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RESEARCH IN PROGRESS

Relating Dispositional Mindfulness and Long-Term Mindfulness Training with Executive Functioning, Emotion Regulation, and Well-Being in Pre-adolescents

Lena Wimmer[1] · **Kate R. Isherwood**[2] · **John Parkinson**[3] · **Dusana Dorjee**[4]

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Abstract The present study examined whether both dispositional mindfulness without mindfulness training and mindfulness resulting from longer-term mindfulness training are positively associated with pre-adolescents' well-being, via enhanced executive functioning (EF) and emotion regulation. EF was assessed in a GoNoGo task via behavioral performance and event-related potentials. Study 1 ($N=62$) investigated associations of dispositional mindfulness without mindfulness training with EF, well-being and emotion regulation; longitudinal Study 2 with an active control group compared the effects of long-term mindfulness training ($N=28$) with a positive psychology intervention ($N=15$). Dispositional mindfulness without training was associated with lower EF, unrelated to emotion regulation and the relationship with well-being was mixed. Long-term mindfulness training was positively related to EF and well-being (reduced negative affect), but was uncorrelated with emotion regulation and mindfulness scores. Taken together, long-term mindfulness training was found to have mixed effects. Further research is required in this area.

✉ Lena Wimmer
lena.wimmer@ezw.uni-freiburg.de

Kate R. Isherwood
krisherwood@cardiffmet.ac.uk

John Parkinson
j.parkinson@bangor.ac.uk

Dusana Dorjee
dusana.dorjee@york.ac.uk

1 Department of Education, University of Freiburg, Rempartstraße 11, 79098 Freiburg, Germany

2 Cardiff Metropolitan University, Cardiff, UK

3 School of Psychology, Bangor University, Bangor, UK

4 Department of Education, University of York, York, UK

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Abbreviations

MBIs	Mindfulness-based interventions
EF	Executive functioning
DMW	Dispositional mindfulness without mindfulness training
DMT	Dispositional mindfulness with mindfulness training
MAAS-C	Mindful Attention Awareness Scale Adapted for Children
CAMM	Child and Adolescent Mindfulness Measure
MAAS-A	Mindful Attention Awareness Scale for Adolescents
ERPs	Event-related potentials
AX-CPT	Continuous Performance Test of the AX type
CNV	Contingent negative variation
PANAS-C short version	10-Item Positive and Negative Affect Schedule for Children
SWLS-C	Satisfaction with Life Scale for Children
ERC	Emotion Regulation Checklist
RT	Reaction time
ICA	Independent Component Analysis
T1	Time 1
T2	Time 2
T3	Time 3
MG	Mindfulness group
CG	Control group

Introduction

With increasing awareness of child and adolescent mental health challenges (e.g., Collishaw, 2015) policy makers, educators, and researchers have been searching for ways to prevent mental ill-health and to increase young people's well-being. Mindfulness, often described as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2003, p. 145), has been associated with improvements in well-being in children and adolescents (Dunning et al., 2019). The term mindfulness has been used to refer to a mental state, i.e., a mindful mode of awareness at a given point in time (e.g., Lau et al., 2006), a trait/disposition, i.e., the general tendency to be mindful in daily life (e.g., Brown & Ryan, 2003), or a range of practices and techniques often combined in alleged mindfulness-based interventions (MBIs). Theoretical models of mindfulness predominantly postulate that attention regulation operates as bootstrap mechanism of more distal effects, such as emotion regulation and well-being (e.g., Bishop et al., 2004; Malinowski, 2013). Attention regulation involves the ability to continuously select the level of attentional activity and its focus in alignment with one's goals (e.g., Malinowski, 2013; Posner & Rothbart, 2007); it is often used synonymously with executive functioning (EF). According to a model by Teper et al. (2013), for instance, mindfulness improves well-being via more efficient EF and emotion regulation. These mechanisms of mindfulness seem particularly relevant in the developmental context: children's self-regulatory abilities, comprising both EF and emotion regulation (e.g., Blair & Raver, 2015), predict a range of key outcomes, including physical, social and intellectual development (e.g., Kochanska, 1997; Moffitt et al., 2011; Padilla-Walker & Christensen, 2011; Spiegel et al., 2021; Tangney et al., 2004). Furthermore, during early and middle childhood, self-regulatory abilities change rapidly (e.g., Fjell et al., 2012), and demonstrate high sensitivity to environmental influences (Blair & Raver, 2012; Durlak et al., 2011; overview: Kaunhoven & Dorjee, 2017).

Whether dispositional mindfulness improves as a result of children/adolescents attending an MBI is a question yet to be answered. This is because the evidence available at present is inconsistent. In the context of this paper, a distinction is made between dispositional mindfulness without mindfulness training (DMW) and dispositional mindfulness with mindfulness training (DMT). Scores in the subscale of the Mindful Thinking and Action Scale for Adolescents (West et al., 2005) and the Mindful Attention Awareness Scale Adapted for Children (MAAS-C; Lawlor et al., 2014) have been found to increase between the start and the end of a multi-week mindfulness program (Himelstein et al., 2012; Schonert-Reichl et al., 2015). In contrast, the two most frequently applied instruments, namely the Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011) and the Mindful Attention Awareness Scale for Adolescents (MAAS-A; Brown et al., 2011), have received lower scores in adolescents with prior meditation/yoga experience, compared to unexperienced adolescents (de Bruin et al., 2011, 2014). This unexpected result has been explained by a response-shift bias: as individuals practice mindfulness more often, they become more aware of attentional lapses; this results in lower ratings after an intervention. Alternatively, the finding could indicate limited construct validity of CAMM and MAAS-A. State mindfulness has not been examined in children since no instrument is available for this age group (Goodman et al., 2017).

In general, existing research investigating mindfulness in youth mostly looked at either well-being (Mendelson et al., 2010) or self-regulation (Flook et al., 2010). When both outcome areas were considered, interrelations between self-regulation and well-being were not explored (Schonert-Reichl et al., 2015). In addition, so far the vast majority of studies on mindfulness with children and adolescents relied solely on questionnaire-based measures rather than behavioral and/or physiological indicators—the latter two can bypass self-report biases (Zenner et al., 2014).

The Present Project

Overarching Methodological Framework

To overcome these limitations, Kaunhoven and Dorjee (2017) proposed an integrative neurodevelopmental framework. Here, theory-driven research hypotheses are tested with data from a concurrent collection of self-report, other-report, behavioral, psychophysiological and neuroscientific measures; Kaunhoven and Dorjee (2017) particularly highlighted the benefits of using event-related potentials (ERPs). ERPs—averaged brain wave responses to stimuli—provide a non-invasive, cost-effective method with high temporal resolution for investigating the neurocognitive processes underlying self-regulation. The current project follows this approach, combining self- and other-report measures with behavioral performance in a computerized task, an AX type Continuous Performance T (AX-CPT; van Leeuwen et al., 1998), and event-related potentials (ERPs). The AX-CPT is a 2 stimuli Go/NoGo paradigm assessing several cognitive and underlying neural processes relevant to EF (Braver & Barch, 2002). Three types of stimuli appear—cue, target, and distractor—in the following trial types: Go trials (cue followed by target) expecting a button press, NoGo trials (cue followed by distractor) requiring inhibition of button presses, and Ignore trials (distractor followed by target) which can be disregarded. Behavioral performance is indexed by accuracy and reaction time. Brain processes modulated by the three conditions can also be assessed by four ERP components. Two of these ERP components are locked to the cue: the Cue-P3 and the contingent negative variation (CNV).

The Cue-P3

The Cue-P3 is a positive peak between 300 and 600 ms after stimulus onset and can index cue utilization (Hämmerer et al., 2010). Superior cue utilization in pre-adolescents is expressed by less positive amplitudes, but bound to the following two conditions: first, that this reduction in amplitude is accompanied by reduced Cue-P3 latency, and second, that behavioral response to the cue is withheld (Hämmerer et al., 2010; Tsai et al., 2009).

The CNV

The CNV is a negative component appearing between 1100 and 1600 ms after cue onset and signals resource optimization (Kononowicz & Penney, 2016). Advantageous levels of resource optimization during pre-adolescence are suggested by more negative CNV amplitudes (Hämmerer et al., 2010). Two further ERP components are locked to targets: the NoGo-N2 and the NoGo-P3.

The NoGo-N2

The NoGo-N2 is a negative deflection occurring 200–300 ms after the target and is related to conflict processing (Groom & Cragg, 2015). Improved conflict processing in pre-adolescents is demonstrated by less negative NoGo-N2 amplitudes (meta-analyses: Hoyniak, 2017; Hoyniak & Petersen, 2019).

The NoGo-P3

The NoGo-P3 is a positive peak between 300 and 500 ms post target indexing response inhibition (Groom & Cragg, 2015). More proficient response inhibition is indicated by more positive NoGo-P3 amplitudes (Jonkman, 2006) and shorter NoGo-P3 latency (Liu et al., 2011).

Study Aims and Hypotheses

In these studies, the overall assumption is tested that DMW, DMT, and long-term attendance of an MBI during pre-adolescence are linked with improved well-being, and that this benefit is achieved via enhancement of EF and emotion regulation. Study 1 focuses on associations of DMW, Study 2 employed a longitudinal controlled design comparing the effects of long-term mindfulness practice with an active control treatment (i.e., a positive psychology intervention).

