Mindfulness (2022) 13:2879–2890
https://doi.org/10.1007/s12671-022-02003-5

ORIGINAL PAPER

Examining the Factorial Structure, Reliability, and Predictive Validity of the Portuguese Version of the Child and Adolescent Mindfulness Measure (CAMM)

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Accepted: 30 September 2022 / Published online: 12 October 2022

Abstract

Objectives The present study examined the factorial structure and reliability of the Portuguese version of the Child and Adolescence Mindful Measure (CAMM) in a sample of pre-teens. We also studied its predictive validity by testing a mediation model assessing the indirect association between CAMM and school achievement via executive functions.

Methods Our main and cross-validation samples were composed by 205 and 176 fourth graders, respectively. Participants completed the Portuguese CAMM and performed behavioral tasks, which provided indicators for the following executive functions: working memory, inhibitory control, and cognitive flexibility. Students' school achievement was measured through their grades in the subjects of Portuguese and Mathematics. Using the R system for statistical computing, we conducted confirmatory factor analyses and structural equation modeling analyses.

Results Results showed good reliability and a very good fit of a unidimensional model, despite the removal of two items. Structural equation modeling analyses revealed a positive association between CAMM and school achievement, fully mediated by executive functions. This is in line with previous findings suggesting that students who are more open to and aware of the ongoing experience may display better executive functioning and, in turn, achieve better results in school.

Conclusions Overall, our results provided further evidence supporting the validity of the 8-item CAMM to assess mindfulness in Portuguese pre-teens.

Keywords Mindfulness · Pre-teens · Executive functions · School achievement · Mediation

Over the past two decades, there has been a growing scientific interest in the study of mindfulness, which is usually defined as "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2003, p. 145). However, conceptualizations of mindfulness may diverge according to two different criteria: the number of dimensions and the stability of the construct.

Regarding the first criterion, uni-, bi-, and multidimensional approaches have been proposed. According to Brown and Ryan (2003, 2004), mindfulness is an open awareness of ongoing events that subsumes a moment-by-moment acceptance. Mindfulness is therefore proposed as a unitary construct comprising attention and emotional aspects, which should not be disjointed. Bishop et al. (2004) cleaved this construct into mindful awareness and mindful acceptance. Whereas mindful awareness refers to the abilities of self-regulating and maintaining attention on the immediate experience, mindful acceptance implies facing this experience with curiosity, openness, and acceptance (Bishop et al., 2004). This bidimensional conceptualization was further refined by other scholars, who identified sub-dimensions within mindful awareness (e.g., internal vs. external awareness) and mindful acceptance (e.g., non-judgment, openness to experience) (Cortazar et al., 2020; Eklund et al., 2017; Johnson et al., 2017; Magalhães & Limpo, 2022).

Concerning its stability, mindfulness is considered either as a momentary condition (i.e., state mindfulness) or a set of characteristics and behavioral patterns that, without training, are relatively stable (i.e., dispositional mindfulness) (Kuby et al., 2015; Roeser et al., 2020; Tomlinson et al., 2018).

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This latter approach assumes that, although everyone has the ability to be focused and keep attention on internal or external experiences, individuals may differ in the extent to which they act mindfully (Brown & Ryan, 2003). Notably, in correlational research with school-aged children, these mindfulness-related individual differences have been linked to school achievement.

Caballero et al. (2019) showed that higher mindful awareness in students from Grade 6 to 8 was associated with better performance in Literacy and Mathematics. Another correlational study with Portuguese Grade 6 students identified a significant and unique contribution of mindful acceptance to the academic skill of writing (Cordeiro et al., 2021a). More recently, a regression analysis conducted with Portuguese fourth graders showed that school achievement was predicted by the mindfulness facets of external awareness and openness to experience (Magalhães & Limpo, 2022).

Concerning experimental research, although academic performance is the less studied outcome of school mindfulness-based programs (Roeser et al., 2020), the scarce evidence available has also been supporting this link (for a systematic review and meta-analysis, see Felver et al., 2016; Zenner et al., 2014). For instance, mindfulness interventions were found to improve students' performance in Mathematics (Schonert-Reichl & Roeser, 2016), Literacy (Cordeiro et al., 2021b), and Reading and Science (Bakosh et al., 2016). Overall, correlational and experimental findings seem to converge on the conclusion that higher dispositional mindfulness is associated with better school achievement. However, recent studies found evidence that this mindfulness-achievement link might not be direct, but rather mediated by other variables (McBride & Greeson, 2021; Miralles-Armenteros et al., 2019). A question still to be answered is what lies beneath this association between dispositional mindfulness and school performance.

Research has been suggesting that mindfulness may enhance academic performance by helping students to sustain attention in school and by improving their cognitive as well as emotional self-regulation (Maynard et al., 2017). Moreover, mindfulness seems also associated with more positive school climates (e.g., less continuous stress and fighting), which are relevant to achieve better school results (Wisner, 2014). Furthermore, some evidence have been pointing out that mindfulness may contribute to better school achievement by improving students' engagement (Miralles-Armenteros et al., 2019) and their ability to recognize thoughts and feelings as temporary (McBride & Greeson, 2021).

