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Neurocognitive study of mindfulness with primary school pupils

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Thesis summary

Pre-adolescence has been highlighted as a pivotal developmental period in which self-regulatory skills including emotion processing and attention control develop. In recent years interest has grown in the potential of mindfulness-based approaches as a method for enhancing these skills in pre-adolescence and initial findings are promising. Mindfulness can also be considered a disposition present in the absence of mindfulness training, and whilst research investigating the association between dispositional mindfulness and self-regulation abilities in pre-adolescents is still limited, findings from adults suggest that higher dispositional mindfulness is linked with more adaptive self-regulatory abilities. This project employed a neurodevelopmental perspective to further the understanding of both the impact of mindfulness training on self-regulation in pre-adolescents (using a non-randomised wait-list controlled design) and the relationship between dispositional mindfulness and self-regulation in pre-adolescents (using a cross-sectional design).

The first chapter of the thesis provides a broad theoretical overview of current research on mindfulness training and dispositional mindfulness with pre-adolescents. The second chapter then introduce the two main research methods which were employed in this project – event-related potentials (ERPs) and heart rate variability (HRV). The third chapter provides a comprehensive review of how mindfulness training could enhance self-regulation in pre-adolescents from a neurodevelopmental perspective. Chapters four, five, six and seven present empirical findings from a total of 76 primary school pupils aged between 7 and 11 years who were recruited from four schools in North Wales. Dispositional findings are explored in chapters four (*N* = 41), five (*N* = 49) and six (*N* = 48) and longitudinal findings are presented in chapters six (*N* = 37) and seven (*N* = 37). Overall the project found

that pre-adolescents with higher dispositional mindfulness had better self-regulatory abilities as indexed by the ERP and HRV markers and self-report findings. With regards to the longitudinal findings, less convergence was found across ERP, HRV and self-report measures of self-regulation, there were, however, indications from the ERP and self-report findings that mindfulness training could have had protective effects on emotion processing in pre-adolescents. A discussion on the implications of these findings is provided in chapter eight, this chapter also outlines suggestions for future research.

Contents

Chapter One – Introduction to mindfulness with pre-adolescents

Models of mindfulness

In the context of secular mindfulness-based approaches, mindfulness is most frequently defined as “the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experiences moment by moment” (Kabat-Zinn, 2003). Mindfulness can be conceptualised in a variety of ways; as a state, it can arise when a mindful approach to experiences is adopted at that moment in time, usually during meditation practice (Brown & Ryan, 2003). In the case of a stable mindfulness trait, the mindful approach is applied more or less continuously in daily life (Kiken, Garland, Bluth, Palsson & Gaylord, 2015). Enhancements in mindfulness states and traits can occur through mindfulness training (Kiken et al., 2015; Quaglia, Braun, Freeman, McDaniel & Brown, 2016). Mindfulness can also be considered as a natural disposition which occurs in the absence of mediation training (Quaglia, Brown, Lindsay, Creswell & Goodman, 2015a).

In the mindfulness literature, a key debate centres around how to define mindfulness in terms of its core mechanisms and many different models have been proposed (e.g., Bishop et al., 2004a; Hölzel et al., 2011; Lutz, Jha, Dunne, & Saron, 2015; Shapiro, Carlson, Aston & Freedman, 2006; Tang, Hölzel & Posner, 2015). The two-component model of mindfulness suggested by Bishop et al., (2004a) was based on the Kabat-Zinn (2003) definition of mindfulness and proposes that self-regulation of attention and the cultivation of a specific orientation towards experiences are the two key components. Attention is sustained on thoughts, feelings and sensations in the present moment and when the mind inevitably wanders from these present moment experiences towards a distraction or secondary elaborative thoughts, attention switching is engaged to return attention back to the present moment whilst inhibiting further elaboration of the distraction. An attitude of curiosity, openness and acceptance is adopted towards experiences which can facilitate self-reflection and reduce avoidance behaviours.

A model proposed by Shapiro et al., (2006) shares similar fundamental principles with the Bishop et al., (2004a) model, particularly regarding the importance of attention and attitude as core mindfulness components. This model, however, adds a further component of intention, where a personal reason for engaging in mindfulness practice can impact on the outcomes observed. These three components can lead to a change in the extent to which an individual identifies with their experiences and includes the ability to reduce automatic habitual responses - this change in perspective on one's own experience is called re-perceiving.

The Liverpool model of mindfulness proposed by Malinowski (2013) also includes attention and intention as core components; in this model, intention is a motivational factor along with motivation, attitudes and expectations, which determines the reasoning behind engaging with mindfulness training. However, in comparison to the proposals suggested by Bishop et al. (2004a) and Shapiro et al. (2006), Malinowski's conceptualisations of the attention mechanisms are specified in much more detail in cognitive and neuroscientific terms. The alerting attention network (Posner & Rothbart, 2007, 2009) is involved in staying focused on an object in the present moment, when the mind wanders from the present moment towards a distraction the default mode network (Seeley et al., 2007) is activated. The salience network (Raichle et al., 2001) is engaged in monitoring the attention focus and detecting mind wandering. This network signals to the executive attention network (Posner

& Rothbart, 2007, 2009) to disengage from the mind wandering episode. The orienting attention network (Posner & Rothbart, 2007, 2009) is then activated to return the focus of attention to the breath. The development of attention control skills facilitates the cultivation of emotion and cognitive regulatory processes resulting in a more balanced non-judgemental attitude which in turn can lead to improved mental and physical well-being.

More recently, Tang et al., (2015) suggested that attention regulation, emotion regulation and self-awareness were core mechanisms of mindfulness which facilitate self-regulation. Attention regulation, including the ability to focus on stimuli of interest (orienting attention), remain vigilant and alert during a task (alerting attention) and the ability to monitor and inhibit distractions (conflict monitoring), are important for staying engaged during meditation. The adoption of present moment non-judgemental acceptance facilitates the detection of affective cues in the environment which enables more adaptive emotion regulation strategies to be applied. According to the process model of emotion regulation (Gross & John, 2003) responses to emotional stimuli can be modulated at several stages of the emotion response, Tang et al., (2015) suggest that mindfulness can modulate the attention deployment, cognitive change and response modulation stages of an emotional response through strengthening the inhibitory effects of the prefrontal cortex (PFC) on the amygdala. After extensive mindfulness practice the development of an accepting approach towards experiences enables a reduction in PFC involvement and an enhanced engagement of brain regions linked with sensory awareness. Finally, self-awareness includes a meta-awareness of the transient nature of the self and a detachment from the idea that the self is a non-changing entity. This is thought to lead to a reduction in the engagement of elaborative and evaluative processes linked with the self (self-referential processing) and an enhanced ability to attend to thoughts, feelings and bodily sensations which arise in the present moment (interoceptive awareness).

Dorjee (2016) suggests that rather than focusing on mechanisms which are specific to a particular meditation approach, it is more advantageous to explore core cognitive and neural mechanisms which are likely modified by a variety of contemplative approaches (including Buddhist and secular conceptualisations of mindfulness). Dorjee (2016) proposed that all contemplative approaches target the enhancement of the metacognitive self-regulatory capacity (MSRC) of the mind, even though the pattern of changes in this capacity may differ across meditation practice types. The MSRC includes components supporting self-regulation including attention control and metacognition, emotion regulation and conceptual processing. Attention control and metacognition skills enable the introspective metacognitive awareness of thoughts, feelings and bodily sensations. Emotion regulation abilities can be developed through utilising these metacognitive attention skills in conjunction with the adoption of an accepting and non-reactive approach to experiences and the cultivation of loving kindness and compassion (and other adaptive affective qualities). Changes in conceptual processing support the adoption of a non-elaborative approach to experiences which can reduce covert and overt language processes often found during rumination and facilitate the development of new conceptual schemas. The MSRC is modulated by the intention or context of practice and overall changes in the MSRC can impact modes of existential awareness (experiential state shifts in self-constructs).

Whilst there are differences across these models, self-regulation appears to be a fundamentally important component of mindfulness across these different conceptualisations. Self-regulation is a broad term which refers to the ability to effectively modulate thoughts, feelings and behaviours in line with a goal (Lewis & Todd, 2007; Posner, Rothbart, Sheese & Tang, 2007). Two key aspects of self-regulation include attention regulation, which refers to the ability to sustain and shift the focus of attention and monitor for and inhibit conflicts (Muris, Meesters & Rompelberg, 2007; Rueda, Posner & Rothbart, 2005) and emotion regulation, which refers to the ability to modify the experience and expression of emotions (Gross & Thompson, 2007; Lewis & Todd, 2007).

Self-regulation in pre-adolescence

Self-regulation skills can have an important impact on mental health and well-being during childhood. For instance, low self-regulation abilities during childhood were found to predict a range of outcomes at 32 years of age, including criminal activity, substance dependence and poor physical health (Moffitt et al., 2011). Childhood is an important period for mental health and well-being development; 50% of all lifetime mental health problems emerge by 14 years of age (Kessler et al., 2005). In addition, anxiety and impulse control disorders were found to have an early median age of onset - 11 years of age (Kessler et al., 2005). In the United Kingdom, a 2005 report showed that 1 in 10 children aged between 5 and 16 years of age have a mental health problem (Green, McGinnity, Meltzer, Ford & Goodman, 2005) and more recently the Understanding Society report (2011-2012) found that 12% of children aged between 10 and 15 years had high levels of difficulty in a self-report measure assessing emotional symptoms, conduct problems, inattention, pro-social behaviour and relationships with peers (Office for National Statistics, 2015). Children with mental health problems were more likely to have higher absences from school, have fewer close relationships with friends and family (Green et al., 2005) and have lower educational attainment (Department of Health, 2012).

Attention control and emotion regulation are core self-regulatory abilities which have been assessed in the literature on mindfulness training and dispositional mindfulness with adults (Chiesa, Calati & Serretti, 2011; Chiesa, Serretti & Jakobsen, 2013; Guendelman, Medeiros & Rampes, 2017). Within the field of mindfulness research the evidence base regarding enhancements in self-regulation with mindfulness training for adults is much stronger than for pre-adolescent children (Greenberg & Harris, 2012; Klingbeil et al., 2017; Tang et al., 2015). Developmental studies investigating the effects of mindfulness training on self-regulation in pre-adolescent children are an emerging area of research and self-report or informant reports are the most frequently employed measures used (Felver, Celis-de Hoyos, Tazanos & Singh, 2016). In comparison, few studies have investigated the association between dispositional mindfulness and self-regulation with pre-adolescents.

Mindfulness training and self-regulation in adults

Mindfulness has its roots in Buddhism and in this traditional contemplative system the mindfulness practices are embedded within a non-harming ethical framework with a focus on the liberation from suffering and the development of wisdom (Grossman & Van Dam, 2011; Kabat-Zinn, 2003). In 1979, Buddhist mindfulness was adapted for use in a secular western setting for the treatment of people with chronic pain (Kabat-Zinn 1982; Kabat-Zinn, 2003), this programme became known as the mindfulness-based stress reduction programme (MBSR; Kabat-Zinn, 1990). This secular adaption of mindfulness did not contain the cultural and religious concepts and terminology linked with Buddhism and instead of focusing on the liberation from suffering and development of wisdom, the secular mindfulness practices aimed to alleviate suffering in a more conventional sense through improving aspects of quality of life (Dorjee, 2010; Kabat-Zinn, 2003). Since the development of MBSR, many secular mindfulness training programmes have been developed for adults and children; these programmes are often heterogeneous in terms of their frequency, format, content and length. Research across these different variations of secular mindfulness programmes has found improvements in attention control and emotion processing for both adults and children (Chiesa et al., 2011; Chiesa et al., 2013; Felver et al., 2016; Lao, Kissane & Meadows, 2016).

Several systematic reviews have examined the impact of secular mindfulness training programmes on several key aspects of attention in adults - including selective attention (orienting attention), sustained attention (alerting attention) and executive attention (Chiesa et al., 2011; Lao et al., 2016). Improvements in selective attention were found after 8-weeks of MBSR (Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2012; Jha, Krompinger & Baime, 2007), however, the effect sizes were small for improvements in this facet of attention (Lao et al., 2016). The facet of executive attention appears to be sensitive to varying levels of mindfulness experience, enhancements in executive attention were found both after brief mindfulness training - including a brief 20-minute session (Wenk-Sormaz, 2005) and after 5 days of brief integrative body-mind training (Tang et al., 2007). In addition, improvements in inhibition (an aspect of executive attention) were found after 8-weeks of MBSR training (Jensen et al., 2012) and after 8-weeks of Mindfulness-based cognitive therapy (MBCT) (De Raedt et al., 2012; Heeren, Van Broeck & Phillippot, 2009). The effect sizes for improvements in executive attention were also small (Lao et al., 2016). For the facet of sustained attention, Lao et al., (2016) found that of the eight studies investigating the impact of 8 weeks of MBSR or MBCT, only one study found improvements after an 8-week MBSR course (Oken et al., 2010). Studies have found better sustained attention abilities in experienced meditators (Jha et al., 2007; Josefsson & Broberg, 2011), suggesting that this facet may require extensive meditation training (Chiesa e al., 2011; Lao et al., 2016).

Neurocognitive studies of mindfulness and attention have mainly focused on studies with experienced Buddhist meditators rather than on secular mindfulness training programmes. Hölzel, et al., (2007) conducted a cross-sectional study with experienced meditators and non-meditators, during a mindful breathing task meditators reported spending more time concentrating than non-meditators. In addition, meditators had greater activation bilaterally in the rostral anterior cingulate cortex (ACC), a brain region linked with attention control processes such as conflict monitoring and inhibition (Bush, Luu & Posner, 2000; Van Veen & Carter, 2002a), and the dorsal medial PFC, a brain region linked with top-down cognitive control (Ochsner & Gross, 2005). Another study found that during a concentration meditation task, brain activation in regions linked with sustained attention including the frontoparietal regions, cerebellum, temporal cortex, parahippocampal cortex and posterior occipital cortex showed an inverted U shape. Experienced meditators showed greater activation in these regions than novice meditators, but the experienced meditators with the lower level of experience showed greater activation in these brain regions than those with the most experience (Brefczynski-Lewis, Lutz, Schaefer, Levinson & Davidson, 2007). It is possible, therefore, that as attention control proficiency increases with meditation training, less engagement of these brain regions underlying attention control is needed. Similar patterns could be observed with increasing training in secular mindfulness, this can be confirmed with further research.

Secular mindfulness-based approaches have also gained widespread attention as an effective method of treatment for a range of psychological and physiological symptoms including stress (Chiesa & Serretti, 2009; Khoury et al., 2013; Khoury, Sharma, Rush & Fournier, 2015), anxiety (Hofmann, Sawyer & Witt, 2010; Khoury et al., 2013; Khoury et al., 2015), depression (Hofmann et al., 2010; Khoury et al., 2015; Piet & Hougaard, 2011; Strauss, Cavanagh, Oliver & Pettman, 2014) and chronic pain (Lakhan & Schofield, 2013; Lauche, Cramer, Dobos, Langhorst & Schmidt, 2013) in adults with and without clinical levels of difficulty. Specifically, MBCT (Segal, Williams & Teasdale, 2002) is NICE recommended as a treatment for individuals with three or more episodes of major recurrent depression (National Institute of Health and Clinical Excellence; NICE, 2009). Secular mindfulness training is thought to alleviate maladaptive psychological and physiological symptoms through the cultivation of effective emotion regulation skills (Chiesa et al., 2013).

Two analytical reviews of neurocognitive findings relating to mindfulness training and emotion regulation (Chiesa et al., 2013; Tang et al., 2015) have found evidence to support the theory that the emotion regulation strategies recruited during mindfulness training change depending on the duration of training. For example, enhancements in top-down emotion regulation through increased recruitment of the PFC was found after 6-weeks mindfulness training (Allen et al., 2012) and after 8-weeks mindfulness training (Hölzel et al., 2013). In contrast, reduced recruitment of the PFC and enhancements in brain regions linked with sensory awareness including the ACC and the insula, which are thought to underlie bottom-up emotion regulation, were found for individuals with extensive experience in Buddhist meditation (Gard et al., 2012; Lutz, McFarlin, Perlman, Salomons & Davidson, 2013; Taylor et al., 2011). Whilst it is unclear whether long term training in secular mindfulness could also induce this emotion regulation shift, it is possible that increasing mindfulness experience increases the ability to adopt a non-judgemental non-reactive approach to experiences and thus modulate early stages of emotion processing (Tang et al., 2015).

Mindfulness training and self-regulation in pre-adolescents

Whilst most research studies have been conducted with adult samples, in recent years a shift in focus towards the potentially beneficial impact of mindfulness training with developmental populations has occurred within the field of research on mindfulness. The applications of mindfulness-based approaches in contexts such as schools seem particularly relevant since despite statistics showing the potentially devastating effects of mental ill health during childhood, evidence from the Good Childhood Inquiry (2008) estimated that 70% of children with mental health difficulties do not receive adequate treatment early enough in development (Mental Health Foundation, 2015).

Government policies have highlighted their commitment to promoting good mental health and well-being in children through improving the early identification of mental health difficulties, enhancing the support available for children and enhancing resilience to prevent the onset of mental health problems through providing social competence, problem solving and self-efficacy skills to respond adaptively to difficulties (Department of Health, 2012; Welsh Government, 2012). Schools have an especially important role here as they are the place where children spend a significant portion of their day, develop close relationships with peers and receive support from teachers. Children who reported being relatively unhappy at school were four times more likely to have high levels of self-reported mental health difficulties in comparison to children who reported being relatively happy at school (Office for National Statistics, 2015). Government policies (Banerjee, McLaughlin, Cotney, Roberts & Peereboom, 2016; Public Health England, 2015) advocate the development of a whole school approach to promoting good mental health and well-being. This includes taking a whole school approach where mental health and well-being support is developed across pupils, teachers and their parents with the aim of developing a positive, nurturing school ethos. The NICE guidelines on social and emotional well-being in primary schools suggest that training teachers to effectively deliver curricula which target social and emotional skills, problem solving, coping, conflict management and the effective management of feelings, is the key to the whole school approach (NICE, 2008).

A systematic review and meta-analysis on 24 primary and secondary school based studies found that mindfulness training had large effect sizes on cognitive performance and small to medium effect sizes on stress and resilience in pupils (Zenner, Herrnleben-Kurz & Walach, 2014). A more recent meta-analysis which included 76 studies with youths (< 18 years) across school and non-school settings found that mindfulness based interventions had medium size effects on self-report measures of mindfulness and small effects on a broad range of measures including metacognition and cognitive flexibility, attention, emotional/behavioural regulation, school functioning and academic achievement, internalising problems, negative emotions and subjective distress, social competence and prosocial behaviours (Klingbeil et al., 2017). Interestingly, a meta-analysis on 28 studies with youths aged between 6 and 21 years found that whilst higher effect sizes were found for clinical developmental samples, mindfulness based interventions were still effective for children without clinical levels of difficulty (Zoogman, Goldberg, Hoyt & Miller, 2015). This suggests that mindfulness-based interventions may be effective for promoting resilience and reducing mental health difficulties in youths with and without clinical self-regulatory difficulties. Whilst these reviews address the impact of mindfulness training across childhood and adolescence, specific studies with pre-adolescents are included in chapter three.

Dispositional mindfulness and self-regulation in adults

Studies on dispositional mindfulness have emerged more recently in comparison to studies on mindfulness training. These studies are cross sectional in nature and measure the relationship between individual differences in dispositional mindfulness (in the absence of mindfulness training) and self-report, behavioural, psychophysiological or neuroscientific assessments. The most prolific measures of dispositional mindfulness are self-report questionnaires. The first self-report measure of dispositional mindfulness created was the mindful attention awareness scale for adults (MAAS; Brown & Ryan, 2003) and since then many different self-report measures of dispositional mindfulness have been developed for adults (Quaglia et al., 2015a; Rau & Williams, 2016). In more recent years dispositional measures of mindfulness have also been developed for youths (Goodman, Madni & Semple, 2017) - including the mindful attention awareness scale for adolescents, which was validated for use with 14 to 18 year olds (Brown, West, Loverich & Biegel, 2011b), the mindful awareness scale for children, which was validated for use with 9 to 13 years (Lawlor, Schonert-Reichl, Gaderman & Zumbo, 2014) and the child and adolescent mindfulness measure, which was validated for use with 10 to 16 year olds (Greco, Baer & Smith, 2011).

There is a debate regarding whether self-report questionnaires can accurately measure dispositional mindfulness (Bergomi, Tschacher & Kupper, 2013; Brown, Ryan, Loverich, Biegel & West, 2011a; Chiesa, 2013; Grossman, 2011). It has been suggested that a background in mindfulness training is needed to accurately interpret the questions on the dispositional mindfulness scales (Chiesa, 2013; Grossman, 2011). Brown et al., (2011a) disagree with this assumption as dispositional mindfulness measures are designed and validated for use with non-meditating populations and, therefore, the questions are easy to interpret. Furthermore, as the conceptualisation of dispositional mindfulness is that it is a natural tendency which can occur outside of mindfulness training, it would be contradictory to assume that a prior background in mindfulness training is necessary (Bergomi et al., 2013).

Another issue is that it is difficult to ascertain whether the scores on the dispositional mindfulness scale are a valid measure of how naturally mindful an individual is. For example, an individual with low levels of mindfulness may artificially inflate their scores on the scale due to a lack of metacognitive introspective awareness of processes in their mind. Similarly, an individual high in mindfulness may reduce the scores they provide on the scale due to an enhanced metacognitive awareness of the times when they were not very mindful (Chiesa, 2013; Grossman, 2011). This is an important consideration which is relevant for self-reports in general (Bergomi et al., 2013), but perhaps even more pertinent for measures of mindfulness which heavily rely on and assess introspective awareness of mental processes. Despite the potential limitations, these measures are still the most predominant and valid method of assessing dispositional mindfulness (Brown et al., 2011a; Quaglia et al., 2015a) and studies have found interesting associations between dispositional mindfulness and self-report, behavioural and neuroscientific measures of attention control and emotion regulation.

These self-reports of dispositional mindfulness are also used to measure changes in trait mindfulness after mindfulness training, Grossman (2011) suggests that it is problematic to use the same self-report to measure both dispositional mindfulness and changes in trait mindfulness through training. Individuals who have undergone mindfulness training may gain greater metacognitive abilities which facilitate self-awareness skills to enable a more accurate assessment of the quality and magnitude of their mindfulness abilities in comparison to individuals who have not received mindfulness training (Chiesa, 2013; Grossman, 2011). It is, however, just as likely that participants who have received mindfulness training may inflate their self-reported levels of mindfulness in line with what they think the researcher would like to find, or because they would like to see a positive improvement after training to justify the time they have given to the programme (Bergomi et al., 2013; Chiesa, 2013; Grossman, 2011). Research has, however, found that these self-report measures are sensitive to both individual differences in dispositional mindfulness (Brown et al., 2011a) and trait changes in mindfulness after training (Quaglia et al. 2016).

Several studies have investigated the relationship between dispositional mindfulness and attention control in adults, Mrazek, Smallwood and Schooler (2012) found that higher dispositional mindfulness was linked with less mind wandering during a mindful breathing task and a sustained attention to response task in adults. Mind wandering occurs when the mind is distracted away from a task towards task unrelated thoughts (Smallwood & Schooler, 2006) and is associated with decrements in attention control (Kam & Handy, 2014). Another study found better sustained attention skills and greater working memory efficiency for adults with higher dispositional mindfulness (Ruocco & Direkoglu, 2013). In addition, Di Francesco et al., (2017) found that higher dispositional mindfulness was associated with better alerting attention abilities on the attention network task, however, executive attention performance became less efficient, possibly due to a reduction in automatic pilot (increased awareness of the present moment and a reduction in non-volitional responding).

Dispositional mindfulness has also been linked with enhanced self-esteem (Pepping, O'Donovan & Davis, 2013), lower perceived stress and higher emotional intelligence (Bao, Xue & Kong, 2015), lower neuroticism and lower negative affect (Brown, Goodman & Inzlicht, 2013). Adults with high dispositional mindfulness showed stronger connectivity between PFC areas linked with top down regulatory control, including the right ventrolateral PFC, ventromedial PFC, medial PFC and right dorsolateral PFC cortex, and brain regions linked with emotional reactivity including the right amygdala during an affect labelling task (Creswell, Way, Eisenberger & Lieberman, 2007). This suggests that higher dispositional mindfulness is associated with an enhanced ability to regulate emotional responses through the recruitment of top-down emotion regulation abilities. Positive correlations between dispositional mindfulness and the self-reported ability to successfully cognitively reappraise, a top down emotion regulation strategy involving the reinterpretation of the meaning assigned to an emotional stimulus, has also been found (Modinos, Ormel & Aleman, 2010). In addition, high dispositional mindfulness was linked with greater activation of the dorsomedial PFC during the reappraisal condition, and activation in this area was found to positively correlate with reappraisal success. In the same study, during the viewing of negative images, a negative correlation was found between the dorsomedial PFC and the left amygdala. These findings suggest that individuals higher in dispositional mindfulness are more effective at employing top-down regulatory strategies which involve recruitment of the PFC to downregulate activity in the amygdala (Modinos et al., 2010).