Study 1

Part of the sample ($n = 20$) constituted the control group in a study by Wimmer and Dorjee (2020). This presented a cross-sectional comparison of mindfulness-experienced pre-adolescents with mindfulness-inexperienced preadolescents regarding EF, emotion regulation, and well-being. The current study investigates a distinct research question and uses statistical analyses different from the ones reported by Wimmer and Dorjee (2020). In the present study it was hypothesized that higher DMW would be associated with better EF, emotion regulation, and well-being. It was also expected that the positive association between DMW and well-being would be mediated by EF and emotion regulation.

Study 2

Study 2 aimed to examine whether long-term mindfulness training is linked with increased DMT. It also aimed to investigate whether changes resulting from mindfulness practice in pre-adolescents show the same pattern of associations with EF, emotion regulation, and well-being as DMW (Study 1). Study 2 tracked a group of pre-adolescents engaging in continuous mindfulness practice in three assessment sessions (i.e. T1 = June 2017 for the mindfulness group, T2 = December 2017 for the mindfulness group, T3 = June 2018 for the mindfulness group) spread over 1 year. At time 1 (T1), the mindfulness training group had practiced mindfulness on average for 2.11 years. An active control group received a positive psychology intervention based on the "Three Good Things" exercise (Seligman et al., 2005) and was also assessed at three time points (i.e. T1 = March 2017 for the control group, T2 = July 2017 for the control group, T3 = December 2017 for the control group)—immediately before and after the 17-week intervention period, plus at 5-month follow-up. A cross-sectional comparison of both groups at T1 is reported in Wimmer and Dorjee (2020). This study extends the previous one since it compares both groups across all three time points by means of distinct statistical analyses.

Positive psychology interventions including "Three Good Things" have proven to increase well-being in school-aged children (Carter et al., 2016; McCabe et al., 2011; Seligman et al., 2009). Here, assumed pathways to enhanced well-being include a more positive attributional style or a memory search bias towards positive events (Carter et al., 2016). As distinct from mindfulness though, improvements of EF and emotion regulation have not been put forward as underlying mechanisms. Hence, use of this comparison group controlled for mindfulness-unrelated improvement of well-being.

To aid comparisons with DMW, Study 2 applied the same measures as those in Study 1. An open question regarding the implementation of MBIs in schools addresses moderating effects of practice, in particular dosage (In the context of this study dosage is defined as self-reported frequency of mindfulness practice). Empirical evidence on dosage effects has so far been inconsistent (e.g., Dunning et al., 2019). One of the recommendations for further research has been that evaluations should also take into the account the impact of relational mindfulness practice characteristics such as practice enjoyment (Jensen, 2014). For instance, it is important to understand whether dosage is positively related to outcomes only when pupils like practicing mindfulness. This can inform adaptations of mindfulness-based programs for children and their implementation based on individual differences. Therefore, indicators of practice frequency and enjoyment were assessed in addition to measures used in Study 1.

It was hypothesized that:

1. Mindfulness group (MG) would show greater improvement in EF than the positive psychology active control group (CG) from T1 to T2 and from T2 to T3 (due to continued mindfulness practice),
2. MG would show greater gains on emotion regulation assessments than CG from T1 to T2 and from T2 to T3 (due to continued mindfulness practice);
3. MG scores on DMT would show greater increase than CG mindfulness scores from T1 to T2 and from T2 to T3 (due to continued mindfulness practice);
4. Both MG and CG would show improvements in well-being from T1 to T2 (because this was the only period during which both groups received training expected to foster well-being). Between T2 and T3, further gains were expected for MG, whereas CG were hypothesized to maintain well-being levels from T2 (due to continued mindfulness practice and previous findings from Carter et al. (2016), indicating sustained gains in well-being after a positive psychology intervention);
5. It was also expected that increases in well-being from T1 to T2 in MG would be mediated by gains in EF and emotion regulation between T1 and T2. A similar mediation pattern was expected to occur from T2 to T3.

In addition, it was explored whether outcomes would be affected by frequency and enjoyment of mindfulness practice in MG.

Materials and Methods

The Ethics Committee in the School of Psychology at Bangor University approved both studies prior to their start.

Table 1 Study 1: descriptive statistics/frequencies of demographic variables, questionnaire-based and behavioral dependent measures

	Total
Mean age (SD)	8.71 (1.03)
Percentage female	53
Percentage right-handed	87
Percentage left-handed	8
Percentage ambidextrous	5
Percentage first language = English	58
Percentage first language = Welsh	42
Mean PANAS-C PA (SD)	18.98 (4.72)
Mean PANAS-C NA (SD)	8.62 (2.96)
Mean SWLS-C (SD)	19.55 (4.20)
Mean ERC Neg (SD)	10.65 (5.62)
Mean ERC ER (SD)	23.72 (4.28)
Mean target RT (SD)	695.78 (190.92)
SD of target RT (SD)	195.71 (59.33)
CPT % impulses to 1st stimulus	1.51 (2.53)
CPT % target omissions	2.28 (2.37)
CPT % disinhibited responses	1.61 (2.39)
CPT % inattentive impulses	4.11 (5.46)

PANAS-C PA Positive and Negative Affect Schedule for Children, positive affect subscale, *PANAS-C NA* Positive and Negative Affect Schedule for Children, negative affect subscale, SWLS-C Satisfaction with Life Scale Adapted for Children, *ERC Neg* Emotion Regulation Checklist, negativity/lability subscale, *ERC ER* Emotion Regulation Checklist, emotion regulation subscale, *CPT* Continuous Performance Test, AX type

Participants

For study 1, parents and children from years 3 to 6 in three schools in North Wales, which expressed interest in the project, were invited to participate in the study and 62 pupils were recruited; see Table 1 for sample characteristics. None of the participants had received training in mindfulness previously, none had a history of brain injury or brain operation in the past or suffered from epilepsy. Self-report questionnaires were completed by all 62 children. 60 children performed the computer task and 56 of them volunteered for EEG recording during the task; data from 43 pupils was useable for the final ERP analyses. An informant-based questionnaire was returned by 44 parents.

For study 2, pupils ($N = 53$) were recruited from two primary schools in North Wales, 33 children from a school with an established mindfulness curriculum, and 20 children from a school without any previous experience with mindfulness. This initial sample constituted the sample of Wimmer and Dorjee (2020). First, the former school was invited to participate in research on their longstanding implementation of mindfulness; the headmaster accepted this invitation. Subsequently, all primary schools within a distance of 30 miles

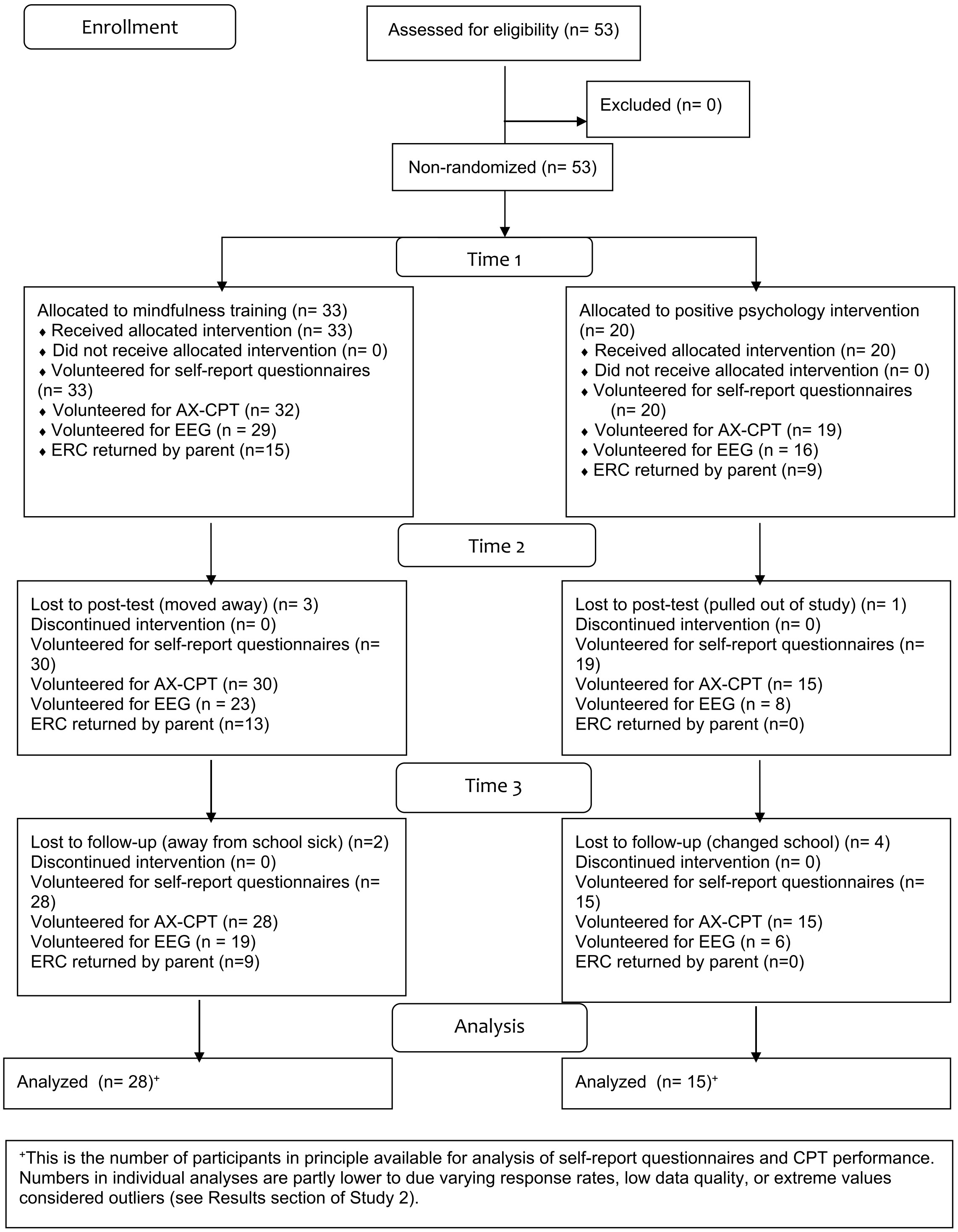

Fig. 1 Flow of participants through study 2

from Bangor University that had not engaged in mindfulness training were sent invitation letters. The latter school was the only one expressing interest. Next, parents and pupils were invited through information letters handed out at the two schools. None of the participants had a brain injury or brain operation in the past or suffered from epilepsy. The flow of participants through the study is illustrated in Fig. 1. The final sample consisted of $N=43$, with $n=28$ in MG and $n=15$ in the positive psychology CG. Sample characteristics are displayed in Table 2. Although children in both

