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RESEARCH ARTICLE

Impact of a mindfulness-based school curriculum on emotion processing in Vietnamese pre-adolescents: An event-related potentials study

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Abstract

The neurocognitive mechanisms associated with mindfulness training in children are not well understood. This randomised controlled study with active and passive control groups examined the impact of an 18-week mindfulness curriculum delivered by schoolteachers on emotion processing in Vietnamese 7- to 11-year-olds. Event-related potential markers indexed emotion processing while children were completing emotional Go/No-Go tasks before and after mindfulness training, and at 6-month follow-up. In an oddball Go/No-Go task with Caucasian faces no changes in P3b and LPP components were detected, but in a Go/No-Go task with Caucasian and Japanese faces changes were observed in P3b latencies and LPP mean amplitudes. Specifically, the P3b in response to angry non-targets for Japanese faces peaked later in the mindfulness training group (TG) at 6-months follow-up in comparison to the non-intervention control group (NCG). The LPP mean amplitudes for averaged Caucasian and Japanese angry non-targets were also attenuated in the TG at 6-month follow-up. In contrast, no changes in the LPP mean amplitudes were observed for the NCG over time. Together, these findings may indicate that mindfulness training in pre-adolescents enhances emotional non-reactivity to negative distractors. A fluctuating pattern of LPP mean amplitude modulations for angry targets was observed in the active control group (ACG) receiving social-emotional learning (SEL) training. Overall, findings from this study suggest that mindfulness training in pre-adolescents enhances emotional non-reactivity to negative distractors and some of the effects are culturally sensitive.

KEYWORDS
children, emotion regulation, event-related potentials, mindfulness, neuroscience

1 | INTRODUCTION

Mindfulness is often defined as attending to present moment experiences with a non-reactive attitude (Dorjee, 2010; Kabat-Zinn, 2003; Shapiro et al., 2006) that can be trained and supports adaptive emotion processing (Bauer et al., 2019; Lutz et al., 2014; Viglas & Perlman, 2018). Difficulties in emotion processing and regulation are a key underlying mechanism of both internalising and externalising psychopathology (Compas et al., 2017; Sheppes et al., 2015). Accordingly, mindfulness-based interventions have been applied widely in both clinical and non-clinical populations with adults and children to improve their mental health and well-being (e.g., Dunning et al., 2019). Compared to the well-documented benefits of mindfulness training (MT) in adults (e.g., Gu et al., 2015; Guendelman et al., 2017), however, evidence on the effects of MT in children is still relatively limited, particularly with regards to longer-term and neurocognitive changes (Kaunhoven & Dorjee, 2017; Klingbeil et al., 2017; Mak et al., 2018).

During pre-adolescence, the transition period from childhood to adolescence (7–12 years of age), the abilities to process and regulate emotions develop rapidly and become more effective, including the abilities to perceive, interpret and respond to emotional stimuli (Belden et al., 2014; Calkins & Fox, 2002; Morris et al., 2011). Faces are key naturalistic emotional stimuli because they carry salient information that is important for social interactions (Herba & Phillips, 2004; Herba et al., 2006; Thomas et al., 2007). Strong bias to faces with negative expressions (e.g., angry or threatening faces) links to behaviour inhibition and social withdrawal in children and adolescents (Pérez-Edgar et al., 2010, 2011). High level of reactivity to faces with negative emotional expressions has been reported in children with anxiety and abuse history (Shackman et al., 2007), while reduced reactivity to emotional faces has been observed in children with high risk of depression (Kujawa, Hajcak, et al., 2012). Both over- and under-reactivity in responding to emotional stimuli, imply difficulties in emotion processing and increased need to regulate emotions (Gross, 2015). This can have negative impact on peer acceptance, social behaviours, aggression, depression and anxiety in adolescence and later stages of development (Bar-Haim et al., 2007; Christ et al., 2019). Fostering of adaptive emotion processing abilities during childhood, therefore, can be a protective factor against psychopathology in adolescence and adulthood (Christ et al., 2019; Durlak et al., 2011; Röll et al., 2012).

MT may enhance adaptive emotion processing and regulation abilities during childhood (e.g., Felver et al., 2016; Pandey et al., 2018; Zoogman et al., 2015). Although mindfulness appears more beneficial in older adolescents (Carsley et al., 2018; Dunning et al, 2019), the effects of mindfulness on mental health and well-being have been observed in pre-adolescents too (Carsley et al., 2018). Indeed, preventative school-based mindfulness programmes targeting executive functions and self-regulation (cognitive control and emotion regulation) (e.g., MindUp, MAPs, Paws b.) with age-appropriate practices enhanced response inhibition, shifting and emotional control abilities in pre-adolescents (e.g., Flook et al., 2010; Schonert-Reichl et al., 2015; Vickery & Dorjee, 2016; Wimmer & Dorjee, 2020). However, little is known about the neural mechanism underlying these changes.

In adults, MT increases the recruitment of medial prefrontal cortex (PFC) to down-regulate amygdala activation in responding to emotional stimuli (Doll et al., 2016; Kral et al., 2018). However, extensive mindfulness practices can lead to reduced activation of medial PFC while increasing activation in dorsolateral PFC, insular and somatosensory cortices (Chiesa et al., 2013). This indicates that mindfulness practice could result in more emotional stability longer term via bottom-up regulation by enhancing emotional non-reactivity and non-elaborative engagement in interoceptive sensory events (Farb et al., 2007; Lutz et al., 2014). This is developmentally salient for pre-adolescents since their PFC is still developing (Kaunhoven & Dorjee, 2017); for this reason, longer-term MT could support pre-adolescent emotion regulation abilities without the need to rely on mature capacity of the PFC. More empirical evidence from studies employing neurocognitive measures is needed to indicate if the enhancement of emotional non-reactivity is the neurocognitive mechanism of changes in mindfulness from a development perspective.

Research Highlights

- A randomised controlled study investigated neurodevelopmental changes in emotion processing resulting from mindfulness training with pre-adolescents in Vietnam.
- The training group (TG) showed delayed P3b latencies for Japanese angry face non-targets compared to non-intervention control group (NCG) over time.
- LPP mean amplitudes attenuated for angry face non-targets at 6-month follow-up in TG, NCG showed no changes in LPP mean amplitudes over time.
- Asian cultural context possibly plays a supportive role in the effects of mindfulness training on emotion regulation.

The P3b and LPP (late positive potential) components are event-related potential (ERP) markers that are sensitive to developmental changes in emotion processing and regulation, and can be modulated by MT (Decicco et al., 2014; Kaunhoven & Dorjee, 2017; Kujawa, Weinberg, et al., 2013; Willner et al., 2015). These ERP components assess different temporal stages of an emotional response. The P3b component is maximal over parietal areas and peaks approximately between 250—300 and 500 ms after infrequent target onset in an oddball paradigm (Hajcak et al., 2010; Polich, 2007). It indexes attentional resource allocation towards target detection (Polich, 2007; Pollak et al., 2001). For emotional stimuli, more positive amplitudes of P3b and earlier P3b latencies suggest greater employment of attentional resources to process emotional information efficiently (Cavanagh & Geisler, 2006; Lewis et al., 2007). No differences in P3b amplitudes for happy and angry faces in an oddball Go/No-Go task (Pollak et al., 1997) reflect a balanced attentional engagement in emotional stimuli regardless of valence amongst children without difficulties in emotion processing. In contrast, maltreated children with anxiety showed more positive P3b amplitudes for angry faces than happy faces, indicating emotional bias (Pollak et al., 2001; Shackman et al., 2007). Increased positive P3b amplitudes for unpleasant stimuli can also imply interference with cognitive processes in a secondary task, evidenced by the association between more positive P3b amplitudes and lower accuracy rates for subsequent non-emotional targets (Kujawa, Weinberg, et al., 2013).

Research on the developmental effects of MT on the P3b as an index of emotion processing is very limited. One recent study with adolescents showed that the P3b amplitudes elicited in an emotional oddball task remained unchanged in the MT group over time while they reduced regardless of face valence in the control group (Sanger et al., 2018). This suggests possible protective effects of mindfulness in maintaining attention to socially relevant stimuli during emotion processing. Hence, MT with pre-adolescents could lead to more efficient allocation of attentional resources and balanced attending to emotional stimuli, indexed by increased P3b amplitudes regardless of emotional valence of faces.

Whist the P3b indexes top-down control in emotion processing, the LPP indexes sustained attention to emotional stimuli, reflecting bottom-up emotional reactivity (Dennis, 2010; Kaunhoven & Dorjee, 2017). The LPP is elicited around 300–2000 ms after stimulus onset, and is observed over central-parietal/occipital areas (Hajcak et al., 2010; Kujawa, Klein, et al., 2012; Kujawa, Weinberg, et al., 2013). In research with children, the LPP is considered a reliable index of emotional reactivity (Kujawa, Klein, et al., 2013; Moran et al., 2013). A more positive LPP for pleasant distractors preceding targets linked to lower accuracy in typically developing children (Kujawa, Klein, et al., 2012). Children with anxiety had more positive LPP amplitudes to angry and fearful faces, while children with depression showed reduced LPP amplitudes (Kujawa et al., 2015).

A study using the LPP component as a neural marker of mindfulness effects on emotion processing in pre-adolescents found less positive LPP amplitudes to emotional stimuli in a passive viewing task after a brief mindfulness induction compared to controls regardless of stimulus valence (Deng et al., 2019). This suggests that the LPP amplitude for emotional stimuli could attenuate in pre-adolescents after MT, possibly as a result of reduced reactivity.

