_Minh (UTC +07:00),British - America/Tortola (UTC -04:00)	2.00
Asia/Hong_Kong (UTC +08:00)	2.00
Asia/Jakarta (UTC +07:00)	9.00
Asia/Jerusalem (UTC +02:00)	4.00
Asia/Karachi (UTC +05:00)	1.00
Asia/Kathmandu (UTC +05:45)	2.00
Asia/Kolkata (UTC +05:30)	38.00
Asia/Kuala_Lumpur (UTC +08:00)	7.00
Asia/Kuching (UTC +08:00)	2.00
Asia/Manila (UTC +08:00)	6.00
Asia/Novosibirsk (UTC +07:00)	1.00
Asia/Riyadh (UTC +03:00)	1.00
Asia/Seoul (UTC +09:00)	1.00
Asia/Shanghai (UTC +08:00)	7.00
Asia/Singapore (UTC +08:00)	1.00
Asia/Tokyo (UTC +09:00)	3.00
Asia/Tomsk (UTC +07:00)	1.00
Asia/Ulaanbaatar (UTC +08:00)	1.00
Asia/Vladivostok (UTC +10:00)	1.00
Asia/Yangon (UTC +06:30)	1.00
Asia/Yekaterinburg (UTC +05:00)	1.00
Atlantic/Canary (UTC)	1.00
Australia/Adelaide (UTC +10:30)	2.00
Australia/Brisbane (UTC +10:00)	4.00
Australia/Darwin (UTC +09:30)	1.00
Australia/Melbourne (UTC +11:00)	5.00
Australia/Perth (UTC +08:00)	2.00

Table A11 continued

Timezone	Number of Participants
Australia/Sydney (UTC +11:00)	2.00
East Africa/Dodoma (UTC +03:00)	1.00
Europe/Amsterdam (UTC +01:00)	19.00
Europe/Athens (UTC +02:00)	3.00
Europe/Belgrade (UTC +01:00)	3.00
Europe/Berlin (UTC +01:00)	53.00
Europe/Bratislava (UTC +01:00)	2.00
Europe/Brussels (UTC +01:00)	4.00
Europe/Bucharest (UTC +02:00)	3.00
Europe/Budapest (UTC +01:00)	2.00
Europe/Busingen (UTC +01:00)	3.00
Europe/Copenhagen (UTC +01:00)	3.00
Europe/Dublin (UTC)	5.00
Europe/Helsinki (UTC +02:00)	9.00
Europe/Istanbul (UTC +03:00)	6.00
Europe/Kiev (UTC +02:00)	1.00
Europe/Lisbon (UTC)	2.00
Europe/Ljubljana (UTC +01:00)	3.00
Europe/London (UTC)	57.00
Europe/Madrid (UTC +01:00)	7.00
Europe/Moscow (UTC +03:00)	8.00
Europe/Oslo (UTC +01:00)	3.00
Europe/Paris (UTC +01:00)	22.00
Europe/Prague (UTC +01:00)	3.00
Europe/Riga (UTC +02:00)	2.00
Europe/Rome (UTC +01:00)	9.00
Europe/Sofia (UTC +02:00)	1.00
Europe/Stockholm (UTC +01:00)	4.00
Europe/Tallinn (UTC +02:00)	2.00

Table A11 continued

Timezone	Number of Participants
Europe/Tirane (UTC +01:00)	1.00
Europe/Vienna (UTC +01:00)	1.00
Europe/Vilnius (UTC +02:00)	5.00
Europe/Warsaw (UTC +01:00)	15.00
Europe/Zagreb (UTC +01:00)	2.00
Europe/Zurich (UTC +01:00)	21.00
European /Skopje (UTC +01:00)	1.00
Iran /Tehran (UTC +0:30)	3.00
Pacific/Auckland (UTC +13:00)	6.00
Pacific/Chatham (UTC +13:45)	1.00
Pacific/Easter (UTC -05:00)	1.00
Pacific/Honolulu (UTC -10:00)	2.00

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Table A12

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.