Individual differences in dispositional mindfulness have also been linked with structural brain changes. After controlling for demographics including age, gender, depression, neuroticism and total gray matter volume, dispositional mindfulness was found to negatively correlate with gray matter volume in the right amygdala, suggesting that individuals higher in dispositional mindfulness are less reactive to stress and negative affect. Dispositional mindfulness also negatively correlated with left caudate gray matter volume, a brain region which is part of the basal ganglia and has a role in the processing of negative affect, sadness and reward; it was suggested that this was because individuals with higher dispositional mindfulness can enter a calmer state (Taren, Creswell & Gianaros, 2013).

Dispositional mindfulness and self-regulation in pre-adolescents

Several studies have examined the relationship between dispositional mindfulness and self-regulation in developmental populations. Due to the limited evidence base of developmental studies on dispositional mindfulness in comparison to mindfulness training studies, no published systematic reviews or meta analyses are available. A study examining the relationship between dispositional mindfulness and attention control with pre-adolescents aged between 9 and 11 years, found that dispositional mindfulness predicted enhanced inhibitory control on a Hearts and Flowers task for pre-adolescents after controlling for gender, age and cortisol levels (Oberle, Schonert-Reichl, Lawlor & Thomson, 2012). Greater dispositional mindfulness was also associated with enhanced self-reports of inhibitory control and working memory for 12 to 14 year olds (Riggs, Black & Ritt-Olsen, 2015). In addition, Shin, Black, Shonkoff, Riggs and Pentz (2016) found that 12 to 13 year olds with higher dispositional mindfulness had higher executive functions (which included inhibition, emotional control, and working memory). Higher dispositional mindfulness has also been found to have a moderating effect on the association between dysphoric affect and life stress in adolescents (14 to 18 years) - a strong association was found between the two for adolescents with low dispositional mindfulness (Ciesla, Reilly, Dickson, Emanuel & Updegraff, 2012). These results are encouraging, however, the evidence base linking higher dispositional mindfulness to adaptive self-regulation is currently limited in this age group in comparison to adults.

The self-regulation abilities present during childhood can impact on developmental outcomes in later life, children who showed ineffective self-regulatory skills were at higher risk of developing anxiety and mood disorders, drug abuse and behavioural difficulties at a 14 year follow up (Althoff, Verhulst, Rettew, Hudziak & van der Ende, 2010). In addition, another study found the presence of orienting attention deficiencies such as an increased orienting bias towards and difficulties disengaging from stimuli of a threatening nature during childhood were associated with increased social withdrawal during adolescence (Pérez-Edgar, et al., 2010). This suggests that the self-regulation skills present during childhood can impact on the developmental trajectory in future years. Therefore, if higher dispositional mindfulness is linked with enhanced self-regulation during pre-adolescence then these children may have greater resilience to manage difficulties in later life. Adult research has found better mindfulness training related outcomes for adults with higher dispositional mindfulness (Shapiro, Brown, Thoresen & Plante, 2011) and improvements in dispositional mindfulness during mindfulness training are linked with enhancements in mental health (Quaglia et al., 2016). For these reasons, furthering the understanding of whether dispositional mindfulness links with higher self-regulation during pre-adolescence could also have important implications for mindfulness training studies in the future.

Research project aims

The current research project aimed to examine whether higher dispositional mindfulness was linked with more adaptive self-regulatory abilities and whether cultivating mindfulness skills through training could effectively modulate aspects of self-regulation in primary school children aged between 7 and 11 years. Whilst many models have been put forward to conceptualise the components of mindfulness, these models have not explored the components of mindfulness within a childhood and adolescent developmental context. As such there is a limited understanding of how mindfulness training impacts on self-regulation during pre-adolescence. The first paper (chapter three) in the current research project outlines how an integrative neurocognitive approach, which involves different research methodologies including self-report, behavioural assessments and event-related potential (ERP) measures, can progress research in this area. This review paper provides clear theory driven hypotheses regarding the potential impact of mindfulness training on the neurocognitive mechanisms underlying self-regulation. The paper also highlights how an integrative approach can provide a sensitive measure of the impact of mindfulness on self-regulatory abilities including attention control and emotion regulation, which self-reports alone may not detect (Banaschewski & Brandeis, 2007). This approach can also strengthen the evidence base through providing converging evidence to facilitate the development of a multi-level understanding of the impact of mindfulness training on self-regulation in pre-adolescents. This information could be particularly informative for facilitating the tailoring of mindfulness programmes to optimise their impact on the self-regulatory needs of pre-adolescents (Tang & Leve, 2016).

The further chapters in the current research project employed self-report, behavioural, electrophysiological (ERP) and psychophysiological (heart rate variability) methods to study the association between mindfulness and self-regulation abilities with pre-adolescent children aged between 7 and 11 years. For this research project a total of 76 pupils aged 7 to 11 years were recruited from four North Wales primary schools, chapters four, five, six and seven each report on a subset of these 76 participants. The samples included in each chapter differed slightly from each other, this is due to differences in the number of participants removed from each analysis because of task incompletion, poor accuracy rates and data artifacts. Details on the number of participants who were excluded for these reasons are provided in each chapter. Chapter four used ERP and self-report measures to investigate the association between dispositional mindfulness and attention control (N = 41). Chapter five employed ERP and self-report measures to study the relationship between dispositional mindfulness and emotion processing (N = 49). Chapter six employed heart rate variability measures and self-report measures to investigate both the relationship between dispositional mindfulness and self-regulation (N = 48) and the impact of the Paws b mindfulness curriculum on self-regulation (N = 37). Chapter seven employed these measures to investigate the impact of the Paws b curriculum (Paws b) on emotion processing (N = 37).

Chapter Two – Event related potential and heart rate variability measures

Introduction to event related potentials (ERPs) and heart rate variability (HRV)

This chapter aims to provide an overview of event related potential (ERP) and heart rate variability (HRV) methodology. ERPs are a derivative of the electroencephalogram (EEG) signal which can measure neurocognitive processes such as attention and emotion processing (Hajcak, MacNamara & Olvet, 2010; Polich, 2007; Yeung & Cohen, 2006). HRV is a measure of the dynamic interaction between two branches of the autonomic nervous system activity- the parasympathetic (PNS) and sympathetic nervous system (SNS; Acharya, Joseph, Kannathal, Lim & Suri, 2006). The current research project collected ERP and HRV data to investigate the impact of mindfulness training on emotion processing in pre-adolescents aged between 7 and 11 years and to also investigate the association between dispositional mindfulness, emotion processing and attention control in this age group.

A brief overview of EEG and ERP measures will be provided and the advantages and limitations of employing ERP measures to assess neurocognitive processes in developmental populations will be discussed. Following this, the chapter will explore the methodological issues surrounding the data collection and analysis of ERP measures which were considered for the current research project with pre-adolescents in school settings. In addition, this chapter will provide a brief introduction to HRV measures and then focus specifically on a HRV measure called respiratory sinus arrhythmia (RSA), a measure of PNS activity which is thought to index self-regulatory abilities in adults and children (Graziano & Derefinko, 2013; Porges, 2007). A discussion of the methodological issues involved in using HRV measures with pre-adolescent children will also be explored.

Introduction to event related potentials (ERPs)

Electroencephalogram (EEG)

The electroencephalogram (EEG) measures the ongoing postsynaptic activity summed from large populations of neurons which are activated simultaneously and all have the same orientation, lying perpendicular to the surface of the skull (Light et al., 2010; Woodman, 2010). Primarily, the signal is generated from cortical pyramidal cells (Woodman, 2010) and is detected by electrodes placed on the scalp (Light et al., 2010). When the neurotransmitter binds to the receptors of the postsynaptic cell the opening or closing of ion channels occurs; the voltage change which occurs from this process is called the postsynaptic potential (Luck, 2005). The EEG signal is a measure of postsynaptic potentials rather than action potentials (the voltage which travels down the neuron from the axon at the cell body to the axon terminal, which is involved in the release of the neurotransmitters), because unlike action potentials which last around a millisecond, the postsynaptic potential can last several hundred milliseconds (Luck, 2005). The EEG signal measures the postsynaptic potentials of large populations of neurons rather than a single neuron because the electrical field generated from one neuron would not be large enough to propagate through the brain to be recorded at the scalp surface (Hallez et al., 2007; Woodman, 2010). The spatial alignment of the neurons is also important because if the neurons do not lie in the same orientation it is possible that the postsynaptic potentials from different neurons will cancel each other out and no signal will consequently be recorded at the scalp (Hallez et al., 2007; Luck, 2005).

Research with EEG started with its discovery by Hans Berger in 1929 (Luck, 2005). The EEG signal can be divided into different frequency bands which can provide a measure of different cognitive processes (Taylor & Baldeweg, 2002). Each frequency band has a different oscillation frequency; delta (< 4Hz), theta (4-7Hz), alpha (8-12Hz), beta (13-30Hz) and gamma (30-70Hz). Previous research on meditation in adults examined changes in EEG frequency bands when assessing the brain's neural response during meditation (Cahn & Polich, 2006). In addition, a growing number of meditation studies in adults have used a derivative of EEG called ERPs (Brown et al., 2013; Moore, Gruber, Derose & Malinowski, 2012), which have been employed in the current project with pre-adolescent children.

Event related potentials (ERPs)

ERPs are the averaged EEG responses time locked to the onset of an event, such as the presentation of a stimulus or the onset of a behavioural response (Woodman, 2010). ERPs can provide a measure of specific sensory, perceptual or cognitive processes which occur in response to an event (Light et al., 2010). Research with ERPs was first conducted in 1935 by Pauline and Hallowell Davis and since 1964 the number of ERP research studies has grown exponentially (Luck, 2005). ERP waveforms are derived from averaging the EEG signal across many trials, this is necessary as the voltage fluctuations in response to an event are small in comparison to the EEG signal which is unrelated to the event and the electrical noise present from non-neural sources. Including as many trials as possible can therefore improve the signal to noise ratio (Luck, 2012), whilst some studies have included participants with a sweep count as low as 12 (Kujawa, MacNamara, Fitzgerald, Monk & Phan, 2015), this research project used a more conservative minimum cut off point of 20 trials per condition, in line with other ERP studies (Cohen & Polich, 1997; Hajcak & Dennis, 2009). The ERP waveform consists of peaks and troughs which can be divided into ERP components - these components are defined based on their polarity, timing, scalp distribution and sensitivity to task manipulation (Light et al., 2010). A comprehensive review of ERP components which are sensitive to developmental changes in self-regulatory processes including attention and emotion processing are provided in chapter three. This chapter also explores how these ERP components can be used to measure the impact of mindfulness training on attention and emotion processing with pre-adolescent children.

Strengths and limitations of event related potentials (ERPs)

ERPs have several advantages in comparison to other neuroscientific methods, firstly, ERPs can provide a non-invasive, direct measure of neural brain activity (Light et al., 2010; Woodman, 2010) unlike methods such as fMRI which infers brain activity based on changes in the blood oxygen level dependent (BOLD) response (de Hann & Thomas, 2002).

Secondly, ERPs have excellent temporal resolution, they can measure neural brain activity with precision in the scale of milliseconds and are therefore a good tool for tracking how a neural response unfolds over time (Light et al., 2010). This can be particularly useful in intervention research as it might be possible to determine the stage in a cognitive process, such as in emotion or attention processing, which has been modified by the intervention. For example, when an emotional stimulus is presented, ERPs can be used to track the emotional response to that stimulus starting with the initial perception of the stimulus in the first 100ms through to the prolonged emotional response occurring several seconds after the stimulus has been presented. In the context of mindfulness research, it could be possible to determine the stage of processing at which mindfulness training has an impact on the response to an emotional stimulus. In contrast, functional magnetic resonance imaging (fMRI) has poor temporal resolution as the changes in BOLD signal occur over approximately 4 to 6 seconds and therefore there is a temporal delay between the neural brain activation and the changes detected in the BOLD signal which are driven by the associated metabolic demand (Crosson et al., 2011; de Haan & Thomas, 2002; Mayer et al., 2014).

Thirdly, ERPs are relatively inexpensive in comparison to fMRI (Light et al., 2010), this is particularly advantageous when participants need to be tested over several time points, for example, when conducting studies with longitudinal pre-post designs with a treatment and control group.

Fourthly, techniques such as fMRI can be difficult to employ with developmental populations as testing takes place in a scanner which children can find noisy and claustrophobic (Kedareshvara, Dhorigol, Mane & Gogate, 2016). In comparison, ERP research can take place in a normal environment such as a school.

Finally, the development of portable EEG systems has enabled research to be conducted outside of laboratory settings, this can make the EEG method more accessible for working with certain populations such as school children.

ERPs also have some limitations; whilst fMRI has excellent spatial resolution which makes it possible to pinpoint activation associated with specific brain regions, ERPs have poor spatial resolution in comparison and it is not possible to determine the precise neural generator of the signal based on the scalp distribution of the ERP component (de Haan & Thomas, 2002; Luck, 2012). This is because the postsynaptic potential does not propagate in a straight line from the neurons to the scalp, the signal follows the path of least resistance through the brain. As a result, when the signal reaches the skull it often travels laterally due to the high resistance of the skull and this has the effect of blurring the distribution of the voltage at the scalp (Luck, 2005). It is therefore possible that several different neural generators could produce similar voltage distributions at the scalp (de Haan & Thomas, 2002). This difficulty of trying to determine the localisation of the neural generators based on the scalp distribution of the signal is known as the inverse problem (Woodman, 2010). Dipole source modelling can, however, provide an estimate of the likely neural generators of ERPs (Grech et al., 2008; Hallez et al., 2007; Swick, Kutas & Neville, 1994). In addition, there are also difficulties associated with detecting signal at the scalp from deep cortical and subcortical brain regions such as the hippocampus and basal ganglia (Attal et al., 2007; Morita, Asada & Naito, 2016). This is because brain regions situated further from the scalp may have more pronounced blurring of the signal as it travels through the brain (Luck, 2012) and because the neurons in these structures may not have the spatial alignment needed to record the signal at the scalp (Attal et al., 2007).

Another limitation of neuroscientific techniques in general is that it is possible to draw incorrect conclusions from data due to making problematic reverse inferences about neural activity. This is where the engagement of specific cognitive processes is inferred based on the observation of neural activity even though the brain activity could be indexing several possible cognitive processes (Hutzler, 2014; Plassmann, Venkatraman, Huettel & Yoon, 2015; Poldrack, 2006). These incidences can be reduced using converging evidence from other techniques such as behavioural data and through the testing of theory driven research hypotheses (Hutzler, 2014; Plassmann et al., 2015; Poldrack, 2006). Reverse inferences can, however, be useful - for example in novel studies where they can be used to create hypotheses or explanations about data which can then be further tested in future studies (Poldrack, 2006).

Measuring event related potentials (ERPs)

The current research project conducted ERP research with pre-adolescents aged between 7 to 11 years across four schools in North Wales using a portable 32-channel EEG system including Neuroscan NuAmps amplfiers. This EEG system was brought into the schools and data collection was carried out on school premises. The advantage of using a portable EEG system was that it made this study more logistically feasible than a laboratory based study; pupils could be tested with ease without causing major disruptions to the daily routine of the pupils and their parents. In the context of the current intervention study which involved mindfulness training, the use of the portable EEG system also enabled testing sessions to take place as close as possible to the start and end of the mindfulness programme. One difficulty with this type of testing was that it was not possible to conduct data collection in a Faraday cage - a cage containing copper shielding which can reduce electrical noise from non-neural sources (Luck, 2005). This, however, was not an issue for the current research project as Faraday cages are more essential when analysing data in the frequency of 50Hz and above as this is the frequency range in which many electrical devices have contaminating effects (Light et al., 2010; Luck, 2005). For this current research project the ERP data derived for analysis was lower than 30Hz.

The EEG electrode cap, which can detect the EEG signal at the scalp, contains electrodes which are placed at the locations of interest around the scalp, a ground electrode, and a reference electrode. All these electrodes are necessary as the ERP signal is not a measure of electrical activity at a specific location but rather a measure of the potential for current to flow from one point to another (Luck, 2005). Therefore, the EEG signal does not index the voltage at a specific electrode of interest, the EEG signal is measured using differential amplifiers to measure the voltage change between the electrodes of interest, the reference electrode and the ground electrode. The ground electrode is used as a common reference point and is connected to the EEG amplifiers, which can often be contaminated by non-neural sources of electrical activity; therefore, when measuring the voltage change between the electrode of interest and the ground electrode it is necessary to remove this noise to receive a more accurate measure of the neural activity. This is enabled through also measuring the difference between the ground electrode and the reference electrode, the electrical noise which is common to both these measurements is then subtracted using the differential amplifiers (Luck, 2005). Studies vary in where they place the reference electrode, in general the reference electrode should be placed in a location which is comfortable, convenient, not distracting and not biased to one hemisphere (Luck, 2005). Some studies use the average across all electrodes as the reference, the voltage distribution across the head should equal zero. Therefore, for each electrode site the mean of all electrodes is subtracted away to reveal the neural activity at that electrode site (Dien, 1998). However, this can only be effectively used when enough electrodes cover the head to enable a more accurate measurement of the average voltage across the head (Dien, 1998; Luck, 2012), usually 64 electrodes or more. The average mastoid channels are recommended for studies which use fewer electrodes; for the current research project a 32-electrode cap was used and for the reasons given above the average across the mastoid channels were considered the best reference site to use. This meant an electrode was placed on the bony protrusion behind the right ear at the right mastoid (A2) and then averaged offline with the left mastoid electrode (A1), see *Figure* 1. The ground electrode was placed on the forehead at FPz.

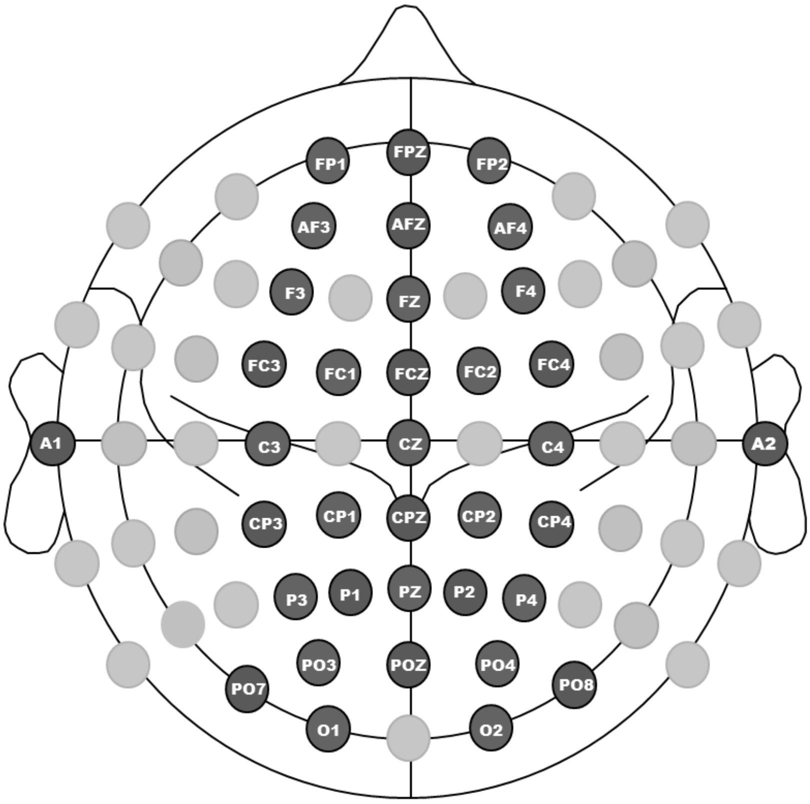


Figure 1. 32-channel EEG set up for the current research project

The EEG signal recorded at the scalp is typically less than 1/100,000th of a volt and to accurately detect and record the signal it must be first amplified by 10,000-50,000 times and then converted into a digital signal using an analog to digital converter. As previously mentioned, the EEG signal in comparison to the non-neural sources of electrical activity is small and it is necessary to improve the signal to noise ratio to provide a more accurate measure of EEG activity from the experimental manipulation (Luck, 2005; Luck, 2012). Filters can be applied to the data to filter out electrical signal which could be attributed to non-neural sources. Online a broad filter of between 0.01 Hz and 200Hz is typically applied to the data, this is sufficiently broad to capture relevant neural electrical activity. Offline, a more stringent bandpass filter can be applied to the data to enable frequencies higher and lower than a specific range, determined by the EEG or ERP indexes of interest, to be filtered out of the data. In the current research project with 7 to 11 year olds the bandpass filter applied offline after data collection was between 0.1 Hz and 30Hz. The 0.1 Hz high pass cut off point enables higher frequencies to pass through whilst low gradual shifts in voltage from non-neural sources such as sweating or moving will be filtered out. Whilst many studies with adults use a high pass filter of 0.01 Hz, the high pass cut off point of 0.1 Hz is useful to apply when working with children to reduce the slow voltage drifts which commonly occur in developmental populations as they have a greater tendency to move around (Luck, 2005). This cut off point has been used in previous developmental studies (Kujawa, Klein & Hajcak, 2012b; Kujawa, Weinberg, Hajcak & Klein, 2013b). The low pass cut off point of 30 Hz enables lower frequencies to pass through and higher frequencies associated with environmental electrical noise to be filtered out (Luck, 2005).

To remove the electrical activity caused by ocular movements (blinking), an electrode was placed above and below the left eye to record the eye blinks during data collection and then an algorithm was applied during data cleaning which identified eye blinks and subtracted the electrical activity corresponding to these eye blinks from the data. Alongside the filtering and ocular artefact rejection processes, the data can be cleaned through manually rejecting movement artifacts and irregular eye blinks which may not have been detected by the eye blink algorithm. In the process of deriving ERPs, ERP waveforms were extracted from the EEG signal through epoching the continuous EEG signal into segments of interest (starting 100ms prior to stimulus onset to 900ms or 1000ms after stimulus onset). As the emotion processing studies in the current project were only interested in measuring the ERP responses to correct trials, event files were created to ensure that only correct responses from the EEG signal were extracted during the epoch and averaging processes. Baseline correction was applied, this reduces pre-stimulus fluctuations and provides a clear baseline point at which to make clear comparisons between the pre-stimulus and post-stimulus activity. Epochs were then averaged together for each experimental condition and sweep counts were measured to check the minimum number of trials per participant in each condition (in the current study 20 trials was the minimum allowed per condition). Grand average waveforms (average of each participant's ERP waveforms) were then computed.

Event related potential (ERP) data analysis

During data analysis either the mean amplitude, which provides a measure of the mean voltage over a specific time period (Luck, 2010) or the peak amplitude, which provides a measure of the point at which the voltage of a peak reaches its maximum (at the peak or trough), can be analysed (Luck, 2005). Mean amplitudes are the preferred measurement to use for several reasons, firstly, the peak amplitude is thought to be an arbitrary point of a waveform which does not necessarily provide useful information about the underlying ERP component (Luck, 2005). Secondly, the peak amplitude is more affected by noise in the data in comparison to the mean amplitude. Whilst noise will be averaged out across the mean amplitude measurement, the peak amplitude measurement is based on the most extreme point of the waveform and so more impacted by this noise (Clayson, Baldwin & Larson, 2012; Luck, 2010). For the reasons above the current study calculated mean amplitudes for each component of interest. Latencies for each component can also be calculated, this is point in time after stimulus onset in which the maximum amplitude of a peak occurs within a specified time window (Luck, 2005). Latency analysis can be problematic for broad flatter peaks for several reasons, the point at which the peak reaches its maximum amplitude may not provide useful information about that component, for example the peak may occur at the very start or end of the time window (where the component rises or falls). Also, latency analysis for broad peaks can be more prone to noise than for sharp peaks. This is because for broad peaks where there is a slower change in voltage over time, high frequency noise could arbitrarily become the highest point and latency analysis could pinpoint that peak for measurement, even though it is not a true reflection of the characteristics of the component.

The way in which ERP data is analysed can also impact on the results of a study, Luck and Gaspelin (2017) suggest that the time windows and electrodes of interest for specific ERP components should be based on previous literature rather than choosing these parameters based on eyeballing of the data. This is because researchers could be tempted to choose electrodes and time windows which look statistically significant and this can be considered as visual multiple comparisons of the data, which if conducted during statistical analysis, would require the implementation of corrections for multiple comparisons. Luck and Gaspelin (2017) do acknowledge that it is not always possible to choose electrodes and time windows based on previous research without eyeballing the data as inevitably variations exist across studies and in the situation of novel studies often there is not a wealth of literature which is applicable directly to the study's data. There is also an approach which can combine both ways of selecting electrodes and time windows outlined above. This approach is particularly relevant in intervention research and was employed in the current research project. Following this 'combined' approach, the first step in the ERP analysis was to select electrodes of interest and time windows based on relevant previous literature. The data was then examined to check that these parameters included the specific component of interest, no direct comparisons of the waveforms for the training and control group and pre-test and post-test were made to avoid choosing electrodes and time windows which would arbitrarily improve the chances of confirming the study's hypotheses.

