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SHORT REPORT

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External validity of the reduced Morningness–Eveningness Questionnaire for Children and Adolescents: an actigraphic study

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Summary

The aim of this study was to examine the external validity of the reduced Morningness–Eveningness Questionnaires for Children and Adolescents, using circadian motor activity, assessed through actigraphy, as an external criterion. Overall, 458 participants (269 females), with a mean (standard deviation) age of 15.75 (1.16) years, took part in this study. Each adolescent was requested to wear the actigraph Micro Motionlogger Watch actigraph (Ambulatory Monitoring, Inc., Ardlsey, NY, USA) around the non-dominant wrist for 1 week. At the end of the actigraphic recording, participants completed the reduced Morningness–Eveningness Questionnaires for Children and Adolescents. We extracted the motor activity counts, minute-by-minute over the 24 h, to depict the 24-h motor activity pattern, and we adopted the statistical framework of functional linear modelling to examine its changes according to chronotype. According to the reduced Morningness–Eveningness Questionnaires for Children and Adolescents cut-off scores, 13.97% of participants ($n = 64$) belonged to the evening-types category, 9.39% ($n = 43$) to morning-types, while the remaining (76.64%, $n = 351$) to the intermediate-types category. Evening types moved significantly more than the intermediate and morning types from around 10:00 p.m. to 2:00 a.m., while the opposite pattern of results was observed around 4:00 a.m. The results highlighted a significant difference in the 24-h motor activity pattern between chronotypes, in line with the expectations based on their well-known behaviour. Therefore, this study shows that the external validity of the reduced Morningness–Eveningness Questionnaire for Children and Adolescents, established by considering motor activity (recorded through actigraphy) as an external criterion, is satisfactory.

KEYWORDS
actigraphic assessment, adolescence, circadian typology, questionnaire, reduced Morningness–Eveningness Questionnaires for Children and Adolescents, validity

1 | INTRODUCTION

Chronotype refers to one of the most marked inter-individual differences in human circadian rhythm (Adan et al., 2012). Three groups can be clearly differentiated: (i) morning types, those who prefer to go to bed and wake-up early; (ii) evening types, those who prefer to go to bed and wake up late; and (ii) intermediate types (∼60% of the adult population), those belonging to an intermediate area between the other two extreme chronotypes (Adan et al., 2012; Tonetti, 2012).

Age differences in chronotype have been consistently observed, with a shift from a prevalent morning- to a prevalent evening-types category at the beginning of adolescence (Roenneberg et al., 2004). This change has been acknowledged as a risk factor for behavioural problems. As a consequence, as recently pointed out by Cooper et al. (2022), 'public health intervention programmes might be suited to target evening-oriented individuals early in development in order to prevent or ameliorate poorer mental and neurobiological health outcomes' (page 9). In order to properly detect evening-type adolescents, the use of a reliable and valid measure is necessary.

While a review on the psychometric properties of the measures commonly used to assess chronotype in adolescents (Tonetti et al., 2015) has suggested the use of the Morningness–Eveningness Questionnaire for Children and Adolescents (MEQ-CA) (19 items) because validated by the highest number of external objective criteria (actigraphy and oral body temperature), the reduced MEQ-CA (rMEQ-CA), composed of just five items taken from the MEQ-CA, may be of interest due to its brevity. However, strong evidence of external validity, assessed through objective-external criteria in large samples, is still not available yet (Paciello et al., 2022).

To fill in this gap of knowledge, the aim of the present study was to examine the external validity of the rMEQ-CA, using the circadian motor activity, assessed through actigraphy, as an external criterion, in a large sample of adolescents.

2 | METHODS

2.1 | Participants

An overall number of 458 adolescents (269 females), attending secondary schools took part in the study conducted in Italy. The mean (standard deviation [SD]) age was 15.75 (1.16) years. The age of the girls (mean [SD] 15.76 [1.17] years) was not significantly different from that of the boys (mean [SD] 15.74 [1.15] years) ($t_{455} = 0.14$; $p = 0.89$).