Table 2 Study 2: sample characteristics

	Mindfulness training group	Positive psychology intervention group	Inferential statistics
Mean year in school at time 1 (SD)	4.39 (0.50)	4.13 (0.83)	$t(19.48) = -1.28$, $p = 0.207$
Mean age at time 1 (SD)	9.73 (0.64)	9.27 (0.80)	$t(41) = -2.08$, $p = 0.044$
Mean age at time 2 (SD)	10.23 (0.64)	9.60 (0.80)	$t(41) = -2.84$, $p = 0.007$
Mean age at time 3 (SD)	10.73 (0.64)	10.02 (0.80)	$t(41) = -3.20$, $p = 0.003$
Percentage female	64.29	40.00	$\chi^2(1) = 2.34$, $p = 0.126$
Percentage right-handed	85.71	86.67	$\chi^2(1) = 0.01$, $p = 0.932$
Percentage first language = English	100.00	13.33	$\chi^2(1) = 34.78$, $p < 0.001$
Percentage first language = Welsh	0.00	86.67	

Table 3 Study 2: descriptive statistics and reliabilities of questionnaire-based and behavioral dependent measures

	ω_{RT}			Mindfulness training group			Positive psychology intervention group		
	T1	T2	T3	T1: M (SD)	T2: M (SD)	T3: M (SD)	T1: M (SD)	T2: M (SD)	T3: M (SD)
CAMM	0.69	0.77	0.81	24.14 (5.25)	25.50 (4.44)	24.75 (5.50)	24.20 (7.37)	24.93 (6.42)	24.07 (8.64)
PANAS-C—PA	0.82	0.83	0.81	18.71 (3.36)	19.86 (2.32)	19.56 (3.55)	19.08 (5.56)	20.00 (4.34)	20.15 (3.85)
PANAS-C—NA	0.82	0.88	0.89	7.00 (1.92)	7.21 (2.08)	7.61 (2.66)	8.20 (2.51)	8.87 (4.17)	9.33 (3.54)
SWLS-C	0.74	0.86	0.88	20.78 (3.21)	21.85 (3.16)	22.44 (2.91)	21.14 (2.80)	20.71 (3.83)	22.57 (3.30)
ERC—N/l	0.95	0.89	0.89	6.00 (4.36)	5.56 (3.43)	4.33 (2.83)	N/A	N/A	N/A
ERC—ER	0.92	0.91	0.90	24.44 (4.69)	25.78 (4.24)	26.78 (3.77)	N/A	N/A	N/A
AX-CPT									
RT	N/A	N/A	N/A	650.01 (176.44)	667.09 (251.96)	641.97 (269.35)	774.51 (299.79)	781.20 (380.43)	776.82 (293.66)
SD of RT	N/A	N/A	N/A	170.90 (49.44)	184.23 (59.01)	177.05 (61.17)	195.73 (48.40)	209.89 (65.48)	217.04 (39.15)
% impulses to 1st stimulus	N/A	N/A	N/A	0.57 (0.87)	0.25 (0.51)	0.52 (0.87)	1.33 (3.38)	1.67 (0.35)	1.00 (1.56)
% target omissions	N/A	N/A	N/A	2.57 (3.02)	0.80 (1.32)	0.93 (1.09)	1.36 (1.80)	2.72 (2.47)	2.58 (1.95)
% disinhibitions	N/A	N/A	N/A	0.20 (0.44)	0.30 (0.58)	0.40 (0.80)	1.29 (2.31)	1.59 (1.84)	1.21 (1.95)
% inattentive impulses	N/A	N/A	N/A	2.66 (4.01)	2.30 (3.91)	1.67 (2.55)	4.39 (4.15)	8.03 (8.86)	3.79 (4.63)

T1 time 1, *T2* time 2, *T3* time 3, *CAMM* Child and Adolescent Mindfulness Measure, *PANAS-C–PA* 10-item Positive and Negative Affect Schedule for Children, positive affect scale, *PANAS-C–NA* 10-item Positive and Negative Affect Schedule for Children, negative affect scale, *SWLS-C* Satisfaction with Life Scale for Children, *ERC–N/l* Emotion Regulation Checklist, negativity/lability scale, *ERC–ER* Emotion Regulation Checklist, emotion regulation scale, *AX-CPT* Continuous Performance Test, AX type

groups were from the same year in school, the MG children were older than CG children at T1, T2, and T3. Both groups also differed in their primary language: While the primary language in MG was exclusively English, Welsh dominated as primary language in CG. However, both groups were exposed to English in everyday life. Furthermore, children in CG didn't have difficulty understanding the assessments. Groups did not differ in gender or handedness.

In both studies, parents provided written informed consent for themselves (for the informant-based assessments) and their children to participate in the respective study. In addition, children were asked for verbal consent on the day of assessment. Data was collected only if both parents and children consented to participation. Pupils received a small gift, such as a pencil, after each assessment.

Measures

The following instruments were employed in Study 1 and Study 2 (see Table 3 for internal consistencies observed in Study 2).

Self-report Measures Participants' DMW was assessed using the Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011; please note that in Study 2, CAMM was used to measure DMT). Internal consistency in Study 1 was $\omega_{RT} = 0.67$.[1] This 10-item self-report instrument

[1] Revelle's omega total (ω_{RT}; McNeish, 2018), calculated using the omega function in the R psych package, served as indicator of reliability. The internal consistency of CAMM was just under the threshold of 0.70 indicating acceptable levels of reliability. However, only

assesses mindfulness skills in youths from 10 years of age. 53 children (85%) in Study 1 were younger than 10 years (age range 7.50–11.50 years). Nevertheless CAMM was used with the whole sample because there is no comprehensive published mindfulness measure for children below 10 years. It should be acknowledged that the Mindful Attention Awareness Scale for Children (MAAS-C; Lawlor et al., 2014) has been validated for application with children from the age of 9 years; however, as distinct from CAMM, MAAS-C is restricted to assessing present-moment awareness, so does not cover the non-judgmental aspect of mindfulness. Furthermore, even though most of the current participants were younger than 10 years, they seemed to understand the items correctly. Immediately before the questionnaire was handed out to participants, they were asked to turn to the examiner if they did not or not fully understand any of the items. Immediately after each child had filled in the CAMM, the examiner again asked the participant how they had got along and if anything had been unclear to them. None of the pupils raised any issues.

The 10-item Positive and Negative Affect Schedule for Children (PANAS-C short version; Ebesutani et al., 2012) was administered to measure well-being. In the children's short version, which has a target group of 6- to 18-year-olds, higher subjective well-being is indicated by a relatively high positive affect score and/or a relatively low negative affect score. In Study 1 ω_{RT} coefficients were 0.80 and 0.81, respectively. Several studies investigating mindfulness in (pre-)adolescents (Bluth & Blanton, 2014; Lawlor et al., 2014; Schonert-Reichl & Lawlor, 2010) used the PANAS as a proxy measure of subjective/emotional well-being. Thus the use of this measure made the current study comparable with previous research.

As a second measure of child well-being the 5-item Satisfaction with Life Scale for Children (SWLS-C; Gadermann et al., 2010) was employed. Study 1 showed an internal consistency of $\omega_{RT} = 0.70$.

Informant-Based Measure Children's emotion regulation was assessed with the parent version of the 24-item Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997). This consists of the subscales negativity/lability and emotion regulation (Adrian et al., 2011). The age group targeted is six to 18 years. Internal consistencies in Study 1 were $\omega_{RT} = 0.89$ for negativity/lability and $\omega_{RT} = 0.86$ for emotion regulation.

Experimental Task EF was assessed using a visual version of the AX-CPT (adapted from Brocki & Bohlin, 2004) as outlined above. Participants were presented with five different simple black and white stimuli, one of which is a cue, two are targets, and two are distractors. Each trial is composed of 2 consecutive stimuli, each with a display time of 1000 ms and an inter-stimulus interval varying randomly between 1810 and 2043 ms. The following trial types were implemented: 40 (33.33%) Go trials, 40 (33.33%) NoGo trials, and 40 (33.33%) Ignore trials. Trials were presented in a random order except that the same cue or target type did not appear twice in a row. Behavioral responses were assessed using the following indicators: Mean reaction time (RT) and SD for correct Go trials, i.e., hits; error percentages—impulsive responses to 1st stimulus defined as an unexpected button press in response to the cue; target omissions; disinhibited responses defined as an unexpected button press in response to the 2nd stimulus in a NoGo trial; and inattentive impulses defined as an unexpected button press in response to the 2nd stimulus in an Ignore trial.