Finally, another issue associated with analysing ERP data is that often the analysis involves the use of large ANOVAs with multiple factors, this has the effect of creating multiple main effects and interactions which can enhance the chance of Type 1 errors (Luck & Gaspelin, 2017). One method for dealing with this problem is to reduce the number of factors included in the ANOVA by removing factors which are not directly relevant for testing the study hypothesis. In the current study, there were no predictions based on the factor of electrode and so the electrode factor was removed from data analysis and data was collapsed across the electrodes of interest.

Introduction to heart rate variability (HRV)

Autonomic nervous system (ANS)

The ANS regulates physiological functions including heart rate and respiratory rate and has an important role in the development of adaptive self-regulatory behaviours including attention control and emotion regulation (Marcovitch et al., 2010; Musser et al., 2011). The ANS consists of the SNS and the PNS; the SNS is involved in the stress response and is active during situations which require metabolic demands including exercise and threatening situations, this system is responsible for activating fight and flight behaviours (Acharya et al., 2006; Obradović, Bush, Stamperdahl, Adler & Boyce, 2010). The PNS is involved in restorative functions and metabolic conservation during situations which are low in stress (Acharya et al., 2006; Thayer, Yamamoto & Brosschot, 2009).

The Polyvagal theory (Porges, 2007) introduces an evolutionary approach to understanding the links between peripheral autonomic functions and biobehavioural processes. This theory suggests that autonomic responses are controlled by three neural circuits - the social communication system, the mobilisation system and the immobilisation system. These circuits have a phylogenetically determined hierarchy - the social communication system, is the most recently evolved and therefore is the most often engaged. This circuit is most active during stress free, safe environments and prioritises PNS activity including physiological restoration and social engagement behaviours. The mobilisation system is a more primitive system which is activated during stress inducing situations and is involved in SNS activity including fight or flight behaviours. Finally, the immobilisation circuit is the oldest in evolutionary terms, this circuit is active during potentially life threatening situations which require freeze behaviours including the feigning of death. Neuroception is the process which decides upon which system to activate based on the interpretation of cues from the environment (Porges, 2007). Neuroception is associated with activity in several brain regions including the temporal lobe, fusiform gyrus and superior temporal sulcus which support the evaluation of body movements, facial expressions and vocalisations for potential risks (Porges, 2007).

The interactions between the PNS and SNS determines autonomic activity including variability in heart rate; changes in the timing of heart beats (R-R intervals, also known as interbeat intervals) due to changing situational demands (Acharya et al., 2006). HRV can be measured using an electrocardiogram (Sztajzel, 2004). An effective balance between PNS and SNS activity is needed to enable adaptive responses to the environment (Acharya et al., 2006; Sztajzel, 2004). During threatening situations, the SNS activity will be increased and the PNS activity will be decreased to enable the quick mobilisation of metabolic resources, this will result in an acceleration of heart rate (shorter R-R intervals). In situations of low threat, conservation of metabolic resources is needed and an increase in PNS activity and decrease in SNS activity will result in a deceleration of heart rate (longer R-R intervals; Acharya et al., 2006). High HRV is indicative of an effective balance between PNS and SNS activity, as this indexes a greater ability to flexibly respond to environmental demands when appropriate (Thayer et al., 2009). In contrast, low HRV is indicative of a less effective balance between PNS and SNS activity due to hypoactive PNS activity and hyperactive SNS activity (Hinnant & El-Sheikh, 2009; Thayer et al., 2009). This is associated with higher vigilance during rest and during a challenging situation and over time these metabolic demands can put the ANS under extreme pressure and reduce its ability to effectively respond to challenging situations. Indeed, low HRV is linked with psychopathological and physiological disorders including cardiovascular disease (Thayer et al., 2009) and internalising disorders such as depression and anxiety (Gorman & Sloan, 2000).

Indexes of heart rate variability (HRV)

The impact of the PNS and SNS on HRV can be measured through dividing the HRV waveform into different oscillations which occur at different frequencies (variations in the amplitude of an oscillation in a time-period), this is known as power spectral density analysis (Borresen & Lambert, 2008; Sztajel, 2004). The PNS and SNS have an impact at different frequencies; the PNS has a rapid effect on heart rate during high frequencies (HF) of between 0.15 - 0.4Hz (Borresen & Lambert, 2008). The PNS can therefore produce rapid changes in the cardiac timing of the heart (Borresen & Lambart, 2008; Thayer, Åhs, Fredrikson, Sollers & Wager, 2012). The SNS has an impact during longer periods of time during low frequencies (LF) of between 0.04 – 0.15Hz, however, it should be noted that PNS activity also has an impact during LF as well as HF frequencies (Achten & Jeukendrup, 2003; Borresen & Lambart, 2008; Thayer et al., 2012). The LF: HF ratio can provide a measure of the balance between PNS and SNS activity, with high values indicating high SNS activity (Achten & Jeukendrup, 2003; Borresen & Lambart, 2008).

HRV can also be measured over time (time domain; Borresen & Lambart, 2008; Sztajzel, 2004; Thayer et al., 2012). Some of the time domain indices of HRV such as total heart rate variability (total HRV) and the standard deviation of the interbeat interval series, do not distinguish between PNS and SNS activity but rather provide an overall measure of HRV (Allen, 2002; Allen, Chambers & Towers, 2007). Several time domain indices can provide specific measures of either SNS or PNS activity - possibly the most researched measure of PNS activity is RSA. RSA has been found to negatively correlate with the cardiac sympathetic index (CSI), a time domain measure of SNS activity (Allen, 2002; Allen et al., 2007) and positively correlate with measures of total HRV at rest, this is likely due to the high ratio of PNS activity in comparison to SNS activity when at rest due to a priority for metabolic conservation (Allen, 2002; Allen et al., 2007). We will now examine RSA in more detail.

Respiratory sinus arrhythmia (RSA)

RSA is the natural variability in heart rate (R-R interval fluctuations) which occurs at the same ‘fast frequency’ as spontaneous breathing (Grossman & Taylor, 2007; Porges, 2007). The amplitude of RSA can provide a measure of parasympathetic cardiac control in response to a stressor (RSA withdrawal; Graziano & Derefinko, 2013) and at rest (resting RSA; Chapman, Woltering, Lamm & Lewis, 2010). Naturally the heart beats at a fast pace which is adaptive for threatening situations which require the quick mobilisation of resources. However, these metabolic demands are not required in non-threatening situations, it is therefore also adaptive to be able to slow the heart rate down to facilitate the conservation of metabolic resources (Porges, 2007; Porges & Furman, 2011). RSA amplitude is a measure of the ability to change the heart rate pattern to either slow the heart rate down or speed it up depending on the demands of the situation (cardiac vagal control; Graziano & Derefinko, 2013).

In non-stressful safe situations, PNS activity is high - the cardiac vagal efferent pathways of the myelinated vagal nerves send signals form the nucleus ambiguous in the reticular formation of the brain stem to the pacemaker cells in the sinoatrial node of the heart. This has the effect of acting like a vagal brake to slow down the natural firing rate of the pacemaker cells resulting in an increase in R-R intervals of heart rate and promotes adaptive responding through enabling the conservation of metabolic resources for pro-social behaviours (Porges, 2007; Porges & Furman, 2011). In these situations, high resting levels of RSA would be expected. The Polyvagal perspective suggests that the social communication system is responsible for activating the vagal brake on the sino-atrial node of the heart and inhibiting the mobilisation and immobilisation systems underling defensive fight, flight or freeze behaviours. The social communication system can facilitate self-regulation and pro-social behaviours as the myelinated vagal pathway underlying this system is linked with facial muscles responsible for prosocial behaviours and social communication (Porges, 2007).

During stressful situations, there is a need to quickly mobilise resources through increasing the influence of the SNS and reducing the influence of the PNS, in these situations the inhibitory effect of the vagal brake on the sino atrial node would be reduced to enable a decrease in R-R heart rate intervals. The Polyvagal theory suggests this would involve the activation of the mobilisation system and a reduction in RSA amplitude (Porges, 2007), known as RSA withdrawal (Graziano & Derefinko, 2013). Greater levels of resting RSA are thought to provide more adaptive responses in the event of a stress inducing situation as it enables greater potential RSA withdrawal which facilitates faster mobilisation of metabolic resources (El-Sheikh, 2005; Hinnant & El-Sheikh, 2009).

During development, it is thought that the more primitive systems (mobilisation and immobilisation systems) develop earlier than the later social communication system. From infancy through to adolescence the myelinated vagal fibres underlying the social communication system mature substantially, this enhances the ability to engage or disengage the vagal brake depending on the environmental context, facilitating self-regulation and social engagement behaviours (Porges & Furman, 2011).

The current research project focused on resting RSA which can be measured during normal non-stressful situations over several minutes (Chapman et al., 2010; Hinnant & El-Sheikh, 2009). Resting RSA indexes stable trait measures of emotional reactivity (Chapman et al., 2010). High levels of resting RSA are adaptive as they reflect greater flexibility in the potential to respond to stressful situations (changes in RSA can occur with a greater magnitude and shorter latency) compared with individuals with lower resting RSA (El-Sheikh, 2005; Hinnant & El-Sheikh, 2009). Indeed, children with greater resting RSA have also been found to have greater RSA withdrawal during stress inducing tasks (El-Sheikh, 2005; Graziano & Derefinko et al., 2013). Greater RSA withdrawal is also thought to be adaptive and indexes an increased ability to respond flexibly to environmental stressors (Porges, 2007). Indeed, greater RSA withdrawal during a negative emotion inducing film clip was linked with more adaptive emotion regulation abilities on parent reports and lower symptoms of depression on clinician reports for children aged between 5 and 13 years (Gentzler, Santucci, Kovacs & Fox, 2009). A recent meta-analysis of studies with children up to 18 years of age found small significant associations between greater RSA withdrawal and lower cognitive/academic problems, internalising problems and externalising problems (Graziano & Derefinko, 2013).

Resting RSA is, however, more stable during childhood than RSA withdrawal which is measured during a challenging task (El-Sheikh, 2005). El-Sheikh (2005) found that RSA withdrawal was found to be stable over a two-year period during a star tracing problem solving task but less stable over time during a stressful conflict task. Therefore, whilst the relationship between resting RSA and RSA withdrawal remained constant for children during the problem solving star tracing task, this relationship was not constant during the stress inducing conflict task. This could be due to maturational changes in the ability to manage different challenging situations and suggests that careful consideration of the task employed when measuring RSA withdrawal during pre-adolescence is needed.

In comparison to children with clinical difficulties, non-clinical samples of children seem to have significantly higher levels of resting RSA (Graziano & Derefinko, 2013). High resting RSA levels have been linked with higher parental reports of effortful control whilst lower levels of resting RSA indexed regulatory difficulties including higher parental reports of aggression in typically developing children aged between 8 and 17 years of age (Chapman et al., 2010). Higher resting RSA levels have also been linked with greater performance on working memory and cognitive efficiency tasks for children aged between 6 and 13 years without clinical difficulties (Staton, El-Sheikh & Buckhalt, 2009). A study with 8 to 12 year olds from low socioeconomic status homes found that children with low levels of resting RSA scored high on self-reports of depression, in comparison children with high resting RSA only scored high on self-reports of depression if their mother had maternal melancholia (Shannon, Beauchaine, Brenner, Neuhaus & Gatzke-Kopp, 2007).

Resting RSA is not, however, always associated with differences in regulatory ability, Calkins, Graziano and Keane (2007) found that resting RSA levels did not differ between 5 year olds children rated on parental reports as low in behavioural problems, at risk of externalising behavioural problems or at risk of both internalising and externalising behavioural problems. One reason for this lack of discriminability could have been because the children in this study were given a cartoon to watch during the resting RSA recording and so the measurement taken was not a true resting state. Another study found that for typically developing 8-year-olds, resting RSA levels and RSA withdrawal levels separately were not direct predictors of future internalising symptoms measured 2 years later, however, the interaction between resting and RSA withdrawal was found to predict internalising disorders (Hinnant & El-Sheikh, 2009).

Measuring indexes of heart rate variability (HRV)

The QRSTool and CMetX software (Allen, 2002; Allen et al., 2007) are tools which can be used to identify time domain indices of HRV. The QRSTool derives the interbeat interval series from the electrocardiogram signal and the CMetX tool derives the time domain indices of HRV based on this interbeat interval series (Allen, 2002; Allen et al., 2007). One issue which needs to be considered when collecting HRV data is the filter range which should be applied to the data. The CMetX tool applies a default filter of between .12 - .40Hz to identify the high frequency band in which PNS activity is found (Allen et al., 2007).

Previous studies have applied this filter to derive HRV indices with developmental populations, including children with anxiety aged between 7 and 12 years of age (Alkozei, Creswell, Cooper & Allen, 2015) and teenage boys with a history of maltreatment (Ardizzi et al., 2013). However, the respiratory systems and autonomic nervous systems underlying self-regulatory behaviours are still undergoing maturational changes during pre-adolescence (Bar-Haim, Marshall & Fox, 2000; Porges & Furman, 2011). Specifically, tidal volume (depth of ventilation) has been found to increase and respiratory rate (number of breaths per minute) has been found to decrease during development (Bar-Haim et al., 2000). In conjunction with this the variability within the high frequency band and R-R interval variability has been found to increase during development (Bar-Haim et al., 2000). To account for these differences between adults and children, alternative high frequency filters have been applied for studies with children. A filter which has often been applied with younger infants is 0.24-1.04Hz, however, Bar-Haim et al., (2000) suggested that this filter does not adequately capture high frequency activity in children older than 4 years. Another filter of between .15 - .50Hz was applied for children aged between 4.5 and 7 years of age (Marshall & Stevenson-Hinde, 1998), 5 to 13 years of age (Gentzler et al., 2009) and between 8 and 12 years of age (Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011). Based on this previous research a filter of .15-.50Hz appears to be an appropriate filter to apply with pre-adolescents.

Some suggest that the high frequency band should be calculated based on respiration rates, however, Graziano and Derefinko (2013) conducted a meta- analysis with children up to the age of 18 years and found that the relationship between RSA withdrawal and adaptive functioning did not change when either the 0.12 – 0.4Hz filter or a filter based on respiration rates was applied. For this current research project, a high frequency band filter of 0.15-0.5 Hz was applied to the HRV data to study the association between resting RSA and dispositional mindfulness, and to study the impact of mindfulness training on resting RSA in pre-adolescents aged between 7 and 11 years (see chapter six). This filter was in line with the filter range previously applied with pre-adolescents (Gentzler et al., 2009; Marshall & Stevenson-Hinde, 1998; Schmitz et al., 2011).

As RSA occurs in the same fast frequency as respiration (Grossman & Taylor, 2007; Porges, 2007), another issue which should be addressed is whether a measure of respiration need to be taken to accurately disentangle the effects of RSA from respiration (Grossman & Taylor, 2007). There is a relationship between respiration and RSA; during inspiration, the impact of the vagal brake is reduced and heart rate accelerates, during expiration the vagal brake is active and heart rate decreases (Grossman & Taylor, 2007). During steady conditions, resting RSA magnitude is negatively related to respiration rate and positively related to tidal volume, for example, slow deep breaths will maximise the resting RSA magnitude whilst fast shallow breathes will reduce resting RSA magnitude (Grossman & Taylor, 2007). There are several methods which have been proposed to control the effect of respiration, one method is using a paced breathing task which enables the respiration rate and tidal volume to remain constant across the electrocardiogram measurement (Bar-Haim et al., 2000). For children, this can be problematic as children can find it challenging to use a paced breathing task (Bar-Haim et al., 2000), and it could change the natural breathing rate of children at rest, which may reduce the ecological validity of the recording (Denver, Reed & Porges, 2007).

Another method involves measuring respiration during RSA recordings and then statistically controlling for the influence of respiration rates (Grossman & Taylor, 2007). It has been suggested that the need to control for respiration may be more relevant for RSA withdrawal measures where respiration rates and tidal volume are more likely to change due to the induction of stress (Grossman & Taylor, 2007; Oveis et al., 2009). Resting RSA measures would be less susceptible to the impact of respiration as they are taken during steady conditions (Grossman & Taylor, 2007; Oveis et al., 2009). Indeed, Denver et al., (2007) found that RSA was not affected by respiration frequency at baseline. Paced breathing tasks and measures of respiration are rarely used in studies with children (Bar-Haim et al., 2000; Chapman et al., 2010; Marcovitch et al., 2010; Obradović, et al., 2010). For the reasons given above paced breathing tasks and measures of respiration were also not included in the current research project examining the relationship between resting RSA and mindfulness (dispositional and acquired through training) with pre-adolescents (see chapter six).

Finally, demographics such as age and gender could also have an impact on measures of HRV (Acharya et al., 2006), although findings regarding the impact of these demographics are not consistent. Positive associations between age and HRV indices have previously been found (Acharya et al., 2006; Massin & von Bernuth, 1997). A meta-analysis with children up to 18 years of age found that resting RSA levels increased with age (Graziano & Derefinko, 2013); however, other studies have found no effect of age on resting RSA levels (Chapman et al., 2010; Gentzler et al., 2009) and a study with 6 to 13 year olds found that resting RSA levels remained stable over a two-year period (El-Sheikh et al., 2005).

Similarly, inconsistent trends have been found between gender and resting RSA levels; in a study with 6 to 13 year olds greater resting RSA levels were reported for boys in comparison to girls (El-Sheikh, 2005). Salomon, (2005) also found pre-adolescent and adolescent boys had higher resting levels of RSA. In contrast, Bar-Haim et al., (2000) found no effect of gender on HRV in children aged between 4 months and 4 years. In addition, no association between gender and resting RSA levels were found for children aged 6 to 13 year olds (Gentzler et al., 2011) or children aged 5.5 year olds (Graziano, Keane & Calkins, 2007a). In the current research project age and gender were assessed and matched across both high and low dispositional mindfulness groups when studying the association between resting RSA levels and dispositional mindfulness. In addition, gender and age were matched across both training and wait-list control groups when examining the impact of mindfulness training on resting RSA levels (see chapter six).

Table 1.

A summary of how event related potential (ERP) measures can provide an index of the impact of mindfulness training on top down and bottom up aspects of self-regulation in pre-adolescents.

ERP components	Aspects of self-regulation	Neural generators	Developmental ERP trends	Predictions for changes in self-regulation for pre-adolescents after mindfulness training
N2				
Fronto-central negativity elicited between approximately 200 and 400ms after stimulus onset (Lewis et al., 2006b).	**Executive attention** A more negative N2 is found after the successful inhibition of a pre-potent response during a Go/No-Go task (Falkenstein et al., 1999).	Dorsal caudal ACC (Lewis et al., 2006b; Van Veen & Carter, 2002a), which is a node of the cingulo-opercular network (Fair et al., 2007).	During development, the N2 amplitude becomes less negative, the latency decreases and the N2 topography becomes more anterior, reflecting an increase in neural efficiency within the executive attention network (Chapman et al., 2010; Lewis et al., 2006b). Mixed developmental patterns have been found with regards to the N2 elicited for No-Go stimuli during an emotionally demanding task; some studies have found a less negative N2 (Chapman et al, 2010) and others have found a more negative N2 with development (Lewis et al., 2006b).	A less negative N2 for No-Go stimuli during a neutral Go/No-Go task after mindfulness training would index more efficient executive attention skills. For an emotionally demanding Go/No-Go task a more negative N2 alongside improvements in self-reports of emotion regulation would index an increased ability to inhibit emotional distractions. For children with self-regulatory difficulties a reduction in the N2 amplitude for No-Go stimuli along with decreases in reports of anxiety would reflect an aligning of their regulatory performance with that of children without regulatory difficulties.

Error related negativity (ERN) and Error positivity (Pe)				
The ERN is a fronto-central negativity elicited approximately 50ms after an error response (Hajcak, 2012). The Pe is a parietal positivity elicited between 200 and 400ms after an error response (Olvet & Hajcak, 2012).	**Executive attention and error processing.** The ERN reflects the monitoring for and detection of errors (Van Veen & Carter, 2002b). A more negative ERN reflects increased error processing efficiency (Segalowitz & Davies, 2004). The Pe indexes the conscious detection and emotional response to errors (Endrass et al., 2007). The Pe is more positive when the emotional salience of an error is high (Endrass et al., 2007).	Several likely neural sources of the ERN include the dorsal caudal ACC (Ladouceur et al., 2006; van Veen & Carter, 2002b) and rostral ACC (Mathalon et al., 2003). The Pe is linked to the rostral ACC and parietal cortex (Herrmann et al., 2004; van Veen & Carter, 200b).	The ERN amplitude becomes more negative reflecting increased error processing efficiency (Segalowitz & Davies, 2004). The Pe does not significantly change during development (Davies et al., 2004).	For the ERN, more negative ERN along with enhancements in self-reports of empathy and acceptance after mindfulness training could reflect improvements in executive attention abilities, specifically error processing. Modulations of the ERN would be greater after longer durations of mindfulness training. After a short duration of mindfulness training an attenuation of the Pe could reflect a reduction in the emotional reaction to errors. For children with ADHD, who show a reduced ability to recognise and respond to errors, a more positive Pe after mindfulness training along with increases in self-reports of acting with awareness would reflect a more adaptive response to errors.

P3a				
Fronto-medial positivity found approximately 300 to 400ms after stimulus onset (Bush et al., 2000).	**Stimulus driven orienting** A more positive P3a for infrequent distracter stimuli in an oddball paradigm reflects increased automatic orienting of attention resources (Polich, 2007; Wetzel et al., 2006).	Medial and superior frontal gyrus, the right parietal lobe and the ACC (Volpe et al., 2007). Activations in the ventral attention network and dorsal attention network have been found for oddball distractors (Bledowski, 2004; Kim, 2014).	An anterior shift in topography from central to frontal sites (Gumenyuk et al., 2011; Lewis et al., 2006b) and an attenuation of the P3a amplitude (Stige et al., 2007) reflects reductions in the automatic orientation of attention during development.	A less positive P3a for distractor oddballs during an active oddball task after mindfulness training would index a reduction in exogenous attention. The elicitation of a less positive P3a for emotional distractors after mindfulness training could reflect reduced emotional reactivity towards emotional non-targets.
P3b				
Parietal positivity found approximately 300 to 500ms after stimulus onset (Hajcak et al., 2010; Polich, 2007).	**Endogenous orienting, mind wandering and context updating** A more positive P3b to target oddballs during an oddball task reflects a greater ability to focus and allocate attention resources	Right temporo-parietal junction (Linden, 2005), which is a node of the ventral attention network (Bledowski et al., 2004).	The P3b latency decreases (van Dinteren et al., 2014) in conjunction with faster reaction times and increased accuracy rates during development, reflecting more efficient stimulus evaluation (Hillman et al., 2005).	A more positive P3b to targets during a demanding oddball task along with faster reaction times and increased accuracy rates would reflect an improvement in the ability to focus on task relevant stimuli. During less demanding tasks a less positive P3b along with no decrement in accuracy rates or reaction time after mindfulness

	in a goal directed way (Polich, 2007). A less positive P3b is linked with increased mind wandering and reduced availability of attention resources (Smallwood et al., 2008).			training would reflect attention resource efficiency. After mindfulness training a more positive P3b together with higher target accuracy during the SART task would reflect reductions in episodes of mind wandering after mindfulness training. Reductions in the P3b to negative stimuli after mindfulness training would reflect a greater ability to disengage from negative affect. These modulations would be expected to be greater for children exposed to environmental stressors.
Late positive potential (LPP)				
Sustained centro-parietal positivity elicited approximately 300ms after stimulus onset and sustained up to 2000ms after a stimulus onset (Hajcak et al., 2010).	**Top-down and bottom-up emotion regulation** During passive picture paradigms, a more positive LPP reflects increased emotional reactivity to emotional stimuli (Hajcak & Dennis, 2009).		The LPP topography shifts from occipital to parietal sites reflecting an increase in connectivity between frontal and parietal brain regions during development (Wessing et al., 2015). The ability to regulate emotions using top-down regulatory strategies such as cognitive reappraisal increases during pre-	During passive picture paradigms, an attenuation of the LPP to emotional stimuli would reflect reduced emotional reactivity after mindfulness training. During an active emotion regulation task which involves employing mindfulness to regulate emotions, an attenuation of the LPP amplitude for negative stimuli, in conjunction with self-

	During active emotion regulation tasks, an attenuation of the LPP reflects successful top-down regulation of an emotional response (Dennis & Hajcak, 2009).		adolescence, resulting in a greater attenuation of the LPP to emotional stimuli (Dennis & Hajcak, 2009).	reported reductions in state anxiety and depression would reflect improvements in emotion regulation after mindfulness training.