2.2 | The rMEQ-CA

The Italian version (Tonetti et al., 2006) of the rMEQ-CA is a questionnaire composed of five items (two multiple choices and three open choices) extracted from the MEQ-CA (Natale & Bruni, 2000). Participants are requested to indicate the ideal get-up time, the tiredness after the morning awakening, the usual bedtime, at what time of the day their 'best peak' is reached, and which type of people ('morning' or 'evening' type) they consider themselves to be. Adding up the score of each item, the total score is obtained, ranging between 4 and 25. Morning types are those with a total score between 19 and 25, intermediate types between 11 and 18, and evening types between 4 and 10 (Tonetti et al., 2006).

2.3 | Actigraphy

The actigraph model Micro Motionlogger Watch (Ambulatory Monitoring, Inc., Ardsley, NY, USA) was used in this study and initialised, in zero crossing mode to collect data in 1-min epochs using the software Motionlogger Watchware software (Ambulatory Monitoring Inc.). In order to obtain the main sleep and wake actigraphic parameters (for a definition, see Tonetti et al., 2019), records were analysed through the software Action W2 (Ambulatory Monitoring, Inc.) using the algorithm by Cole and Kripke (1988). Finally, the software Action 4 (Ambulatory Monitoring, Inc.) was used to extract the raw motor activity counts, minute-by minute, over the 24 h in order to depict the 24-h motor activity pattern.

2.4 | Procedure

Adolescents examined in this study are participating in the ongoing European Research Council (ERC)-Consolidator project IDENTITIES 'Managing identities in diverse societies: A developmental intergroup perspective with adolescents'.

Active consent from parents was obtained prior to their children's participation. Active consent was also obtained from adolescents of age while their underage peers provided their assent to participate in the project. Participation in the study was voluntary, and students were informed that they could withdraw their consent at any time.

The present study was approved by the Ethics Committee of the Alma Mater Studiorum University of Bologna (Italy), Prot. no. 263836 on October 14, 2021, as part of the IDENTITIES project.

Participants in this study were asked if they consented to wear the actigraph around the non-dominant wrist for 1 week for 24 h/day. If so, they received the actigraph during a school day. All adolescents were attending a morning school schedule (Arrona-Palacios et al., 2021). Data were collected in January–February 2022. During this period, to contrast the spread of the COVID-19 pandemic, students could attend school in person if (a) they were not affected by COVID-19 and (b) they were not in isolation because they had been in contact with somebody affected by COVID-19.

2.5 | Data analysis

We performed a multivariate analysis of variance, with chronotype as the independent variable and actigraphic sleep and wake parameters as the dependent variables. In case of significant effect of chronotypes, the honestly significant difference Tukey test for unequal

TABLE 1 Means and standard deviations (SDs) of actigraphic sleep/wake measures in chronotypes; statistics and post hoc comparisons are also reported. Significant results are in italics.

	MT	IT	ET	Statistics $F_{2,455}$	p (η_p^2)	Post hoc comparisons	Correlation (p value)
Sleep, mean (SD)							rMEQ-CA score
BT, clock time (h:min)	10:58 p.m. (0:50)	11:26 p.m. (0:50)	12:02 a.m. (0:49)	23.69	*<0.001* (0.09)	MT vs. IT (*p < 0.05*); MT vs. ET (*p < 0.001*); IT vs. ET (*p < 0.001*)	−0.37 (*<0.001*)
GUT, clock time (h:min)	6:44 a.m. (0:34)	7:08 a.m. (0:34)	7:25 a.m. (0:33)	17.69	*<0.001* (0.07)	MT vs. IT (*p < 0.005*); MT vs. ET (*p < 0.001*); IT vs. ET (*p < 0.05*)	−0.30 (*<0.001*)
TIB, min	468.45 (51.08)	464.64 (45.99)	445.49 (45.56)	5.02	*<0.01* (0.02)		0.18 (*<0.001*)
MS, clock time (h:min)	2:51 a.m. (0:34)	3:17 a.m. (0:36)	3:44 a.m. (0:35)	29.01	*<0.001* (0.11)	MT vs. IT (*p < 0.005*); MT vs. ET (*p < 0.001*); IT vs. ET (*p < 0.001*)	−0.40 (*<0.001*)
SMA, counts	13.29 (3)	12.96 (3.88)	12.47 (4.83)	0.63	0.53		0.01 (0.88)
SOL, min	12.86 (4.68)	12.81 (9.03)	11.22 (4.54)	1.04	0.35		−0.02 (0.68)
TST, min	413.38 (45)	428.93 (44.20)	413.50 (45.04)	3.50	*<0.05* (0.02)		0.17 (*<0.001*)
WASO, min	21.70 (13.05)	20.22 (13.74)	18.30 (15.11)	0.84	0.43		0.06 (0.21)
SE, %	92.16 (2.60)	92.34 (3.49)	95.59 (3.93)	0.22	0.80		0.02 (0.73)
AWK, *n*	12.24 (4.67)	11.85 (5.27)	10.81 (5.30)	1.29	0.28		0.06 (0.20)
AWK >5, *n*	2.20 (0.85)	2.18 (1.02)	2.04 (1.12)	0.59	0.56		0.05 (0.31)
Wake, mean (SD)							
DMA, counts	205.92 (19.58)	203.65 (21.98)	200.07 (19.79)	1.09	0.34		0.09 (0.07)
DTST, min	20.51 (33.04)	22.29 (28.70)	29.40 (29.59)	1.78	0.17		−0.11 (*<0.05*)
NAP, *n*	2.73 (2.38)	2.97 (2.89)	2.73 (2.38)	1.64	0.20		−0.09 (0.05)
NAPD, min	9.91 (13.71)	11.06 (13.96)	15.03 (15.66)	2.42	0.09		−0.12 (*<0.05*)