Recently, a promising research line has also been proposing that mindfulness contribute to the development of executive functions (Bigelow et al., 2021; Cordeiro et al., 2021b; Dunning et al., 2019; Mak et al., 2017; Geronimi et al., 2020; Maynard et al., 2017), which underlie a wide range of academic skills, closely related to school success (Amukune & Józsa, 2021; Bouzaboul et al., 2020; Cordeiro et al., 2019; Magalhães et al., 2020; Mulder & Cragg, 2014; Samuels et al., 2016; Spiegel et al., 2021; Willoughby et al., 2019).

Executive functioning is an umbrella term covering the mental capacities required to engage in deliberate and goal-directed thought and action (Lezak, 1982; Mulder & Cragg, 2014). Among them, Diamond (2013) included working memory, inhibitory control, and cognitive flexibility, which have been associated not only with mindfulness (Bigelow et al., 2021; Geronimi et al., 2020; Mak et al., 2017), but also with school achievement (Magalhães & Limpo, 2022; Maynard et al., 2017; Mulder & Cragg, 2014). In a study by Lu et al. (2017), results from regression analyses showed that Chinese, Mathematics, and English grades were predicted by higher mindfulness and executive functions. However, the mindfulness–grades link disappeared after controlling for executive functions, suggesting that the association between dispositional mindfulness and school achievement was totally mediated by executive functions.

The growing body of research exploring mindfulness and its association with other psychological constructs (e.g., executive functions) as well as specific outcomes (e.g., school achievement) called for the development of valid instruments to assess mindfulness, especially among school-aged children and adolescents (Felver et al., 2016; Goodman et al., 2017; Pires et al., 2015; Zenner et al., 2014). Self-report instruments, besides showing good reliability in gauging trait-related characteristics of mindfulness, are a cost-effective option of easy and quick administration, allowing to expedite data collection in large-scale studies (Gomis, 2018; Paulhus & Vazire, 2007; Pires et al., 2015; Semple & Burke, 2012).

Goodman et al. (2017) identified seven self-report instruments to assess dispositional mindfulness in children and/or youth up to 18 years old: The Mindful Attention Awareness Scale for Adolescents (MAAS-A; Brown et al., 2011); the Mindful Attention Awareness Scale for Children (MAAS-C; Lawlor et al., 2014); the Comprehensive Inventory of Mindfulness Experiences for Adolescents (CHIME-A; Johnson et al., 2017); the Mindful Thinking and Action Scale for Adolescents (MTASA; West et al., 2007); the Mindfulness Scale for Pre-Teens, Teens, and Adults (MSPTA; Droutman, 2015); the Mindfulness Inventory for Children and Adolescents (MICA; Briere, 2011); and the Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011). This last one is among the most popular ones (Royuela-Colomer & Calvete, 2016).

In addition to the amount of research revealing CAMM as a sound instrument for young people (Eklund et al., 2017; Greco et al., 2011; Kuby et al., 2015; Pires et al., 2015; Tomlinson et al., 2018), the small number of items (10) and

the short time to complete it (less than 5 min) are seen as considerable advantages (Goodman et al., 2017; Greco et al., 2011). Originally developed in the USA (Greco et al., 2011), CAMM has also been validated across several contexts, namely, Australia (Kuby et al., 2015), Iran (Mohsenabadi et al., 2020), the Netherlands (Bruin et al., 2014), France (Roux et al., 2019), Italy (Bartoccini et al., 2017), Catalunya/Spain (Viñas et al., 2015), and Portugal (Cunha et al., 2013).

Despite the generally satisfying psychometrics qualities, CAMM's factorial structure seems inconsistent across different populations. Whereas most versions replicated the original CAMM's single-factor structure (Greco et al., 2011), two dimensions emerged from the Iranian and Dutch versions (Bruin et al., 2014; Mohsenabadi et al., 2020). One dimension was related to awareness and the other to acceptance (or, conversely, avoidance of thoughts and feelings). Similar inconsistent findings have been found for the Portuguese version.

After the removal of one item, Cunha et al. (2013) validated the original single factor CAMM structure ($\alpha = 0.80$) in a sample of 410 Portuguese adolescents from 12 to 18 years old. However, results from recent studies conducted with Portuguese students diverged in what concerns to the number of CAMM's items and dimensions. As in the validation of Cunha et al. (2013), Magalhães et al. (2022), using a sample of 272 students 10 to 18 years old, observed that the original CAMM showed a poor model fit, which only improved after removing one item with a very low factor loading (0.04). This item was the same of that removed from the study of Cunha et al. (2013) (i.e., "*I push away thoughts that I don't like*"). By contrast, Cordeiro et al. (2021a), using a sample of 187 students 11 and 12 years old, found evidence for an even shorter instrument, composed of seven items organized in two distinct factors. This two-factor structure already emerged from the Iranian as well as Dutch versions and is in line with the operational definition of mindfulness proposed by Bishop et al. (2004), comprising mindful acceptance and mindful awareness. Despite the excellent model fit achieved and the high reliability of the mindful acceptance factor ($\omega = 0.83$ in the preliminary study and $\omega = 0.86$ in the main study), the reliability coefficients of the mindful awareness factor were not so good ($\omega = 0.66$ and $\omega = 0.46$, respectively).