Chapter Four - The relationship between dispositional mindfulness and attention control: An event-related potential (ERP) study with pre-adolescent children

Abstract

Dispositional mindfulness has been associated with better attention control in adults - this includes a greater ability to sustain attention and lower engagement in episodes of mind wandering during a task. Initial research using self-reports and behavioural data also suggests this link between dispositional mindfulness and attention control is present during pre-adolescence. This cross-sectional study explored the association between dispositional mindfulness and attention control in pre-adolescents (high dispositional mindfulness group n = 20; low dispositional mindfulness group n = 21) using event-related potentials (ERPs). Participants completed a three-stimulus auditory oddball task whilst EEG signal was recorded, self-reported mind wandering was also assessed during the task. The findings revealed that whilst the higher dispositional mindfulness group showed better self-reported attention focusing (p = .011, d = 0.83) and attention shifting (p = .032, d = 0.70) abilities, no group differences in the P3b or No-go P300 ERP indexes of attention control were found. In addition, self-reported mind wandering did not differ between groups. Overall, this suggests that there isn't a robust relationship between dispositional mindfulness and P3 markers of attention control in pre-adolescents and further research is needed to investigate the links between dispositional mindfulness and various psychophysiological markers of attention.

Dispositional mindfulness is a psychological trait which involves the ability to direct the focus of attention in an accepting and non-judgemental way to present moment experiences (Quaglia et al., 2015a); individual differences in dispositional mindfulness occur naturally in the absence of mindfulness training (Quaglia et al., 2015a). Attention control is considered a core feature of mindfulness - individuals with higher dispositional mindfulness seem to have a greater ability to direct and sustain attention in a goal directed way towards present moment experiences (Oberle et al., 2012; Quaglia et al., 2015b).

In developmental literature, several studies have reported enhanced self-reported attention control for adolescents with higher dispositional mindfulness (in the absence of mindfulness training). These include enhanced self-reports of inhibition, emotional control, and working memory skills for 12 to 13 year olds (Shin et al., 2016) and enhanced self-reports of inhibitory control and working memory for 12 to 14 year olds (Riggs et al., 2015). So far only one study investigated the relationship between dispositional mindfulness and attention control with pre-adolescents; the study found that higher dispositional mindfulness was linked with greater inhibitory control during a Hearts and Flowers task for 9 to 11 year olds (Oberle et al., 2012).

Attention control skills including inhibition, conflict monitoring and conflict resolution, which facilitate goal directed behaviour through the detection and inhibition of stimuli in conflict with a goal, undergo rapid development during childhood (Berger et al., 2007; Posner, Rothbart, Sheese & Voelker, 2014). This is due to maturational changes within brain networks such as the fronto-parietal network, which underlies short term top-down attention control (Fair et al., 2007; Petersen & Posner, 2012) and the cingulo-opercular network, which enables sustained top-down attention control (Fair et al., 2007; Petersen &

Posner, 2012). In addition, increasingly stronger connections between the default mode network, salience network and central executive attention network also occurs during development (Uddin et al., 2011). The default mode network is activated during incidences of mind wandering - a psychological process, linked with poor attention control, where the mind is diverted away from the present moment towards task irrelevant thoughts (Mason et al., 2007; Smallwood et al., 2007). The salience network has a role in detecting mind wandering and can act as a task switcher to reduce activity in the default mode network and initiate the central executive attention network to return attention to the goal oriented task (Uddin et al., 2011). The development of adaptive attention control skills could have a significant impact on socio-emotional outcomes and academic functioning during pre-adolescence (Riggs, Jahromi, Razza, Dillworth-Bart & Mueller, 2006). Specifically, higher levels of mind wandering have been linked with poorer reading comprehension, higher levels of stress, more negative affect and lower self-esteem in youths aged 11 to 13 years (Mrazek, Phillips, Franklin, Broadway & Schooler, 2013b).

Several studies with adults have found that higher dispositional mindfulness is linked with lower episodes of mind wandering. Specifically, higher dispositional mindfulness has been found to correlate with lower self-reports of mind wandering during a mindful breathing task where individuals engaged in attending to their breath and then at varying time points during the task they were asked to report on whether their mind had wandered away from the task (Mrazek et al., 2012). This is possibly due to an enhanced ability to recruit metacognitive attention skills to monitor the present moment for potential distractions (Mrazek et al., 2012). In the same study an inverse relationship between dispositional mindfulness and mind wandering was also found during a sustained attention to response task where participants were required to respond to frequently presented non-targets and inhibit responding to infrequently presented targets. More accurate responding to targets was linked with higher dispositional mindfulness; in addition, greater response time variability was linked with lower dispositional mindfulness, reflecting greater fluctuations in attention control (Mrazek et al., 2012). Another study with adults found that higher dispositional mindfulness was associated with better working memory on the Penn N back test and lower response time variability during a continuous performance task, which reflected a greater ability to consistently sustain attention during the task (Ruocco & Direkoglu, 2013). Furthermore, dispositional mindfulness and internal/external encoding style (the ability to attend to the external features of the environment rather than relying on preformed internal schemas) were found to mediate the relationship between mind wandering and psychological distress in adults (Stawarczyk, Majerus, Van der Linden & D'Argembeau, 2012). This suggests that regular engagement in mind wandering is associated with a reduced ability to attend to the external features of the environment in a mindful way, which in turn is linked with higher psychological distress.

Event-related potentials (ERPs) can provide a non-invasive measure of the brain's neural response to a stimulus (Luck, 2005), and can index attention control processes when measured during an attention task (Polich, 2007). The P3b is an ERP component with a positive amplitude which is observed between approximately 300 and 500ms after stimulus presentation at parietal electrode sites (Polich, 2007). It is most frequently elicited to infrequent target stimuli which require a response during an oddball paradigm (Linden, 2005; Polich, 2007). The P3b is one of the most widely researched ERP indexes of attention (Luck, 2005), and can provide a measure of attention control abilities including attention resource allocation (Chennu et al., 2013; Moser et al., 2005). A more positive P3b amplitude to task relevant targets is associated with greater attention resource availability (Hillman et al., 2005; Willner et al., 2015). In contrast, a less positive P3b to task relevant stimuli is associated with mind wandering, reflecting a reduction in the availability of attention resources for task relevant processing due to the re-orienting of attention away from the task and towards task irrelevant thoughts (Smallwood et al., 2008). Indeed, during a three-stimulus oddball task, individuals who reported greater task unrelated mind wandering elicited a less positive P3b amplitude for infrequent targets, reflecting a suppression in the attention resources available to process the task relevant targets (Barron et al., 2011).

A study with experienced Vipassana meditators found that the P3b elicited to target stimuli during a two-stimulus auditory oddball paradigm was more positive after a 30-minute meditation session compared to the P3b elicited to target stimuli after a 30-minute mind wandering session (Delgado-Pastor et al., 2013). This suggests that sustaining attention in a non-reactive and non-judgemental way towards present moment experiences can improve the ability to allocate attention towards task relevant stimuli. In addition, another study found that after a three-month meditation retreat meditators showed a more efficient and balanced allocation of attention resources during an attentional blink paradigm. This task involves the rapid successive presentation of two target stimuli within a stream of non-targets, often during this task the second target is not detected due to an excessive allocation of resources allocated to the first target. After the retreat meditators showed higher accuracy rates for the detection of the second target stimulus together with a less positive P3b for the first of the two targets, suggesting a better ability to allocate attention resources in a balanced, consistent way (Slagter et al., 2007).

The P3b is a developmentally sensitive marker of attention resource efficiency (Hillman et al., 2005; St-Louis-Deschênes et al., 2015), however, to date no known studies have used the P3b amplitude as an index of the association between dispositional mindfulness and mind wandering with pre-adolescents. Given the research suggesting that dispositional mindfulness is associated with enhanced attention control in pre-adolescents and adolescents (Oberle et al., 2012; Riggs et al., 2015), it could be expected that pre-adolescents with higher dispositional mindfulness would engage in less mind wandering and elicit a more positive P3b to target stimuli requiring a response in an oddball paradigm.

It has been proposed that mind wandering is not just limited to task relevant stimuli which require a response, but rather reflects a diversion of attention resources towards internal processes and away from all external events including external non-target distractors (Barron et al., 2011; Smallwood, 2010). The No-go P300 could provide an index of the attention resources allocated towards external distractors which do not require a response. This central/parietal positivity is elicited between approximately 300-500ms after stimulus onset for infrequently presented stimuli which do not require a response. A more positive No-go P300 indexes a greater ability to inhibit responding to stimuli, in line with task instructions (Polich, 2007). An association between higher dispositional mindfulness and a more positive No-go P300 for emotional and non-emotional No-go trials during an emotional Go/No-go task has previously been found in adults (Quaglia et al., 2015b). Another study measured the impact of mindfulness-based cognitive therapy on the No-go P300 during a continuous performance task for adults with ADHD, a disorder associated with impairments in attention control (Schoenberg et al., 2014). The task involved participants responding to frequently presented stimuli whilst avoiding responses to infrequent stimuli. The No-go P300 elicited for the infrequent stimuli was more positive after MBCT training and this correlated with increases in the act without judgement facet of mindfulness and decreases in self-reports of inattention symptoms. This suggests that mindfulness can positively impact on the ability to sustain attention resources during a task.

The No-go P300 can also be elicited to non-novel infrequent non-targets (distractors) in a three-stimulus oddball paradigm (Polich, 2007). If indeed there is an association between dispositional mindfulness and attention control in pre-adolescents, then it could be expected that higher dispositional mindfulness would be associated with a more positive No-go P300 to distractor stimuli, reflecting a greater ability to sustain attention on the task and correctly inhibit responses to distractors.

The current study employed electrophysiological, behavioural and self-report measures to examine the association between dispositional mindfulness and attention control in pre-adolescents aged between 7 and 11 years. The P3b and No-go P300 ERP components were measured during a three-stimulus auditory oddball paradigm – this involved the presentation of frequent standard stimuli, infrequent target stimuli which required a response and infrequent non-novel distractor not requiring a response. An oddball task was chosen as it has previously been found to be a robust measure of attention resource allocation efficiency both in adults (Debener, Kranczioch, Herrmann & Engel, 2002; Polich, 2007) and children (Hillman et al., 2005; Johnstone, Barry, Anderson & Coyle, 1996; Senderecka et al., 2012) and has previously been used to measure mind wandering (Barron et al., 2011). It was expected that higher dispositional mindfulness would be associated with the elicitation of a more positive P3b to infrequent targets stimuli and a more positive No-go P300 to infrequent distractor stimuli, reflecting a greater availability of attention resources to allocate to task relevant stimuli. It was also predicted that higher dispositional mindfulness would be associated with higher accuracy rates for targets and fewer false alarms for distractor stimuli. There is a lack of consensus regarding the association between mindfulness and response time measures during attention tasks (Di Francesco et al., 2017; Sanger & Dorjee, 2016) and therefore no specific response time hypotheses were made. Lower self-reports of mind wandering during the task and enhancements in self-reports of attentional control were also expected for pre-adolescents with higher dispositional mindfulness.

Method

Participants

Ethical approval was gained from Bangor University and the NHS Research Ethics Committee before participant recruitment, participants were given some stationary for taking part. Convenience sampling was used to recruit primary school children aged 7 to 11 years from four North Wales primary schools. Participants had normal or corrected to normal vision and hearing, the only exclusion criterion was a diagnosis of epilepsy. As part of an overarching project investigating mindfulness and self-regulation with pre-adolescents, informed parental consent and informed child assent was received for a total of 76 participants. For this section of the project, thirty-five participants were excluded from analysis for the following reasons: incompletion of the ERP task (n = 5), poor accuracy rates (< 65%; n = 13) and high levels of artifacts in the ERP data (n = 17). Complete data was available for 41 participants, a median split of scores on the Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011) was used to separate participants into a high dispositional and low dispositional mindfulness group (see *Figure 1*).

Between the high and low dispositional mindfulness group no significant differences in age [$t(39) = .791$, $p = .434$, $d = 0.25$] or gender were found [$X^2(1, N = 41) = 1.21$, $p = .354$, V

= .171]. In addition, no difference in the number of participants recruited from schools scoring high or low in the socioeconomic criteria of free school meals was found [X^2(1, N = 41) = .034, p = 1.00, V = -.029]. In the high dispositional mindfulness group, one participant was ambidextrous, no significant group differences in right or left handedness were found [X^2(1, N = 41) = .129, p = 1.00, V = .057]. A significant group difference was found for English as a first language [X^2(1, N = 41) = 5.98, p = .021, V = .382] - English was the first language learned for all participants in the low mindfulness group, for five participants in the high dispositional mindfulness group, Welsh was the first language (for demographic information see Table 1).

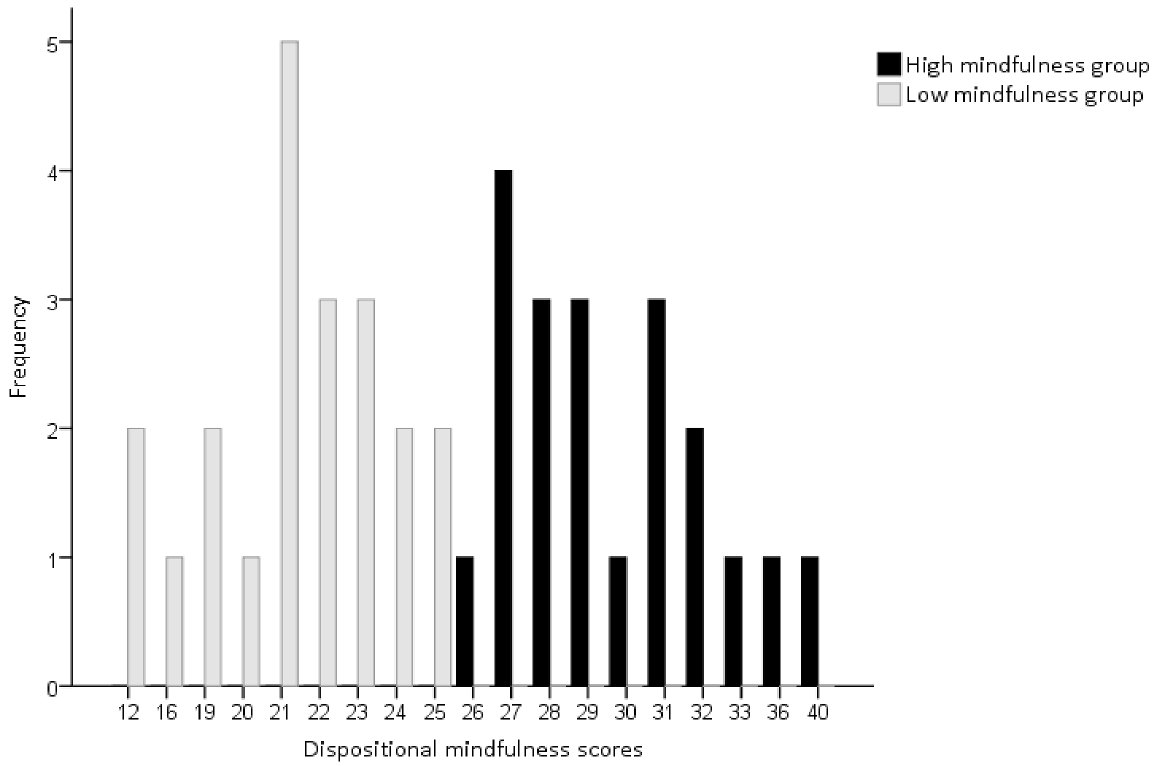


Figure 1. A histogram showing the distribution of mindfulness scores in the high and low dispositional mindfulness groups.

Table 1.

A summary of the demographic information for the participants included in the dispositional data analysis (High dispositional mindfulness group n = 20, Low dispositional mindfulness group n = 21).

	Demographic information			
	High mindfulness group		Low mindfulness group	
	(*n*)	(*%*)	(*n*)	(*%*)
Participants	20		21	
Gender: Female	8	40	12	57.14
Handedness: Right	17	85	18	85.71
First language: English	15	75	21	100
First language: Welsh	5	25	0	0
Age (Year 3)	1	5	2	9.5
Age (Year 4)	7	35	7	33.3
Age (Year 5)	2	10	9	42.9
Age (Year 6)	10	50	3	14.3
Age (*M*)	9.93 years		9.66 years	
Age (*SD*)	1.15 years		1.01 years	
Age (Range)	7.07 – 11.04 years		7.09 – 11.03 years	

Self-report measures

A pre-screening form detailing demographic information including age, language skills, handedness and whether the participant had epilepsy was completed by participants at the beginning of data collection. For the age variable, there was one missing value, this was replaced using the multiple imputation method.

The Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011) was administered to measure the dispositional ability to attend to present moment experiences in a non-judgmental, accepting way. This measure used a 5-point Likert scale (0 = never true to 4 = always true), all 10 items were reversed and summed to create a total mindfulness score. The CAMM is suitable for 10 to 16 year olds (Greco et al., 2011), a study focusing on the use of the CAMM with pre-adolescents aged 10 to 12 years found good internal consistency for this scale (α = .71; de Bruin, Zijlstra & Bögels, 2014). The CAMM was divided into two subscales for this age group - present moment non-judgemental awareness (items 1, 2, 4, 6, 7, 8, 9) which had good internal consistency for 10 to 12 year olds (α = .72) and suppressing or avoiding thoughts and feelings (items 3, 5, 10) which had poor internal consistency in this age group (α = .58). This current study will analyse the present moment non-judgemental awareness subscale and total mindfulness scores.

The Attentional Control Scale for Children (ACS-C; Muris, de Jong & Engelen, 2004) was administered to assess attention control abilities, the questionnaire is divided into two subscales; attentional focusing and attentional shifting. This measure uses a 4-point Likert scale (1 = almost never, 4 = always); after reversing some questions, items for each subscale were summed to generate total attentional focusing and total attentional shifting scores. The ACS-C is suitable for pre-adolescents aged 8 to 13 years (Muris et al., 2004). Good internal consistency was found for the attentional focusing subscale (α = .65) and the attentional shifting subscale (α = .71) for this age group (Muris et al., 2004).

The mind wandering questionnaire is a simple non-standardized self-report developed by Dr Dusana Dorjee in the Mindful brain lab. It was administered to assess the frequency of occurrences when participants engaged in task unrelated thoughts during each block of the three-stimulus oddball task. At the start of the task it was explained that mind wandering is when your mind wanders away from thinking about the task. After each of the three blocks participants would be asked to report on whether they found their mind had wandered during that part of the task. Answers were recorded on a 6-point Likert scale (ranging from never to always). Total mind wandering scores were also obtained by summing scores across the three blocks.

Three stimulus oddball paradigm

The three-stimulus auditory oddball paradigm involved the presentation of a frequent standard sound which was presented for 70% of total trials (210 trials), an infrequent target sound which was presented for 15% of total trials (45 trials) and an infrequent distractor sound which was presented for 15% of total trials (45 trials). A fixation cross was presented during the presentation of the sounds and participants were instructed to look directly at the fixation cross on the screen while listening to the sounds. They were asked to respond to the infrequent target sound by pressing the spacebar on the keyboard and inhibit responding to the standard and distractor sounds. The standard stimulus was a dial tone (Intensity = 2.99; Arousal = 3.20) which was presented for 850ms, the target stimulus was a bicycle bell (Intensity = 3.27, Arousal = 3.10) which was presented for 837ms and the distractor stimulus was an alarm clock (Intensity = 1.59, Arousal = 3.67) which was presented for 853ms (for more information on the valence and arousal ratings see Thierry & Roberts, 2007). All three sounds taken from royalty free libraries (Dorjee, Devenney & Thierry, 2010) and were resampled at a rate of 44.1 kHz, 16-bit mono encoding and all sounds were normalised to 70%, to avoid clicking transitions, 50ms rise and fall envelopes were applied at the start and end of the sounds. Participants had 1000ms to respond to the sounds (this included the presentation of the sound) and there was an inter-stimulus interval of 700ms. The duration of the task was 9 minutes. The task was divided into three blocks; the proportion of frequent standards, infrequent targets and infrequent distractors were kept the same across each block and the order of sounds was randomised within each block. After each block participants were asked to report on their frequency of mind wandering during that block using the mind wandering questionnaire. At the start of the task participants were given 10 practice trials to make sure they understood the task instructions and could distinguish between the three different sounds.

Design and procedure

The data collection took place on school premises in a small room designated for the study, all equipment was brought into the school including a portable 32-channel EEG system (EasyCap, Brain Products) with Neuroscan Nuamp amplifiers. Each testing session was approximately an hour in duration, participants completed the self-report questionnaires with support from a research assistant who read the questions aloud to aid participants in their understanding of them. The three-stimulus oddball task was delivered on a laptop and participants were seated in front of the laptop and asked to remain still and look ahead at the fixation cross on the screen. The sounds were delivered through hydraulic headphones using Etymotic ear inserts for children. In addition to the oddball task, an emotional oddball task and resting RSA measures were also completed by participants in the same sessions (reported in chapter five, six and seven).

Event related potential (ERP) analysis

During the three-stimulus auditory oddball task the EEG signal was measured using 32 Ag/AgCl electrodes referenced online to the right mastoid. The electrodes were re-referenced offline to a new reference which was generated by creating an average of the right mastoid and left mastoid channels using linear derivation. The signal was recorded using Neuroscan NuAmp amplifiers at a sampling rate of 1 kHz. Ocular movements were recorded using two additional electrodes placed above and below the left eye. Electrode impedances were kept below 7kOhms. Online the EEG signal was bandpass filtered with a range of 0.01-200Hz. Offline a filter with a zero-shift higher cut off point of 30Hz and a 48/Db/Oct slope and a lower cut off point of 0.1Hz with a 12/Db/Oct slope was applied to the EEG signal. Subsequently, motor and irregular ocular artefacts were removed from the EEG signal through manual cleaning. The Neuroscan ocular artifact removal algorithm was then applied to the data to remove regular ocular artefacts. The data was epoched into 1.1 second segments and baseline corrected using the 100ms preceding stimulus onset as a baseline. ERP averages for each participant were computed for each condition and then grand ERP averages were computed for each condition across participants in each group.

The grand mean global field power across the scalp was used to define the search intervals for ERP components of interest, electrodes were selected based on previous studies. For the P3b amplitude a time window of between 275-370ms was chosen and the mean amplitude was averaged across three electrodes of interest; P1, Pz and P2. This parietal topography and time window is consistent with previous studies measuring the P3b in pre-adolescents (Boucher et al., 2010; Zenker & Barajas, 1999). For the No-go P300 amplitude a time window of between 275-370ms was chosen and the mean amplitude was averaged across six electrodes; CP1, CPz, CP2, P1, Pz and P2. This time window and topography is consistent with previous studies on the No-go P300 with pre-adolescents and adults (Johnstone et al., 2007; Polich, 2007). To account for differences in the volume of sound presentation across participants, difference waves were calculated for each ERP component, for the P3b this involved subtracting grand average responses to standard stimuli from grand average responses to target stimuli, for the No-go P300 this involved subtracting grand average responses to standard stimuli from grand average responses to distractor stimuli. In line with previous studies investigating mind wandering using an oddball paradigm (Barron et al., 2011; Sanger & Dorjee, 2016) correct and incorrect trials were included in the analysis as the inclusion of both is needed to assess the impact of mind wandering on the ERP components.

Results

Data analysis was conducted for 41 participants (high mindfulness group n = 20; low mindfulness group n = 21) for the self-report, behavioural and electrophysiological measures. To assess group differences in these measures independent samples t-tests were conducted for the self-reports, behavioural assessments (response times and accuracy rates), P3b and No-go P300 difference waves with Cohen's d providing an estimate of effect size. To assess whether there were converging patterns across the different measures, correlational analysis was conducted between total mindfulness scores and the self-report, behavioural and ERP measures. There was no missing data for any of the measures. Extreme outliers (>3 x interquartile range) were winsorised. Due to the large age range included in the sample (7 to 11 years), additional analysis was run to explore whether age had an effect on the results by including age as a factor in the self-report, behavioural and ERP analysis. Children were divided into older (years 5 and 6; 9.58 – 11.33 years) and younger (years 3 and 4; 7.58 – 9.42 years) age categories. Chi square tests revealed no significant group difference for these age categories [$X^2(1, N = 41) = 0.034, p = 1.00, V = .029$].

Self-report Results

Child and Adolescent Mindfulness Measure (CAMM)

Acceptable internal consistency was found for the 10-item CAMM total scores (α = .676). When the CAMM was divided into two subscales, the present-moment non-judgemental awareness subscale had acceptable internal consistency (α = .674). The suppression of thoughts and feelings subscale had poor internal consistency (α = .427) and was therefore not analysed. Significant group differences in the total CAMM scores [$t(39) = 8.45$, $p < .001$, $d = 2.64$] and total present moment awareness subscale scores were found [$t(39) = 7.00$, $p < .001$, $d = 2.19$], as expected the high dispositional mindfulness group had higher total CAMM scores and higher present moment awareness subscale scores than the low dispositional mindfulness group, see *Figure 2*.