The following variables were assessed in Study 2 only: Here, the mindfulness training group responded to three questions related to their mindfulness practice. The first two questions were about practice frequency. On a 6-point Likert scale ranging from 0 = 'never', 'about once a month', 'a few times in a month', 'about once a week', 'a few times in a week', to 5 = 'every day' pupils rated how often they practiced mindfulness at school (question one) and at home (question two). The third question assessed enjoyment of practicing mindfulness expressed on a 4-point scale with response options 0 = 'I don't like it at all', 1 = 'I mostly don't like it', 2 = 'I mostly like it', 3 = 'I like it very much'.

Children in the positive psychology intervention group kept logs indicating the days on which they had completed the "Three Good Things" diary.

Interventions Implemented in Study 2

Mindfulness Training The MG received continuous training in the Paws b curriculum developed by Sarah Silverton, Tabitha Sawyer, and Rhian Roxburgh in collaboration with the Mindfulness in Schools Project (https://mindfulnessinschools.org/). This curriculum is intended for children aged 7–11 years. Paws b consists of classroom-based activities with a total duration of approximately 360 min. Depending on preferences activities can either be delivered over twelve single, 30-min sessions, or grouped into pairs of six double, 60-min sessions. Each of the twelve lessons is designed to impart a specific mindfulness skill: Lesson one offers fundamental information about the human brain and how mindfulness training can impact on the brain. Lesson two conveys how humans can focus their minds and make adaptive choices using mindfulness. In lesson three,

Footnote 1 (continued)

coefficients under 0.60 are commonly considered to indicate poor levels of reliability (George & Mallery, 2003).

attendees experience how a mindful attitude can help them widen and constrict the focus of their attention. Lesson four addresses the application of mindfulness in daily life. In lesson five, children learn about the dynamic nature shaping human mind and body. Lesson six invites children to experience how mindful attention can settle their mind and body. Lesson seven deals with ways of coping with challenging situations. In lesson eight, participants learn how mindfulness can help them enhance their well-being. Lesson nine addresses the power of thoughts and mental habits. Lesson 10 informs about the relationship of thoughts with emotions, behavior, and bodily reactions, and how this connection can be regulated using mindfulness. In lesson eleven, pupils learn how mindfulness is related to taking care of themselves and others. Lesson twelve deals with embracing moments of joy and happiness.

Schoolteachers in the participating school were formally trained in mindfulness and in Paws b instruction. Teachers attended an 8-week secular mindfulness course, such as mindfulness-based stress reduction (MBSR). This course was led by a mindfulness teacher with more than 10 years of teaching experience. After this, regularly practicing mindfulness for at least 2 months was required to be admitted to an intensive 3-day Teach Paws b course. Teachers also promised to continuously implement mindfulness in their lessons. In the partaking school, Paws b lessons were incorporated into regular lessons throughout the school year; in addition, pupils were provided with the option to practice mindfulness during voluntary lunchtime sessions.

Positive Psychology Intervention "Three Good Things" The positive psychology intervention was based on the "Three Good Things" exercise (Seligman et al., 2005). Within this exercise one writes down three good things that happened over a number of days (historically one or more weeks).

Children were asked to keep four versions of the "Three Good Things" diary for a duration of 2 weeks (i.e., 10 school days), each. When all diaries had been completed once (after 8 weeks), pupils started again with version 1 and continued until version 3. Thus, pupils did the exercise over a duration of 14 weeks. The intervention period was interrupted by one 2-week and one 1-week school holidays break. Version 1 was the original version reported by Seligman et al. (2005). Pupils were asked to write down 3 good things that had occurred each day and how or why the good things happened. Version 2 was a neutral version that was not restricted to positive events but encouraged respondents to simply write down three things that had occurred each day and how or why the things happened. Version 3 incorporated self-determination theory (Ryan & Deci, 2000): as in the original version, pupils were asked to write down 3 good things that had occurred each day and how or why the good things happened. In addition, pupils were asked whether these events were associated with the basic needs postulated by self-determination theory. These needs are competence, autonomy, and relatedness (Ryan & Deci, 2000). The question regarding competence was "Did you achieve something? If yes, which event?". The question regarding autonomy was "Did you have a choice? If yes, which event?". And the question regarding relatedness was "Did you spend time with your friends? If yes, which event?". Version 4 was geared towards future planning: Pupils were asked to write down 3 events they were looking forward to the next day; they were also prompted to indicate who had planned the events. Diaries were administered confidentially, i.e., without teachers or researchers reading the diary entries. This took place during normal school hours, usually at the end of a day's lessons. Diaries remained at school. Researchers received a log kept by pupils indicating the days on which "Three Good Things" was performed.

Procedures

Study 1 Study 1 followed a correlational design. Participants were tested individually during school hours. Quiet testing spaces were provided on school premises. Measures were collected in the following sequence for all participants: PANAS-C, CAMM, SWLS-C, EEG-setup (for children participating in the EEG recordings), computerized task with EEG recording. EEG was recorded using a portable system consisting of acquisition and stimulus presentation laptops, a Brain Products actiCHamp amplifier, and actiCAP electrodes.

EEG signal was recorded with 30 Ag/AgCl electrodes; TP10 was the reference site and Fpz served as the ground. Data was obtained at a sampling rate of 1 kHz with a Brain Products actiCHamp system. Two electrodes, situated above and below the right eye, recorded ocular movements. The impedance of all electrodes were kept below 25 kΩ. Online, the EEG signal was filtered with a bandpass filter range of 0.01–200 Hz, 48 dB/Oct slope. ERP data was processed in BrainVision Analyzer. It was first cleaned automatically so that the maximal allowed difference within 200 ms intervals was 1500 μV and the lowest activity in 100 ms intervals was 0.5 μV. Independent Component Analysis (ICA) followed by an inverse ICA was employed to regress out eye-blinks. Offline bandpass filter with a range of 0.1–30 Hz, 48 dB/Oct slope, was applied. Residual artefacts were cleaned manually and then the data was re-referenced to the average of T7 and T8. For the 1st stimulus (cue or distractor) of a trial the data was epoched into 2100 ms segments starting at − 200 ms, and baseline corrected using the signal 200 ms before stimulus onset. For the 2nd stimulus of a trial (target or distractor) the data was epoched into 1000 ms segments starting at − 100 ms, and baseline corrected using the signal 100 ms before stimulus onset. Finally, averages for each condition and participant, and then grand averages across participants for each condition and group were computed.

Study 2 In Study 2, measures for all participants at T1, T2, and T3 were taken in the same sequence as in Study 1: PANAS-C, CAMM, SWLS-C, EEG-setup (for children participating in the EEG recordings), computerized task with EEG recording. The protocol for EEG recordings was the same as in Study 1. Participants in MG answered the questions about mindfulness practice at the beginning of each testing session, however only the data from T2 and T3 were used for analyses, since the T1 data on mindfulness practice were already analyzed in Wimmer and Dorjee (2020). Logs recording frequency of the positive psychology interventions were filled in at school during the intervention period, and not during testing sessions.

Mindfulness training was practiced continuously. Pupils reported that they had on average started mindfulness practice 2.11 years (SD = 1.01) before T1 (see Wimmer & Dorjee, 2020). T2 tests were conducted 6 months after pre-tests, T3 assessments were carried out 6 months after T2.

The positive psychology interventions started immediately after T1; T2 tests in this group happened 17 weeks after time 1, T3 assessments were taken 5 months after time 2.

Data Analysis

Study 1 Questionnaire measures of well-being and emotion regulation, as well as behavioral indicators of EF, were analyzed using bivariate correlations with DMW.

ERP analysis was carried out using ANCOVAs assessing mean amplitude and peak latency data (except for the CNV since its latency is not commonly reported due to the broad peak nature of this component) for electrodes of interest. The following clusters of electrodes were selected for analyses for each of the components based on previous literature and observed maximal signal: Cue-P3—Pz, P3, and P4 across the time window 240–360 ms (comparable to Hämmerer et al., 2010); CNV—Fz, Cz, and Pz in the time windows (early) 800–1000 ms and (late) 1400–1800 ms (similar to Jonkman et al., 2003); NoGo-N2—P3, P4, P7, and P8, in the time window 160–260 ms (similar time windows were used by, e.g., Hämmerer et al., 2010, however at predominantly frontal sites); NoGo-P3—Pz, P3, P4, CP1, and CP2, in the time window 280–360 ms (comparable to Hämmerer et al., 2010).[2] For the two cue-locked components, i.e., Cue-P3 and CNV, ANCOVAs were run with condition (Cue vs. NonCue) as a factor and CAMM score as a covariate for peak latency; for mean amplitude the set of factors were complemented by an *n*-ary electrode factor.[3] An additional factor of time window (early vs. late) was included for CNV mean amplitude. For the two components locked to the 2nd stimulus of a trial, i.e., NoGo-N2 and NoGo-P3, ANCOVAs were run with condition (Go vs. NoGo) as a factor and CAMM score as a covariate for peak latency; for mean amplitude the set of factors were complemented by *n*-ary electrode factor. All artefact free correct trials were included in the ERP analyses for all participants with at least 15 trials per condition. Twelve out of the 55[4] participants did not meet this criterion and therefore were excluded from analyses resulting in final $N = 43$ for the ERP analyses.