The inconsistencies in the number of CAMM's items and its factorial structure in Portuguese samples may be due to the different ages (10–12 vs. 12–18 years old) and data analytic approaches (e.g., estimator) used in the studies. Together, these findings raised questions about the suitability of the 10-item CAMM to assess mindfulness in Portuguese youngsters. Thus, more research seems needed to examine CAMM's items and factorial structure in Portuguese settings, especially because this has already been questioned in other contexts and populations.

The present study aimed to examine the psychometric properties and predictive validity of the Portuguese version of the CAMM in a sample of pre-teens. We expected to replicate the unifactorial structure and to find a mediation link between CAMM and school achievement via executive functions. Overall, findings will provide further information about the validity and reliability of a widely used tool for the measurement of dispositional mindfulness, whose structure has been found to be inconsistent between and within populations. This will help to clarify the most suitable version of CAMM in Portuguese pre-teens. Moreover, our research will also extend current knowledge by enlightening the processes underlying the association between mindfulness and school achievement.

Method

Participants

The main sample was composed of 205 Portuguese-speaking students in Grade 4, with a mean age of 9.71 years ($SD = 0.39$; 105 girls). The cross-validation sample included 176 fourth-grade students, with a mean age of 9.83 years ($SD = 0.57$; 76 girls). This sample size meets the minimum criterium for conducting SEM analyses, which should include more than 10 participants per indicator (Kline, 2016). Participants were obtained through a non-probability sampling by convenience, including all fourth graders who were attending school at the moment of data collection. The presence of special education needs and the lack of legal guardian authorization were used as exclusion criteria. Students' socioeconomic status was assessed through their parents' educational level, which is shown in Table 1. It is worth

Table 1 Educational level of the participants' parents by sample

	Main sample ($n = 205$)		Cross-validation sample ($n = 176$)	
	Mother (%)	Father (%)	Mother (%)	Father (%)
Grade 4 or below	6.80	5.90	9.10	13.1
Grade 6	35.1	39.0	31.3	31.3
Grade 9	34.1	29.8	18.8	15.3
High school	20.5	12.2	6.30	4.50
College	1.00	0.50	2.30	1.10
Above college	1.00	3.90	1.10	1.70
No information	1.50	8.80	31.3	33.0

In 2021, Portuguese national statistics regarding females' and males' educational level was as follows: 20.4% and 18.1% completed Grade 4 or less; 7.4% and 10.6% completed Grade 6; 16% and 21.2% completed Grade 9; 23.2% and 28% completed high school; and 27.8% and 20% completed college or college plus some postgraduate study (Francisco Manuel dos Santos Foundation, 2022)

noting that parents' educational level in these samples was generally lower than the Portuguese population.

Procedure

Participants completed the CAMM in classroom groups of 20–25 students and then, individually in a quiet room, they performed three behavioral tasks assessing the following executive functions: working memory, inhibitory control, and cognitive flexibility. All tasks were administered by highly trained research assistants with a graduate degree in Psychology. Students' grades in Portuguese and Mathematics were provided by the school.

Measures

Mindfulness Participants' dispositional mindfulness was assessed with the CAMM, which was developed by Greco et al. (2011) and validated to the Portuguese population by Cunha et al. (2013). Responses are given in a 5-point Likert scale and all items are reverse scored, with lower results indicating more self-reported dispositional mindfulness (Greco et al., 2011; Kuby et al., 2015). As previously described, this instrument is composed of 10 items commonly assumed to load on a single factor, although some versions identified a bidimensional structure (Bruin et al., 2014; Cordeiro et al., 2021a; Mohsenabadi et al., 2020).

Working memory We used the Forward and Backward digit span task from the Wechsler Intelligence Scale for Children-III (WISC-III), which was validated to the Portuguese population aged between 6 and 17 years by Simões et al. (2003). In this task, children recall sequences of numbers with increasing length in forward and in backward orders. The final score corresponds to the average of sequences successfully completed, with higher scores suggesting higher working memory. This test exhibits good coefficients of stability ($r = 0.80$; Simões et al., 2003) and internal consistency ($\alpha = 0.83$; Waters & Caplan, 2003).

Inhibitory control We used the Inhibition subtest of the battery A Neuropsychological Assessment (NEPSY-II), which was developed by Korkman et al. (2007). Although there is no normative data for the Portuguese population, this is a language-independent measure often used in clinical practice and successfully applied in Portuguese researches (Cordeiro et al., 2021a; Magalhães et al., 2020). This task evaluates the ability to quickly inhibit automatic responses in favor of novel ones. When shown a sheet with black and white shapes (Part I) or arrows (Part II), participants are asked to state the opposite form (say square when they see a circle and vice versa) or the opposite arrow direction (say up when it is pointing down and vice versa). The final score of the test, which is performed for a maximum of 240 s, is the combination of the completion time with errors, with higher combined scores suggesting better inhibition. The test presents good coefficients of test–retest reliability ($r = 0.81$; Brooks et al., 2009) and internal consistency ($\alpha = 0.92$; Korkman et al., 2007).