Attentional Control Scale for Children (ACS-C)

The attentional shifting subscale had good internal consistency (α = .724), the attentional focusing subscale had poor internal consistency (α = .435). There were significant group differences in attentional focusing [$t(39) = 2.66$, $p = .011$, $d = 0.83$] and attention shifting [$t(39) = 2.22$, $p = .032$, $d = 0.70$], the high dispositional mindfulness group had higher scores for these subscales compared to the low dispositional mindfulness group, see *Figure 2*.

No significant correlation between total CAMM scores and attention shifting and attention focusing scores were found (all *p*s > .1).

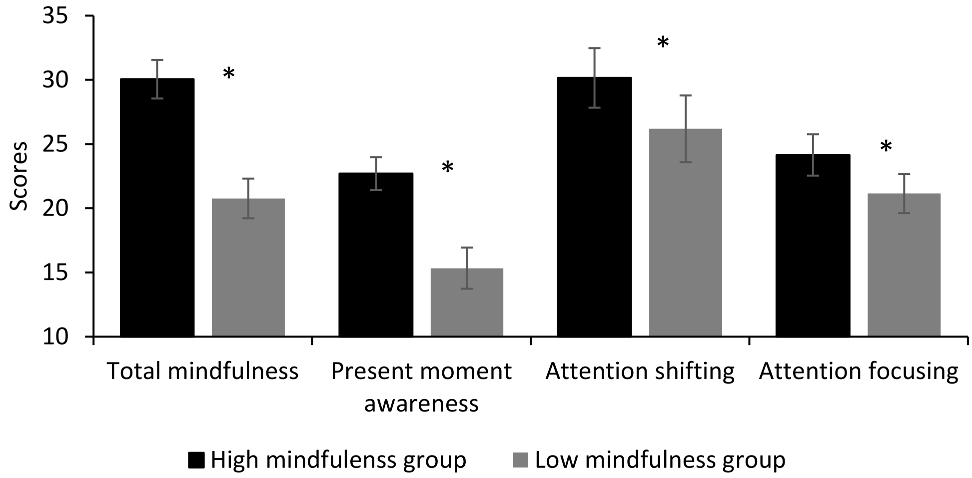
Mind Wandering Questionnaire

No significant group differences in mind wandering were found for each of the three blocks (all *p*s > .1). In addition, no group differences in total mind wandering (which was created through summing mind wandering scores across the three blocks) were found (all *p*s > .1), see *Figure 2*.

No significant correlation between total CAMM scores and mind wandering scores were found (all *p*s > .1).

Age analysis

2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs revealed that age had no impact on total CAMM, attentional shifting, attentional focusing or mind wandering scores on the self-report questionnaires (all *p*s > .1).



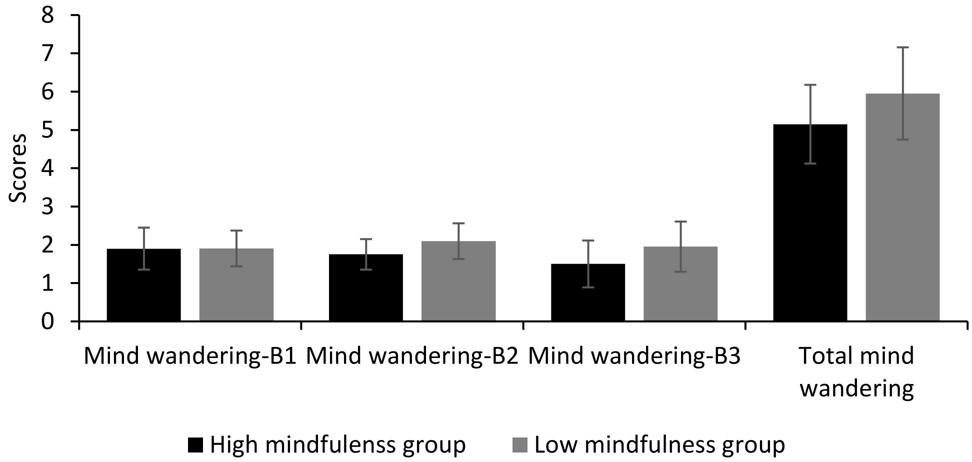


Figure 2. High dispositional mindfulness (n = 20) and low dispositional mindfulness (n = 21) group differences in A) total mindfulness scores; present moment non-judgemental awareness scores attentional shifting scores and attentional focusing scores. B) group differences in self-reports of mind wandering for block1, block 2, block 3 and total mind wandering. Error bars indicate 95% confidence intervals (CI).

Behavioural Results

For infrequent target stimuli accuracy rates (% of correct responses) and response times were analysed. Response times which were slower than 199ms or faster than 1000ms were excluded from the analyses. A chi square analysis revealed no group differences for the proportion of children excluded from the analysis due to poor error rates [$X^2(1, N = 54) = 1.30, p = .343, V = .155$].

Target accuracy rates and response times

Marginal group differences in accuracy rates for the infrequent target stimuli were found [$t(22.46) = -1.93$, $p = .072$, $d = -0.60$], contrary to expectations the accuracy rates were higher for the low dispositional mindfulness group. With inclusion of extreme outliers this finding was not significant [$t(39) = -.604$, $p = .549$, $d = -0.19$]. No group differences in response time for the infrequent targets was found ($p > .1$), see *Figure 3*.

Distractor and standard false alarm rates

For the frequent standard and infrequent distractor stimuli false alarm rates (% of keyboard press responses when response withholding was the correct response) were analysed. No group differences in the false alarm rates for the frequent standard or infrequent distractor stimuli were found (all *p*s > .1), see *Figure 3*.

No significant differences between total mindfulness scores and behavioural measures for targets, distractors and standards were found (all *p*s > .1), see *Figure 3*.

Age analysis

To explore the impact of age on the behavioural result 2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs were conducted.

For target accuracy rates there was a significant main effect of age [$F(1, 37) = 5.48$, $p = .025$, $\eta^2 = .11$], accuracy rates were higher for older children. There was also a marginally significant group x age interaction [$F(1, 37) = 2.94$, $p = .095$, $\eta^2 = .06$], for older children there was no dispositional mindfulness group differences in accuracy rates ($p > .1$), for younger children accuracy rates were marginally higher for children in the low dispositional mindfulness group [$t(7.97) = -2.21$, $p = .058$, $d = -1.10$].

For target response times there was a marginally significant main effect of age [F(1, 37) = 3.68, p = .063, η^2 = .09], response times were faster for older children. There was no significant interaction between group or age (p > .1).

For distractor false alarm rates there was no significant main effect of age and no significant group x age interaction (all ps > .1).

For standard false alarm rates there was a significant age x group interaction [F(1, 37) = 6.81, p = .013, η^2 = .15], for older children there was no dispositional mindfulness group differences (p > .1), for the younger children, false alarm rates were marginally higher for the low dispositional mindfulness group [t(22) = -1.95, p = .07, d = -0.08].

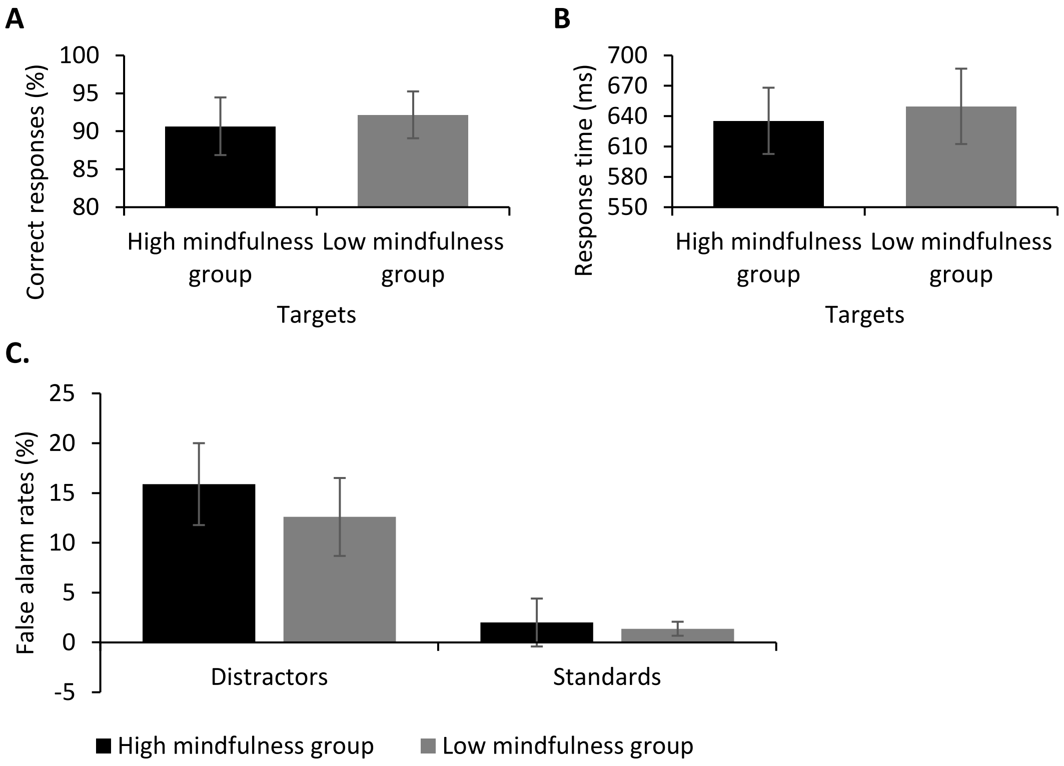


Figure 3. High dispositional mindfulness (n = 20) and low dispositional mindfulness (n = 21) group differences in A) accuracy rates (%) for targets; B) response times (ms) for targets and C) false alarm rates (%) for distractors and standards. Error bars indicate 95% confidence intervals (CI).

ERP Results

Data analysis was conducted on the P3b difference wave (Target P3b mean amplitude minus Standard P300 mean amplitude) and the No-go P300 difference wave (Distractor No-go P300 mean amplitude minus Standard P300 mean amplitude). The minimum number of trials included for each condition was 38 trials. When the assumption of Sphericity was violated, Greenhouse Geisser correction was applied during analysis.

P3b difference wave

No group differences in the P3b difference wave were found [$t(39) = .559$, $p = .579$, $d = 0.17$], see *Figure 4*. No significant correlations between total mindfulness scores and the P3b difference waves were found ($p > .1$)..

No-go P300 difference wave

No group differences in the No-go P300 difference wave were found [$t(39) = 1.45$, $p = .155$, $d = 0.45$], see *Figure 4*. No significant correlations between total mindfulness scores and the No-go P300 difference waves were found ($p > .1$).

Age analysis

To explore the impact of age on the P3b and No-go P300 ERP components. 2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs were conducted. No significant main effects of age and no significant age x group interactions were found (all *p*s > .1).

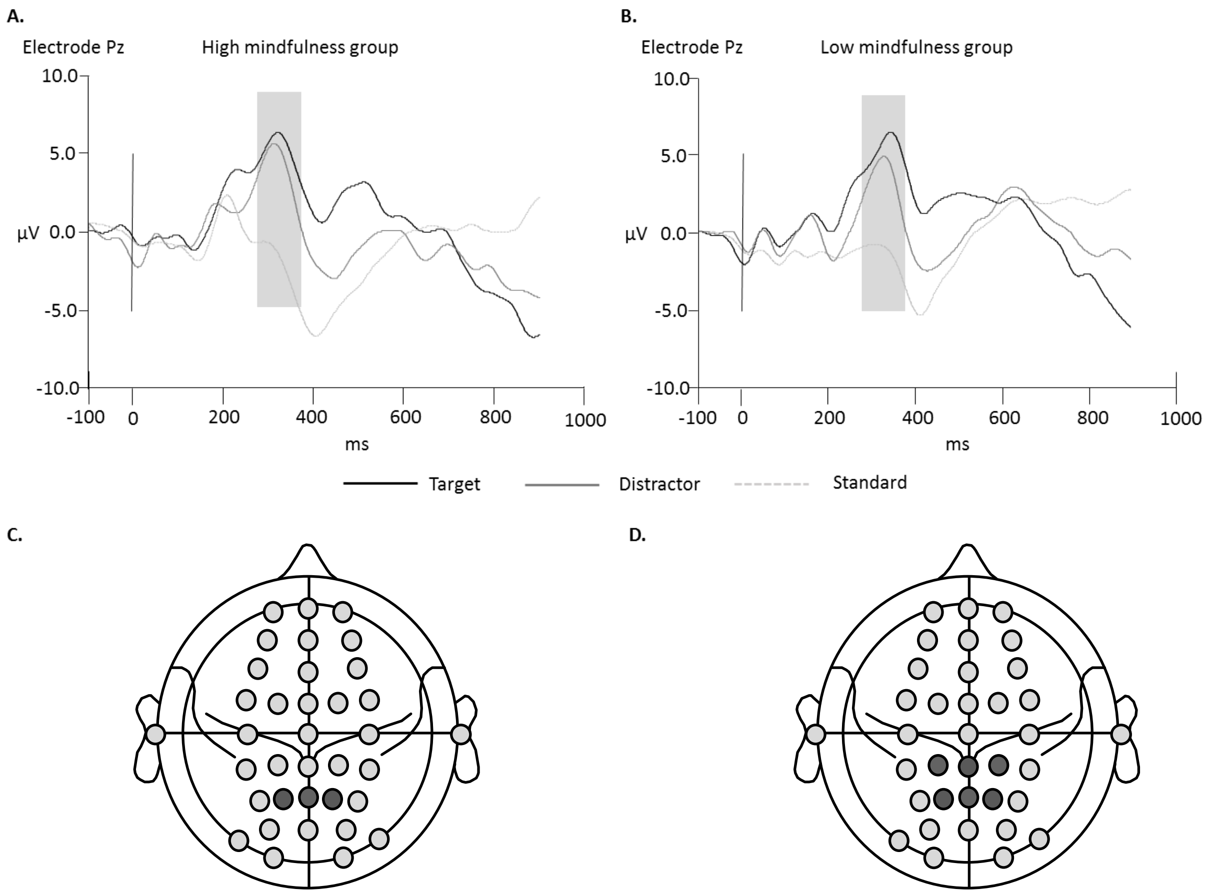


Figure 4. The P3b mean amplitude (275-370ms) elicited for targets at maximal electrode Pz and the No-go P300 mean amplitude (275-370ms) elicited for distractors at maximal electrode Pz for the (A) high dispositional mindfulness group (*n* = 20) and B) low dispositional mindfulness group (*n* = 21). C) shows the position of the electrodes the P3b mean amplitude was averaged across and D) shows the position of the electrodes the No-go P300 mean amplitude was averaged across. A 16Hz filter was applied to the ERP graphs for display purposes only.

Discussion

The current study investigated the relationship between dispositional mindfulness and attention control in pre-adolescents using electrophysiological markers (P3b, No-go P300) during a three-stimulus auditory oddball paradigm in conjunction with self-report measures. As expected the high dispositional mindfulness group had higher self-reported attention shifting and attention focusing abilities. In contrast to the study predictions, no group differences in the P3b difference waves (P3b mean amplitude for infrequent targets minus P300 mean amplitude for frequent standards) or No-go P300 difference waves (No-go P300 mean amplitude for infrequent distractors minus P300 mean amplitude for frequent standards) were found. In addition, there were no group differences in accuracy rates and response times for infrequent targets or false alarm rates for distractor and standard stimuli. Self-reports of mind wandering also did not significantly differ between groups.

The higher self-reports of attention shifting and attention focusing (facets of attentional control) for pre-adolescents with higher dispositional mindfulness is supported by previous developmental studies which have used self-report measures (Riggs et al., 2015; Shin et al., 2016). However, the ERP, behavioural and mind wandering self-report findings contradict this finding. This lack of significant findings contrasts with a previous study with 11 to 13 year olds which found that higher dispositional mindfulness was linked with enhanced attention control during an inhibitory control behavioural task (Oberle et al., 2012).

However, a lack of relationship between dispositional mindfulness and self-reports of mind wandering has previously been found in adults who completed a mindful breathing task which involved pressing a button during the task when they self-detected an episode of mind wandering (Mrazek et al., 2012). In addition, a study with older adolescents also did not find significant improvements in self-reported mind wandering during a Go/No-go oddball task after mindfulness training (Sanger & Dorjee, 2016). A potential reason for the lack of significant relationship between dispositional mindfulness and mind wandering could be due to the self-report assessments which were used. One difficulty of using self-report measures is that they require an accurate metacognitive awareness of internal states

(Bergomi et al., 2013). Therefore, in the context of self-reporting on mind wandering, the individual can only provide an accurate self-report if they are aware that their mind has indeed wandered away from the task. It is possible that the pre-adolescents in this study did not possess adequate metacognitive skills to self-report on their mind wandering, especially considering that these skills are still undergoing development during childhood (Davis et al., 2011; Dignath & Büttner, 2008).

Perhaps a relationship between mind wandering and dispositional mindfulness would be present for pre-adolescents if assessed via well-designed behavioural tasks which do not rely on the participants self-detecting episodes of mind wandering. For example, whilst Mrazek et al., (2012) did not find a relationship between dispositional mindfulness and mind wandering during a mindful breathing task when participants were required to self-detect mind wandering, a relationship was found during this task when thought probes were used to assess frequency of mind wandering.

With regards to the lack of relationship between dispositional mindfulness and the P3b difference waves and No-go P300 difference waves, this too was unexpected and in contrast to previous mindfulness studies with adults (Delgado-Pastor et al., 2013; Schoenberg et al., 2015; Quaglia et al., 2015b). A previous study with older adolescents also did not find P300 modulations for infrequent distractor and infrequent targets during a Go/No go oddball task after mindfulness training (Sanger & Dorjee, 2016), suggesting that perhaps these ERP components are not developmentally sensitive markers of mindfulness related modulations.

The lack of significant differences in behavioural performance suggests that both the high and low dispositional mindfulness group found the task equally challenging. During demanding tasks, the processing of task irrelevant distractors (such as task irrelevant episodes of mind wandering) can be suppressed to reduce distractibility and preserve the allocation of limited attention resources towards task relevant stimuli (Corbetta et al., 2008; Frank & Sabatinelli, 2012; Smallwood & Schooler, 2006). In contrast, mind wandering tends to be higher during undemanding tasks as these tasks do not require extensive attention resources (Smallwood & Schooler, 2006). Perhaps group differences in dispositional mindfulness would become apparent during a less demanding task in which mind wandering potential is greater. The effect of task demands on the link between dispositional mindfulness and mind wandering in pre-adolescents is a potential research direction which could be studied in the future. As the findings from this study have found, older pre-adolescents are often more accurate and have faster response times than younger children (Lewis et al., 2006b). Therefore, age is an important factor to consider when investigating the effects of task demands on dispositional mindfulness and mind wandering.

Limitations and future research

This study had several limitations, firstly, the study relied on self-reports of mindfulness and mind wandering. The Child and Adolescent Mindfulness Measure, which was used to assess dispositional mindfulness in this study as well as the reports of mind-wandering heavily rely on metacognitive introspective awareness of mental contents and processes, which are still undergoing development during childhood (Davis et al., 2011; Dignath & Büttner, 2008). Whilst there are limitations of using self-reports to assess dispositional mindfulness, it is to date the most frequently used research method of assessing dispositional mindfulness (Brown et al., 2011a) and therefore currently the most validated. Future studies could explore the use of more experimental rather than self-report methods of mindfulness and mind wandering, such as thought probes, to measure the association between dispositional mindfulness and mind wandering (Levinson, Stoll, Kindy, Merry & Davidson, 2014) in pre-adolescents. Aside from the limitations of self-reports, another limitation of this study is that it followed a cross sectional design and therefore it is not possible to make inferences about causal links between dispositional mindfulness and attention control in pre-adolescents based on its findings.

To date no published studies investigated the link between dispositional mindfulness and attention control in pre-adolescents using ERP components and therefore further research on the links between dispositional mindfulness and attention control using an integration of behavioural and ERP research methods is needed to extend these findings. Previous studies of dispositional mindfulness with developmental populations have focused on specific attention control skills such as inhibitory control (Oberle et al., 2012; Riggs et al., 2015). Perhaps recording electrophysiological measures during tasks such as the Go/No-go task (without the oddball manipulation) which measures response inhibition and conflict monitoring, may be more sensitive to group differences in dispositional mindfulness in pre-adolescents. It is, however, also possible that the P300 family components are developmentally not sensitive markers of dispositional and trained mindfulness.

Conclusion

This study explored the relationship between dispositional mindfulness and attention control in pre-adolescents using neural, behavioural and self-report assessments. Whilst individuals higher in dispositional mindfulness had higher self-reports of attention control, the behavioural and ERP results did not support this self-report finding. This study therefore did not find robust converging evidence in support of a relationship between dispositional mindfulness and attention control in pre-adolescence across the different research methods used. The lack of consistent findings across the neural, behavioural and self-report measures highlights that using an integration of these measures might be useful in providing a detailed assessment of the strength of the relationship between dispositional mindfulness and attention control in pre-adolescents. Further research employing the integrative approach which combines neural, behavioural and self-report measures is needed to examine in depth whether higher dispositional mindfulness is linked with better attention control in pre-adolescence.

Chapter Five - Investigating the associations between dispositional mindfulness and event-related potential (ERP) markers of emotion processing in pre-adolescents

Abstract

The cultivation of adaptive emotion processing during childhood has been linked with socioemotional wellbeing. It has been suggested that higher dispositional mindfulness, a natural tendency to monitor and direct attention resources towards present moment experiences in an open and non-judgemental way, is linked with better emotion processing abilities in adults. This study employed a neurodevelopmental approach to explore the relationship between dispositional mindfulness and emotion processing in pre-adolescents. EEG signal was recorded whilst pre-adolescents completed an emotion oddball task. Pre-adolescents in the high dispositional mindfulness group (n = 25) elicited a less positive LPP mean amplitude to emotional (angry and happy) and neutral faces after controlling for self-reports of attentional control (p = .05, η^2 = .08). In addition, the high dispositional mindfulness group reported lower negative affect (p = .05, d = -0.57), fewer difficulties with emotional awareness (p < .001, d = -1.30) and expression (p < .001, d = -1.08) as well as higher attention shifting (p = .002, d = 0.96) and focusing (p = .017, d = 0.71) compared to the low dispositional mindfulness group (n = 24). No group differences in P1, N2 or P3b mean amplitudes were found. This study suggests that pre-adolescents with higher dispositional mindfulness might be less emotionally reactive during the later stages of stimulus processing and have better self-reported emotion processing and attention control abilities.

Emotions, as multifaceted responses involving changes in physiology, thoughts and behaviour, arise when environmental stimuli have a biological or motivational significance to individuals (Gross & Thompson, 2007). Emotional facial expressions, for example, are salient due to their potential to convey important social information (Batty & Taylor, 2006; Pollak & Kistler, 2002). The ability to identify and respond appropriately to these emotional expressions increases during development (Herba, Landau, Russell, Ecker & Phillips, 2006; Thomas, De Bellis, Graham & LaBar, 2007; Wu et al., 2016) and has been linked with adaptive socioemotional functioning (Dennis et al., 2009; Van Bockstaele et al., 2014).

There are individual differences in the emotional responses to emotional facial expressions; for example, attentional biases towards sad faces were found in youths at risk of depression (Joormann, Talbot & Gotlib, 2007), and biases towards angry faces were found for children with anxiety (Waters et al., 2008a; Waters et al., 2010). Whilst some studies have also found heightened responses towards happy faces in children with anxiety (Bradley, Mogg, White, Groom & Bono, 1999; Martin, Williams & Clark, 1991; Waters et al., 2008a), others found an under-engagement with happy faces in children with anxiety (Gamble & Rapee, 2009) and with a history of physical abuse (Pollak et al., 1997). In contrast, pre-adolescents without clinical difficulties responded in a balanced way to both positive and negative emotions (Bar-Haim et al., 2007; Waters et al., 2008a).

Mindfulness is a self-regulatory capacity where metacognitive skills are engaged to monitor and direct attention towards experiences which arise in the present moment in a non-judgemental, accepting and non-reactive way (Bishop et al., 2004a; Dorjee, 2016; Shapiro et al., 2006). Mindfulness can be cultivated through mindfulness training and can also occur as a disposition **-** dispositional mindfulness describes gradients of the natural tendency to direct attention in an accepting, non-judgemental way towards experiences, without prior meditation training (Quaglia et al., 2015a). The association between dispositional mindfulness and emotion processing has not been examined in pre-adolescents, however, promising findings have been found with adults and adolescents. Most studies focus on individual differences in dispositional mindfulness for individuals without prior mindfulness training**.** For adults, high dispositional mindfulness has been associated with lower perceived stress, lower resting cortisol levels (Zimmaro et al., 2016) and reduced depression and anxiety (Bränström, Duncan & Moskowitz, 2011). Regarding positive traits, dispositional mindfulness has been linked to higher wellbeing (Zimmaro et al., 2016), a greater ability to cognitively reappraise negative emotions (Modinos et al., 2010) and better perceived health (Bränström et al., 2011). Dispositional mindfulness was also found to be a moderator between physiological arousal during a stress inducing task and self-reported experiences of negative affect; adults with lower dispositional mindfulness experienced an increase in negative affect as physiological arousal increased during the task (Feldman, Lavallee, Gildawie & Greeson, 2016).