Table A12 continued

F1
I spend between 30 minutes and 1 hour per day (in total) outside.
F3
I look at my mobile phone screen immediately after waking up.
I use my mobile phone within 1 hour before attempting to fall asleep.
I check my phone when I wake up at night.
F4
I use a blue-filter app on my computer screen within 1 hour before attempting to fall asleep.
I seek out knowledge on how to improve my light exposure.
I dim my computer screen within 1 hour before attempting to fall asleep.
I discuss the effects of light on my body with other people.
I modify my light environment to match my current needs.
I dim my room light within 1 hour before attempting to fall asleep.
I use as little light as possible when I get up during the night.
F5
I wear blue-filtering, orange-tinted, and/or red-tinted glasses indoors during the day.
I wear blue-filtering, orange-tinted, and/or red-tinted glasses outdoors during the day.
I wear blue-filtering, orange-tinted, and/or red-tinted glasses within 1 hour before attempting to fall asleep.

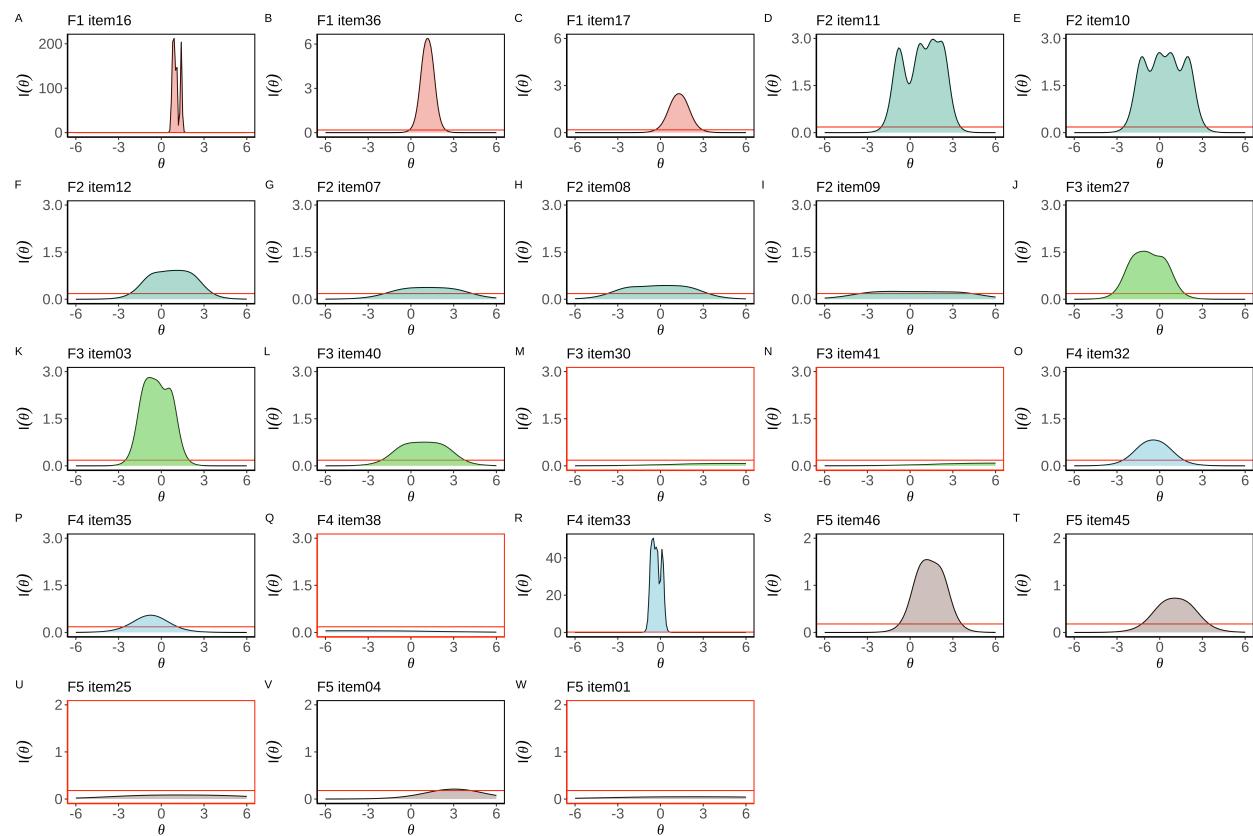


Figure A1. Item information curve

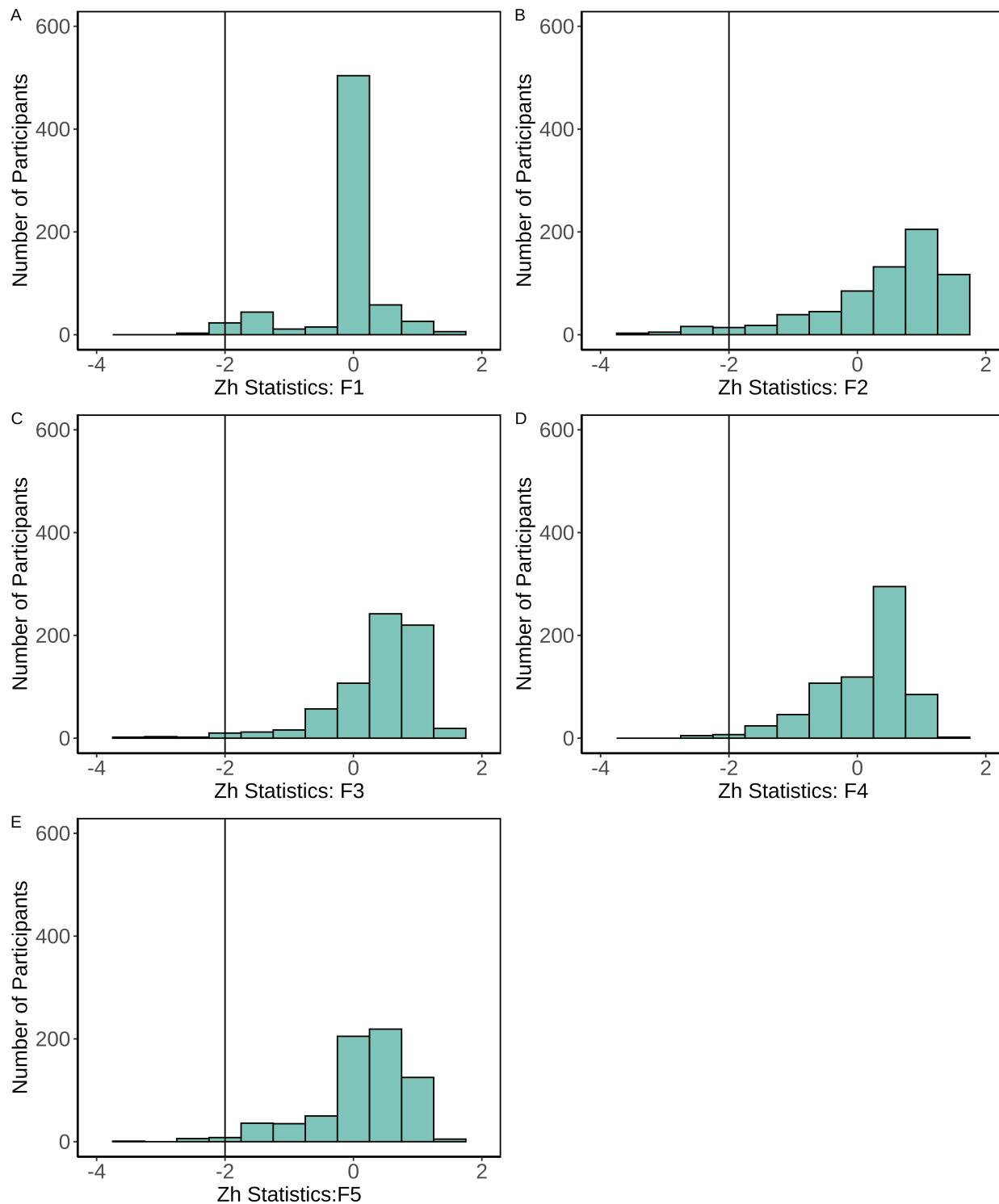


Figure A2. Person fit of the five fitted IRT models (a) Wearing blue light filters (b) Spending time outdoors (c) Using phone and smartwatch in bed (d) Using light before bedtime (e) Using light in the morning and during daytime