Cognitive flexibility We used the Cognitive flexibility subtest of the NEPSY-II (Cordeiro et al., 2021a; Korkman et al., 2007; Magalhães et al., 2020), which assesses the ability to quickly inhibit automatic responses as well as the ability to switch between response types. Participants use the same sheet of black and white shapes and arrows described above to either say the correct shape or arrow direction (when those are colored black) or the opposite shape or arrow direction (when those are colored white). The final score test is also obtained from the combination of the completion times with errors, with higher combined scores pointing to higher cognitive flexibility. This test shows a good test–retest reliability ($r = 0.82$; Brooks et al., 2009) and an excellent internal consistency ($\alpha = 0.99$; Korkman et al., 2007).

School achievement To assess participants' school achievement, we considered their 1st-term grades in the subjects of Portuguese and Mathematics. These grades are given by students' schoolteacher, in a scale ranging from 1 (*lowest score*) to 5 (*highest score*).

Data Analyses

Data analyses started with a preliminary step in the IBM SPSS Statistics 26 to inspect descriptive statistics of all items. Then, given the clustered nature of the data due to group data collection, we used the lavaan.survey package for the R system for statistical computing (Oberski, 2014; R Development Core Team, 2005) to test the suitability of the Portuguese CAMM through a three-step strategy.

On step 1, we conducted a confirmatory factor analysis (CFA) in the main sample ($N = 205$) using the diagonally weighted least square estimator, which is suitable to metric indicators with ordered-categorical indicators (Li, 2016). Latent variables were scaled by imposing unit of loading identification constraints. Specifically, to allow the free estimation of all factor loadings, the variance of latent factors was constrained to equal 1.0. Based on Kline (2016), model fit was tested with the following indices: chi square statistic (χ^2), confirmatory fit index (CFI), root-mean-square error of approximation (RMSEA), and standardized root mean residual (SRMR). CFI values > 0.95 and 0.90, RMSEA values < 0.06 and 0.10, and SRMR values < 0.06 and 0.09 are considered good and adequate fits, respectively (Hu & Bentler, 1999). Items with factor loadings bellow 0.30 were

removed (based on Brown, 2006; Tabachnick & Fidell, 2007), and a new CFA was conducted.

On step 2, we cross-validated the CAMM version achieved in the previous step, using a new, independent sample of 176 fourth graders. After conducting the CFA on the cross-validation sample, we examined model invariance across the main and cross-validation samples. Using multiple-group structural equation modeling, four models with increasing stringency were sequentially tested: configural model in the two samples (configural invariance), model with factor loadings constrained to be equal in both samples (metric invariance), model with both factor loadings and intercepts constrained to be equal in both samples (scalar invariance), and model with factor loadings and intercepts as well as error variances and covariances constrained to be equal across samples (strict invariance). Chi-square difference tests were used to compare models. In both samples, we additionally examined CAMM's reliability via Cronbach's α and McDonald's ω coefficients (see Revelle & Zinbarg, 2008).

On step 3, to further explore the validity of the achieved CAMM structure, we examined the pattern of relationships between CAMM and external correlates, namely, executive functions and school achievement. After examining correlations between these variables, we tested the putative mediating role of executive functions on the expected link between CAMM and school achievement. For that, we specified a latent variable model composed of the following latent variables (with variance constrained to 1.0) and indicators: CAMM—CAMM's items 1, 2, 3, 4, 6, 7, 8, and 9; executive functions—working memory, inhibitory control, and cognitive flexibility scores; and school achievement—Portuguese and Mathematics grades (cf. Fig. 1). We conducted a CFA to test a measurement model with these latent constructs allowed to correlate among each other, followed by structural equation modeling analyses to test a partial versus full mediation model.

In the partial mediation model, we specified direct and indirect (via executive functions) paths of CAMM on school achievement. This was based on research showing that factors other than executive functions, namely, sustained attention, emotional self-regulation, school climate, and engagement, might explain the association between mindfulness and school achievement (Maynard et al., 2017; Miralles-Armenteros et al., 2019; Wisner, 2014). In the full mediation model, we only specified indirect paths of CAMM on school achievement via executive functions. This was grounded on a study by Lu et al. (2017), who found that the mindfulness–achievement link disappeared when executive functions were accounted for in a regression model. Due to previous evidence showing that gender and age were associated with mindfulness (Thirumaran et al., 2020), executive functioning (Grissom & Reyes, 2019), and academic performance (Douglas et al., 2020), we controlled for gender and age in both models by specifying direct paths from these to each of our latent variables.