Studies on mindfulness, and emotion regulation in children more broadly, ignored cultural context influences so far. Given that the development of emotion processing and regulation abilities is a socialisation process (Thompson, 1994), adaptive emotion processing is culture-dependent. Indeed, research in adults suggested that the P3b and LPP markers of emotion processing could be modulated by culture (Murata et al., 2013; Yuan et al., 2015). For example, adult Asian participants showed attenuation of the parietal LPP compared to Western participants during suppression of negative emotions (Murata et al., 2013), supporting adaptive nature of this emotion regulation strategy in Asian cultures to maintain relationships (e.g., Matsumoto et al., 2008). In line with these findings, suppression increased P3b amplitude but attenuated LPP amplitude for unpleasant stimuli compared to passive viewing in Chinese adults (Yuan et al., 2015). The P3b enhancement may indicate an initial increase in attention resources due to more effortful inhibition. Interestingly, Asian culture encourages down-regulation of both negative and positive emotions because of beliefs in advantages of balanced experiencing of emotions (Miyamoto & Ma, 2011; Miyamoto & Ryff, 2011; Tsai et al., 2006). In the context of cultural influences on MT, a behavioural study with adults reported that Asian cultural values tended to predict quicker recovery from sad mood when applying mindfulness strategy relative to suppression (Keng et al., 2017). However, there have been no studies on brain indexes of mindful emotion regulation across cultures in adults or children so far. Based on the findings from adults, reductions in LPP amplitudes to both negative and positive stimuli could be expected after MT.

No empirical study on mindfulness with pre-adolescents has been conducted in Vietnamese culture. Vietnam is lacking resources for mental health support services for children and adolescents (Weiss et al., 2014). Social and life skill programmes started to be implemented in schools in Vietnam to reduce the risk of mental health problems but are costly due to external provider delivery. Preventative programmes implemented in schools by pupils' own teachers would be more cost-effective and possibly more impactful given the opportunities for longer-term implementation. Mindfulness-based school programmes might be particularly suitable for implementation in Vietnam, given that Vietnamese culture values emotional control of negative emotions (Le & Trieu, 2016) and prefers low positive arousal (e.g., Miyamoto & Ryff, 2011). This is aligned with non-striving for pleasant experiences and reduced avoidance of negative experiences cultivated through mindfulness (Bishop et al., 2004; Dorjee, 2016; Shapiro et al., 2006). Thus, the Vietnamese cultural context may amplify the effects of MT (Le & Trieu, 2016).

The current study investigated whether a mindfulness-based curriculum delivered by children's own schoolteachers can modify the P3b and LPP components as neural markers of emotion processing and regulation in pre-adolescents (age range from 7 to 11) in Vietnamese cultural context. It was a part of larger longitudinal project which found that MT improved emotion processing through increased emotional non-reactivity together with increased behavioural expression of emotions (preprint, 2021). The current study aimed to investigate the neural underpinnings of these changes. We employed a randomised controlled design with training (TG), active control (ACG) and non-intervention control (NCG) groups. The TG received MT programme. The ACG received social-emotional learning (SEL) programme. Data was collected at 3-time points, before training (pre-test, T1), after training (post-test, T2) and 6-month follow-up (T3) after the training finished.

The present study included two experiments using angry and happy faces to assess the effect of MT on positive and negative socially salient stimuli. The first experiment employed Caucasian face stimuli from Karolinska faces database (Lundqvist et al., 1998) in an emotional oddball Go/No-Go task, replicating a study on the impact of MT with children in Western context (Kaunhoven & Dorjee, in prep.) and testing whether Vietnamese children would show same effects on the LPP mean amplitudes as children in the United Kingdom. Experiment 2 employed both Caucasian and Japanese faces (Matsumoto & Ekman, 1989) in an emotional Go/No-Go task to test whether cultural in-group advantages impact responses to emotions after MT.

1.1 | Hypotheses

An increase of the P3b for happy and angry targets was expected after MT, together with earlier peak P3b latency, increased accuracy rates (ACC) and shorter response times (RT) reflecting an improvement in efficient deployment of attention resources towards task-relevant emotional stimuli. In addition, an attenuation of the LPP for both angry target and non-target faces was expected after MT indicating a decreased tendency in sustained attention to negative emotions as evidenced in adult mindfulness literature (e.g., Sobolewski et al., 2011; Uusberg et al., 2016). However, due to the characteristics of Vietnamese culture which values low-positive arousal experiences, we predicted the LPP amplitude for happy faces (positive stimuli) would also reduce after MT.

2 | OVERVIEW OF DESIGN AND PROCEDURE

2.1 | Ethical approval

Ethical approval was granted for the study prior to its commencement from the Ethics Committee in the UK and from Ho Chi Minh City Department of Education and Training. The Head of Education and Training Department then selected four schools in Ho Chi Minh city matched on socioeconomic status, quality of teaching and school facilities. Participants were recruited in parents' meetings before the four schools were assigned randomly to either TG (n = 2 schools) or ACG (n = 1 school) or NCG (n = 1 school). At each testing session, children received a small stationary item (e.g., a notebook, a pencil) for their participation.

Ninety-nine children from the larger sample of a longitudinal project (N = 171, TG n = 108; ACG n = 33; NCG n = 30) participated in ERP assessments reported in this study. The participants in TG were from only one school because the other TG school did not have a separate room required for EEG data collection. The total sample size of the longitudinal project (calculated in G*Power software) was 164 to detect a medium effect with the obtained 0.95 power. The effect size was based on small to medium effect sizes found for mental health and well-being when comparing MT groups to control groups in school settings (e.g., Carsley et al., 2018).

2.2 | Mindfulness and well-being programme – The present Course

The Present Course for Primary Schools was developed for 3- to 11-years-old children (Silverton et al., 2016). The Present Course was delivered over 18 weeks between October 2017 and February 2018 by pupils' own classroom teachers, with two 2-week breaks in between and four extra weeks for review of all seven themes (total duration of delivery from the start to the end was 22 weeks) (see Supplement 1 for a more detailed description of The Present Course; Silverton et al., 2016). Mindfulness practices and activities were integrated into regular school curriculum. Children were instructed to do regular classroom activities (e.g., measuring, listening to music, writing) in a mindful way, together with age-appropriate mindfulness practices designed to be suitable for developing and changing needs of different age groups in terms of duration, content of practices and the depth of inquiry (see examples in the Supplement 1). Each practice or activity required from 2—3 min to 5—7 min, or maximum 10 min according to childrens' ability to focus and sustain attention on the present moment (Rueda et al., 2005) and childrens' capacity for metacognitive awareness of mental events (Davis et al., 2010; Greenberg & Harris, 2012).

Fidelity of the intervention was assessed by a research assistant who visited classroom during curriculum delivery to observe activities and practices implemented, took photos and recorded videos as evidence of implementation fidelity. Furthermore, schoolteachers completed a pre-designed diary, including activities and practices introduced to children and time spent on delivery (see Supplement 2 for teachers' implementation dairy). Schoolteachers (N = 7, one male) with at least 10 years of teaching experience (except for one teacher with 7 years of teaching experience) were initially trained in an adapted Mindfulness-Based Stress Reduction (MBSR) programme over two consecutive weekends (eight 3-h sessions). Then, they were given 6 months to develop a regular mindfulness practice before receiving a 3-full-day course of The Present curriculum training. A mindfulness trainer with a master's degree in Mindfulness-based Approaches and over 15 years of mindfulness teaching experience led both training courses.

2.3 | Control conditions

To identify specific effects of MT, the NCG received no intervention while the ACG received SEL programme delivered by external trainers as an additional subject in regular school curriculum during the same time frame as The Present (total duration of delivery from the start to the end was 22 weeks). The SEL programme was designed to be comparable in duration of delivery with The Present but did not include any mindfulness components (see Supplement 1 for a more detailed description of the SEL programme). The external trainers were graduates from an undergraduate Educational Psychology programme and had at least 2-years of experience in teaching social emotional skills to children but no experience with mindfulness.

2.4 | Design and procedure

TG received The Present curriculum over 22 weeks integrated into classroom activities, the ACG received the SEL programme delivered by external trainers over 22 weeks, one 40 min-long session per week. Each school delivered only one of the interventions to control for possible diffusion effects (Schonert-Reichl et al., 2015). NCG received usual school curriculum. EEG data was collected from TG first, then ACG and lastly NCG; this order was followed at all three time points to ensure the same time gap between assessments amongst groups. Testing sessions were conducted on school premises in a separate room from classrooms.

3 | EXPERIMENT 1

Experiment 1 aimed to replicate a study on the impact of MT on P3b and LPP components conducted previously with children in the United

TABLE 1 Experiment 1_A summary of the demographic information for participants in DS1 and DS2

Demographic information	T1-T2 (DS1) (N = 60) TG (n = 33)	ACG (n = 14)	NCG (n = 13)	Total/Average	T2-T3 (DS2) (N = 40) TG (n = 15)	ACG (n = 12)	NCG (n = 13)	Total/Average
Age (*years*)								
M	9.38	9.12	8.83	9.20	8.85	9.07	8.77	8.91
SD	1.02	0.53	0.56	0.86	0.93	0.56	0.57	0.71
Gender (%)								
Female	48.5	50.0	46.2	48.3	33.3	58.3	46.2	45.0
Male	51.5	50.0	53.8	51.7	66.7	41.1	53.8	55.0

Note. DS1 = Pre-Post data set. DS2 = Post-Follow-up data set. T1 = Pre-test. T2 = Post-test. T3 = 6-month follow-up-test. TG = Training group. ACG = Active control group. NCG = Non-intervention control group.

Kingdom (Kaunhoven & Dorjee, in prep.) in the Vietnamese cultural context to test whether Vietnamese children would show same effects on the P3b and LPP mean amplitudes after MT as children in the United Kingdom.

3.1 | Materials and methods

Data from sixty children was used in the final analysis (see Supplement 3 for exclusion criteria and Table 1 for detailed demographic information). Experiment 1 used an emotional Go/No-Go oddball task (Kaunhoven & Dorjee, in prep.) with Caucasian face stimuli from the Karolinska faces database (Lundqvist et al., 1998), including 38 happy faces (15% of total trials), 38 angry faces (15% of total trials) and two neutral faces presented as standard frequent non-targets in 70% of total trials. Each face was presented in colour for 900 ms with a gap of 750 ms between stimuli on a computer screen using E-Prime 2.0 software. The task had 504 trials in total comprised of four blocks with breaks in between which took approximately 14 min to complete. For two consecutive blocks, happy faces were targets while neutral and angry faces were non-targets. For the remaining two consecutive blocks, targets were angry faces and non-targets were neutral and happy faces. The order of every two consecutive blocks was counterbalanced and the faces were distributed randomly within each block. There were no group differences in the counterbalancing versions of the task at three time points T1, T2 and T3 ($ps > 0.10$). EEG signal was recorded while children completed the task (see Supplement 3 for EEG recording and processing details).