Note: The table also shows the correlations between the reduced Morningness–Eveningness Questionnaire for Children and Adolescents (rMEQ-CA) score and each actigraphic parameter.
Abbreviations: AWK >5, awakenings lasting >5 min; AWK, awakenings; BT, bedtime; DMA, diurnal motor activity; DTST, diurnal total sleep time; ET, evening types; GUT, get-up time; IT, intermediate types; MS, midpoint of sleep; MT, morning types; NAP, diurnal sleep episodes; NAPD, duration of the longest sleep episode; SE, sleep efficiency; SMA, sleep motor activity; SOL, sleep onset latency; TIB, time in bed; TST, total sleep time; WASO, wake after sleep onset.

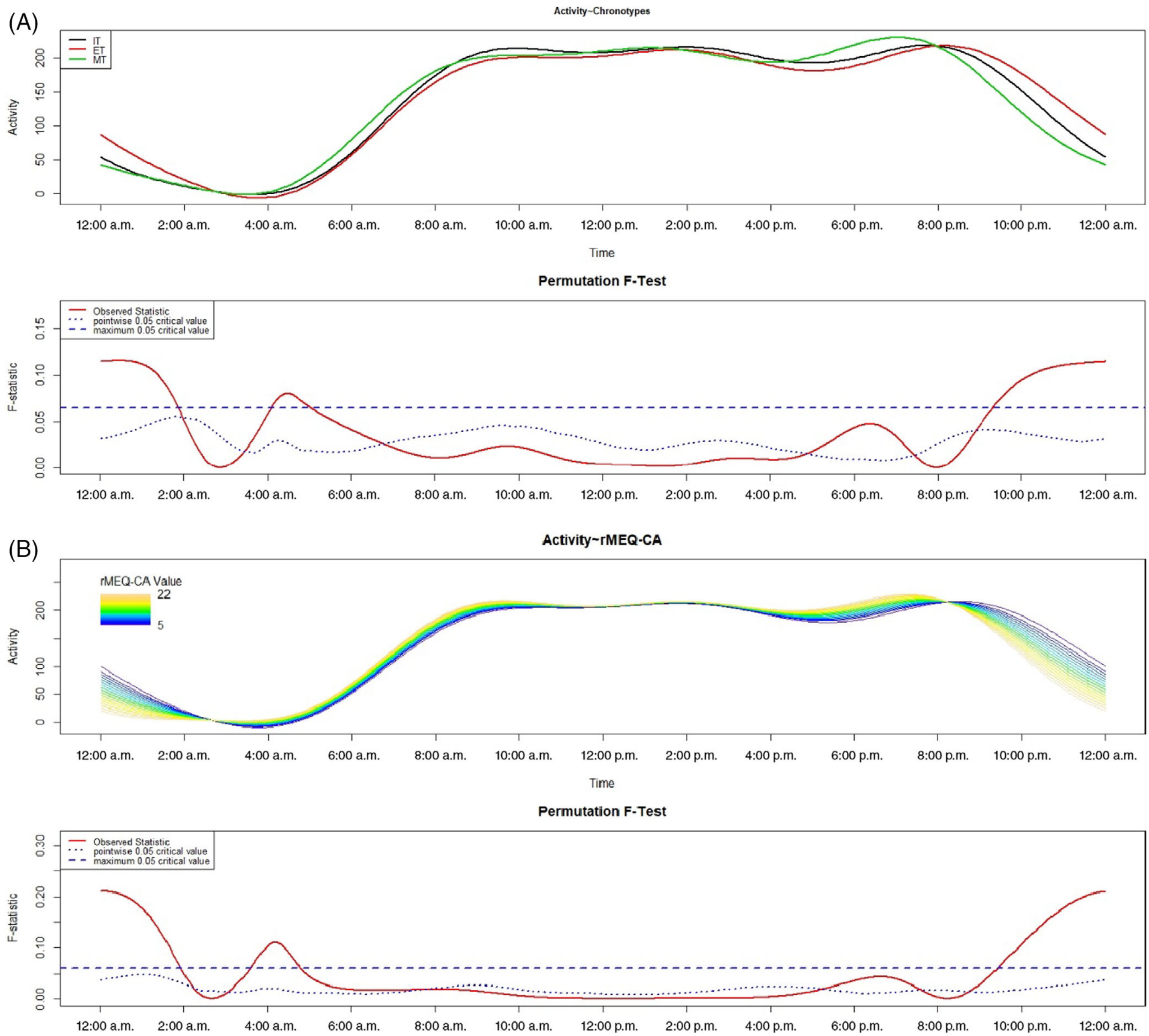

FIGURE 1 (a) Results of the categorical functional linear modelling (FLM) analysis. The upper panel shows the functional form of the 24-h motor activity pattern of morning types (MT), intermediate types (IT), and evening types (ET). The lower panel shows the results of the non-parametric permutation *F* test; significant results are observed when the red solid line (observed statistic) is above the blue dashed (global test of significance) and dotted line (point-wise test of significance). (b) Results of the continuous FLM analysis. While the description of the lower panel is the same as the Figure 1a, the upper panel shows as many lines as the number of participants, with each line representing the 24-h motor activity pattern plotted against the total reduced Morningness–Eveningness Questionnaire (rMEQ) score as a continuous value. Dark colours point towards lowest total rMEQ score, while light colours towards highest total rMEQ score.