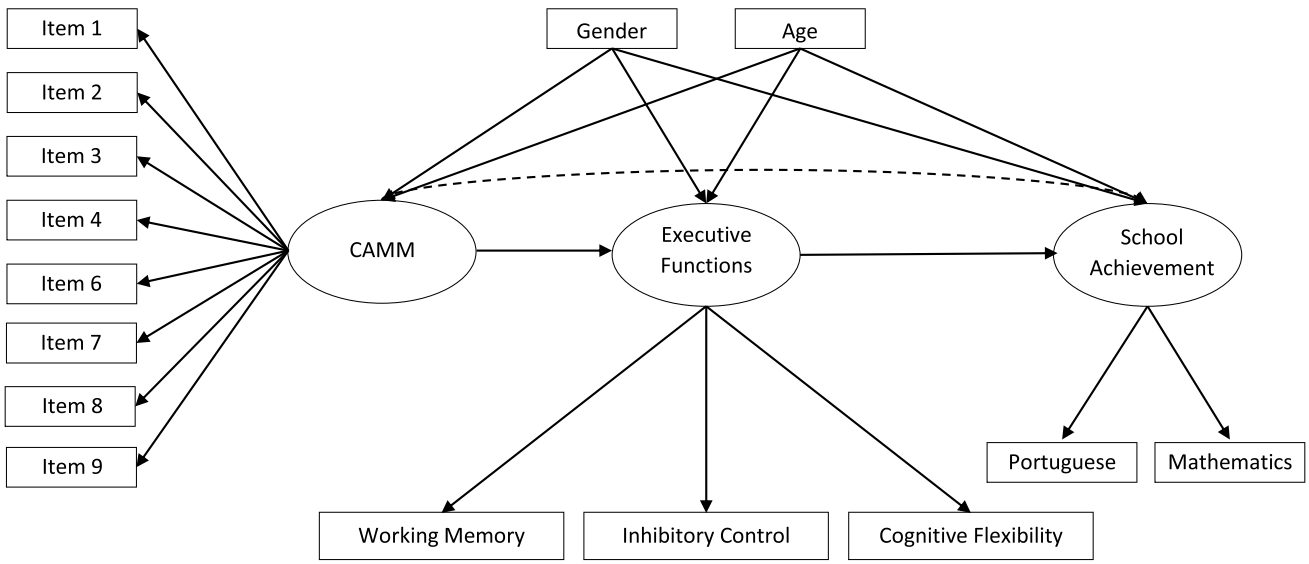

Fig. 1 Mediation models tested to examine the effects of mindfulness in school achievement via executive functions, while controlling for gender and age. Errors of observed variables and disturbances of endogenous latent variables were omitted from the figure to make it more legible. The dashed path was included in the partial mediation model and removed from the full mediation model

Results

Preliminary Analyses

The inspection of descriptive statistics for all items revealed no severe distributional problems, as absolute values of skewness and kurtosis were below 2 (Kline, 2016). Information concerning the means and standard deviations for each item by sample may be found in Table 2.

Confirmatory Factor Analysis

The CFA on the single-factor CAMM composed of 10 items revealed an adequate model fit, χ^2 (35, $N = 205$) = 51.99, $p = 0.03$; CFI = 0.96; RMSEA = 0.05, RMSEA 90% CI [0.02, 0.08], $p = 0.50$; SRMR = 0.07, but item 5 displayed an unacceptable factor loading (0.11). After removing this item, results showed an excellent model fit, χ^2 (27, $N = 205$) = 27.36, $p < 0.001$; CFI = 1.00; RMSEA = 0.008, RMSEA 90% CI [0.00, 0.06], $p = 0.91$; SRMR = 0.06. However, because item 10 revealed a factor loading of 0.29, this item was removed, and a final CFA was conducted. The final 8-item version achieved an excellent model fit, χ^2 (28, $N = 205$) = 22.20, $p = 0.33$; CFI = 1.00; RMSEA = 0.02, RMSEA 90% CI [0.00, 0.07], $p = 0.81$; SRMR = 0.06, with factor loadings above 0.33 (all $ps < 0.001$). Both Cronbach's α and McDonald's ω were 0.75.

Cross-Validation and Measurement Invariance Tests

To cross-validate the 8-item CAMM achieved in the previous step, we conducted a CFA in a new, independent sample. Results revealed a good model fit, χ^2 (20, $N = 176$) = 26.04, $p = 0.17$; CFI = 0.99; RMSEA = 0.04, RMSEA 90% CI [0.00, 0.08], $p = 0.59$; SRMR = 0.07, with factor loadings above 0.39 (all $ps < 0.001$). Both Cronbach's α and McDonald's ω were 0.77. In this sample, the 8-item version was also slightly better than the 10-item version, χ^2 (35, $N = 176$) = 44.34, $p = 0.13$; CFI = 0.98; RMSEA = 0.04, RMSEA 90% CI [0.00, 0.07], $p = 0.68$; SRMR = 0.07, with factor loadings above 0.34 (all $ps < 0.001$). Thus, we proceeded the data analyses with the 8-item version. Information concerning factor loadings and item-total correlations for each sample and item from CAMM's final version is presented in Table 3.

Multiple group analyses showed that the configural model fitted the data well, χ^2 (40, $N = 48$) = 93.98, CFI = 0.91, RMSEA = 0.08, as well as the model with factor loadings constrained to be equal across groups, χ^2 (47, $N = 41$) = 96.24, CFI = 0.91, RMSEA = 0.07. There was no decrement in model fit, $\Delta\chi^2$ (7) = 2.26, $p = 0.94$, indicating metric invariance across both samples. The model with both factor loadings and intercepts constrained to be equal across groups also achieved an adequate fit, χ^2 (54, $N = 34$) = 102.96, CFI = 0.92, RMSEA = 0.07. Again, there was no decrement in model fit, $\Delta\chi^2$ (8) = 10.23, $p = 0.25$, suggesting scalar invariance across both samples. The more stringent model, in which both factor loadings and intercepts as well as error variances and covariances were constrained, achieved an acceptable fit, χ^2 (62, $N = 26$) = 113.20, CFI = 0.91, RMSEA = 0.07. As before, model fit did not