In adolescents, dispositional mindfulness was also found to be a moderator of the relationship between life hassles and symptoms of depression, anxiety and stress; for adolescents with lower dispositional mindfulness, as life hassles increased the experience of these clinical symptoms also increased (Marks, Sobanski & Hine, 2010). In other studies, higher dispositional mindfulness was linked with greater inhibitory control (Oberle et al., 2012) and better executive functions (Riggs et al., 2015; Shin et al., 2016) in adolescents. Higher parental mindfulness was also linked with lower reports of negative parenting and internalising and externalising disorders in their children (Parent, McKee, Rough & Forehand, 2016).

From a neurocognitive perspective, higher dispositional mindfulness is associated with greater top-down inhibitory connections between the ventrolateral and ventromedial prefrontal cortex and the amygdalae in adults (Creswell et al., 2007; Modinos et al., 2010). This is of relevance for pre-adolescents as the ability to adaptively respond to emotions becomes more efficient during development as a result of increasing connectivity between these top-down and bottom-up regulatory areas (Lewis & Todd, 2007; McRae et al., 2012; Qin et al., 2012). Pre-adolescents with higher dispositional mindfulness may therefore have more adaptive emotion regulation abilities.

Event-related potentials (ERPs), non-invasive electrophysiological measures of neural brain changes which occur in response to the presentation of a stimulus (Sur & Sinha, 2009), can provide developmentally sensitive markers of the association between dispositional mindfulness and emotion processing at different stages of an emotional response (Hajcak et al., 2010; Luck, 2014; Woodman, 2010). For example, the P3b component indexes voluntary attention resource allocation - this parietal positivity is elicited approximately 300ms after stimulus onset (Chennu et al., 2013; Polich, 2007). A more positive P3b is typically observed for task relevant targets, which are usually presented infrequently in an oddball paradigm (Kok, 1997; Polich, 2007). For children without clinical difficulties in emotion processing the P3b for positive and negative emotional stimuli is similar (Kujawa et al., 2013b; Pollak et al., 1997; Shackman et al., 2007). In contrast, more positive P3b amplitudes in response to negative emotional stimuli have been found for children with a history of maternal maltreatment (Shackman et al., 2007) and linked with decrements in task performance for typically developing children (Kujawa et al., 2013b). The association between dispositional mindfulness and emotion processing has not previously been explored using the P3b in either children or adults. However, the P3b amplitude was found to be sensitive to the impact of a brief mindfulness induction in adults (Eddy et al., 2015). In this study whilst no relationship between the P3b and dispositional mindfulness was found, a less positive P3b to negative stimuli was linked with greater decentering (the ability to observe thoughts and feelings as transient states rather than stable unchangeable traits; Fresco et al., 2007). Mindfulness theories suggest that decentering is important for enabling present moment thoughts and feelings to be viewed without the bias of preconceived perceptions (Shapiro et al., 2006).

Just like the P3b, the LPP is also elicited at approximately 300ms after stimulus onset, however, this component is a more sustained wave than the P3b and can produce a modulation lasting up to 2000ms after stimulus onset at parietal/occipital sites (DeCicco et al., 2012; Hajcak & Dennis, 2009; Kujawa et al., 2013b). The LPP provides a measure of sustained emotional responses and is modulated by both valence and arousal (Hajcak et al., 2010; Schupp et al., 2000), a more positive LPP is often found for emotional stimuli and stimuli of higher arousal (Hajcak et al., 2010; Schupp et al., 2000). Higher dispositional mindfulness was linked with less positive LPP amplitudes for highly arousing negative images, suggesting that adults with higher levels of dispositional mindfulness naturally show less sustained reactivity to negative stimuli. Interestingly, no significant association between dispositional mindfulness and the LPP for highly arousing positive stimuli was found, except for those involving highly arousing adult content which is unsuitable for use with children (Brown et al., 2013).

No studies have so far used the LPP amplitude as an index of emotion processing in pre-adolescents in association with dispositional mindfulness. The LPP amplitude has, however, previously been found to be a developmentally sensitive marker of emotion processing in typically developing and clinical samples of pre-adolescents. For typically developing pre-adolescents aged between 8 and 13 years, a more positive LPP for positive distractors was linked with reduced accuracy rates to targets presented after these distractors (Kujawa et al., 2012b). This suggests that the enhanced emotional response to the distractor restricted the resources available to effectively respond to the target leading to a reduction in task performance. For children aged between 7 and 19 years with a diagnosis of social anxiety, a more positive LPP amplitude was found for angry and fearful faces during an emotional face matching task in comparison to typically developing children (Kujawa, MacNamara, Fitzgerald, Monk & Phan, 2015). The LPP amplitude could, therefore, be used to explore whether pre-adolescents with higher dispositional mindfulness (associated with more adaptive emotion processing in adult studies, e.g. Brown et al., 2013) would show lower sustained emotional responses to negative stimuli.

The N2 component, a negativity approximately elicited between 200 and 400ms after stimulus onset at fronto-central sites, indexes executive attention processes including response inhibition and conflict monitoring (Buss et al., 2011; Lewis et al., 2006b; van Veen & Carter, 2002b). A more negative N2 is found for trials in which a participant is required to inhibit a response (No-Go trials; Chapman et al., 2010; van Veen & Carter, 2002b). For typically developing children, a more negative N2 during negative emotion inducing tasks was found in conjunction with better task performance (Lewis et al., 2006b), possibly due to an increased ability to recruit executive attention resources when needed. In adults, higher dispositional mindfulness was associated with more negative N2 amplitudes for neutral, positive and negative non-targets and better behavioural performance in an emotional Go/No-go task (Quaglia et al., 2015b). Pre-adolescents with higher dispositional mindfulness may therefore be able to recruit executive attention abilities in a more efficient way during both non-emotion inducing and emotion inducing situations compared to individuals with lower dispositional mindfulness.

The P1 component indexes the initial stages of stimulus processing and is a positivity elicited approximately 100ms after stimulus onset at occipital electrodes (Batty & Taylor, 2006; Todd, Lewis, Meusel & Zelazo, 2008). This component is particularly sensitive to facial expressions, with a more positive P1 amplitude indexing greater attention allocation for visual processing (Batty & Taylor, 2006; Dennis et al., 2009; O'Toole & Dennis, 2012). Mixed results have been found regarding whether the P1 amplitude is sensitive to different emotions in pre-adolescents (Batty & Taylor et al., 2006; Todd et al., 2008). Gradual reductions in the positivity of the P1 amplitude have been found during pre-adolescence for both emotional and non-emotional stimuli, suggesting that early stages of stimulus processing become more automatic and efficient (Batty & Taylor, 2006; MacNamara et al., 2016).

Enhanced P1 amplitudes for angry, happy and calm faces have been found for children with anxiety in comparison to typically developing children (Hum, Manassis & Lewis, 2013a). For adults with social anxiety, larger scores on a self-report of fear were linked with more positive P1 amplitudes for emotional and non-emotional faces (Kolassa & Miltner, 2006). These findings suggest that for individuals with anxiety, early stages of stimulus processing could be less effective. The association between dispositional mindfulness and early stimulus processing has not been explored using the P1 amplitude, however, a mindfulness intervention study found that in comparison to pre-adolescents who had received mindfulness training, pre-adolescents in a wait-list control group showed a more positive P1 amplitudes over time for emotional and non-emotional stimuli (chapter seven). Mindfulness is considered an antecedent focused strategy which facilitates the efficient allocation of attention resources during early stages of an emotional response (Teper et al., 2013) and the P1 amplitude may therefore be a useful index of the association between dispositional mindfulness and emotion processing during these early stages of stimulus processing.

This study explored the association between dispositional mindfulness and emotion processing in pre-adolescents aged between 7 and 11 years. To provide a neurocognitive assessment of the association between dispositional mindfulness and the processing of emotional faces, the P1, N2, P3b and LPP ERP markers were measured during an emotion oddball paradigm with Go and No-go oddballs. This task involved the presentation of happy and angry faces as infrequent targets (Go oddballs) and non-targets (No-go oddballs) randomly displayed amongst frequent neutral non-targets. It was expected that pre-adolescents with higher dispositional mindfulness would elicit less positive P3b for angry targets and also less positive LPP amplitudes for angry targets and non-targets. This would reflect a more balanced non-reactive response to negative stimuli during the voluntary stages of attention resource allocation (indexed by the P3b) and during the subsequent sustained emotional response (indexed by the LPP). A more negative N2 for happy and angry non-targets was also expected, reflecting an increased ability to recruit executive attention abilities during an emotionally demanding situation. In addition, an exploratory analysis was conducted on the P1 amplitude to examine whether higher dispositional mindfulness was linked with less positive amplitudes to all facial expressions, which would suggest more efficiency during the early stages of stimulus processing. No specific hypotheses were given for the association between dispositional mindfulness and behavioural measures due to the lack of consistent findings in previous literature (Creswell et al., 2007; Quaglia et al., 2015b). Finally, pre-adolescents with higher dispositional mindfulness were also expected to have higher self-reports of positive affect, attention shifting and attention focusing alongside lower self-reports of negative affect, difficulties with emotional awareness and emotional expression.

Method

Participants

As part of a larger study on mindfulness and self-regulation, participants (pre-adolescents aged between 7 and 11 years) were recruited from four primary schools in North Wales using convenience sampling. The study received ethical approval from Bangor University Ethics committee and the NHS Research Ethics Committee prior to participant recruitment. Pupils received a small gift of stationary in recompense for their participation. All participants had normal or corrected to normal vision and hearing, participants with a diagnosis of epilepsy were excluded from ERP testing. Informed parental consent and informed child assent was gained for 76 participants (one participant out of initial 77 did not provide informed verbal assent and therefore did not take part in the study). For this section of the study twenty-seven participants were removed from the analysis due to incompletion of the testing sessions (n = 6), high error rates (> 35%; n = 16) or excessive artifacts in the ERP data (n = 5).

The remaining 49 participants were divided into high dispositional mindfulness and low dispositional mindfulness groups based on a median split of scores on the child and adolescent mindfulness measure (CAMM; Greco et al., 2011), *see Figure 1.*

An independent samples t-test revealed no significant differences in age between the two groups [$t(47) = .346$, $p = .731$, $d = .10$] and a 2 x 2 chi squares test revealed no significant group differences in gender [$X^2(1, N = 49) = .987$, $p = .387$, $V = .142$]. There was no group differences in the number of participants recruited from schools scoring high and low on the socioeconomic criteria of free school meals $X^2(1, N = 49) = .234$, $p = .769$, $V = .069$]. There was a significant difference in English as a first language [$X^2(1, N = 49) = 6.56$, $p = .022$, $V = .366$], all participants in the low mindfulness group spoke English as a first language; in the high mindfulness group five pupils spoke Welsh and one pupil spoke German as a first language. Two participants in the high dispositional mindfulness group were ambidextrous, a 2 x 2 chi square revealed no significant differences in right or left handedness between the two group [$X^2(1, N = 47) = 1.4$, $p = .286$, $V = .209$], see Table 1.

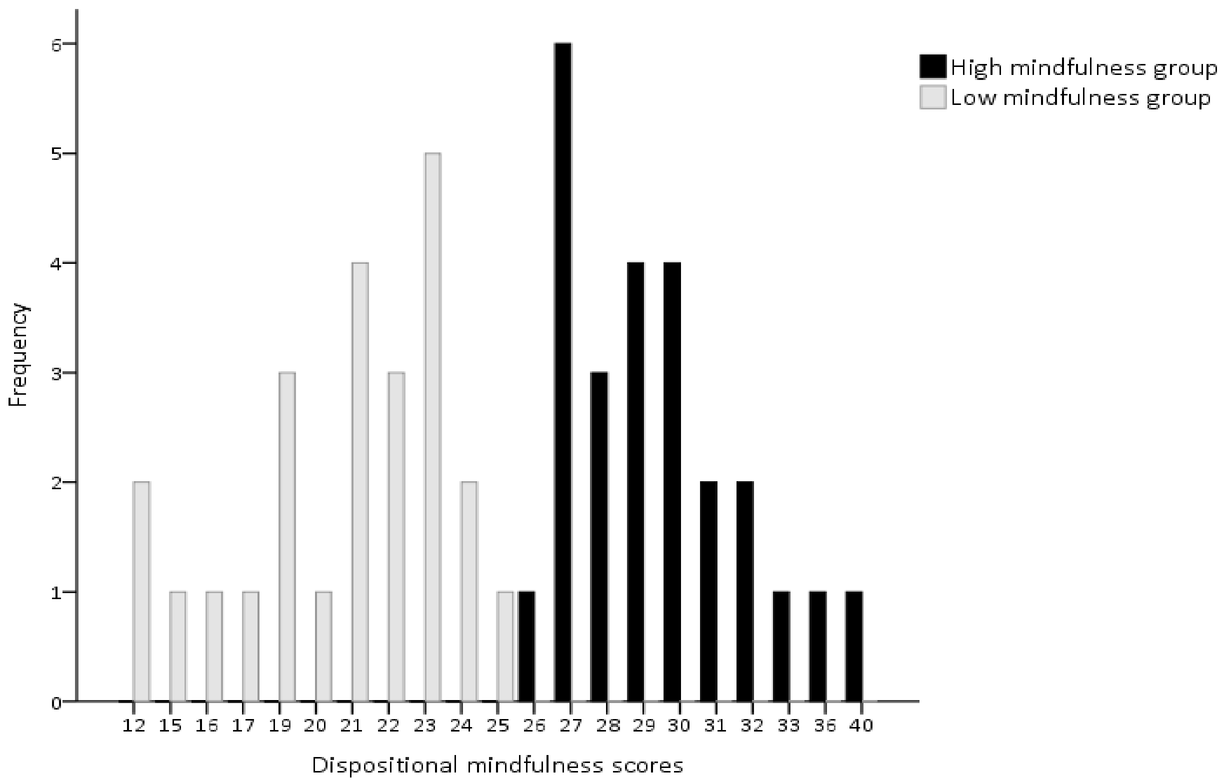


Figure 1. A histogram showing the frequency of dispositional mindfulness scores.

Table 1.

A summary of the demographic information for the participants (high dispositional mindfulness group n = 25, low dispositional mindfulness group n = 24)

	Demographic information			
	High mindfulness group		Low mindfulness group	
	(*n*)	(*%*)	(*n*)	(*%*)
Participants	25		24	
Gender: Female	8	32	11	45.83
Handedness: Right	17	68	21	87.50
First language: English	19	76	24	100
First language: Welsh	5	20	0	0
First language: Other	1	4	0	0
Age (Year 3)	1	4	2	8.33
Age (Year 4)	9	36	6	25
Age (Year 5)	4	16	11	45.83
Age (Year 6)	11	44	5	20.83
Age (*M*)	9.97 years		9.87 years	
Age (*SD*)	1.05 years		0.93 years	
Age (Range)	8.50 – 11.33 years		7.83 – 11.25 years	

Self-report measures

Participants completed a pre-screening form at the start of each session which collected demographics, handedness, language skills and brain injury/epilepsy information.

The 10-item Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011) evaluates the non-judgmental awareness and acceptance of experiences in the present moment. This measures uses a 5-point Likert scale (0 = never true to 4 = always true), all scores are reversed and a total mindfulness score is generated from the sum of the answers. The CAMM has been validated for use with children and adolescents aged between 10 and 16 years (Greco et al., 2011), another study found good internal consistency for children aged between 10 and 12 years (α = .71; de Bruin et al., 2014). The CAMM can be divided into two factors: present moment non-judgemental awareness (items 1, 2, 4, 6, 7, 8, 9) with good reliability for 10-12 year olds (α = .72) and suppressing or avoiding thoughts and feelings (items 3, 5, 10) which has lower internal consistency for 10-12 year olds (α = .58). In the current study, total CAMM scores and present moment non-judgemental awareness scores were calculated. Total CAMM scores were not impacted by gender in previous research (de Bruin et al., 2014; Greco et al., 2011). Good divergent and convergent validity has been found; the CAMM has medium negative correlations with self-reports of stress, self-blame, rumination and catastrophizing and small to medium positive correlations with self-reports of self-regulation and physical, emotional and social aspects of quality of life (de Bruin et al., 2014).

The 10-item Positive and Negative Affectivity Scale for Children (PANAS-C short version; Ebesutani et al., 2012) measures the frequency of positive and negative emotions experienced over the past few weeks. This measure uses a five-point Likert scale (1 = very slightly/ not at all, 5 = extremely) and has been validated for children aged 6 to 18 years (Ebesutani et al., 2012). High internal consistency was found for the negative affect subscale (α = .82) and the positive affect subscale (α = .86) for 6 to 18 year olds (Ebesutani et al., 2012). Good divergent validity has been reported for the negative affect subscale; children with anxiety and mood disorders scored higher on this subscale compared with children without anxiety disorders (Ebesutani et al., 2012). Good divergent validity has also been demonstrated for the positive affect subscale; children with mood disorders scored lower on the positive affect subscale compared with children without mood disorders (Ebesutani et al., 2012).

The 16-item Emotion Expression Scale for Children (EESC; Penza-Clyve & Zeman, 2002) measures poor awareness (reduced emotional awareness) and expressive reluctance (reduced motivation to express negative emotions). This measure uses a 5-point Likert scale (1 = not at all true, 5 = very true) and total scores for each subscale are calculated by summing the answers. This EESC has been validated for use with children aged between 9 and 12 years of age (Penza-Clyve & Zeman, 2002). High internal consistency was found for the poor awareness subscale ($\alpha = .83$) and the expressive reluctance subscale ($\alpha = 81$) for 9 to 12 year olds (Penza-Clyve & Zeman, 2002). This measure was not impacted by gender in a previous study (Penza-Clyve & Zeman, 2002). The poor awareness subscale has good divergent validity - it showed a small negative correlation with self-reports of regulation coping (Penza-Clyve & Zeman, 2002). Both subscales had medium to large positive correlations with self-reports of inhibition of behavioural expressions of negative emotions and self-reports of internalising symptoms, suggesting good convergent validity (Penza-Clyve & Zeman, 2002).

The 20-item Attentional Control Scale for Children (ACS-C; Muris et al., 2004) measures attentional focusing and attentional shifting. This measures uses a 4-point Likert scale (1 = almost never, 4 = always); some items are reversed and total scores for each subscale are calculated. The ACS-C has been validated for use with children aged between 8 and 13 years of age (Muris et al., 2004). Acceptable internal consistency was found for the attentional focusing subscale ($\alpha = .65$) and the attentional shifting subscale ($\alpha = .71$) for 8 to 13 year olds (Muris et al., 2004). Both attentional focusing and shifting showed medium to large negative correlations with self-reports of neuroticism and anxiety, suggesting that these subscales have good divergent validity (Muris et al., 2004).

Emotion Oddball paradigm

For the emotion oddball task, see *Figure 2*, emotional faces (neutral, happy, angry) from the Karolinska faces database (Lundqvist, Flykt, & Öhman 1998) were presented one at a time for 900ms with a gap of 750ms between each stimulus. For the happy and angry stimuli, faces of the same 38 actors with happy and angry facial expressions (19 male and 19 female) were used. The angry faces were presented for 15% of total trials, once as a target (38 trials) and once as a non-target (38 trials). The happy faces were also presented for 15% of total trials, once as a target (38 trials) and once as a non-target (38 trials). For the neutral faces one male and one female face was repeated for 70% of total trials (each presented for 176 trials).

The task consisted of four blocks with a break after each block. For two consecutive blocks, participants were instructed to respond to happy targets by pressing the keyboard and not respond to angry non-targets or neutral non-targets (neutral non-targets presented in these two blocks were given the abbreviation: neutral-Blocks1&2 non-targets). Then for two consecutive blocks the instructions were reversed; participants were instructed to respond to angry targets and not respond to happy non-targets or neutral non-targets (neutral non-targets presented in these two blocks were given the abbreviation: neutral-Blocks3&4 non-targets). The order of the consecutive blocks was counterbalanced and the faces presented within each block were randomised (each block maintained the proportion of neutral, angry and happy targets specified above). There were no group differences in the counterbalancing versions of the task which participants completed ($p < .1$). No differences in arousal or intensity were found between happy and angry faces or between male and female faces across the whole task or between the two halves of the task (all *p*s > .1). Based on ratings of correct identification of the emotional expressions reported in the Karolinska database, all faces used in the task had a correct identification rate above 70%; there were no differences in correct identification rate between the selected happy and angry faces (*p* > .1).

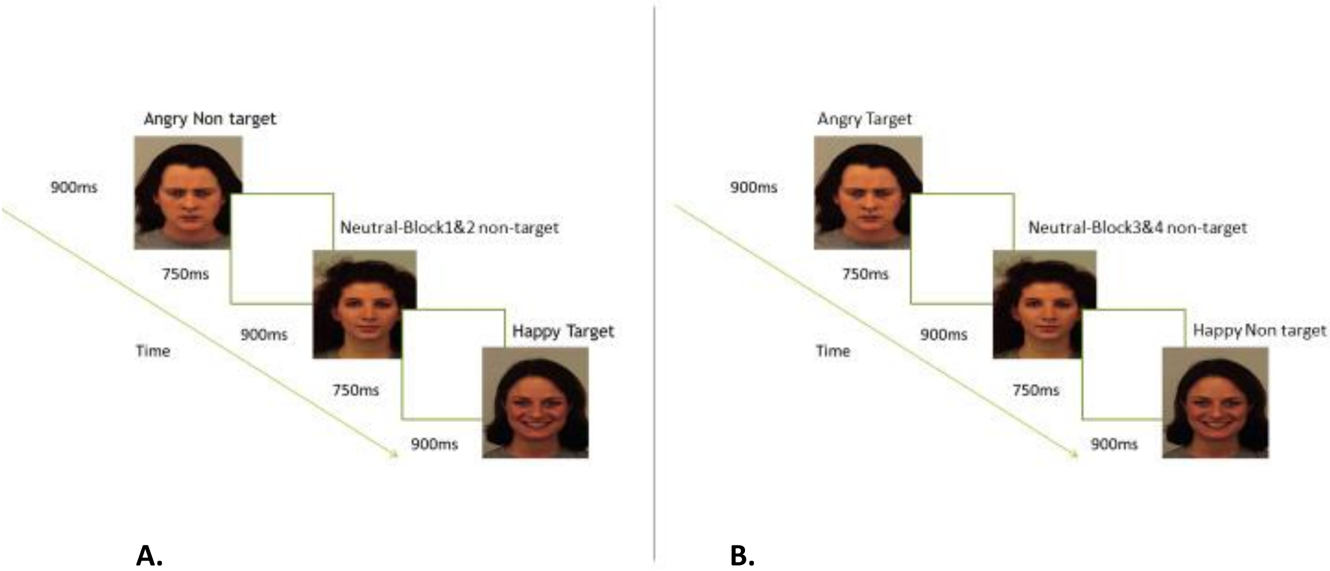


Figure 2. The emotion oddball task was divided into four blocks, A) shows two consecutive blocks where angry faces were infrequent non-targets and happy faces were infrequent targets and B) shows two consecutive blocks where happy faces were infrequent non-targets and angry faces were infrequent targets.

Design and procedure

Each data collection session took approximately an hour (the emotion oddball task took around 14 minutes and the self-report measures took approximately 25 minutes). The participants were assisted by a research assistant when completing the self-report questionnaires by reading the questions aloud. All data collection was conducted on school premises in a small private testing room using a portable EEG system. Participants were seated in front of a laptop which displayed the task. EEG signal was recorded during the task with a 32-channel EEG recording cap (EasyCap, Brain Products). Throughout the task, participants were instructed to remain still and focused on the computer screen, there were short breaks after each block. In addition to the emotion oddball task, participants also completed an attention oddball task and a resting heart-rate variability recording - results of these two additional tasks are reported in chapters four and six.