samples was used. We computed the partial eta-squared (η_p^2) as a measure of effect size and interpreted a value of 0.01 as a small effect, a value of 0.04 as a medium effect, and a value of 0.10 as a large effect (Huberty, 2002). Moreover, a set of Pearson's correlation analyses between the rMEQ-CA score and each actigraphic sleep/wake measure was computed.

We also used the statistical framework of functional linear modelling (FLM; Wang et al., 2011) in order the examine the differences in the 24-h motor activity pattern between chronotypes, originally obtained in a raw form through the Action 4 software (Ambulatory Monitoring, Inc.). Moreover, the FLM was also used to examine the variation in the 24-h pattern of motor activity against the total rMEQ-CA score as a continuous variable. FLM analyses were carried out through the R statistical software using the package 'actigraphy'.

3 | RESULTS

The sample was found to be composed of 43 morning types (26 females), 351 intermediate types (204 females), and 64 evening types (39 females). The distribution of boys and girls among the three chronotypes was not significantly different ($\chi^2_2 = 0.24$; $p = 0.89$).

As shown in Table 1, a significant effect of chronotype was observed for the bedtime, get-up time, midpoint of sleep, time in bed, and total sleep time. The whole set of post hoc comparisons reached significance with reference to the markers of sleep phase (bedtime, get-up time, midpoint of sleep), with the earlier times in the morning types, and the latest times in the evening types. On the contrary, no post hoc comparisons were significant with reference to markers of both sleep quantity and quality.