Table 2 Descriptive statistics of the items by sample

Items	Main sample ($n = 205$)				Cross-validation sample ($n = 176$)			
	M	*SD*	*Sk*	*Ku*	*M*	*SD*	*Sk*	*Ku*
1. I get upset with myself for having feelings that don't make sense	2.91	1.44	0.07	−1.30	3.13	1.44	−0.06	−1.26
2. At school, I walk from class to class without noticing what I'm doing	3.78	1.40	−0.79	−0.73	3.82	1.29	−0.77	−0.53
3. I keep myself busy so I don't notice my thoughts or feelings	2.96	1.38	0.08	−1.22	3.07	1.34	−0.01	−1.10
4. I tell myself that I shouldn't feel the way I'm feeling	2.79	1.40	0.26	−1.12	2.83	1.37	0.22	−1.07
5. I push away thoughts that I don't like[a]	2.16	1.38	0.83	−0.69				
6. It's hard for me to pay attention to only one thing at a time	3.11	1.38	−0.06	−1.22	3.01	1.50	0.01	−1.40
7. I think about things that happened in the past instead of thinking about things that are happening right now	2.75	1.33	0.10	−1.09	2.68	1.37	0.29	−1.09
8. I get upset with myself for having certain thoughts	2.98	1.47	0.06	−1.34	3.20	1.41	−0.23	−1.16
9. I think that some of my feelings are bad and that I shouldn't have them	2.61	1.42	0.28	−1.24	2.86	1.44	0.07	−1.31
10. I stop myself from having feelings that I don't like[a]	2.86	1.57	0.14	−1.50				

Sk skewness, *Ku* kurtosis

[a]Removed items

Table 3 Factor loadings and item-total correlations for the 8-item Portuguese CAMM

Item	Main sample ($n=205$)		Cross-validation sample ($n=176$)	
	Factor loadings (CFA)	Item-total correlation	Factor loadings (CFA)	Item-total correlation
Item 1	.57	.47	.64	.53
Item 2	.38	.34	.40	.37
Item 3	.49	.44	.50	.44
Item 4	.57	.47	.57	.49
Item 6	.33	.30	.39	.36
Item 7	.59	.50	.53	.46
Item 8	.71	.58	.83	.70
Item 9	.52	.42	.52	.43

decrease, $\Delta\chi^2$ (8) = 10.23, $p=0.25$, suggesting strict invariance across both samples.

Concurrent and Predictive Validity

Table 4 displays all bivariate correlations between CAMM and external correlates. Two results are worth mentioning. First, CAMM was correlated with cognitive flexibility and inhibitory control ($rs=0.18$), but neither with working memory nor Portuguese and Mathematics grades ($rs<0.12$). Second, all executive functions as well as grades were correlated with each other ($0.22<rs<0.72$).

SEM analyses showed that the fit of both the partial and the full mediations models was adequate, respectively, χ^2 (82, $N=205$) = 132.45, $p<0.001$; CFI = 0.91; RMSEA = 0.06, RMSEA 90% CI [0.04, 0.07], $p=0.31$; SRMR = 0.06 (factor loadings between 0.32 and 0.92, all $ps<0.001$), and χ^2 (83, $N=205$) = 133.08, $p<0.001$; CFI = 0.91; RMSEA = 0.05, RMSEA 90% CI [0.04, 0.07], $p=0.33$; SRMR = 0.06 (factor loadings between 0.32 and 0.93, all $ps<0.001$). Moreover, chi-square difference tests revealed that both models were equally good, $\Delta\chi^2$ (1) = 0.64, $p=0.42$. Because the direct path from mindfulness to school achievement was not significant ($p=0.42$) and for the sake of parsimony, the full mediation model was chosen. Findings revealed a single effect of age on executive functions ($b=0.40$, $p<0.001$). After controlling for this, we found significant direct paths from mindfulness to executive functions ($b=0.25$, $p=0.006$) and from these latter to school achievement ($b=0.56$, $p<0.001$). In addition, there was evidence that executive functions mediated the link between mindfulness and school achievement ($b=0.14$, $p=0.01$).

Discussion

In the present study, we tested an instrument that, due to its briefness and number of translated versions, is widely used and deemed a good tool to assess dispositional mindfulness. However, research has been showing inconsistent findings between and within cultures. To contribute to its validation, we examined the factorial structure and the psychometric properties of the Portuguese version of the CAMM in preteens. We also explored its predictive validity by testing the association between CAMM and school achievement, mediated by executive functions. Overall, results supported a valid and reliable unidimensional scale composed of eight items as well as a full mediation link between CAMM and school achievement via executive functions.

Replicating findings of previous studies conducted in Portuguese settings (Cordeiro et al., 2021a; Cunha et al., 2013; Magalhães et al., 2022), our preliminary analysis failed to support the original 10-item CAMM (Greco et al., 2011). Together, these studies suggest that the 10-item version should be used cautiously with Portuguese children and adolescents either for research or applied purposes. After removing items 5 and 10, we achieved a model that fitted the data very well in both samples and was invariant across them. Item 5 was already acknowledged by Cunha et al. (2013) as a potential source of misfit and was shown to work poorly in the studies of Cordeiro et al., (2021a) and Magalhães et al. (2022). Clearly, evidence accumulates in support of the removal of item 5 from the Portuguese version.