Event related potential (ERP) analysis

During the emotion oddball task, the EEG signal was collected using 32 Ag/AgCl electrodes referenced online to the right mastoid. Offline the right mastoid and left mastoid channels were averaged together using linear derivation to create the averaged mastoid reference to which the remaining electrodes were re-referenced. Neuroscan NuAmp amplifiers recorded the signal at a sampling rate of 1 kHz. To measure ocular movements, two additional electrodes were placed above and below the left eye. Electrode impedances were kept below 7kOhms. A bandpass filter of 0.01-200Hz was used to filter the EEG signal online. Offline a zero-shift higher cut off point of 30Hz and a 48/Db/Oct slope and a lower cut off point of 0.1Hz with 12/Db/Oct slope was applied to the EEG signal. The EEG signal was then manually cleaned to remove motor artefacts and irregular ocular artefacts. Following this, the Neuroscan ocular artifact removal algorithm was applied to remaining regular ocular artefacts. Incorrect trials were excluded from the ERP analysis. The data was epoched into 1 second segments and baseline corrected with the 100ms segment before the onset of the stimulus as a baseline. ERP averages were computed for each condition for each participant, then grand averages were computed across participants in each group for each condition. The grand mean global field power across the scalp was used to define the search intervals for ERP components and electrodes were selected at sites based on previous literature. The time window identified for the P1 amplitude was between 100-180ms and the mean amplitude was averaged across four electrodes: PO7, PO8, O1 and O2. This posterior topography is consistent with previous studies of P1 with children (Dennis et al., 2009; Hum et al., 2013a). The time window identified for the N2 amplitude was between 340-425ms and the mean amplitude was averaged across 8 electrodes: F3, F4, Fz, FC1, FC2, FC3, FC4 and FCz. The fronto-central topography and time window of the N2 component is consistent with previous N2 studies with pre-adolescents (Buss et al., 2011; Shackman et al., 2007). The time window identified for the P3b amplitude was between 425-620ms and the mean amplitude was averaged across five electrodes: P1, P2, P3, P4 and Pz. This parietal topography is consistent with previous P3b findings with adults and children (Polich, 2007; Shackman et al., 2007). The time window identified for the LPP amplitude was between 300-700ms and the mean amplitude was averaged across four electrodes: PO7, PO8, O1 and O2. This posterior topography is consistent with previous studies with pre-adolescents (Kujawa et al., 2012b; Kujawa et al., 2013a, Kujawa et al., 2013b; Kujawa et al., 2015). Latency was conducted for the P1, P3b and N2 components using the maximal electrode of interest which was electrode O1 for the P1 component, electrode P4 for the P3b component and electrode F3 for the N2 component.

Results

Self-reports, response times, accuracy rates and ERP components were analysed for 49 participants (high mindfulness group n = 25; low mindfulness group n = 24). The multiple imputation method was used to replace missing data during the analysis. Dispositional group differences were evaluated using independent samples t-tests (Cohen's *d* assessed effect size) or mixed factorial analysis of variance (ANOVA; with η^2 providing an estimate of effect size). Correlational analysis was also conducted to assess converging patterns across the different measures. Extreme outliers (>3 x interquartile range) were winsorised. Additional analysis, including age as a factor, was conducted to examine whether age impacted on the results. Children were divided into two age categories; older (years 5 and 6; 9.58 – 11.33 years) and younger (years 3 and 4; 7.83 – 9.42 years). Chi square tests revealed no significant group difference for these age categories [$X^2(1, N = 49) = .234$, $p = .769$, $V = .069$].

Self-report Results

Child and Adolescent Mindfulness Measure (CAMM)

There was no missing data. Fair internal consistency was found for the 10-item CAMM ($\alpha = .562$). The 10-item CAMM was further divided into the two subscales suggested by de Bruin et al., (2014), present non-judgemental awareness, which had good internal consistency ($\alpha = .692$), and suppressing or avoiding thoughts and feelings, which had poor internal consistency ($\alpha = .257$) – for this reason statistical analyses were not conducted on this subscale. Significant group differences were found [$t(47) = 9.77$, $p < .001$, $d = 2.79$], as expected the high mindfulness group had significantly higher mindfulness scores for the 10-item CAMM. The high mindfulness group also had significantly higher scores for the present moment non-judgemental awareness subscale [$t(47) = 8.72$, $p < .001$, $d = 2.49$], see *Figure 3*.

Positive and Negative Affectivity Scale for Children (PANAS-C)

There was no missing data. Good internal consistency was found for the negative affect subscale (α = .760) and the positive affect subscale (α = .715). For negative affect scores significant group differences were found [$t(47) = -2.01$, $p = .050$, $d = -0.57$], as expected the low mindfulness group scored higher in negative affect. For the positive affect scores there was no significant difference between groups ($p > .1$), see *Figure 3*.

There was a significant negative correlation between dispositional mindfulness and negative affect [$r(47) = -.42$, $p = .003$], dispositional mindfulness wasn't significantly correlated with positive affect ($p > .1$).

Emotion Expression Scale for Children (EESC)

For the EESC, one participant had missing data for question 11 (< 2%) which was replaced using multiple imputation. There was good internal consistency for the poor awareness subscale (α = .777) and for the expressive reluctance subscale (α = .778). There were significant group differences for the poor awareness [$t(47) = -4.56$, $p < .001$, $d = -1.30$] and expressive reluctance [$t(47) = -3.76$, $p < .001$. $d = -1.08$] subscales, as expected the low mindfulness group scored higher in both these subscales, see *Figure 3*.

Significant negative correlations were found between dispositional mindfulness and poor emotional awareness [$r(47) = -.615$, $p < .001$] and expressive reluctance [$r(47) = -.605$, $p < .001$].

Attentional Control scale for Children (ACS-C):

For the ACS-C acceptable internal consistency was found for the attentional shifting subscale (α = .659), and poor internal consistency was found for the attentional focusing subscale (α = .416). Good internal consistency was found for total attentional control (α = .720). There were significant group difference in attention shifting [$t(47) = 3.36$, $p = .002$, $d = 0.96$] and attention focusing [$t(47) = 2.47$, $p = .017$, $d = 0.71$], as expected the high mindfulness group scored higher in both of these subscales, see *Figure 3*.

Dispositional mindfulness positively correlated with attention shifting [$r(47) = .490$, $p < .001$] and attention focusing [$r(47) = .453$, $p = .001$].

Age analysis

To examine whether the self-report findings were impacted by age, 2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs were conducted. For poor emotional awareness there was a marginally significant group x age interaction [$F(1, 45) = 121.88$, $p = .063$, $\eta^2 = .01$], for younger children there was no dispositional mindfulness group differences in emotional awareness ($p > .1$), for older children scores were higher for the low dispositional mindfulness group [$t(29) = -5.00$, $p < .001$, $d = -1.81$]. No significant main effects or interactions were found for the total CAMM, positive affect, negative affect, expressive reluctance, attentional shifting or attentional focusing self-report questionnaires (all *p*s > .1).

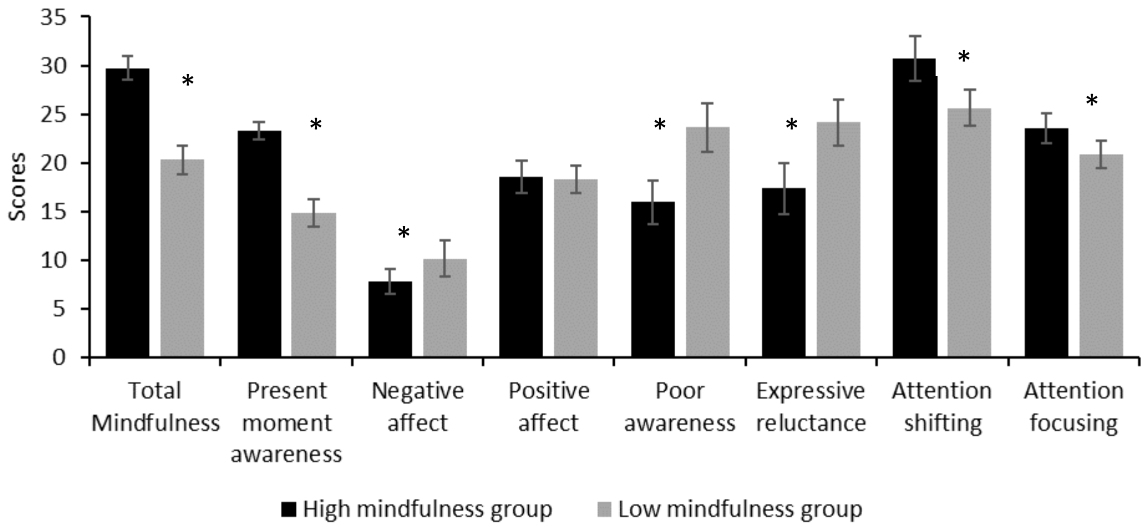


Figure 3. High dispositional mindfulness (n = 25) and low dispositional mindfulness (n = 24) group differences in total mindfulness scores, present moment non-judgemental awareness scores, PANAS-C negative affect and positive affect scores, EESC poor emotional awareness and expressive reluctance scores, ACS-C attentional shifting and attentional focusing scores. Error bars indicate 95% confidence intervals (CI).

Behavioural Results

Accuracy rates (% of correct responses) were calculated for angry and happy targets and false alarm rates (% of responses where a response was not withheld were considered incorrect) were calculated for angry and happy non-targets, neutral-Blocks1&2 non-targets and neutral-Blocks3&4 non-targets. Response times were calculated for only happy and angry correct targets. Response times were excluded if they were below 199ms or over 900ms. No missing data was found for the behavioural analysis. There were no group differences in the proportion of children excluded from data analysis due to poor error rates [X^2(1, N = 65) = 0.88, p = .399, V = .117].

Group differences in accuracy rates for angry and happy targets were assessed by a 2 (group; high mindfulness; low mindfulness) x 2 (condition; angry targets, happy targets) mixed factorial ANOVA. There was no significant main effects of condition or group and no significant condition x group interaction (all *p*s > .1) see *Figure 4*.

Group differences in false alarm rates for non-targets were assessed by a 2 (group; high mindfulness; low mindfulness) x 4 (condition; happy non-target, angry non-target; neutral-Blocks1&2 non-targets, neutral-Blocks3&4 non-targets) mixed factorial ANOVA. There was a significant main effect of condition [$F(1.80, 84.69) = 37.44$, $p < .001$, $\eta^2 = .44$], pairwise comparisons revealed higher false alarms for angry and happy non-targets compared to neutral non-targets (all *p*s < .1). There was no significant main effect of group or condition x group interaction ($p > .1$), see *Figure 4*.

Group differences in response times for the angry and happy targets were assessed using a 2 (group) x 2 (condition; angry targets, happy targets) mixed factorial ANOVA. There was no significant main effect of group, condition or condition x group interaction (all *p*s > .1), see *Figure 4*.

Age analysis

2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) x 2 (condition; angry targets, happy targets) mixed factorial ANOVAs were conducted to examine the impact of age on target accuracy rates and response times. For target accuracy rates there was a significant condition x group x age interaction [$F(1, 45) = 6.01$, $p = .018$, $\eta^2 = .11$], no dispositional mindfulness group differences were found for younger children (all *p*s > .1), for older children accuracy rates for happy targets were higher for the high dispositional mindfulness group [$t(29) = 2.28$, $p = .03$, $d = 0.83$]. For response times there was a significant main effect of age [$F(1, 45) = 7.26$, $p = .01$, $\eta^2 = .02$], response times were faster for older children. There was a marginally significant group x age interaction [$F(1, 45) = 2.97$, $p = .092$,

η^2 = .05], for the older children response times were faster for the high dispositional mindfulness group [$t(29) = -2.25$, $p = .032$, $d = -0.81$]. For the younger children, there were no dispositional mindfulness group differences ($p > .1$). There were no other significant main effects or interactions (all *p*s > .1).

To examine the effect of age on false alarm rates for non-targets a 2 (group; high mindfulness; low mindfulness) x 2 (age; younger children, older children) x 4 (condition; happy non-target, angry non-target; neutral-Blocks1&2 non-targets, neutral-Blocks3&4 non-targets) mixed factorial ANOVA was conducted. There was a marginally significant group x age interaction [$F(1, 45) = 3.04$, $p = .088$, $\eta^2 = .06$], follow up t tests were not significant (all *p*s > .1). There were no other significant main effects or interactions (all *p*s > .1).

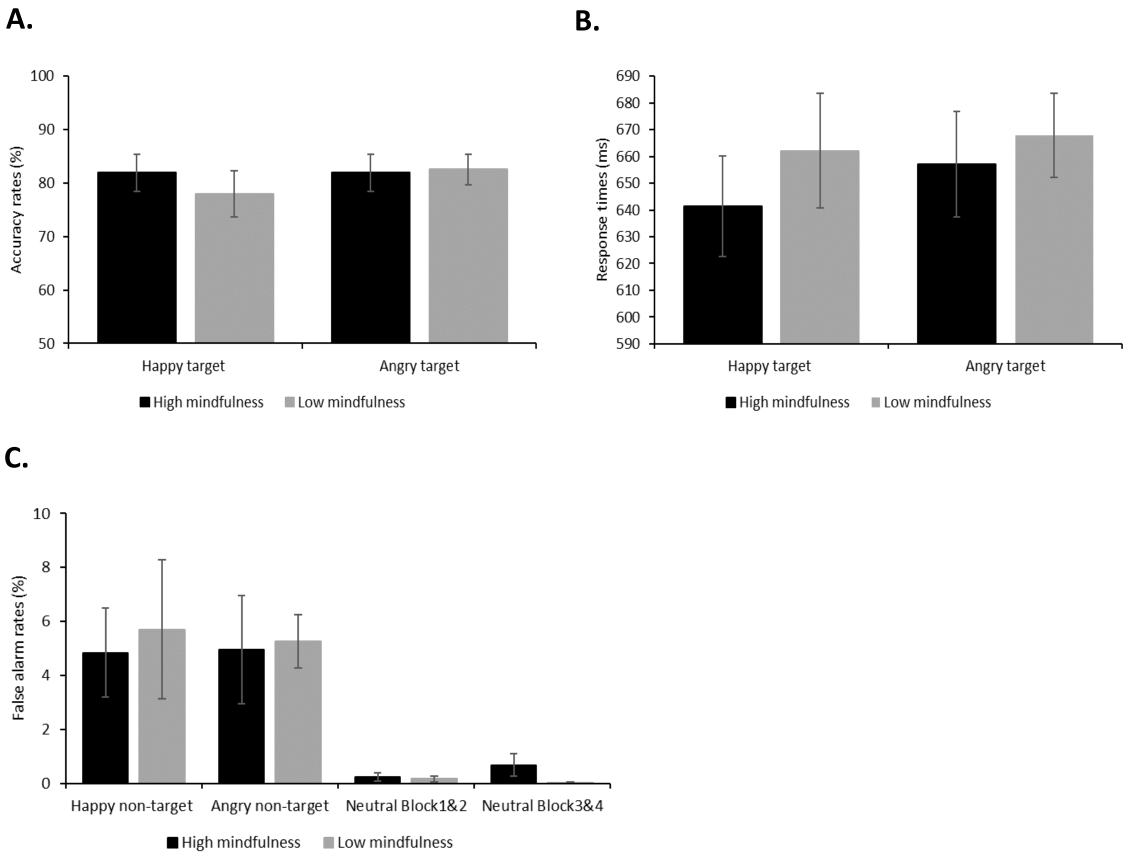


Figure 4. High dispositional mindfulness (n = 25) and low dispositional mindfulness (n = 24) group differences in A) accuracy rates (%) for happy and angry targets; B) response times (ms) for happy and angry targets and C) false alarm rates (%) for happy and angry non-targets and neutral non-targets. Error bars indicate 95% confidence intervals (CI).

ERP Results

Analyses were conducted on the P1, N2, P3b and LPP components. Each condition had a minimum of 23 trials. Greenhouse Geisser correction was applied during data analysis if the assumption of sphericity was violated. There was missing data for electrode FCz for one participant, this was replaced using multiple imputation.

P1 component

Group differences in the P1 mean amplitude were assessed by a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was no significant main effect of group or condition and no significant condition x group interaction (all *p*s > .1), see *Figure 5*.

Latency analysis was conducted on the maximal electrode of O1 using a 2 (group; training, control) x 6 (condition; angry non-targets, angry targets, happy non-targets, happy targets, neutral Block1&2 non-targets, neutral Block3&4 non-targets) mixed ANOVA. There was no significant main effect of condition or group and no significant group x condition interaction (all *p*s < .1).

N2 component

A 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA showed a significant main effect of condition [$F(4.01, 188.68) = 9.04$, $p < .001$, $\eta^2 = .16$]. Pairwise comparisons across conditions revealed that the N2 mean amplitude was significantly more negative for angry non-targets than all other stimuli (all *ps* > .1). In addition, the N2 mean amplitude for happy non-targets was significantly more negative than for neutral non-targets (all *ps* < .1) and marginally more negative than for happy targets. The N2 mean amplitude for angry targets was significantly more negative than neutral non-targets and happy targets (all *ps* < .1). There was no significant main effect of group and no significant condition x group interaction (all *p*s > .1), see *Figure 6*.

Latency analysis was conducted on the maximal electrode F3 using a 2 (group; training, control) x 6 (condition; angry non-targets, angry targets, happy non-targets, happy targets, neutral Block1&2 non-targets, neutral Block3&4 non-targets) mixed ANOVA. There were no significant main effects of condition or group and the group x condition interaction was also non-significant (all *p*s < .1).

P3b component

A 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA revealed a significant main effect of condition [$F(4.00, 188.35) = 67.53$, $p < .001$, $\eta^2 = .59$]. Pairwise comparisons across conditions revealed that, as expected, the P3b mean amplitude was significantly more positive for angry and happy targets compared to happy, angry and neutral non-targets. In addition, the P3b for angry targets was more positive than for happy targets. Angry and happy non-targets were also significantly more positive than neutral non-targets (all *p*s < .1). There was no significant main effect of group and no significant condition x group interaction (all *p*s > .1), see *Figure 7.*

Latency analysis was conducted on the maximal electrode P4 using a 2 (group; training, control) x 6 (condition; angry non-targets, angry targets, happy non-targets, happy targets, neutral Block1&2 non-targets, neutral Block3&4 non-targets) mixed ANOVA. There was a significant main effect of condition [$F(3.76, 176.77) = 18.13$, $p < .001$, $\eta^2 = .28$], pairwise comparisons revealed that the P3b latency was significantly earlier for neutral non-targets compared to angry and happy targets and non-targets, the P3b latency for angry non-targets was earlier than for happy non-targets and marginally earlier than for happy targets. Finally, the P3b latency for angry targets was earlier than for happy non-targets (all *p*s < .1).

LPP component

A 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA showed a main effect of condition [$F(3.71, 174.55) = 34.95$, $p < .001$, $\eta^2 = .42$]. Pairwise comparisons revealed that the LPP mean amplitude was significantly more positive for happy and angry targets compared to happy, angry and neutral non-targets. In addition, the LPP mean amplitude for happy and angry non-targets was more positive than for neutral non-targets (all *p*s < .1). There was no difference between happy and angry targets ($p > .1$).

There was also a marginally significant main effect of group [$F(1, 47) = 3.77$, $p = .058$, $\eta^2 = .07$], the LPP mean amplitude was more positive for the low mindfulness group compared to the high mindfulness group, see *Figure 8*. There was no significant group x condition interaction ($p > .1$). A 2 (group) x 6 (condition) mixed ANCOVA was also conducted on the LPP mean amplitude with self-reported attentional control as a covariate to control for the possible contribution of attention to the LPP difference between the two dispositional mindfulness groups. The main effect of condition remained significant [$F(3.77, 173.31) = 3.91$, $p = .005$, $\eta^2 = .07$] and there was a significant attentional control x condition interaction [$F(5, 230) = 2.87$, $p = .016$, $\eta^2 = .05$]. Importantly, the group effect became significant when self-reported attentional control was controlled for [$F(1, 46) = 4.04$, $p = .050$, $\eta^2 = .08$]. A partial correlation was conducted to measure the relationship between dispositional mindfulness scores and the LPP mean amplitude averaged across all conditions whilst controlling for the effects of attention control. This correlation did not reach significance [$r(47) = -.175$, $p = .234$].

Age analysis

To explore the impact of age on the P1, N2, P3b and LPP ERP component mean amplitudes, 2 (group; training, control) x 2 (age; younger children, older children) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVAs were conducted.

For the P1, N2 and LPP mean amplitudes, age did not impact on the findings (all *p*s > .1). For the P3b mean amplitude, there was a significant group x age interaction [$F(1, 45) = 5.92$, $p = .019$, $\eta^2 = .10$], for younger children the P3b mean amplitude was more positive across all stimuli for the low dispositional mindfulness group [$t(10.6) = -2.44$, $p = .034$, $d = -1.19$]. For older children, there was no dispositional mindfulness group differences ($p > .1$). There was also a significant condition x group x age interaction [$F(5, 225) = 2.68$, $p = .022$, $\eta^2 = .02$]. For younger children the P3b mean amplitude was more positive for the low dispositional mindfulness group for angry non-targets [$t(16) = -4.48$, $p < .001$, $d = -2.10$], and marginally more positive for neutral Block1&2 non-targets [$t(16) = -1.89$, $p = .078$, $d = -0.87$] and neutral Block3&4 non-targets [$t(16) = -2.05$, $p = .057$, $d = -0.96$]. For older children, there was no dispositional mindfulness group differences in the P3b mean amplitudes for the different conditions (all *ps* > .1).

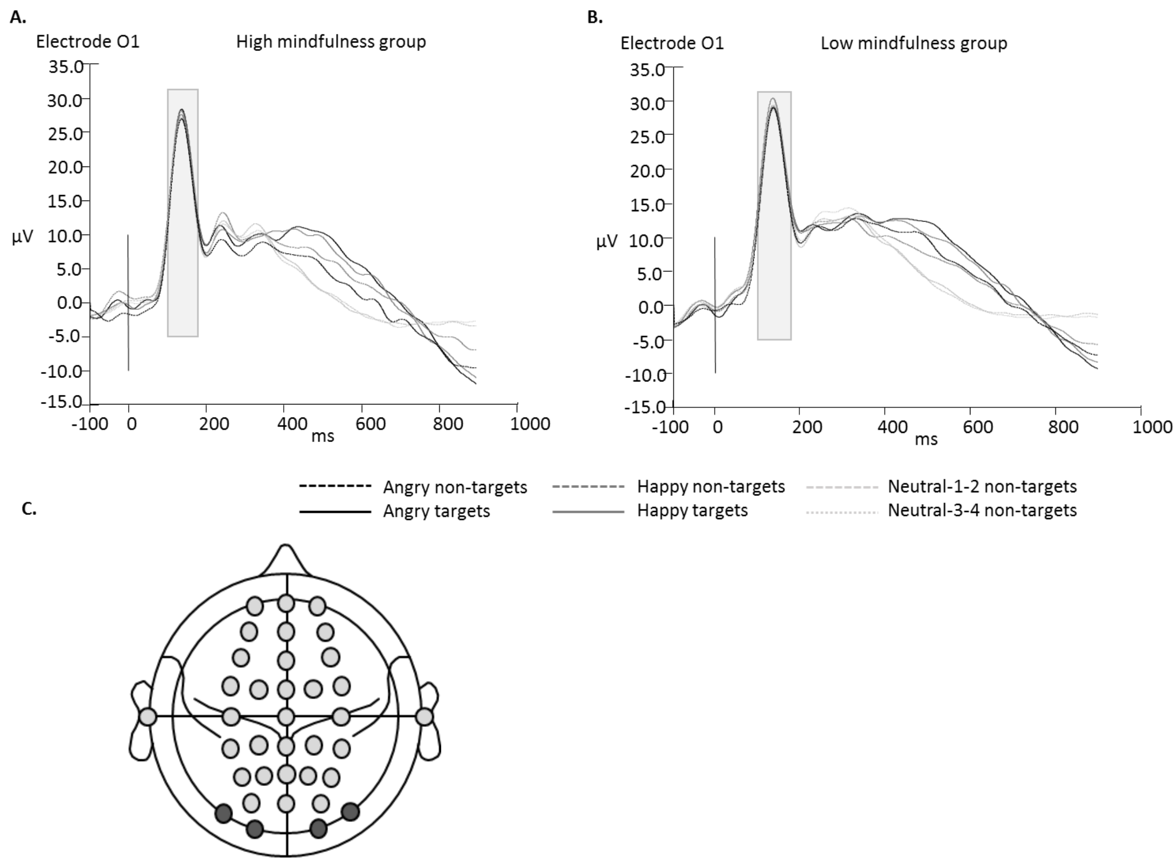


Figure 5. The P1 mean amplitude (100-180ms) elicited for happy and angry targets and non-targets and neutral non-targets at maximal electrode O1 for the (A) high dispositional mindfulness group (*n* = 25) and B) low dispositional mindfulness group (*n* = 24). C) shows the position of the electrodes the P1 mean amplitude was averaged across. A filter of 16Hz was applied to the graphs for display purposes only.