3.2 | Results

We did not find any modulation of the P3b or LPP components after MT in the TG or either of the two control groups (see Supplement 3 and Table 2, Figure 1 for detailed baseline comparisons, behavioural and ERP results). Also, there was no P3b oddball effect (difference between targets and non-targets) in any of the three groups.

3.3 | Discussion

The lack of change in both P3b and LPP mean amplitudes for all groups over time was not expected. Although P3b is sensitive to processing of threatening stimuli in children with anxiety or maltreatment history (Pollak et al., 2001; Rossignol et al., 2012; Shackman et al., 2007), this component is not always sensitive to detecting differences in adaptive or maladaptive responses to emotional stimuli between healthy participants and participants displaying anxious or depressed symptoms but not at a clinical level (Campanella et al., 2010).

The absence of the oddball effect could be explained by children having difficulties in recognising neutral facial expressions due to ambiguity of the information they convey and associated increased cognitive load (Herba & Phillips, 2004). Neutral stimuli in Experiment 1 were Caucasian faces and this might have further exacerbated difficulties in recognising the emotional expression for children from a different ethnic background, thus reducing the differential effect of targets and non-targets. Therefore, the neutral faces were excluded from Experiment 2.

Furthermore, the LPP can be modulated by familiar faces (Todd et al., 2008) and emotional faces of in-group lead to more arousal (Chiao et al., 2008). Given that only Caucasian faces (out-group) were used as stimuli for Vietnamese children in Experiment 1, this might have diminished the sensitivity of the task in detecting effects of MT. Indeed, the LPP can be sensitive in cross-cultural context, it has been found that culturally different emotional control values seem to modulate the LPP (Murata et al., 2013; Yuan et al., 2015). To explore further whether the ethnicity of faces impacted on the lack of effects of MT on emotion processing, we conducted Experiment 2 with Caucasian and Japanese faces.

4 | EXPERIMENT 2

Experiment 2 used equiprobable Go/No-Go task and repetition of emotional stimuli (happy and angry faces) without neutral condition to eliminate the possible ambiguity effect of neural faces from

TABLE 2 Experiment 1_Descriptive statistics (residuals after age corrections) in each condition for P3b latency and mean amplitudes, LPP mean amplitudes and behavioural indexes in TG, ACG and NCG at T1 (baseline)

	TG (*n* = 33)	ACG (*n* = 14)	NCG (*n* = 13)
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
P3b latency			
Happy target	0.024 (0.99)	0.421 (0.87)	−0.514 (0.97)
Angry target	0.109 (0.95)	0.107 (1.00)	−0.392 (1.06)
Happy non-target	0.282 (1.00)	−0.076 (0.93)	−0.635 (0.74)
Angry non-target	−0.022 (0.98)	0.449 (0.81)	−0.428 (1.06)
Neutral non-target	0.240 (0.93)	−0.392 (0.72)	−0.187 (1.26)
P3b mean amplitude			
Happy target	0.064 (1.14)	−0.141 (0.95)	−0.011 (0.59)
Angry target	0.054 (1.07)	−0.110 (1.05)	−0.019 (0.74)
Happy non-target	0.185 (1.03)	−0.420 (0.90)	−0.018 (0.90)
Angry non-target	0.103 (1.11)	−0.158 (0.84)	−0.092 (0.99)
Neutral non-target	0.087 (1.13)	−0.214 (0.87)	0.009 (0.71)
LPP mean amplitude			
Happy target	−0.059 (1.05)	0.001 (1.17)	0.147 (0.59)
Angry target	−0.035 (1.03)	−0.007 (1.21)	0.096 (0.65)
Happy non-target	0.071 (1.02)	−0.259 (1.06)	0.098 (0.87)
Angry non-target	0.014 (1.02)	0.137 (0.94)	−0.184 (1.01)
Neutral non-target	−0.091 (0.98)	0.003 (1.27)	0.228 (0.64)
Accuracy rate			
Happy target	−0.005 (1.03)	−0.024 (1.13)	0.039 (0.79)
Angry target	−0.204 (0.94)	0.180 (1.00)	0.323 (1.07)
Response time			
Happy target	−0.063 (0.98)	−0.011 (1.29)	0.171 (0.66)
Angry target	0.060 (1.06)	0.244 (1.02)	−0.415 (0.68)
False alarm rate			
Happy non-target	−0.062 (0.98)	0.050 (1.16)	0.103 (0.88)
Angry non-target	0.043 (1.04)	0.037 (1.17)	−0.148 (0.68)
Neutral non-target	0.200 (1.13)	−0.082 (0.83)	−0.418 (0.60)

Abbreviations: ACG, active control group; NCG, non-intervention control group; TG, training group.

Experiment 1. In a study with adults, mindfulness induction gradually attenuated and ultimately nullified the LPP amplitude modulations during repetition of negative stimuli, suggesting extinction of habitual emotional reaction (Uusberg et al., 2016). Therefore, if the effect of mindfulness is observed in the task with repetition of emotional stimuli, indexed by less positive LPP mean amplitudes for emotional faces, it would provide more robust evidence in support of a reduction in emotional reactivity after MT.

Additionally, Experiment 2 aimed to investigate the effects of MT on the P3b and LPP indexes of emotion processing in a task with facial stimuli that were either culturally in-group (East Asian faces) or culturally out-group (Caucasian faces). If the in-group faces elicit more arousal (e.g., Chiao et al., 2008) and MT reduces emotional reactivity (e.g., Schonert-Reichl et al., 2015), the modulations of the P3b and LPP were expected to be more pronounced for East Asian faces.

5 | MATERIALS AND METHODS

5.1 | Participants

From 99 children whose parents gave consent for participation in ERP study, at T1, five children dropped out after completing Experiment 1 (TG $n = 3$, ACG $n = 1$, NCG $n = 1$) and data from 28 children were excluded from analyses due to ACC below 65%, excessive EEG artefacts, and incompletion. This resulted in a pre-test sample of N = 66 participants (TG $n = 28$, ACG $n = 16$, NCG $n = 22$). At T2, four more children did not participate due to special circumstances, drop out, and moving to a different school; two more children with ACC below 65% were excluded from data analyses. Hence, the final post-test sample was $N = 60$ (TG $n = 26$, ACG $n = 14$, NCG $n = 20$). At T3, 11 children moved to other schools, four children were excluded from data analyses due to ACC below 65% and extreme artefacts, resulting in the final follow-up sample of $N = 45$ (TG $n = 14$, ACG $n = 12$, NCG $n = 19$).

Therefore, a complete data set from T1 to T2 (DS1) included data from 60 children and T2-T3 dataset (DS2) included data from 45 children. See Table 3 for specific demographic information of children for each dataset. A Pearson Chi-Squared test found no significant group difference in gender in both DS1 [$\chi^2(2, N = 60) = 1.42, p = 0.493$] and DS2 [$\chi^2(2, N = 45) = 2.77, p = 0.250$]. For age, because assumption of homogeneity of variance was violated in DS1 [$F(2,57) = 13.03, p < 0.001$], Brown-Forsythe *F*-ratio was used to reveal significant group differences in age [$F(2,50.91) = 3.66, p = 0.033$] wherein children in NCG were significantly younger than those in TG [$t(38.97) = 2.41, p = 0.021, d = -0.69$], no differences in age between TG and ACG and between ACG and NCG were found ($ps > 0.10$). In DS2, a one way factorial analyses of variance (ANOVA) compared ages of children across groups and showed no significant group differences in age [$F(2,42) = 0.90, p = 0.413$].

5.2 | Acceptability

Four multi-choice questions about acceptability of the training courses were administered to children from TG and ACG at T2 and T3 (see Supplement 4 for detailed multi-choice questions).

5.3 | Emotional Go/No-Go task

The emotional Go/No-Go task employed eight happy faces (four Caucasian and four Japanese) and eight angry faces (four Caucasian and four Japanese) from Japanese and Caucasian Facial Expression of Emotions (JACFEE; Matsumoto & Ekman, 1989). Numbers of female and male faces were evenly distributed across ethnicities and emotions. All

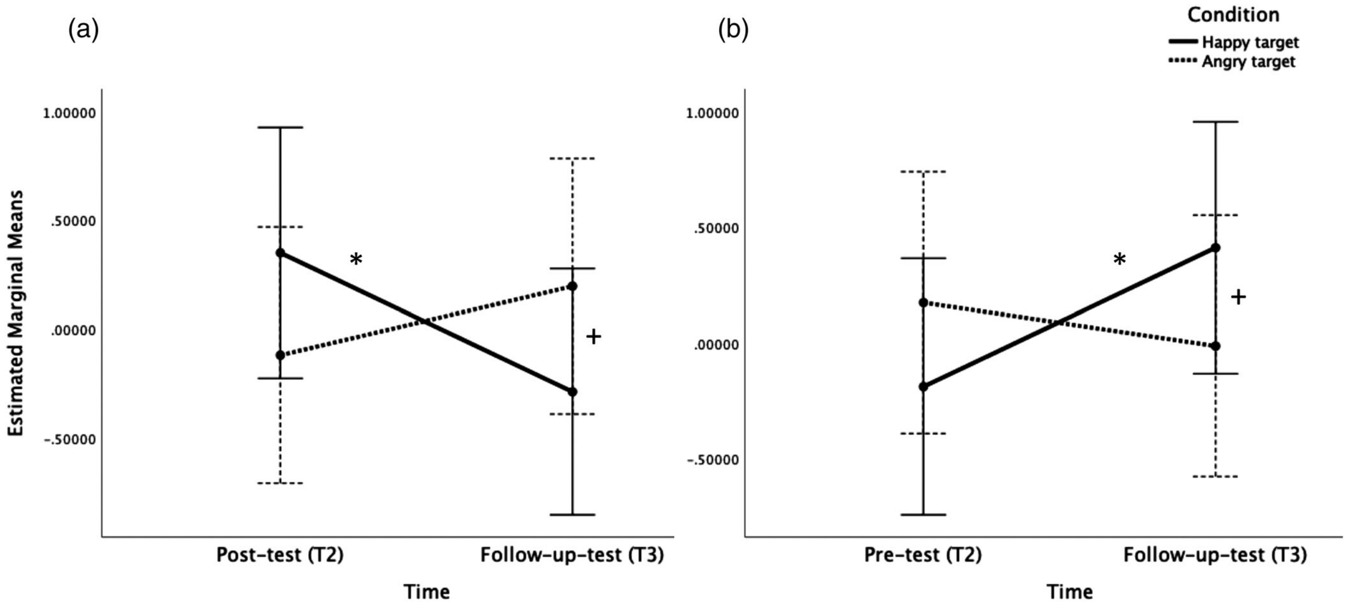

FIGURE 1 Experiment 1_Changes in response times to happy and angry targets from T2 to T3. (a) Changes within ACG. (b) Changes within NCG.