Table 4 Descriptive statistics for all measures and bivariate correlations between them

Measures	Descriptive statistics		Bivariate correlations				
	M	*SD*	1	2	3	4	5
1. Mindfulness	23.89	6.73					
2. Working memory	5.78	1.22	.12				
3. Inhibitory control	10.08	3.50	.18**	.27**			
4. Cognitive flexibility	9.37	3.29	.18*	.22**	.49**		
5. Portuguese grades	3.66	0.75	.10	.37**	.35**	.31**	
6. Mathematics grades	3.64	0.89	.05	.32**	.29**	.30**	.72**

*$p<.05$. **$p<.01$

Results were not so clear concerning item 10. As happened here, the CAMM's final version achieved by Cordeiro et al., (2021a) did not include this item. Although kept in the final version of Magalhães et al. (2022), item 10 also displayed the poorest factor loading (0.32). We believe that the wording and content of these two items, using terms that might be too abstract for children and adolescents ("*I push away thoughts that I don't like*"; "*I stop myself from having feelings that I don't like*") may explain why they tend to not work properly in young samples. These sentences reflect a nonaccepting, avoidant stance toward unpleasant thoughts and feelings, which may require high levels of metacognition (Greco et al., 2011). Indeed, these mindfulness aspects, captured by an accepting and nonjudgmental facet in multidimensional approaches, were already shown to be problematic in a previous study using a sample of Portuguese 9–10-year-olds (Magalhães & Limpo, 2022).

Despite the removal of these items, we confirmed the unidimensionality of the Portuguese CAMM, which is in line with Brown and Ryan's (2003, 2004) unitary definition of mindfulness. As noted by these authors and Tolle (1999), individuals are unlikely to sustain full attention to internal and external experiences if they keep resisting to what is happening. This was the core idea underlying the creation of CAMM, which was supported by many validation studies, including the current research. Still, concerning the Portuguese version, we cannot ignore the study of Cordeiro et al. (2021a), which found evidence of a two-factor version.

This inconsistency may be due to differences in the data analytic approaches. In the current study, we applied the diagonally weighted least square estimation method, which is suitable to ordered-categorical responses (Li, 2016), such as those used in CAMM. In opposition, Cordeiro et al. (2021a) treated their indicators as metric and used the full-information maximum-likelihood estimation method, which might not be the best option to deal with categorical data, leading to low model fit and spurious multidimensionality (Li, 2016). Cross-cultural studies examining CAMM's items and factorial structure with sound estimation methods are therefore warranted to understand the extent to which this instrument works properly across languages and ages.

To further explore the validity of CAMM, we analyzed its association with external correlates, namely, executive functions and school achievement. We found that mindfulness was associated with inhibitory control and cognitive flexibility, but not with working memory. The association of mindfulness with inhibitory control and cognitive flexibility is consistent with earlier findings suggesting that students with higher mindful abilities have more facility in suppressing goal-irrelevant stimuli as well as adapting their thinking and behavior to the environment (Bigelow et al., 2021; Cordeiro et al., 2021a; Geronimi et al., 2020).

Still, the lack of association between mindfulness and working memory contrasts with previous findings (Bigelow et al., 2021; Quach et al., 2016), probably due to the different measures used to assess working memory. Whereas we used the Forward and Backward digit span task from the WISC-III, Bigelow et al. (2021) employed the Leiter-3 Reverse Memory Subscale. Although both represent the so-called *N*-back tasks, they differ in terms of items' presentation modality and content: the first is an auditory verbal task including numbers, while the second is a visual non-verbal task involving pictures. By contrast, Quach et al. (2016) used the Automated Operation Span task, which is a complex span task containing two simultaneous components: recalling letters while solving math equations. Given their distinctive features, it is likely that these tasks tap into different dimensions of working memory (Bühner et al., 2006; Jaeggi et al., 2010; Kane et al., 2007) that may relate differently with mindfulness.

Results concerning the link between executive functions and academic achievement were clearer, with positive and significant associations between all executive functions and grades. This finding broadly supports the work of other studies linking mental capacities to engage in deliberate and goal-directed thought and action with success in school (Amukune & Józsa, 2021; Bouzaboul et al., 2020; Magalhães et al., 2020; Spiegel et al., 2021). Contrary to our expectations, we found no association between mindfulness and school achievement. This result differs from general previous findings (Bakosh et al., 2016; Cordeiro et al., 2021b; Magalhães & Limpo, 2022; Schonert-Reichl & Roeser, 2016) showing that higher dispositional mindfulness is related to better school achievement. Neverthless, a closer look at these studies shows that the mindfulness–grades link depends on the specific mindfulness aspects and subjects being targeted.