As regards the results of the correlation analyses, with reference to the actigraphic sleep measures (Table 1), there was a significant negative correlation between the rMEQ-CA score on one side and bedtime, get-up time, and midpoint of sleep on the other; moreover, there was a significant positive correlation between the rMEQ-CA score and time in bed, as well as total sleep time. With reference to the actigraphic wake measures (Table 1), a significant negative correlation between the rMEQ-CA score and diurnal total sleep time besides the duration of the longest diurnal sleep episode was highlighted.

Moving to the categorical FLM analysis, as reported in Figure 1a, there was a significantly different motor activity between chronotypes within two time intervals over the 24 h: (i) from around 9:00 p.m. to 2:00 a.m., with more motor activity in the evening types, followed by the intermediate and morning types as last; (ii) around 4:00 a.m., with more motor activity in the morning types, followed by the intermediate types and lastly by the evening types.

With reference to the continuous FLM analysis, as reported in Figure 1b, participants with lower rMEQ-CA scores (i.e., greater eveningness tendency) moved significantly more than those with higher rMEQ-CA scores (i.e., greater tendency towards morningness) from around 10:00 p.m. to 2:00 a.m., while the opposite pattern of results was observed around 4:00 a.m.

4 | DISCUSSION

As regards the differences between chronotypes in the actigraphic sleep/wake parameters (Table 1), there was a significantly delayed bedtime, get-up time, and midpoint of sleep—parameters of the sleep timing—in evening-types compared to both the intermediate and morning types. The results of the correlation analysis (Table 1) were in line with these data with the addition of a shortening of the total sleep time—marker of sleep quantity—to the increasing of the eveningness preference, which was counterbalanced by an increasing of the diurnal total sleep time, potentially interpretable as a sleep recovery strategy in those with a greater tendency towards eveningness. Considering this pattern of results, as well as the partial eta-squared and correlation values (Table 1), this study shows that chronotypes primarily differ in the sleep timing and secondarily in sleep quantity, while they do not differ in sleep quality.

With reference to the 24-h motor activity pattern, the results of both categorical and continuous FLM (Figure 1a,b) pointed out a consistent pattern of results, that is, evening types' motor activity was significantly greater than the intermediate and morning types in the late evening and the first part of the night, while the opposite pattern of results was observed in the second part of the night/before the morning awakening. It is as evening types, from a behavioural point of view, 'switch-off' later than the intermediate and morning types, while the latter 'switch-on' early in preparation for the new day. Basically, this pattern of results is in line with the well-known behavioural differences between chronotypes (Adan et al., 2012). Moreover, the fact that the differences in motor activity between chronotypes also appear before the morning awakening leads to suggest that biological factors, such as the cortisol release where production starts before the morning awakening (Randler & Schaal, 2010), may play a primary modulating role in the different phase relationship of the 24-h motor activity pattern between chronotypes. An alternative potential explanation of the differences in motor activity between chronotypes before the morning awakening may be related to the lowering of melatonin levels (Montaruli et al., 2017).

While this study is not free from limitations (e.g., the absence of control of the exposure or use of screens), the large sample size and the ecological assessment of the adolescents' motor behaviour in their everyday life give strength to the conclusion that the external validity of the rMEQ-CA is satisfactory, therefore suggesting its potential usefulness in the assessment of adolescents' chronotype, especially in large-scale research with screening purposes.

AUTHOR CONTRIBUTIONS

Conceptualisation; Vincenzo Natale and Elisabetta Crocetti; methodology: Vincenzo Natale and Elisabetta Crocetti; formal analysis: Lorenzo Tonetti and Sara Giovagnoli; investigation, Lorenzo Tonetti, Alice Andreose, Valeria Bacaro, Martina Grimaldi, Vincenzo Natale and Elisabetta Crocetti; data curation: Alice Andreose, Valeria Bacaro, Martina Grimaldi; writing—original draft preparation: Lorenzo Tonetti; writing—review and editing: Lorenzo Tonetti, Alice Andreose, Valeria Bacaro, Sara Giovagnoli, Martina Grimaldi, Vincenzo Natale and Elisabetta Crocetti; supervision, Vincenzo Natale and Elisabetta Crocetti; funding acquisition: Elisabetta Crocetti. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors have no relevant financial or non-financial interests to disclose. The funder had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results. The views and opinions expressed in this presentation are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

DATA AVAILABILITY STATEMENT

The database will be made available in a repository after the completion of the review process.

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