Note. Asterisk symbol (*): p < .05. Plus symbol (+): 05 = < p < .10. Error bars: 95% CI. ACG = Active control group. NCG = Non-intervention control group

TABLE 3 Experiment 2_A summary of the demographic information for participants in DS1 and DS2

	T1-T2 (DS1) (*N* = 60)				T2-T3 (DS2) (*N* = 45)			
Demographic information	TG (*n* = 26)	ACG (*n* = 14)	NCG (*n* = 20)	Total/Average	TG (*n* = 14)	ACG (*n* = 12)	NCG (*n* = 19)	Total/Average
Age (*years*)								
M	9.33	8.93	8.73	9.03	8.74	9.07	8.77	8.84
SD	1.09	0.59	0.56	0.87	0.95	0.52	0.55	0.69
Gender (%)								
Female	42.3	50.0	60.0	50.0	35.7	41.7	63.2	48.9
Male	57.7	50.0	40.0	50.0	64.3	58.3	36.8	51.1

Notes: DS1 = Pre-Post data set. DS2 = Post-Follow-up data set. T1 = Pre-test. T2 = Post-test. T3 = 6-month follow-up-test. TG = Training group. ACG, active control group. NCG, non-intervention control group.

selected faces were previously tested with a Vietnamese adult sample with agreement rate of 98.5% for happy faces and 80.9% for angry faces (Biehl et al., 1997).

The task comprised of 256 trials in total divided into two blocks with one break in between. Each block with 128 trials contained four Caucasian and four Japanese happy faces, four Caucasian and four Japanese angry faces, with each face repeated eight times. Faces were distributed randomly and repeatedly within each block. For one block, happy faces were presented in 50% of total trials as targets while angry faces were presented in 50% of total trials as non-targets. For the other block, happy faces were presented in 50% of total trials as non-targets while angry faces were presented in 50% of total trials as targets. The order of blocks was counter-balanced, there were no group differences in the counterbalancing versions of the task at T1, T2 or T3 (*ps* > 0.10). Each face was presented in colour for 1000 ms with a fixation cross shown for 750 ms between faces on a computer screen using E-Prime 2.0 software. The task took approximately eight minutes to complete; it was relatively short to minimise possible fatigue effects due to overall duration of the sessions (EEG setup, Experiments 1 and 2).

5.4 | Procedure

Children sat in front of a laptop and were fitted with a 32-electrode cap on their heads (Easy cap, Asian cut, Brain Products). After they finished Experiment 1, they were asked if they wished to continue with Experiment 2 after a short break. Task instructions were explained verbally and also shown on the screen at the beginning of each block. Participants pressed spacebar to either happy or angry faces depending on the block.

5.5 | EEG recording, processing and statistical analyses

ActiCHamp amplifiers with a sampling rate of 1000 Hz and 32-channel actiCAP cap referenced online to the right mastoid were used to record EEG data while children were performing the task. Electrode impedances were kept below 25kOhms. A bandpass filter of 0.01–200 Hz was used to filter the EEG signal online. Data were processed offline in BrainVision Analyzer. Bad channels were excluded before EEG analysis. EEG data was then off-line band-pass filtered with range of 0.1—30 Hz, slope of 12/Db/Oct for low pass and 48/Db/Oct for high pass. EEG activity with absolute difference above 1500 μV or below 0.5 μV was automatically excluded before eye-blink correction using Independent Component Analysis (ICA) and then inverse ICA was conducted. Following this, excluded channels in the first step were interpolated into data set then data was re-referenced off-line to an averaged mastoid reference. All residual artefacts were manually cleaned.

ERP analysis was only conducted on correct trials with minimum 12 trials per condition (average number trials of 26.86, ranging from 12 to 32 trials). The data was epoched into 1100 ms segments, starting 100 ms before the stimulus onset (used for baseline correction) and ending 1000 ms after stimulus onset. ERP averages were computed for each condition for each participant, then grand averaged across participants for each condition. Peak detection was based on previous literature (Luck, 2014) and local search was used to define peak of the P3b component. The P3b mean amplitude (220—320 ms) was averaged across three electrodes where the P3b signal was maximal – P3, P4 and Pz. The LPP mean amplitude was averaged across three electrodes (P3, P4 and Pz) in two time-windows, early time window of 400—700 ms and late time window of 701—1000 ms. These topographies and time windows are consistent with previous P3b and LPP findings with adults and children (Kujawa et al., 2015; Kujawa, Hajcak, et al., 2012; Kujawa, Klein, et al., 2013; Kujawa, Weinberg, et al., 2013; Polich, 2007; Shackman et al., 2007).

5.5.1 | Statistical analyses

Extreme values (> 3 × interquartile range) were winsorised and age was corrected for all dependent variables by applying simple linear regression due to significant group differences in age in the DS1 (see Section 5.1). Resulting standardised residuals served as new dependent variables for further analyses (Böhning et al., 2016; Casaletto et al., 2015; Rosenbaum & Rubin, 1984). Regressed age residuals were also used in DS2 analyses despite no group differences in age for consistency in the approach to analyses across the three time points.

Pre-existing differences at the baseline in all dependent measures across groups were tested using mixed factorial ANOVAs with 4(condition: happy target, angry target, happy non-target, and angry non-target) and 2(ethnicity: Caucasian, Japanese) as within-group factors and 3(group: TG, ACG, NCG) as between-group factor for the P3b mean amplitudes and latencies. A similar mixed factorial ANOVA with an additional within-group factor (window: early, late) was conducted for the LPP mean amplitudes. Similarly, baseline differences in behavioural data were assessed using mixed factorial ANOVAs with condition, ethnicity, and group factors for ACC, RT (RT before 199 ms and after 1000 ms were excluded), and false alarm rates (FA, percentage of responses where a response was not correctly withheld for happy and angry non-targets). Where significant group differences were found at baseline, difference scores of new outcome variables derived by subtracting scores (T2–T1) and (T3–T2) were used in longitudinal analyses.

Before longitudinal analyses, possible differences between emotional responses to Caucasian and Japanese faces in DS1 and DS2 were assessed. Mixed factorial ANOVAs with 2(ethnicity: Caucasian, Japanese) × 4(condition: happy target, angry target, happy non-target, angry non-target) × 2(time: T1, T2 or T2, T3) x 3(group: TG, ACG, NCG) factors were conducted for P3b mean amplitudes and latencies. For the LPP component, a similar mixed factorial ANOVA with additional window factor was conducted. Similarly, mixed factorial ANOVAs with ethnicity, condition, time, and group factor were conducted for ACC, RT and FA. Where main effects of ethnicity or interactions with the ethnicity factor were significant or marginally significant, mixed factorial ANOVAs with condition, time and group factors were run separately for Caucasian and Japanese faces; otherwise, averages across Caucasian and Japanese faces were calculated to use in longitudinal analyses. Greenhouse-Geisser (G-G) adjusted degree of freedom was used when the assumption of Sphericity was violated (Mauchley's Sphericity test, $p < 0.05$). Changes over time were of a core interest of this study, therefore, significant main effects of time or interaction effects of time with other factors took priority in reporting results, followed up by pairwise comparisons with Bonferroni corrected p-values and Cohens' d was calculated as an estimate of effect size.

6 | RESULTS

6.1 | Acceptability results

Please note that full sample acceptability rates, including the current sample, are reported in a preprint (2021). Here we are reporting acceptability rates for the subsample of participants who participated in Experiment 2 for intervention fidelity purposes.

For the TG, at T2, 92.3% of participants reported that they liked The Present. A total 100% of participants would like to continue learning The Present at school. 19.2% of participants reported practising mindfulness at home every day, 50.0% shared that they practised few times a week and 7.7% shared that they practised few times a month. At T3, 57.2% of participants reported they still practised mindfulness at home, ranging from few times a week to few times a month.

For the ACG, at T2, 85.7% of participants reported that they liked SEL. Hundred percent of participants would like to continue the SEL programme at school. Total 28.6% of participants reported practising skills from SEL at home every day, 50.0% shared that they practised few times a week and 14.3% shared that they practised few times a month. At T3, 75% of participants reported they still practised SEL skills at home, ranging from few times a week to few times a month.

TABLE 4 Experiment 2_Descriptive statistics (residuals after age corrections) in each condition for behavioural indexes in TG, ACG and NCG at T1 (baseline)

	TG	ACG	NCG
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
Accuracy rate			
Caucasian			
Happy target	−0.108 (*1.06*)	0.330 (*0.68*)	−0.091 (*1.07*)
Angry target	0.002 (*0.98*)	0.379 (*0.66*)	−0.268 (*1.15*)
Japanese			
Happy target	−0.040 (*0.82*)	0.330 (*0.84*)	−0.179 (*1.25*)
Angry target	−0.085 (*1.13*)	−0.152 (*1.02*)	0.217 (*0.76*)
Response time			
Caucasian			
Happy target	−0.011 (*0.95*)	−0.130 (*0.72*)	0.105 (*1.21*)
Angry target	−0.088 (*1.02*)	0.311 (*1.13*)	−0.103 (*0.85*)
Japanese			
Happy target	0.033 (*0.97*)	0.020 (*0.79*)	−0.056 (*1.17*)
Angry target	0.001 (*1.05*)	−0.067 (*0.59*)	0.045 (*1.17*)
False alarm rate			
Caucasian			
Happy non-target	0.119 (*0.96*)	−0.029 (*1.00*)	−0.134 (*1.06*)
Angry non-target	−0.158 (*0.99*)	0.061 (*0.93*)	0.163 (*1.06*)
Japanese			
Happy non-target	−0.140 (*1.04*)	−0.078 (*1.05*)	0.236 (*0.88*)
Angry Non-target	−0.107 (*0.83*)	0.279 (*1.24*)	−0.057 (*1.01*)

Abbreviations: ACG, active control group; NCG, non-intervention control group; TG, training group.