Study 2 Questionnaire-based measures and behavioral performance in AX-CPT were analyzed using mixed factorial ANOVA, involving one between subjects factor, group (MG vs. CG), and one within subjects factor, time (T1, T2, T3). Due to a low retention rate of the ERC and ERP components for the control group, analysis of these indicators was restricted to MG. Hence, the factor of group was dropped for ERP analyses.

Electrode clusters and time windows used in ERP analyses were the same as in Study 1. For the two cue-locked ERP components, i.e., Cue-P3 and CNV, initial ANOVAs were run with condition (Cue *vs* NonCue) and time (T1 vs. T2 vs. T3) as factors for peak latency; for mean amplitude an electrode factor was added (as in Study 1). An additional factor of time window (early vs. late) was included for CNV mean amplitude. For the two components locked to the target of a trial, i.e., NoGo-N2 and NoGo-P3, initial ANOVAs were run with condition (Go vs. NoGo) and time (T1, T2, T3) as factors for peak latency; for mean amplitude an electrode factor

[2] Since EF, emotion regulation, and well-being can change as a result of development, bivariate correlations of age with all dependent measures explored the need to control for a potential impact of age. Only the following outcomes were correlated with age: PANAS-PA ($r = -0.27$, $p = 0.037$), mean RT in the AX-CPT ($r = -0.281$, $p = 0.038$), NoGo-N2 mean amplitude ($r = 0.36$, $p = 0.017$). Therefore, the associations of CAMM with PANAS-PA and mean RT in the AX-CPT were reanalyzed as partial correlations with age as control variable. Regarding NoGo-N2 mean amplitude, age was entered as covariate. All significances remained the same.

Footnote 2 (continued)

[3] This means that an additional factor was added in the respective ANCOVAs which represented the location of electrodes; the levels of this factor depended on the ERP component under investigation: For instance, as outlined above, electrodes included in the analysis of the Cue-P3 were Pz, P3, and P4, and so these electrodes were the 3 levels of the respective electrode factor. Including an electrode factor is a common practice in ERP research to investigate whether amplitude differs depending on electrode site (e.g., Dien et al., 2004; Rozenkrants & Polich, 2008).

[4] This is one participant less than the number of children volunteering for EEG—data of one participant was excluded from analysis due to an excessively high score on the PANAS-C negative affect subscale (see below for further explanations).

was added. Just as in Study 1, all artefact free correct trials were included for all participants with at least 15 trials per condition. The final sample was $n = 13$ for the ERP analyses.

All dependent measures, practice enjoyment, and practice frequency were corrected for age by regressing each outcome on age. The resulting standardized residual served as an age-corrected variable in all analyses reported below.

Results

Study 1

Descriptive statistics for questionnaire-based and behavioral dependent measures are summarized in Table 1. An outlier analysis detected one participant with an extremely high score on PANAS-C negative affect that was more than 3SD above the sample mean. Therefore this data was removed from the dataset. In addition, less than 3.43% of data per measure was excluded from analyses because they were more than 3SD from the sample mean or because they had RTs in the AX-CPT below 200 ms.

Correlational Analyses CAMM was significantly negatively correlated with PANAS-C negative affect, $r = -0.323$, $p = 0.011$, but also significantly negatively correlated with subjective well-being measured by SWLS-C, $r = -0.266$, $p = 0.037$ (remaining indicators of emotion regulation and well-being: $ps > 0.43$). Furthermore, CAMM was significantly positively correlated with percentage of impulses to the 1st stimulus of a trial, $r = 0.31$, $p = 0.023$, meaning that those with higher DMW showed more impulses (remaining behavioral indicators of EF: $ps > 0.21$).

ERP Components For Cue-P3, there was a mean amplitude main effect of DMW, $F(1, 244) = 25.30$, $p < 0.0001$, $\eta^2_p = 0.094$, with children high in DMW displaying less positive amplitudes than individuals low in DMW (other $ps > 0.20$; cf. Fig. 2A). After exclusion of three outlying values for Cue-P3, significances remained the same. For CNV mean amplitude, the ANCOVA revealed only an interaction of condition with CAMM, $F(1,484) = 4.58$, $p = 0.033$, $\eta^2_p = 0.009$, indicating that children with high and low DMW did not differ in the NonCue condition, however in the Cue condition children high in DMW demonstrated more negative CNV amplitude than children low in DMW (cf. Fig, 2B; other $ps > 0.22$). After exclusion of two outliers for CNV, the interaction of condition with CAMM became marginal, $p = 0.072$ (other $ps > 0.08$). The ANCOVAs for NoGo-N2 mean amplitude and peak latency did not reveal any main effects or interactions, $ps > 0.26$ (cf. Fig. 2C). As for NoGo-P3, the ANCOVAs yielded a significant effect of DMW suggesting a negative relationship between CAMM and NoGo-P3 mean amplitude, $F(1, 405) = 66.89$, $p < 0.0001$, $\eta^2_p = 0.142$ (cf. Fig. 2D; other $ps > 0.09$). After exclusion of five outlying values, significances remained the same.

Mediation Analyses A series of mediation analyses were carried out using the PROCESS macro for SPSS (model 6 with two mediators; Hayes, 2013). CAMM served as predictor in each model; the first mediator was one of the indicators of EF (RT and SD for hits; error percentages of impulsive responses, target omissions, disinhibited responses, and inattentive impulses; Cue-P3 latency, Cue-P3 amplitude, CNV amplitude, NoGo-N2 latency, NoGo-N2 amplitude, NoGo-P3 latency, and NoGo-P3 amplitude), the second mediator was one of the indexes of emotion regulation (ERC negativity/lability, ERC emotion regulation), and the outcome was one of the indicators of well-being (PANAS-C positive affect, PANAS-C negative affect, SWLS-C). Since the 95% confidence intervals of all indirect effects included zero, mediation models did not suggest a mediational role of either EF or emotion regulation within the relationship between DMW and well-being.

Study 2

Outliers more than 3SD away from the sample mean and RTs below 200 ms in the AX-CPT were excluded from analyses; this affected less than 4.66% of data per measure. There were no outliers for ERP components. Descriptive statistics for the questionnaire-based and behavioral dependent measures are summarized in Table 3.

Questionnaires ANOVAs revealed a significant main effect of group for PANAS-C negative affect only, $F(1, 41) = 5.02$, $p = 0.031$, $\eta_p^2 = 0.109$, such that MG scored lower than CG (other $ps > 0.19$).

Task Performance Regarding percentage of disinhibitions and inattentive impulses, ANOVAs revealed significant main effects of group, ($F(1, 34) = 6.55$, $p = 0.015$, $\eta_p^2 = 0.162$, and $F(1, 34) = 4.50$, $p = 0.041$, $\eta_p^2 = 0.117$), suggesting lower numbers of these error types in MG compared with CG. For percentage of target omissions, there was a significant interaction of time with group, $F(2, 70) = 7.37$, $p = 0.001$, $\eta_p^2 = 0.174$. According to repeated contrasts, intervention groups showed different trajectories between T1 and T2, $F(1, 35) = 10.94$, $p = 0.002$, $\eta_p^2 = 0.238$; MG reduced errors, whereas errors increased in CG. T2–T3 comparison was insignificant, $p = 0.887$ ($ps > 0.05$ for remaining main effects and interactions).

ERP Components For Cue-P3, ANOVAs revealed a marginally significant main effect of time for mean ampli-

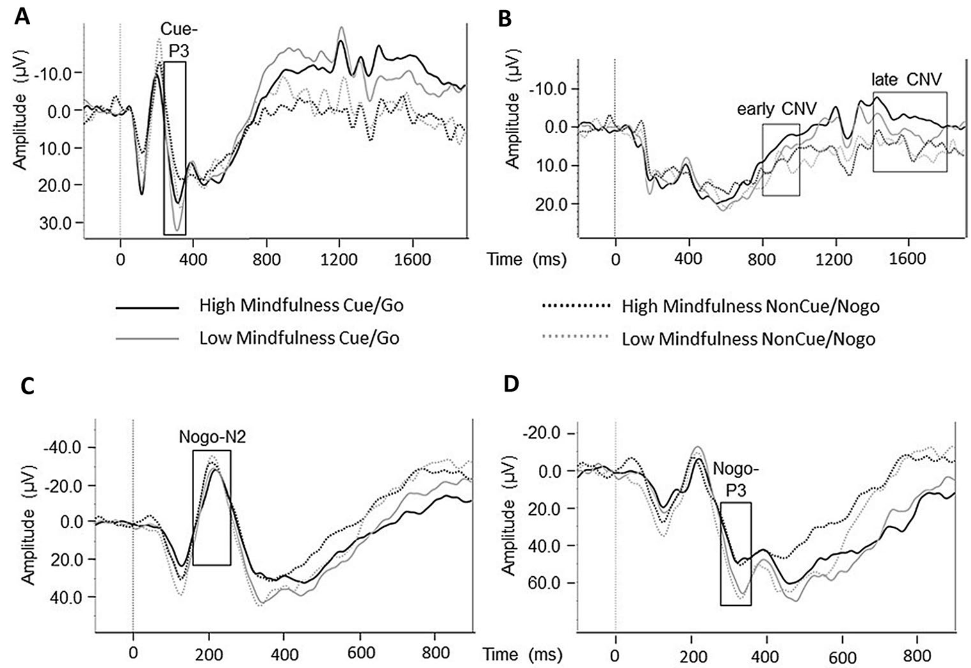

Fig. 2 **A**–**D** Dispositional mindfulness and ERP modulation in a Continuous Performance Test. **A** Cue-P3: Linear derivation (Pz, P3, P4) of group average waveforms for each of the two conditions (Cue vs. NonCue), low-pass filtered at 16 Hz for illustration purposes only. **B** CNV: Linear derivation (Fz, Cz, Pz) of group average waveforms for each of the two conditions (Cue vs. NonCue), low-pass filtered at 16 Hz for illustration purposes only. **C** NoGo-N2: Linear derivation (P3, P4, P7, P8) of group average waveforms for each of the two conditions (Go vs. NoGo). **D** NoGo-P3: Linear derivation (Pz, P3, P4, CP1, CP2) of group average waveforms for each of the two conditions (Go vs. NoGo)