Indeed, only two out of seven mindfulness facets were associated with school achievement in Grade 4 (Magalhães & Limpo, 2022). Moreover, mindfulness interventions in Grades 3–4 were found to improve students' performance in Reading and Science, but not in Writing, Spelling, Mathematics, nor Social Studies (Bakosh et al., 2016). In addition, two other studies revealed no direct link between any mindfulness measure and academic achievement, which seemed to be fully mediated by engagement or decentering (McBride & Greeson, 2021; Miralles-Armenteros et al., 2019). These evidences suggest that mindfulness may not reflect directly in grades, but through its association with other variables that underlie school achievement.

Our SEM analyses confirmed this assumption by showing that mindfulness was linked to school achievement via executive functions, while controlling for participants' age and gender. In other words, the more the children considered themselves to be nonjudgmentally aware of the

here-and-now experience, the greater their cognitive functioning and, in turn, the better their performance at school. Our results also revealed that older students displayed better executive functions, which is a well-stablished finding in the field (see Grissom & Reyes, 2019). The mediating effect corroborates the results from a previous study using the Mindful Attention Awareness Scale (Lu et al., 2017). This cross-sectional study conducted with migrant fifth graders in China revealed that mindfulness predicted students' grades in Chinese, Mathematics, and English by enhancing their executive functions.

These findings make sense because mindfulness, defined as the ability for paying attention to the immediate experience with openness and curiosity, is closely related to the attentional ability, which is at the root of executive functions (Diamond, 2013; Petersen & Posner, 2012) and school performance (Spaniol et al., 2018; Trentacosta & Izard, 2007). By being in line with previous research, the mediation role of executive functions in the association between CAMM and school achievement here found provides further evidence on the validity of this instrument to assess mindfulness in Portuguese pre-teens.

Overall, as observed in the present study, even a short 8-item instrument is capable of gauging central aspects of mindfulness, which can be particularly useful to conduct universal screening in schools and determine eventual intervention needs. Indeed, our study joined to a growing body of research showing that students with low dispositional mindfulness may be at a disadvantage in school. Identifying these students and enrolling them in mindfulness-based programs may be a means to potentiate their school success.

Our study showed that students' achievement in school benefited from the increased executive functioning provided by high levels of mindfulness. Thus, by improving children's abilities to pay attention, open and receptively, to the subjects' content, while ignoring potential distractors, mindfulness interventions may promote students' cognitive skills and, therefore, their academic success (Bigelow et al., 2021; Lu et al., 2017; Magalhães & Limpo, 2022).

Limitations and Future Directions

At least three limitations should be considered when interpreting findings of the current study. First, while the generally low educational level of the participants' parents limits the generalization of the current findings, the cross-sectional and correlational nature of our study prevents us from extracting development conclusions or causal inferences. Experimental and longitudinal methodologies including more representative samples might help us to understand the association of mindfulness with executive functions and academic achievement in the Portuguese population.

Second, we restricted executive functioning to working memory, inhibitory control, and cognitive flexibility, which correspond to the trilogy proposed by Diamond (2013). These functions represent a subset of the so-called cool executive functions, which are manifested under relatively decontextualized and non-emotional conditions (Peterson & Welsh, 2014). In future studies, it would be relevant to include other cool executive functions, such as reasoning, attention, planning, and organizing (Miyake et al., 2000; Simões et al., 2003) as well as hot executive functions, such as insight, empathy, interpersonal skills, affective decision-making, and emotional regulation (Bourke et al., 2019; Poon, 2018).

Hot executive functions represent self-management and goal-directed skills used in situations that generate emotion, motivation, and tension between gratification and long-term rewards (Bourke et al., 2019). In other words, hot executive functions account for the engagement in adaptive or maladaptive emotion regulation strategies, which may be connected with mindfulness and school performance (Meuwissen & Zelazo, 2014; Poon, 2018). These connections merit consideration in future research, especially using bi- or multidimensional approaches to mindfulness. For example, as cool executive functions are more cognitively oriented, it is reasonable to expect stronger links between them and attentional or awareness-related aspects. Conversely, as hot executive functions are more emotionally oriented, they are likely to be more closely related to the acceptance-related aspects of mindfulness.

Finally, we evaluated students' school achievement via their Portuguese and Mathematics grades. In spite of these being core subjects in Portuguese primary schools, there are other relevant subjects (e.g., Social Studies, Physical Education, Arts), whose link with mindfulness are worthy of exploration. Intervention studies already showed that mindfulness interventions improve some but not all school subjects (Bakosh et al., 2016), suggesting that the mindfulness–grades link may depend on the targeted subject. Overall, more studies are needed that cover a wider range of school subjects when examining their association with mindfulness.

Author Contribution TL designed the study. TL and IR analyzed and interpreted the data, and wrote the manuscript. SA drafted a preliminary version of the introduction and discussion. SM collected the data. All authors reviewed and approved the final version of the manuscript.

Funding This research was supported by the M2S Project funded through the Operational Programme for Competitiveness and Internationalization, supported by FEDER and national funds allocated to the Portuguese Foundation for Science and Technology (FCT; ref. NORTE-01–0145-FEDER-028404).

Data Availability All data are available at the Open Science Framework (https://osf.io/fce64/).

Declarations

Ethics This research involved underaged human participants and was approved by the ethical committee of the University of Porto.

Informed Consent Oral assent from participating children and written informed consent from their legal guardians was gathered.

Conflict of Interest The authors declare no competing interests.

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