Pearson Chi-Squared tests found no significant group differences in acceptability in both DS1 and DS2 (*ps* > 0.10).

6.2 | Baseline comparisons

Baseline assessments did not show any significant differences between groups in behavioural data and the P3b, LPP components (*ps* > 0.10). See Tables 4 and 5.

6.3 | Longitudinal changes in behavioural data

6.3.1 | Accuracy

Tests of ethnicity differences between Caucasian and Japanese faces showed a marginally significant ethnicity x condition x group interaction in DS1 [$F(2,57) = 3.06$, $p = 0.055$, $\eta_p{}^2 = 0.097$] and in DS2 [$F(2,42) = 3.20$, $p = 0.051$, $\eta_p{}^2 = 0.132$]. All remaining main effects and interactions were not significant (*ps* > 0.10). Thus, further separate analyses on Caucasian and Japanese faces were conducted for ACC in both data sets.

TABLE 5 Experiment 2_Descriptive statistics (residuals after age corrections) in each condition for P3b latency and mean amplitudes and LPP mean amplitudes in TG, ACG and NCG at T1 (baseline)

	TG	ACG	NCG
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
P3b latency			
Caucasian			
Happy target	0.216 (*1.00*)	−0.134 (*0.90*)	−0.187 (*1.03*)
Angry target	0.097 (*0.91*)	−0.090 (*0.94*)	−0,064 (*1.15*)
Happy non-target	−0.035 (*1.07*)	−0.022 (*0.84*)	0.061 (*1.02*)
Angry non-target	0.211 (*0.87*)	−0.056 (*0.90*)	−0.235 (*1.18*)
Japanese			
Happy target	0.075 (*0.94*)	0.073 (*1.00*)	−0.148 (*1.08*)
Angry target	0.209 (*0.82*)	−0.364 (*0.86*)	−0.017 (*1.22*)
Happy non-target	−0.057 (*0.96*)	0.266 (*1.22*)	−0.112 (*0.87*)
Angry non-target	0.107 (*1.01*)	0.029 (*1.02*)	−0.159 (*0.97*)
P3b mean amplitude			
Caucasian			
Happy target	0.143 (*1.05*)	0.270 (*1.04*)	−0.375 (*0.80*)
Angry target	0.062 (*1.03*)	−0.103 (*1.03*)	−0.009 (*0.95*)
Happy non-target	0.057 (*1.08*)	0.103 (*0.95*)	−0.146 (*0.93*)
Angry non-target	0.066 (*1.04*)	−0.111 (*0.97*)	−0.008 (*0.98*)
Japanese			
Happy target	0.042 (*1.03*)	0.061 (*1.05*)	−0.097 (*0.94*)
Angry target	0.085 (*1.11*)	0.003 (*1.04*)	−0.113 (*0.82*)
Happy non-target	0.002 (*0.90*)	0.084 (*1.12*)	−0.061 (*1.06*)
Angry non-target	0.107 (*0.93*)	−0.019 (*1.06*)	−0.125 (*1.06*)
LPP mean amplitude			
(400 – 700ms)			
Caucasian			
Happy target	0.098 (*1.11*)	0.195 (*0.89*)	−0.263 (*0.87*)
Angry target	0.010 (*1.02*)	−0.080 (*1.27*)	0.044 (*0.75*)
Happy non-target	0.102 (*1.06*)	−0.006 (*1.00*)	−0.128 (*0.93*)
Angry non-target	0.068 (*1.08*)	−0.159 (*0.94*)	0.023 (*0.95*)
Japanese			
Happy target	0.019 (*0.89*)	−0.014 (*1.24*)	−0.015 (*0.98*)
Angry target	−0.001 (*1.16*)	0.014 (*1.13*)	−0.009 (*0.99*)
Happy non-target	0.018 (*0.97*)	0.094 (*1.41*)	−0.089 (*0.67*)
Angry non-target	0.009 (*0.94*)	0.031 (*1.11*)	−0.033 (*1.02*)
(701 – 1000ms)			
Caucasian			
Happy target	0.065 (*1.04*)	0.170 (*1.07*)	−0.203 (*0.89*)
Angry target	0.020 (*1.16*)	−0.104 (*1.08*)	0.047 (*0.69*)
Happy non-target	0.002 (*1.06*)	0.069 (*1.16*)	−0.051 (*0.80*)
Angry non-target	0.053 (*1.09*)	−0.310 (*1.02*)	0.148 (*0.82*)

(Continues)

TABLE 5 (Continued)

	TG Mean (*SD*)	ACG Mean (*SD*)	NCG Mean (*SD*)
Japanese			
Happy target	0.017 (*0.97*)	−0.057 (*1.17*)	0.018 (*0.94*)
Angry target	−0.047 (*1.18*)	−0.005 (*1.13*)	0.065 (*0.58*)
Happy non-target	−0.037 (*0.98*)	−0.001 (*1.39*)	0.049 (*0.68*)
Angry non-target	−0.051 (*1.11*)	0.102 (*0.99*)	−0.004 (*0.85*)

Abbreviations: ACG, active control group; NCG, non-intervention control group; TG, training group.

Longitudinal analyses for ACC showed a significant main effect of group [$F(2,57) = 3.24$, $p = 0.047$, $\eta_p^2 = 0.102$] for Caucasian faces and a marginally significant condition × group interaction [$F(2,57) = 2.96$, $p = 0.060$, $\eta_p^2 = 0.094$] for Japanese faces in DS1. Because group × condition was not an interaction of interest, follow-up analyses with pairwise comparisons were not conducted. Remaining main effects and interactions were found non-significant ($ps > 0.10$). In DS2, all main effects and interactions were not significant ($ps > 0.10$).

6.3.2 | Response time

Tests of ethnicity differences between Caucasian and Japanese faces showed a significant ethnicity × condition × group interaction [$F(2,57) = 3.37$, $p = 0.041$, $\eta_p^2 = 0.106$] only in DS1. No other significant main effects or interactions were found in DS2 ($ps > 0.10$). Longitudinal analyses for RT were conducted separately on Caucasian and Japanese faces in DS1 while analyses of averaged Caucasian and Japanese faces were used in DS2. No significant main effects or interactions were found ($ps > 0.10$).

6.3.3 | False alarm

Test for possible ethnicity differences between Caucasian and Japanese faces in FA showed no significant main effect of ethnicity or interactions of ethnicity with other factors ($ps > 0.10$). Longitudinal analyses for FA used averaged Caucasian and Japanese faces in both data sets and showed only a marginally significant time × group interaction [$F(2,57) = 2.49$, $p = 0.092$, $\eta_p^2 = 0.080$] in DS1. However, pairwise comparisons did not show any significant differences between or within groups across time ($ps > 0.10$). There were no other significant main effects or interactions ($ps > 0.10$).

6.4 | Longitudinal changes in ERPs

6.4.1 | P3b component

We first tested for possible ethnicity differences between Caucasian and Japanese faces in P3b mean amplitudes and latencies. In DS1, there was a marginally significant ethnicity × condition × time × group interaction [$F(6,171) = 1.84$, $p = 0.095$, $\eta_p^2 = 0.061$] for P3b latencies only. In DS2, there was a marginally significant ethnicity × condition × time × group interaction [$F(6,126) = 2.06$, $p = 0.062$, $\eta_p^2 = 0.089$] for P3b mean amplitudes, and a significant ethnicity x condition x group interaction [$F(6,126) = 2.41$, $p = 0.043$, $\eta_p^2 = 0.096$] for P3b latencies. No other main effects of ethnicity or interactions of ethnicity with other factors were found ($ps > 0.10$). Further mixed factorial ANOVAs on DS1, therefore, were conducted on averaged P3b mean amplitudes across Caucasian and Japanese faces, while separate analyses for Caucasian and Japanese faces were conducted for P3b latencies. Separate analyses for Caucasian and Japanese faces were conducted for P3b mean amplitudes and latencies in DS2.

Longitudinal analyses for P3b mean amplitudes showed no significant main effects or interactions in DS1 ($ps > 0.10$). Similarly, in DS2, all main effects and interactions in P3b mean amplitudes for separate Caucasian and Japanese faces were non-significant ($ps > 0.10$).

Longitudinal analyses for P3b latencies revealed significant time × group × condition interactions for Japanese faces in both DS1 [$F(6,171) = 2.65$, $p = 0.017$, $\eta_p^2 = 0.085$] and DS2 [$F(6,126) = 2.51$, $p = 0.025$, $\eta_p^2 = 0.107$]. Between T1 and T2 in DS1, the pairwise comparisons showed that P3b latencies for Japanese happy non-targets in TG tended to peak later than NCG at T2 ($p = 0.098$, $d = 0.62$). The P3b latencies for Japanese angry non-targets showed similar but significant pattern ($p = 0.047$, $d = 0.73$). Also, P3b latencies for Japanese happy non-targets within TG tended to peak later at T2 compared to T1 ($p = 0.062$, $d = 0.39$) while the ACG showed an opposite tendency ($p = 0.076$, $d = -0.54$). No changes were found within the NCG in P3b latencies between T1 and T2.