tude, $F(2, 216) = 3.04$, $p = 0.050$, $\eta_p^2 = 0.027$ (cf. Fig. 3A). However, repeated contrasts did not reach significance, *p*s > 0.15 (other *p*s > 0.09). The ANOVA for CNV mean amplitude resulted in a marginally significant main effect of electrode, $F(2, 432) = 2.93$, $p = 0.055$, $\eta_p^2 = 0.013$ (cf. Fig. 3B; other *p*s > 0.07). According to ANOVAs for NoGo-N2, mean amplitude was affected by electrode, $F(3,288) = 13.96$, $p < 0.001$, $\eta_p^2 = 0.127$ (cf. Fig. 3C; other *p*s > 0.09). For NoGo-P3, ANOVAs revealed a main effect of electrode for mean amplitude, $F(4,360) = 6.00$, $p < 0.001$, $\eta_p^2 = 0.063$. There was also a significant main effect of time, $F(2,360) = 3.45$, $p = 0.033$, $\eta_p^2 = 0.019$, suggesting continuous reduction in positivity (cf. Fig. 3D). However, repeated contrasts did not reach significance, *p*s > 0.09 (other *p*s > 0.53).

Practice Effects The impact of frequency and enjoyment of mindfulness practice was analyzed in two sets of moderated regressions using the PROCESS macro for SPSS (model 1; Hayes, 2013). The first set tested whether practice frequency and enjoyment, as reported at T2, were associated with changes in all outcome measures between T1 and T2. One moderation was carried out for each dependent measure in terms of a change score (T2 minus T1). Practice frequency was the predictor, enjoyment served as the moderator and both variables were mean centered. The second set of moderations were parallel to the first set, except that the outcome of each analysis was a change score from T2 to T3 (T3 minus T2), and that practice frequency and enjoyment now referred to responses at T3.

At T2, change of PANAS-C negative affect was predicted by practice liking, $b = -0.51$, SE $b = 0.20$, $t = -2.47$, $p = 0.020$, such that higher liking was associated with a decrease of PANAS-C negative affect from T1 to T2. Change of SWLS-C was linked with practice frequency, $b = -0.38$, SE $b = 0.18$, $t = -2.14$, $p = 0.04$, enjoyment, $b = 0.48$, SE $b = 0.18$, $t = 1.63$, $p = 0.01$, and an interaction of practice frequency with enjoyment, $b = 0.47$, SE $b = 0.19$, $t = 2.44$, $p = 0.02$. The Johnson–Neyman technique showed that there was a significant negative relationship between practice frequency and SWLS-C only when the age-corrected practice enjoyment was below 0.03, which applied to 63.33% of the data. Furthermore, there was an association of practice enjoyment with a change for NoGo-N2 latency, $b = -0.88$, SE $b = 0.16$, $t = -5.63$, $p = 0.0003$, indicating that higher liking was related to a decrease of NoGo-N2 latency between T1 and T2 (other *p*s > 0.05).

At T3, ERC negativity/lability was affected by practice frequency, $b = -0.49$, SE $b = 0.20$, $t = -2.53$, $p = 0.03$, suggesting that high practice frequency was associated with a reduction of negativity from T2 to T3, and by practice enjoyment, $b = 0.59$, SE $b = 0.18$, $t = 3.21$, $p = 0.01$, suggesting that high practice enjoyment was associated with an increase of negativity from T2 and T3. In addition, an interaction of practice frequency and enjoyment predicted change for inattentive impulses in the AX-CPT, $b = 0.34$, SE $b = 0.13$, $t = 2.64$, $p = 0.02$. According to the Johnson–Neyman technique, higher practice frequency was linked to a reduction of this error type only at the lowest values of practice enjoyment below -2.63, which included 4% of data (other *p*s > 0.06).

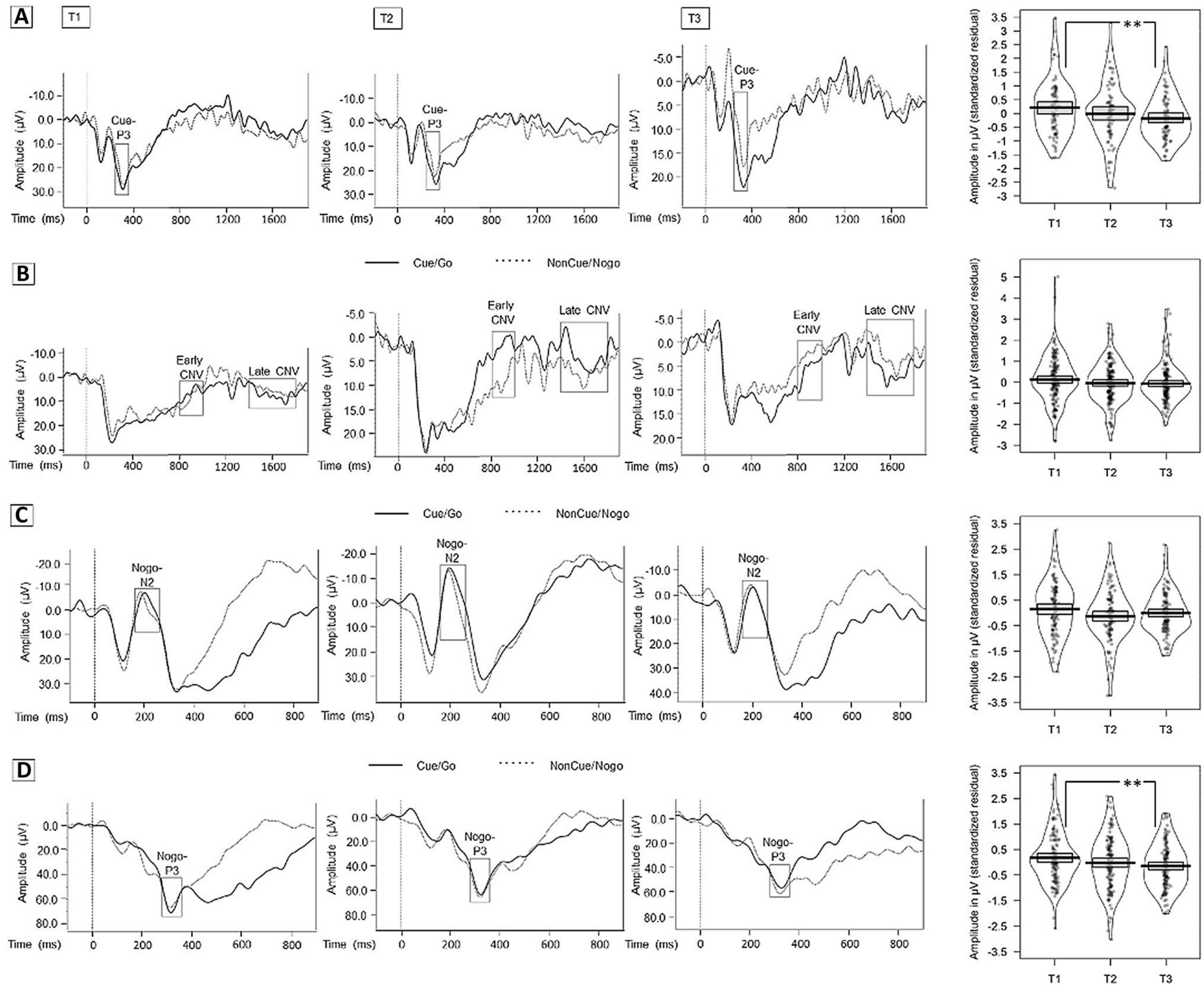

Fig. 3 A–D Long-term mindfulness training and ERP modulation in a Continuous Performance Test. All waveforms low-pass filtered at 16 Hz for illustration purposes only. T1 = time 1, T2 = time 2, T3 = time 3. **A** Cue-P3: Linear derivation (Pz, P3, P4) of average waveforms for each of the two conditions (Cue vs. NonCue). **B** CNV: Linear derivation (Fz, Cz, Pz) of average waveforms for each of the two conditions (Cue vs. NonCue). **C** NoGo-N2: Linear derivation (P3, P4, P7, P8) of average waveforms for each of the two conditions (Go vs. NoGo). **D** NoGo-P3: Linear derivation (Pz, P3, P4, CP1, CP2) of average waveforms for each of the two conditions (Go vs. NoGo)

For the positive psychology intervention group, the impact of practice frequency was tested using bivariate correlations: Number of days at which the intervention was carried out was correlated with change of all dependent measures between T1 and T2 (T2 minus T1). No significant correlations were observed, $ps > 0.05$.