Between T2 and T3 in DS2, the pairwise comparisons showed no differences in P3b latencies for Japanese happy non-targets either between TG and ACG or between TG and NCG ($ps > 0.10$). However, the P3b latencies for Japanese happy non-targets within TG peaked significantly earlier at T3 compared to T2 ($p = 0.025$, $d = -0.83$), the NCG showed an opposite marginally significant pattern ($p = 0.100$, $d = 0.44$). Regarding Japanese angry non- targets, the P3b latencies for NCG peaked earlier than TG ($p = 0.041$, $d = -0.96$) and ACG ($p = 0.091$, $d = -0.82$) at T3. The ACG showed no changes in P3b latencies between T2 and T3 ($p > 0.10$). See Figure 2.

All main effects and remaining interactions for Japanese faces were non-significant ($ps > 0.10$). None of the main effects and interactions for Caucasian faces were significant ($ps > 0.10$).

6.4.2 | LPP component

We tested for possible ethnicity differences between emotional responses to Caucasian and Japanese faces in LPP amplitudes first. In DS1, there was a marginally significant ethnicity × window × group interaction [$F(2,57) = 2.47$, $p = 0.093$, $\eta_p^2 = 0.080$] and a significant ethnicity × condition × time × window × group interaction [$F(5.33,151.89) = 2.59$, $p = 0.025$, $\eta_p^2 = 0.083$]. In DS2, there

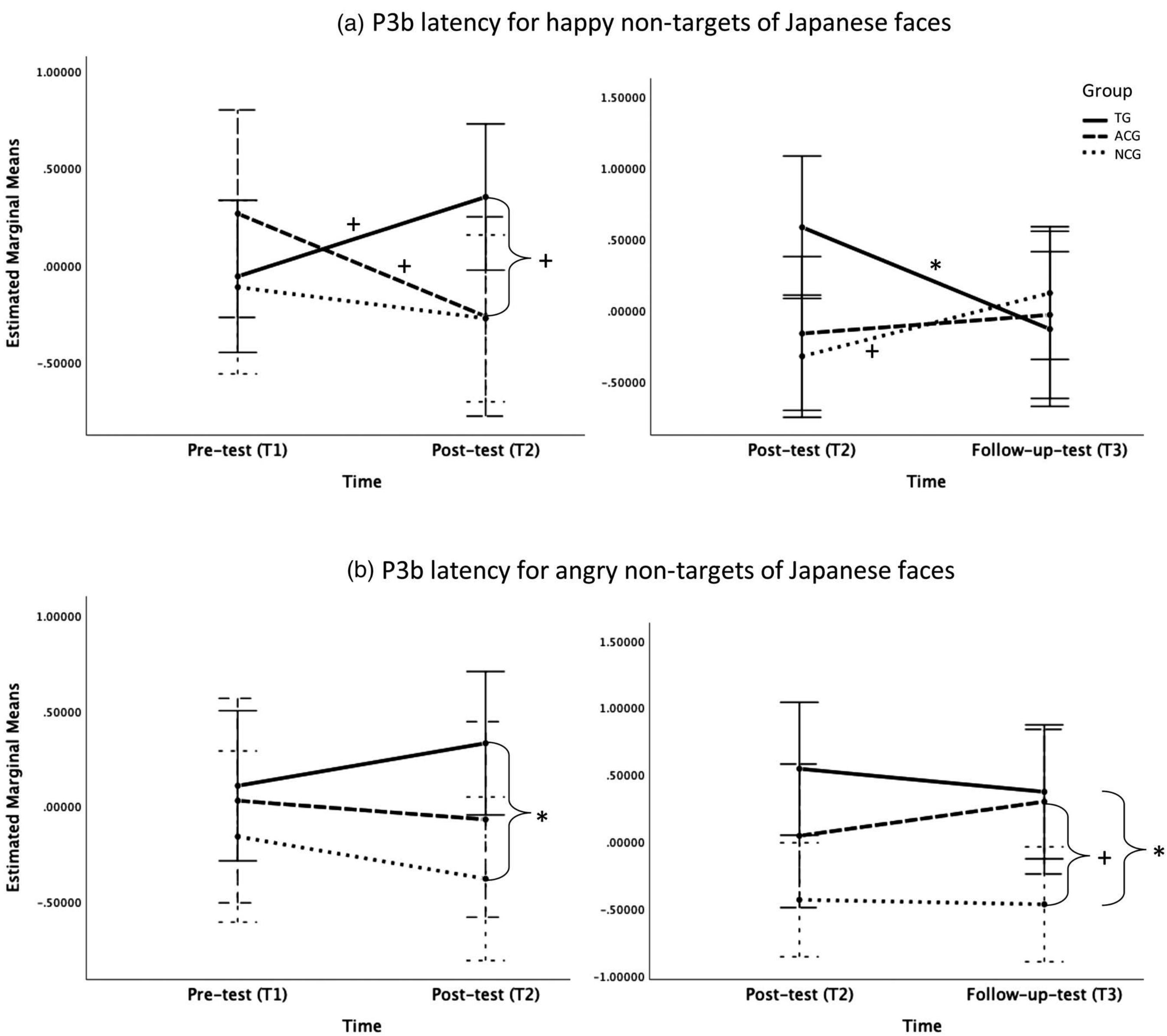

FIGURE 2 Experiment 2_Changes in P3b latency for (a) Japanese happy non-targets and (b) Japanese angry non-targets between and within groups over time.
Note. Asterisk symbol (*): p < .05. Plus symbol (+): 05 = < p < .10. Error bars: 95% CI. TG = Training group. ACG = Active control group. NCG = Non-intervention control group

were no significant or marginally significant main effects of ethnicity or interaction effects of ethnicity with other factors; only window x group interaction [$F(2,42) = 4.33$, $p = 0.019$, $\eta_p^2 = 0.171$] and condition × time × group interaction [$F(4.13,86.63) = 2.61$, $p = 0.039$, $\eta_p^2 = 0.111$] were significant, and condition × window × time × group interaction [$F(3.98,83.54) = 2.13$, $p = 0.085$, $\eta_p^2 = 0.092$] was marginally significant. Therefore, longitudinal analyses for LPP mean amplitudes were conducted for separate Caucasian and Japanese faces in DS1, while analyses for averaged Caucasian and Japanese faces were conducted in DS2. All further analyses were run in two separate windows to reduce number of ANOVA factors thus minimising the likelihood of spurious effects (Luck & Gaspelin, 2017).

Early time window (400–700 ms) LPP mean amplitude

Longitudinal analyses for LPP mean amplitudes in the early time window in DS1 showed non-significant main effects and interactions for both Caucasian and Japanese faces ($ps > 0.10$). Similarly, there were no significant main effects and interactions in averaged LPP mean amplitudes of Caucasian and Japanese faces in DS2 ($ps > 0.10$).

Late time window (701–1000 ms) LPP mean amplitude

Longitudinal analyses for LPP mean amplitudes in late time window in DS1 revealed a marginally significant time × group × condition interaction [$F(6,171) = 1.90$, $p = 0.084$, $\eta_p{}^2 = 0.062$] for Caucasian faces. In DS2, a significant time × group × condition interaction [$F(4.37,91.85) = 3.67$, $p = 0.006$, $\eta_p{}^2 = 0.149$] for averaged Caucasian and Japanese faces was found. All main effects and remaining interaction effects of time with other factors were not significant ($ps > 0.10$).

Pairwise comparisons revealed that differences between TG and control groups in the late time window LPP mean amplitudes were non-significant over time. However, changes over time in the late time window LPP mean amplitudes were significant within each group. From T1 to T2, TG showed no significant differences in LPP mean amplitudes, but within ACG the LPP mean amplitudes for Caucasian angry targets were marginally more positive over time ($p = 0.070$, $d = 0.54$). From T2 to T3, within TG, the LPP mean amplitudes for averaged Caucasian and Japanese angry non-targets became significantly less positive over time ($p = 0.031$, $d = -0.47$). Within ACG, the LPP mean amplitudes were marginally less positive for averaged Caucasian and Japanese angry targets ($p = 0.085$, $d = -0.50$). See Figure 3A–C. The NCG showed no significant differences in late time window LPP mean amplitudes over time ($ps > 0.10$).

To examine if there were differences in the modulations of the P3b latency and the LPP mean amplitude in relation to the amount of children's practice, we ran one-way ANOVAs separately for TG and ACG. The ANOVAs had four levels based on categorical responses children provided to the question about the amount of practice. No significant effects were found ($ps > 0.10$).

7 | DISCUSSION

We expected an improvement in emotion processing in children after MT, indexed by increased P3b amplitudes, earlier peak latency of P3b and reduced LPP amplitudes for emotional stimuli. Contrary to predictions, changes in the P3b component were observed only in latencies for non-targets with Japanese faces across and within groups over time. For Japanese happy non-targets, the P3b latencies in the TG tended to peak later after MT while they tended to peak earlier in the ACG after SEL training and remained unchanged in the NCG. The P3b latencies for Japanese happy non-targets in the TG were also marginally delayed compared to the NCG but not different to ACG at this time point. At 6-month follow-up, the P3b latencies for Japanese happy non-targets changed to peaking significantly earlier in TG while they tended to peak later in the NCG and remained unchanged in the AGC. No differences in P3b latencies for this stimulus across groups at 6-month follow-up were found. For Japanese angry non-targets, the P3b latencies in TG peaked significantly later than in NCG after MT and at 6-month follow-up, ACG also showed a tendency of delayed P3b latencies for Japanese angry non-targets compared to NCG at 6-month follow-up. No differences between TG and ACG were found over time.

A delayed P3b latency reflects longer processing due to task demands (Polich, 2007). Given there was no increase in FA or a decrease in P3b amplitudes for non-targets, the prolonged P3b latency to emotional faces regardless of valence in TG compared to NCG after MT and at 6-month follow-up may indicate that children in TG carefully and non-reactively evaluated emotional faces. Indeed, an opposite pattern of significant earlier P3 latency for emotional stimuli was found in adults with high anxiety compared with low anxiety (Rossignol et al., 2005). Yet, the P3b latency only for happy face non-targets returned to peaking earlier at 6-month follow-up in TG; thus, the changes in P3b latency must be interpreted with caution in the developmental context due to lack of well-established evidence.

Regarding ethnicity effects, changes in P3b latency were observed for Japanese faces only. Research on emotion processing across cultures reported that faces of the same ethnicity as participants' ethnicity were easier to detect (Elfenbein & Ambady, 2002) and activated more arousal (Chiao et al., 2008) in individuals who endorsed collectivism values (Harada et al., 2020). In-group faces are considered to contain motivationally significant information capturing attention (Freeman et al., 2009). Therefore, delayed P3b latency to Japanese faces may indicate that children in TG carefully evaluated in-group faces, whereas Caucasian faces were not perceived as salient enough to activate such response.

For the LPP, reductions in the mean amplitudes in the TG were not found neither in the early nor in the late time window after MT. However, at 6-month follow-up, the LPP amplitudes in the late time window for averaged Caucasian and Japanese angry non-targets decreased significantly in the TG. The ACG showed a tendency of increased LPP mean amplitudes to Caucasian angry targets after SEL training then attenuated LPP mean amplitudes to averaged Caucasian and Japanese angry targets at 6-month follow-up. No changes were found in the LPP mean amplitudes for NCG over time. There were no differences in the LPP mean amplitudes for angry faces across groups. No changes were observed in the LPP amplitudes for happy faces between and within groups over time as predicted.

As an index of sustained attention to emotional stimuli, a less positive LPP indicates less emotional reactivity (e.g., Kujawa, Klein, et al., 2013) and links with successful regulation of negative emotional responses and reduced anxious-depressed symptoms (Babkirk et al., 2015; Dennis & Hajcak, 2009), thus reflecting more adaptive emotion processing in children. Decreased LPP mean amplitudes for negative stimuli were also found in middle (600–1000 ms) and late time windows (1000–1500 ms) in Chinese pre-adolescents after a brief mindfulness induction (Deng et al., 2019). An attenuated LPP mean amplitude in the current study was observed in TG only in the late time window at 6-month follow-up. This could suggest that longer mindfulness practice led to less elaborative processing of negative stimuli which could be linked to less rumination, as reported in MT literature in adults (Sobolewski et al., 2011).

The effects on the LPP component were found for both Caucasian and Japanese faces (averaged Caucasian and Japanese faces) in TG at 6-month follow-up. However, there were no ethnicity differences at baseline either. The attenuated LPP for both faces in the late time window may suggest that emotional reactivity reduced regardless of ethnicity, reflecting unbiased responses to emotional stimuli in later stage of emotion processing. This could further support the

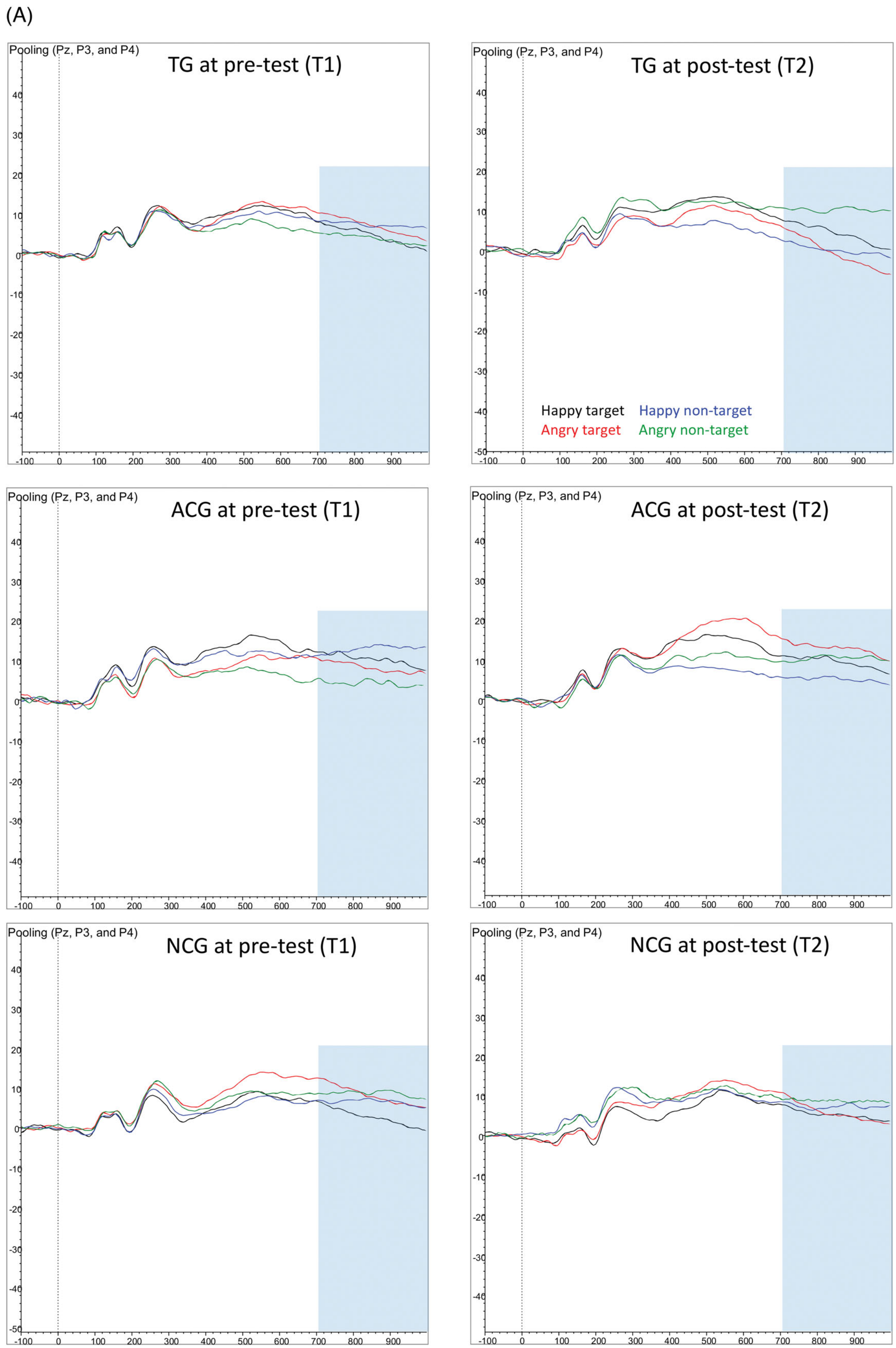

FIGURE 3 (A) Experiment 2_The LPP mean amplitudes for Caucasian faces in the late time window (701—1000 ms) from T1 to T2. (B) Experiment 2_The LPP mean amplitudes for averaged Caucasian and Japanese faces in the late time window (701–1000 ms) from T2 to T3. (C) Experiment 2_Changes in LPP mean amplitudes in the late time window (70–1000 ms) over time for (a) averaged Caucasian and Japanese faces in TG from T2 to T3. (b) Caucasian faces in ACG from T1 to T2. (c) averaged Caucasian and Japanese faces in ACG from T2 to T3.
Note. Asterisk symbol (*): p < .05. Plus symbol (+): 05 = < p < .10. Error bars: 95% CI. TG = Training group. ACG = Active control group