Mediation Analyses Due to a low retention rate, in particular for the ERC and EEG-based indicators, mediation analyses were not conducted. The associations between EF, emotion regulation, and well-being for MG were explored in two sets of correlations. The first set investigated the extent to which a change of EF between T1 and T2 was associated with a concomitant change of emotion regulation and/or well-being, using all outcome measures. The second set looked at change scores between T2 and T3. The significance level was adjusted for multiple comparisons using the method proposed by Cupples et al. (1984), with $p_{crit} = 0.0027$. Between T1 and T2, an increase of mean RT in the AX-CPT was associated with an increase of inattentive impulses to the target only, $r = 0.724$, $p < 0.001$ (other $ps \geq 0.004$). Between T2 and T3, an increase of disinhibitions was linked with an increase in NoGo-P3 latency, $r = 0.790$, $p = 0.001$, and more positive NoGo-P3 amplitude was associated with more positive NoGo-N2 amplitude, $r = 0.782$, $p = 0.0016$ (other $ps \geq 0.003$).

Discussion

Study 1

Study 1 investigated associations between pre-adolescents' DMW and EF, emotion regulation and well-being. The first hypothesis predicted that DMW would be positively associated with EF, reflected by: less positive mean Cue-P3 amplitudes if this amplitude change was accompanied by reduced Cue-P3 latency and withholding of behavioral response to the cue; more negative CNV mean amplitudes; and positive relationships with NoGo-N2 (in terms of less negative amplitudes for more mindful individuals) and NoGo-P3 mean amplitudes, each linked with superior behavioral performance in the CPT. Results did not support this assumption. DMW was negatively correlated with Cue-P3 mean amplitude, suggesting that an increase of DMW corresponds with less positive Cue-P3 mean amplitudes. This pattern could indicate superior cue processing if DMW was also associated with reduced Cue-P3 latency and withholding of behavioral response to the cue. In contrast, DMW was not significantly associated with Cue-P3 latency and positively linked with percentage of impulsive responses to the cue. So compared with children with low DMW, children with high DMW more often prematurely respond to the cue and do not wait for the appearance of the 2nd stimulus of a trial; this 2nd stimulus shows whether a button press is required or not. Even though for correctly withheld responses, they do show more a mature pattern of Cue P3 modulation. Furthermore, after outlier removal, DMW was not significantly correlated with CNV mean amplitude. DMW was not associated with NoGo-N2 amplitude, and negatively linked with Nogo-P3 mean amplitude. Behavioral response to the target was uncorrelated with mindfulness. Although ERP indices suggested inferior response inhibition for higher DMW, this was not accompanied with detriment in behavioral performance. Possibly individuals with high DMW were able to compensate for reduced efficiency of the brain networks involved in response inhibition. Nevertheless, the overarching pattern of findings suggests that DMW was not linked with better EF in contradiction to the first hypothesis.

Hypothesis two, assuming a positive relationship between DMW and emotion regulation, was also not confirmed in the current study. There were no significant associations between CAMM and the two subscales of the ERC. Interestingly, however, DMW was negatively related to PANAS-C negative affect as expected. Theories of mindful emotion regulation in adults (e.g., Chambers et al., 2009; Nykliček, 2011) attribute a reduction of negative affect without a parallel increase of emotion regulation to the non-judgmental quality of mindful awareness: emotions are simply accepted as mental phenomena irrespective of the valence or magnitude of emotion that is experienced; this process is called defusion (Hayes et al., 2012) or decentering (Bishop et al., 2004). As a result of this non-reactivity, individuals with high mindfulness disposition do not feel a strong need to change emotions. While decentering has been proposed as a mechanism of mindfulness (e.g., Brown et al., 2015; Sauer & Baer, 2010), it has also been described as an emotion regulation strategy (Mennin & Fresco, 2009). When considering decentering as an emotion regulation strategy, interpreting the pattern of results as being due to decentering would contradict the findings from informant report. It is, however, at present not clear whether decentering, which relies on meta-awareness, can be effectively applied by pre-adolescents who display immature meta-cognitive skills (Kaunhoven & Dorjee, 2017). Better understanding of the role decentering plays in the relationship between DMW and well-being is essential, due to its close affiliation with non-reactivity supporting adaptive emotion regulation.

The third hypothesis postulated a positive association between DMW and well-being. The evidence in this regard was ambivalent. As predicted, DMW was negatively correlated with PANAS-C negative affect. However, DMW was also negatively correlated with SWLS-C. Taken together, these results suggest that DMW was associated with a decrease in negative mood, but not with an increase in positive mood and overall satisfaction with life. The link between DMW with both lower life satisfaction and reduced negative affect could suggest that mindfulness provides a protective mechanism against exacerbation of negative mood in case of worsening of personal circumstances: for highly mindful individuals negative mood decreased despite reduced life satisfaction. Even though it is not clear what mechanisms are responsible for such patterns of findings, somewhat similar results have been found after mindfulness training with primary school children in another study. Here, a reduction in negative affect and no improvement in a well-being measure emerged (Vickery & Dorjee, 2016).

Hypothesis 4 stated that the positive association between DMW and well-being would be mediated by EF and emotion regulation. Mediation analyses did not suggest a mediational role of either EF or emotion regulation. Hence, this hypothesis was not confirmed. However, the current sample may have lacked power to detect mediational effects, which are typically smaller in size than direct effects (Walters, 2019).

Limitations Due to the already relatively long duration of individual testing sessions, an informant-based questionnaire was used for assessment of emotion regulation in children. Prospective studies should ideally combine self-reports with behavioral and psychophysiological (e.g., experimental ERP-based; Hajcak et al., 2010) measures of emotion regulation to provide a more complete picture of the associations between pre-adolescents' DMW and emotion regulation. Finally, the sample size in the present study may have been too small to detect more subtle effects, even though small sample sizes are a common problem in neuroscience (Button et al., 2013); future studies with larger sample sizes may provide more conclusive findings on the relationship between DMW, EF and well-being.

Study 2

Study 2 employed a longitudinal, actively controlled design, in order to examine associations of long-term mindfulness training with EF, emotion regulation, well-being, and DMT. Moderating effects of practice dose and enjoyment were explored as well.

Hypothesis 1 predicted that the MG would improve EF more strongly than the CG from T1 to T2 and from T2 to T3 (due to continued mindfulness practice). Results partially supported this assumption. As for behavioral performance in the AX-CPT, groups did not differ in mean RT and percentage of impulses to the cue; however, the MG demonstrated robust advantages over the CG, across the three time points, in percentage of disinhibitions and inattentive impulses. Furthermore, between T1 and T2, MG reduced percentage of target omissions whereas in CG this error type increased. However, ERP analyses (MG only) revealed only one significant main effect of time in terms of a reduction in positivity of NoGo-P3 mean amplitude. This could suggest detrimental development of response inhibition. Yet, MG's advantages in disinhibitions and inattentive impulses do not suggest such detriment on a behavioral level. The overall pattern of results does not support the idea that long-term mindfulness training in pre-adolescence leads to steady improvement of EF. Nevertheless, the pattern is in line with the assumption that pre-adolescents can achieve stable advantages of EF on a behavioral level, when they have practiced mindfulness regularly for approximately 2 years and keep maintaining practice.

Hypothesis 2 assumed benefits of long-term mindfulness training for emotion regulation in terms of greater gains on emotion regulation assessments for the MG than CG from T1 to T2 and from T2 to T3. The data did not permit a thorough test of this hypothesis. This is because assessment return rates in the active controls were too low to include this group in analyses. However, parents' responses to the ERC in MG were stable over time for the negativity/lability subscale and the emotion regulation subscale. This pattern goes against the assumption that long-term mindfulness practice is associated with continued improvement of emotion regulation.

Hypothesis 3 expected a positive relationship of mindfulness training with DMT, in terms of stronger improvement of CAMM scores for MG than CG from T1 to T2 and from T2 to T3. There was no evidence to support this hypothesis: No significant main effects or interactions were found for CAMM. The lack of differences can indicate the limited psychometric value of CAMM for detecting changes in children's dispositional mindfulness after mindfulness training. In contrast, adult mindfulness measures do reflect such changes (Gu et al., 2015). However, lower scores on CAMM in adolescents with prior meditation/yoga experience than in meditation/yoga unexperienced adolescents (de Bruin et al., 2011, 2014) have been associated with CAMM's sensitivity to response-shift bias (see above). Possibly, such a response shift bias was present during the initial stages of MG's mindfulness training. In this case, MG would have scored lower on CAMM than CG at this stage. After an average practice duration of 2.11 years as in the present sample, this response shift could have started to decline. This could have resulted in equal levels in mindfulness-experienced pupils and controls. Thus, comparable CAMM scores between groups in the present study could trace back to CAMM's susceptibility to response-shift bias. To assess the impact of this potential bias, another testing session for MG could have been added at the start of their mindfulness training (i.e., 2.11 years before T1) and the development of CAMM scores in both MG and CG could have been tracked. Whilst this would have been possible in principle, it may have posed practical challenges. This is because of a considerable degree of drop-out in the study design involving three points of measurement. This problem may have been exacerbated with the addition of a further testing session. Also, response-shift effects could have been investigated more directly by including additional indicators of mindfulness and comparing the trajectories of all indicators under investigation. However, the inclusion of other questionnaires may have increased the length of testing sessions to a point beyond participants' attention span.

Hypothesis 4 predicted that both groups improved well-being from T1 to T2. Between T2 and T3, further gains were expected for MG, whereas CG were hypothesized to maintain levels from T2. This hypothesis was partially supported. Whilst there were no significant findings for PANAS-C positive affect and SWLS-C, MG scored significantly lower on PANAS-C negative affect than CG across all time points.