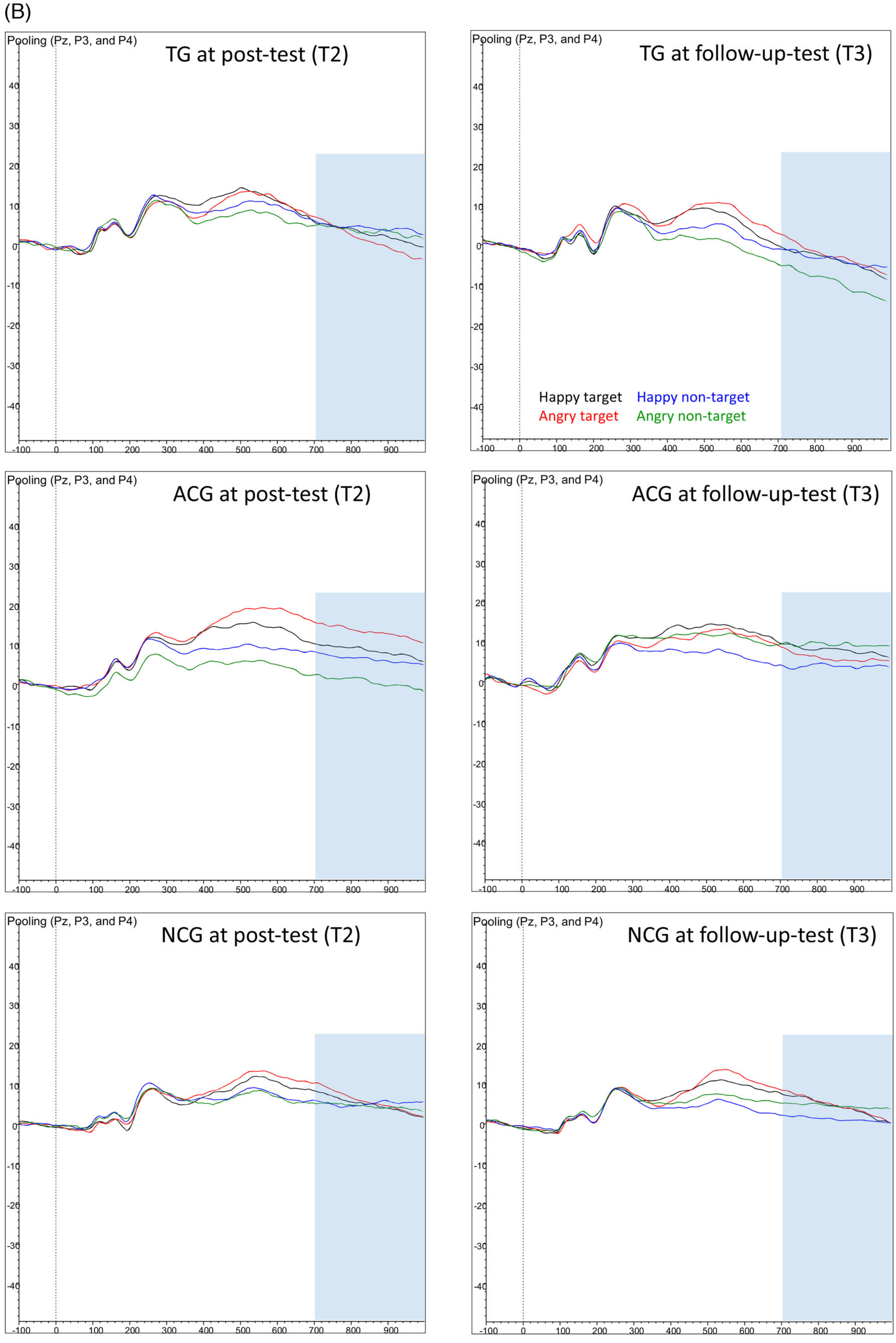

FIGURE 3 Continued

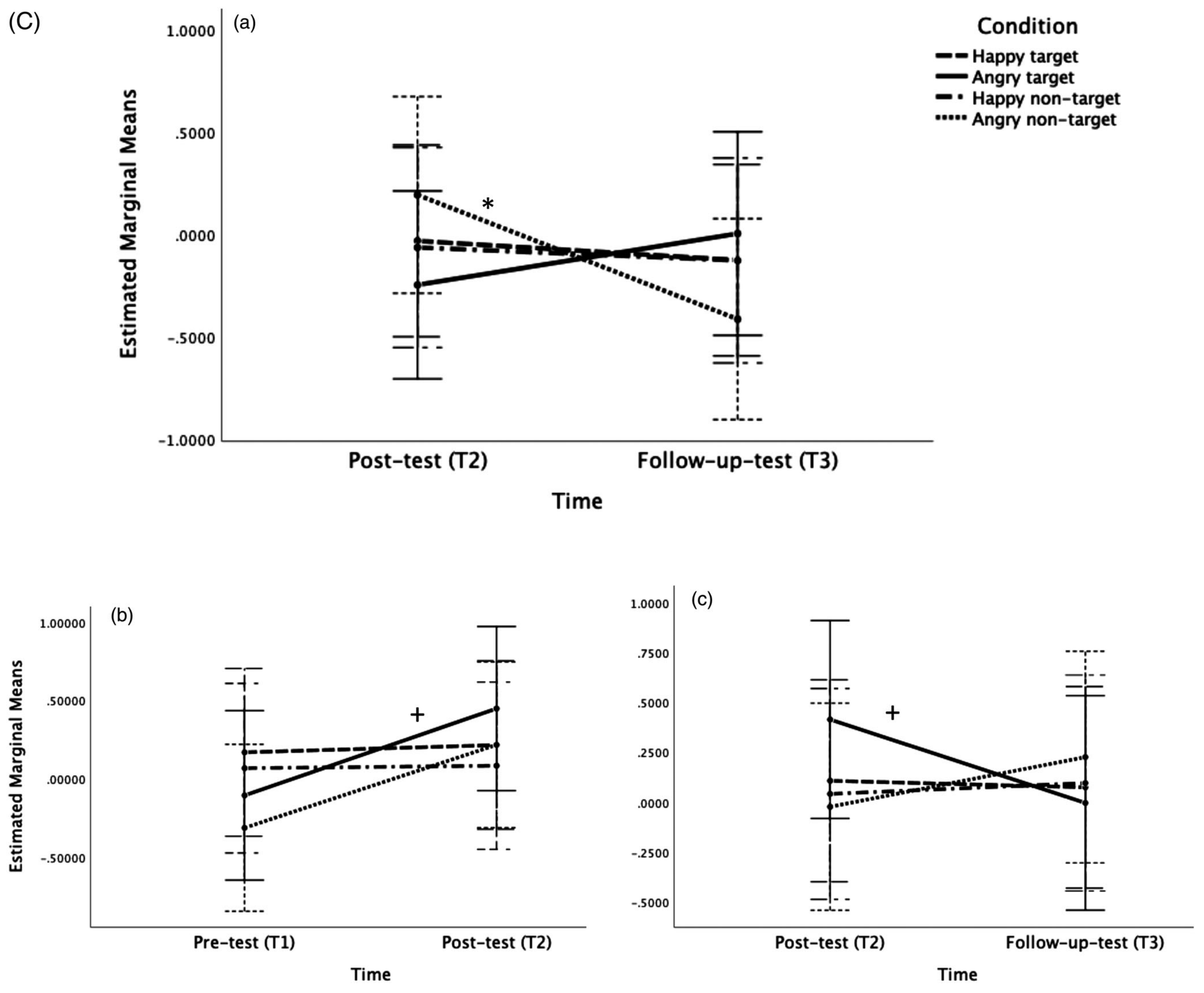

FIGURE 3 Continued

overarching effect of MT on reduction in elaborative (ruminative) processing of emotional stimuli.

A tendency of increased LPP amplitudes to angry targets in the ACG after SEL training could reflect more reactivity to negative stimuli, indicating maladaptive emotion processing. A more positive LPP amplitude to negative images indicates sustained emotional arousal (Hajcak et al., 2010) and is linked to greater anxiety and fear in children (Decicco et al., 2012; Kujawa et al., 2015, 2016; Solomon et al., 2012) and maladaptive strategies including rumination (Lewis et al., 2015; Webb et al., 2017), suggesting difficulties in emotion processing. However, at 6-month follow-up, the LPP amplitude to angry targets tended to reduce in ACG. To conclusively interpret the initial increase in reactivity to negative stimuli as an effect of SEL, more evidence is required because SEL has been shown to improve self-control and well-being (Payton et al., 2000; Taylor et al., 2017).

There was no modulation of the LPP amplitudes for happy faces, contrary to the predicted effect of reductions in LPP for both angry and happy faces due to Vietnamese culture. Internalising culture values is a process of learning where children's behaviours will be aligned with culture expectations during development (Cole et al., 2002). Therefore, effect of culture in children at this stage may not be strongly manifest yet.

Overall, delayed P3b latency for emotional faces after MT and reduced LPP amplitude to negative stimuli at 6-months follow-up could reflect better adaptive emotion processing. This could be interpreted in terms of reduction in emotional reactivity, suggesting that MT could take time to modify neurocognitive underpinnings of emotion processing (e.g., Farb et al., 2007; Taylor et al., 2011), particularly with low-dose programmes delivered at schools. This interpretation is supported by less reactivity compared to the ACG found in the SenseMaker data in a larger sample after MT (preprint, 2021). MT likely enhances emotional non-reactivity in Vietnamese children through reduced elaborative processing when responding to negative emotions.

8 | LIMITATIONS AND IMPLICATIONS FOR FURTHER RESEARCH

This study has several limitations. The Japanese faces were not exactly in-group faces for Vietnamese participants; thus, the effects of culture may not be reflected fully in the results. In addition, the SEL curriculum for ACG was delivered by external trainers in fixed sessions in every week, whereas The Present was delivered by children's own schoolteachers. This could have influenced the intervention effects. The time teachers spent in mindfulness practice and support teachers received could have influenced the quality of delivery but was not assessed in this study. Future studies should address these shortcomings.

Although this study did not control for clinical or behavioural symptoms of children or compare those with clinical and non-clinical levels of emotional dysregulation, we have compared children across groups at the baseline to ensure the samples were comparable. Thus, it is unlikely that the effects observed were due to differences in pre-existing mental health or behavioural problems in children in the three groups. However, future research could assess whether children with and without clinical symptoms benefited from the universal intervention equally and whether further complementary targeted training might be helpful to some sub-groups of children.

Another limitation of the study is the nonindependence of participants within each treatment group (due to one school per treatment group) which may inflate the effect significance (Type 1 error). However, previous studies suggested that effect sizes may provide an unbiased estimate of the effects for designs of this type (Schonert-Reichl et al., 2015; Slavin, 2008), in the current study the effect sizes were in the medium range. Future studies should explore alternative ways of designing and analysing (McNeish & Stapleton, 2016) neuroscience data in intervention studies with small numbers of clusters.

Finally, Experiment 1 in the current study attempted to replicate findings of a previous study in a different cultural context. Lack of findings from Experiment 1 informed modifications implemented in Experiment 2. This process made the study methodologically transparent and rigorous. In addition, both experiments used standardised stimuli with experiment scripts available for further scrutiny; this transparency encouraging further replicability can serve as a springboard for further studies that may want to build and expand on findings from the current research to contribute to this under researched area.

9 | CONCLUSION

This was the first study to investigate longitudinal changes in brain indexes of emotion processing after MT in pre-adolescents in a non-Western context using emotional Go/No-Go tasks. The findings suggest that cultivation of mindfulness skills may have improved emotion processing in children since they showed a shift towards later P3b latencies and attenuated LPP mean amplitudes for angry non-targets indicative of more adaptive (non-reactive) emotion processing in comparison to children who received SEL training and a passive control group. Further research needs to examine longer-term interactive developmental effects between MT (or other wellbeing interventions) and cultural context in which these are delivered.

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CONFLICT OF INTERESTS

Dusana Dorjee received grants for her research and impact work on well-being and mindfulness in education. She co-directs a community interest company providing training in mindfulness and well-being courses for teachers, pupils and general public (including The Present Course investigated in this study), she does not receive royalties from delivery of these courses. She has authored two monographs on the topics of happiness, well-being and meditation (she receives royalties from these).

ETHICS STATEMENT

Ethical approval was granted for the study prior to its commencement from the Ethics Committee in the School of Psychology at Bangor University in the United Kingdom.

AUTHOR CONTRIBUTIONS

Thy U. Nguyen: Conceived and designed the study, the ERP experiment, the data analyses. Recruited participants, collected data, performed data analyses. Prepared, edited and revised the manuscript. Dusana Dorjee: Conceived and provided feedback on study design, the ERP experiment, data collection and analyses. Edited and gave feedback on the revised manuscript. Approved submitted version of the revised manuscript.

DATA AVAILABILITY STATEMENT

No permission to reproduce material were needed. The study has been pre-registered with Open Science Framework (OSF) DOI 10.17605/OSF.IO/EYVGF. Anonymised data will be available via OSF.

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SUPPORTING INFORMATION

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