Hypothesis 5 expected that increases in well-being from T1 to T2 in the MG would be mediated by gains in EF and emotion regulation between T1 and T2. The same pattern was expected to occur from T2 to T3. Due to low retention rates for the ERC and ERP-based indicators, rigorous mediation analysis was not possible. Instead, correlations for the MG only explored bivariate associations between all dependent measures. The results did not provide support for the predicted mediations. Regarding changes between T1 and T2 and between T2 and T3, significant correlations exclusively affected interrelations of same construct indicators, i.e., indicators of EF were positively related with one another. This confirms the validity of respective measures. Yet it does not suggest that mindfulness-related benefits for well-being between T1 and T2 or between T2 and T3 were mediated by enhanced EF and emotion regulation. However, it has to be emphasized again that the correlations conducted were merely exploratory in nature and do not permit solid conclusions regarding mediating effects.

Furthermore, a non-directional research question asked whether intervention outcomes are affected by frequency and enjoyment of mindfulness practice. The vast majority of dependent measures were not influenced by such moderation. Between T1 and T2, reduction of PANAS-C negative affect and decrease of NoGo-N2 latency benefitted from practice enjoyment; and reduction of SWLS-C was associated with high practice frequency only at relatively low levels of practice enjoyment. Between T2 and T3, decrease of ERC negativity/lability benefitted from high practice frequency but was adversely affected by high enjoyment. Furthermore, reduction of inattentive impulses was predicted by high practice frequency only at the lowest levels of practice enjoyment. Taken together, practice enjoyment was linked with positive outcomes between T1 and T2, but with negative outcomes between T2 and T3. However, given the predominant lack of practice effects, it cannot be ruled out that the five exceptional moderations are false positives.

Limitations First of all, it needs to be acknowledged that the assessment of practice frequency via retrospective self-report may have limited validity/reliability, particularly in children. Another limitation stems from non-randomized allocation to treatment groups. This harbors the risks that the two groups differed, not only regarding the type of intervention they received, but also regarding further outcome-relevant variables. Group differences regarding age were statistically corrected. Still, there was another group difference, namely regarding primary language, that could not be statistically controlled and gave an edge to the CG: Children in the MG were predominantly fluent in English only, whereas the primary language of most children in the active control group was Welsh. The latter children were also fluent in English, rendering them bilingual. Bilingualism, in turn, is associated with superior EF (Stocco et al., 2014). Hence, the group difference regarding language abilities may have made it more difficult to detect mindfulness-related benefits for EF.

As in Study 1, a large sample size could not be reached. High drop-out rates for the ERC and EEG-based indicators, especially in the CG, led to further reduction in sample size. This led to reduced overall study quality including both limited statistical power and restricted range of justified conclusions. However, the following strengths underline the novelty and value of this study: an active control group was implemented; the study design involved three time points of assessments spread over a whole year; and finally, an integrative neurodevelopmental framework was adopted.

Now that findings of both studies were discussed, the following sections will derive theoretical and practical implications resulting from an integrative view on these results.

Implications

Theoretical Implications

Both studies tested a theoretical model, in particular the assumption that mindfulness achieves benefits for well-being via improvement of EF and emotion regulation. This model received some tentative support from training effects, resulting from continued longer-term mindfulness practice. In contrast, associations with DMW did not confirm it. This seems to suggest that this theory possibly does not adequately apply to pre-adolescents' DMW. The results also call for efforts to understand this construct better. Furthermore, the findings imply that the possible cognitive and affective mechanisms underlying DMW and mindfulness training effects might be distinct. This is an interesting contrast with the adult literature, where dispositional mindfulness has been found to increase after MBIs (Baer et al., 2019; Goldberg et al., 2019; Quaglia et al., 2016; Visted et al., 2015). However, even for adults, this finding is moderated by measurement instruments. More precisely, the training-related increase in mindfulness disposition is not found in all self-report questionnaires of mindfulness (Baer et al., 2019; see also Tran et al., 2022). Therefore, it could be that the differing pattern of findings in Study 1 and Study 2 reflects particular psychometric properties of CAMM. This is only one out of several measures of child mindfulness. Future research is needed to test whether the present results generalize to other measurement instruments. In previous studies working exclusively with adolescent samples, a negative relationship of CAMM with meditation/yoga experience has been thought to result from response-shift bias (de Bruin et al., 2011, 2014, see above). This sort of bias could explain the lack of group differences observed in Study 2 as well. However, this needs to be ascertained by a targeted investigation of CAMM's sensitivity to response-shift bias.

It is important to note that the model tested here focuses on mechanisms—namely EF and emotion regulation—thought to underly benefits of mindfulness for *pre-adolescents' mental well-being*. Further attempts have been made to explain benefits of mindfulness, which in part deviate from the focus of the present investigations. Hence these attempts could present a promising target for future research. For instance, the mindfulness stress buffering account (Creswell & Lindsay, 2014) proposes that *mindfulness training* exerts its impact on *mental and physical health* via alleviating stress appraisals and lowering stress-reactivity responses.

Furthermore, resonating with the present approach, Tang and colleagues (2015) suggested that *mindfulness meditation* involves attention control (a concept highly overlapping with EF, see above) and emotion regulation, alongside a psychological state not considered here, namely self-awareness.

Regarding mindfulness-specific emotion regulation, these authors assumed that during mindfulness meditation, practitioners monitor arousal but do not downregulate or withhold emotional responses. On a neuronal level, Tang and colleagues (2015) proposed mindful emotion regulation to operate by bolstering prefrontal cognitive control mechanisms. These control mechanism attenuate activity in regions associated with affect processing. Testing these assumptions was beyond the scope of the present approach.

Also, based on a systematic review Tomlinson and colleagues (2018) concluded the following regarding the relationship between *dispositional mindfulness* and *mental health:* it may be driven by first, reduced use of maladaptive cognitive processes including rumination and pain catastrophizing; and second, enhanced emotional processing and regulation. Looking at the effects of pre-adolescents' dispositional mindfulness on rumination and pain catastrophizing seems to be an interesting area for further research.

Practical Implications

Differences between the MG and the positive psychology CG have to be interpreted with caution due to lack of randomization. This feature of the study design limits causal explanations of the observed pattern. Yet benefits for well-being were slightly greater in MG than in the positive psychology CG. More precisely, the MG had lower PANAS-C negative affect scores across the three time points. Potentially, this could suggest that mindfulness training is more effective than "Three Good Things" for improving pre-adolescents' well-being through the reduction of negative affect. Resonating with this, in a study by Mongrain and Anselmo-Matthews (2012) there was no intervention-specific mitigation of depression—i.e. an indicator of mental health difficulties, similar to (enduring) negative affect—after positive psychology interventions. To sum up, alleviation of negative affect in pre-adolescents is more likely to succeed through implementation of a mindfulness curriculum.

So, the present project yielded some evidence that mindfulness training can be successfully applied to foster aspects of EF and well-being in pre-adolescents. However, there was no empirical support for the assumption that DMW is associated with benefits for these two outcomes. Thus, promoting these developmentally important capacities through mindfulness seems to require that children practice mindfulness via a dedicated curriculum. In contrast, merely relying on putative benefits of DMW does apparently not promise effectiveness in this regard. It can be concluded that DMW might not be that beneficial unless developed further through mindfulness training. This reinforces the importance of pre-adolescent mindfulness training initiatives. Mindfulness training is traditionally seen as an emotional tool (to aid well-being, treat depression etc., see introduction). Yet findings from this study provide some evidence suggesting that it can be used as a strategic cognitive tool to aid EF. In that regard, it outperforms positive psychology.

Conclusions

Summarizing the main findings of Study 1 and Study 2, a divergent pattern of results emerged: While Study 1 observed a tendency for DMW to be negatively related to EF, in Study 2 long-term mindfulness training tended to be linked with advantageous levels of EF. Regarding emotion regulation, Study 1 did not detect an association with DMW, and Study 2 likewise did not suggest that long-term mindfulness training is related to this skill. In Study 1, evidence concerning the link between DMW and well-being was ambivalent; in contrast, in Study 2 long-term mindfulness training tended to be positively related to well-being in terms of reduced negative affect. Furthermore, long-term mindfulness training was not correlated with DMT. Taken together, results of both studies differ on most of the measures.

On a theoretical and conceptual level, the notion that mindfulness leads to benefits for well-being through improvement of EF and emotion regulation was tentatively supported, but only by results from continued longer-term mindfulness practice. No support was observed for DMW. Hence, long-term mindfulness training and DMW in pre-adolescence seem to require distinct conceptualizations.

Practically speaking, the present results tend to suggest that mindfulness training is more effective for promoting EF and well-being than DMW, and also than positive psychology interventions. So, spending time on mindfulness training in primary schools, particularly for the longer term, may be worthwhile. Results also highlight mindfulness-based benefits for EF in addition to emotional well-being. Nevertheless, further, rigorous research is needed for a more complete understanding of DMW, DMT, and long-term mindfulness-training.

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Data Availability The data are not publicly available due to privacy or ethical restrictions—parents were not asked to provide permission to share data.

Code Availability Analysis codes are not publicly available.

Declarations

Conflict of interest The last author is a co-director of a community interest company providing training to schoolteachers in mindfulness and well-being courses (not the mindfulness program investigated in this study).

Ethics Approval Ethical approval for all research reported within this article has been granted by the ethics committee of the School of Psychology, Bangor University, UK.

Consent to Participate Parents of all participants have given written informed consent in addition to participants' oral consent.

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