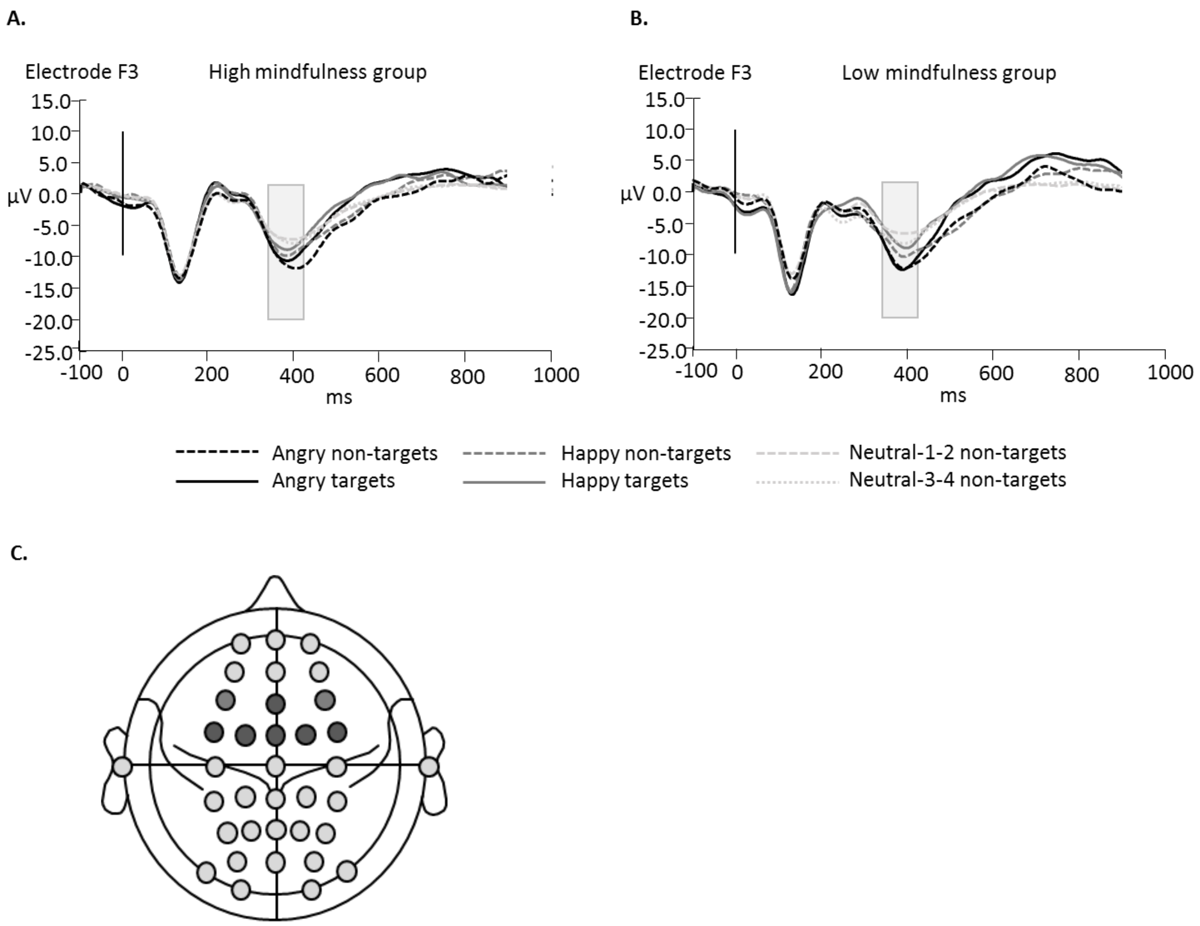


Figure 6. The N2 amplitude (340-425ms) elicited for happy and angry targets and non-targets and neutral non-targets at maximal electrode F3 for the (A) high dispositional mindfulness group (n = 25) and B) low dispositional mindfulness group (n = 24). C) shows the position of the electrodes the N2 mean amplitude was averaged across. A filter of 16Hz was applied to the graphs for display purposes only.

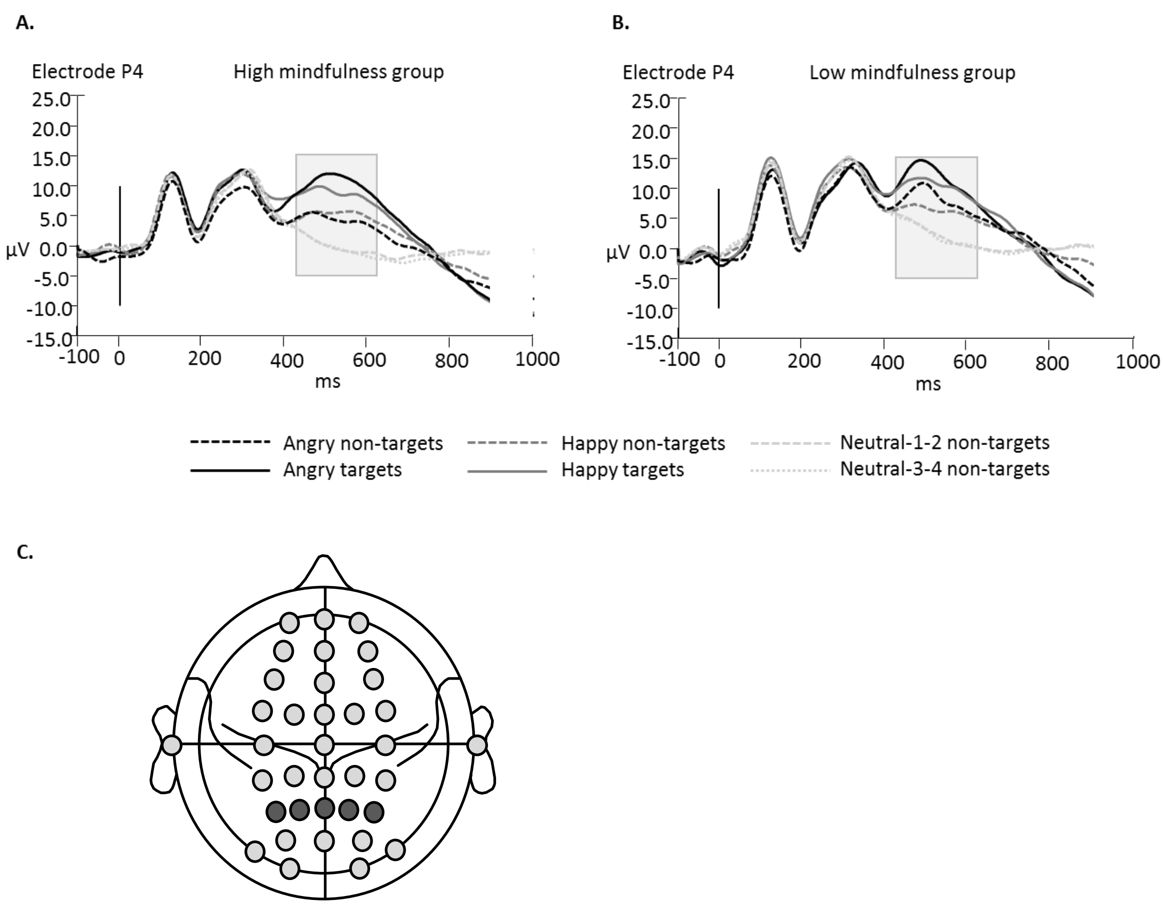


Figure 7. The P3b mean amplitude (425-620ms) elicited for happy and angry targets and non-targets and neutral non-targets at maximal electrode P4 for the (A) high dispositional mindfulness group (*n* = 25) and B) low dispositional mindfulness group (*n* = 24). C) shows the position of the electrodes the P3b mean amplitude was averaged across. A filter of 16 Hz was applied to the graphs for display purposes only.

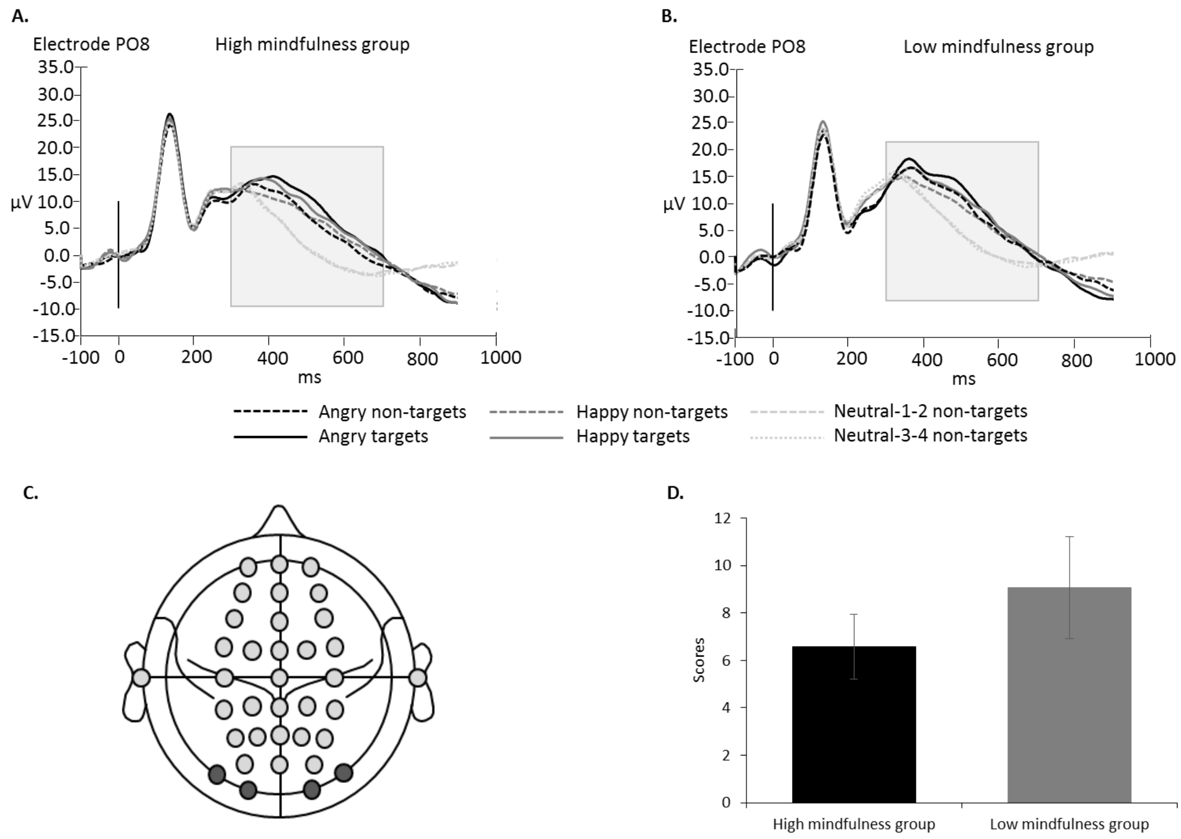


Figure 8. The LPP mean amplitude (300-700ms) elicited for happy and angry non-targets and neutral non-targets at maximal electrode PO8 for (A) the high dispositional mindfulness group (n = 25) and B) the low dispositional mindfulness group (n = 24). C) shows the position of the electrodes the LPP mean amplitude was averaged across, and D) is a bar chart displaying the group difference. A 16 Hz filter was applied to the graphs for display purposes only.

Discussion

This study aimed to investigate the relationship between dispositional mindfulness and emotion processing in pre-adolescent children; it was expected that self-report and electrophysiological measures would indicate that pre-adolescents with higher dispositional mindfulness would have more efficient emotion processing abilities. As expected the higher dispositional mindfulness group scored significantly lower in self-reports of negative affect, poor emotional awareness and expressive reluctance and higher in attentional shifting and focusing than the lower dispositional mindfulness group. No group differences in self-reports of positive affect were found. Regarding electrophysiological findings, for the high dispositional mindfulness group the LPP mean amplitudes were less positive across angry, happy and neutral face stimuli in comparison to the low dispositional mindfulness group after controlling for self-reported attention control. No group differences were, however, found for the N2 mean amplitude and P3b mean amplitude and exploratory analysis did not find group differences in the P1 mean amplitude either.

The self-report findings support previous self-report studies with pre-adolescents and adolescents suggesting that higher dispositional mindfulness is associated with better self-regulatory abilities. Marks et al. (2010) found that whilst adolescents with lower dispositional mindfulness showed an increase in self-reports of anxiety, stress and depression as self-reports of life hassles increased, this relationship between life hassles and symptoms was reduced in the higher dispositional mindfulness group. Another study with children aged between 9 and 13 years found that dispositional mindfulness was positively correlated with self-concept whilst at school, optimism and positive affect and negatively correlated with depression, anxiety and negative affect (Lawlor et al., 2014).

The finding that pre-adolescents with higher dispositional mindfulness elicited a less positive LPP mean amplitudes to all stimuli (happy, angry and neutral faces) also lends support to the idea that individuals with higher dispositional mindfulness have more adaptive emotion processing skills. A more positive LPP amplitude can index sustained emotional arousal (DeCicco et al., 2012; Hajcak et al., 2010; Solomon et al., 2012) and is linked with maladaptive emotion regulation strategies including rumination (Lewis, Taubitz, Duke, Steuer & Larson, 2015; Webb et al., 2017). In studies with pre-adolescents, a more positive LPP for negative stimuli was found for pre-adolescents who exhibited more fearful behaviour (Solomon et al., 2012) and for pre-adolescents with social anxiety (Kujawa et al., 2015), suggesting that the LPP amplitude can index difficulties with emotion processing abilities.

In the current study, the less positive LPP mean amplitude for angry faces found for the higher dispositional mindfulness group suggests that these pre-adolescents can process negative stimuli in a more efficient, less reactive way and are perhaps less likely to engage in maladaptive emotion processing strategies. Interestingly, the higher dispositional mindfulness group also showed a less positive LPP to positive and neutral stimuli, in comparison to the low dispositional mindfulness group. This could appear to be maladaptive as the sustained processing of positive emotion is thought to be an adaptive regulatory strategy linked with savouring (Wadlinger & Isaacowitz, 2010). Prolonged processing of positive emotions can, however, also be maladaptive if it disrupts the efficient allocation of attention resources towards other potentially important stimuli in the environment (Wadlinger & Isaacowitz, 2010). Indeed, one study with pre-adolescents found that an enhanced LPP amplitude for positive stimuli was linked with lower accuracy rates to the non-emotional targets following straight after (Kujawa et al., 2012b). In addition, a study with pre-adolescents found that those with severe generalised anxiety displayed a higher attentional bias towards both happy and angry faces on a dot probe task in comparison to healthy controls (Waters et al., 2008a), suggesting that enhanced overall reactivity to negative and positive stimuli can be an index of regulatory difficulties. In contrast, the findings of lower LPP mean amplitudes across angry, happy and neutral faces for pre-adolescents with higher dispositional mindfulness is in line with suggestions that higher dispositional mindfulness is linked with a balanced and non-reactive attitude towards experiences which may facilitate the efficient allocation of attention resources (Brown et al., 2013; Quaglia et al., 2015b).

This overarching LPP finding somewhat contradicts the results of a previous study with adults which found negative associations between the LPP amplitude and dispositional mindfulness for highly arousing negative stimuli and positive stimuli of highly arousing adult content only (Brown et al., 2013). The authors suggested that this was because these stimuli had the highest motivational salience. Whilst Brown et al. (2013) used IAPS images, our study used emotional facial expressions, IAPs images have been found to be more emotionally salient than emotional faces in pre-adolescents. Indeed, Kujawa et al., (2012b) found a more positive LPP for positive and negative IAPs images in comparison to neutral IAPs images, in comparison, emotional faces did not elicit a more positive LPP than neutral faces. For typically developing children attentional biases towards emotional faces in comparison to neutral faces are not found (Bar-Haim et al., 2007; Waters et al., 2008a), possibly because all facial expressions have the potential to signal salient social cues and therefore hold the same motivational salience. This could account for the lack of LPP valence effect found in this current study. Perhaps differences in ERP markers of emotion processing would become apparent for pre-adolescents with higher dispositional mindfulness in comparison to lower dispositional mindfulness in more emotion inducing tasks using IAPs images.

We controlled for the effects of attentional control on the LPP mean amplitude as dispositional mindfulness is often considered to overlap with the construct of attentional control (Brown et al., 2013). Whilst enhanced attentional control is an important aspect of dispositional mindfulness, a non-judgemental, accepting approach to experiences is also considered as an integral component (Coffey, Hartman & Fredrickson, 2010; Rau & Williams, 2016). In line with the Brown et al., (2013) study with adults, a significant LPP group effect was found in this current study when self-reports of attentional control were controlled for, this suggests that the two are separate constructs and that the LPP finding is not just the result of individual differences in attentional control.

No known published studies have investigated the association between dispositional mindfulness and early stages of emotion processing using the P1 amplitude. The lack of group difference in P1 mean amplitude suggests that higher dispositional mindfulness is not associated with enhanced efficiency during the early non-volitional stages of attention allocation, indexed by the P1 amplitude (Batty & Taylor, 2006; MacNamara et al., 2016). This null finding contrasts with the less positive P1 amplitude which was found for angry targets in pre-adolescents after mindfulness training, in comparison to a wait-list control group (chapter seven). This is an interesting disparity between dispositional mindfulness and mindfulness acquired through training and could highlight differences in the mechanisms underlying these two conceptualisations of mindfulness. Whilst both mindfulness training and dispositional mindfulness could be associated with more adaptive responses during the later stages of stimulus processing, perhaps training is needed to cultivate mindfulness skills to modulate the early stages of stimulus processing in pre-adolescents. Further research employing the same emotion processing task to directly compare mindfulness acquired through training and dispositional mindfulness is needed to clarify this point further.

The self-reported improvements in attention control were not supported by group differences in the N2 mean amplitude, an ERP index of conflict monitoring and response inhibition (Buss et al., 2011; Stieben et al., 2007; van Veen & Carter et al., 2002b). This is contrary to our predictions and a previous dispositional mindfulness study with adults (Quaglia et al., 2015b). The difference in the tasks used in the two studies might be the reason - in the dispositional study with adults, target stimuli were presented more frequently than non-target stimuli and so conflict monitoring and response inhibition skills were required to override the automatic response tendency (Quaglia et al., 2015b). In the current study, non-targets were presented more frequently than targets and so the response tendency would have been to not respond to non-targets and therefore the executive attention abilities may have been taxed to a lesser degree. In addition, the low false alarm rates for non-targets in the current study suggest that there was a ceiling effect. Perhaps differences in dispositional mindfulness would become apparent for the N2 amplitude in a task which requires more executive attention skills such as a Go/No-go task with more demanding target/non-target frequency manipulation.

Finally, no differences in the P3b mean amplitudes were found between the high and low dispositional mindfulness groups. This was, to our knowledge, the first study to explore the association between dispositional mindfulness and the P3b to emotional stimuli and the findings suggest that the P3b amplitude for emotional stimuli may not be sensitive to these trait differences in mindfulness in pre-adolescents. Previous studies with adults have also found that the P3b amplitude was not always sensitive to individual differences in traits such as anxiety (Rossignol, Philippot, Douilliez, Crommelinck & Campanella, 2005) or comorbid anxiety and depression (Campanella et al., 2010). A study investigating the effects of mindfulness training on emotion processing for pre-adolescents longitudinally also did not find group differences in the P3b amplitude between the training group and wait-list control group at post-test (chapter seven). Another potential reason which could explain the lack of P3b amplitude differences between pre-adolescents with high and low dispositional mindfulness could be that the task was not sufficiently emotionally arousing to induce group differences. Previously, a more positive P3b for angry target oddballs was found for children with a history of maltreatment in comparison to typically developing children. However, this task induced emotion through asking the mothers of the children to record emotional vocalisations and facial expressions (Shackman et al., 2007). Whilst there are serious ethical implications associated with using stimuli of such an emotionally arousing nature with children, it is possible that dispositional mindfulness group differences may become apparent for the P3b in a task which is more emotionally arousing. IAPs images for example have been found to be more emotionally arousing than emotional faces and are used extensively in research with children (Hajcak & Dennis, 2009; Kujawa et al., 2012b; Solomon et al., 2012).

Interestingly, when the sample was divided into older and younger age categories, dispositional mindfulness group differences did emerge. Older children with higher dispositional mindfulness had better task performance (faster response times and higher accuracy rates) than older children with lower dispositional mindfulness. In addition, the P3b mean amplitude was more positive for younger children with lower dispositional mindfulness in comparison to younger children with higher dispositional mindfulness. Both these findings suggest that higher dispositional mindfulness can be linked with more efficient emotion processing in pre-adolescents. This is the first known study to explore dispositional mindfulness effects in children as young as 7 years of age and these findings suggest that the association between dispositional mindfulness and emotion processing may change over the course of pre-adolescence. Future studies exploring the association should take the age of the sample into account.

Limitations and Future Directions

A key limitation of this study is that dispositional mindfulness was measured using a self-report measure. Whilst this is the most frequently used approach in dispositional mindfulness studies and has been proved effective in several previous neuroscience studies with adults (Brown et al., 2013; Creswell et al., 2007; Quaglia et al., 2015b; Way, Creswell, Eisenberger & Lieberman, 2010), there are shortcomings associated with using self-reports as a sole measure of dispositional mindfulness, especially for pre-adolescents. Self-reports require metacognitive awareness of mental states which pre-adolescents can struggle with for developmental reasons due to less developed metacognitive skills (Davis et al., 2011). In addition, pre-adolescents may have difficulties understanding the questions being asked (Zeman, Klimes-Dougan, Cassano & Adrian, 2007). An alternative approach could be a behavioural assessment of mindfulness, Davidson (2010) suggests that mind wandering, a construct which measures lapses of attention which is thought to be the opposite to mindfulness, could possibly provide a measure of dispositional mindfulness.

A further limitation was that due to the time constraints associated with collecting the data on school premises, the emotion oddball paradigm was shorter than a usual laboratory based experiment - stimulus presentation was shortened to 900ms and this presentation duration may have been too rapid for pre-adolescents. Due to the proportion of participants who were excluded from the analysis for low accuracy rates (> 35%), the sample size was smaller than expected. As the analysis only focused on correct trials, the ERP components were not affected by error rates.

In addition, the LPP findings showing a less positive LPP mean amplitude for the higher dispositional mindfulness group should be taken with caution as these results were not supported by a correlation between dispositional mindfulness and the LPP mean amplitude across all conditions whilst controlling for attention control. Perhaps the lower internal consistency which was found for total mindfulness scores contributed to this lack of significant correlation.

Conclusion

This is one of the first studies to investigate the association between dispositional mindfulness and emotion processing in pre-adolescents using self-report and electrophysiological measures. The findings suggest that higher levels of dispositional mindfulness in pre-adolescents are linked with more efficient emotion processing abilities (indexed by the self-report and LPP mean amplitude findings). The lack of significant group differences for the P1, N2 and P3b ERP components suggests that these components may not be sensitive to differences in dispositional mindfulness in pre-adolescents when assessed in an oddball paradigm. It is unclear at this stage whether these findings are sustained across different tasks. Whilst more research is needed to strengthen the understanding of the associations between dispositional mindfulness and emotion processing, these initial findings are encouraging and suggest that the LPP mean amplitude is a developmentally sensitive marker of individual differences in dispositional mindfulness.

Chapter Six - Mindfulness and heart rate variability with pre-adolescent children: Dispositional and intervention effects

Abstract

Mindfulness can be conceptualised as a disposition which occurs naturally without training and a skill which can be cultivated through training. Mindfulness training has been linked with enhanced self-regulation abilities in pre-adolescents, very few studies have explored the relationship between dispositional mindfulness and self-regulation in children. This study employed resting heart rate variability (HRV) indices alongside self-report measures to assess both the relationship between dispositional mindfulness and self-regulation (N = 48) and the impact of mindfulness training on self-regulation with pre-adolescents (N = 37). The high dispositional mindfulness group showed more effective self-regulation abilities as indexed by higher resting respiratory sinus arrhythmia (RSA; p = .047, d = -0.58) and total HRV (p = .037, d = 0.85) and lower cardiac sympathetic index (CSI; p = .071, d = 0.54) levels alongside fewer self-reported difficulties with emotional awareness (p < .001, d = 1.24) and expression (p = .005, d = 0.87) as well as better attentional shifting (p = .002, d = -0.99) and attentional focusing (p = .002, d = -0.95) abilities. In contrast, for pre-adolescents who received mindfulness training the RSA levels became lower (p = .014, d = 0.58) and CSI levels became higher (p = .002, d = -0.75) after training, these HRV indices did not change for the control group over time. The control group also showed increased negative affect over time (p = .004, d = -0.88), no other changes in self-report measures of attention control and emotion processing were observed for either group over time. Overall these findings suggest that the positive relationship between dispositional mindfulness and physiological measures of self-regulation does not necessarily map onto

longitudinal changes in physiological indexes of self-regulation with mindfulness training. This discrepancy needs to be investigated in future studies.

Mindfulness is a metacognitive self-regulatory capacity which involves the non-judgemental, non-reactive monitoring of experiences arising in the present moment (Dorjee, 2016). Dispositional mindfulness refers to the natural tendency to direct and sustain attention on the present moment with an accepting and non-judgemental attitude in the absence of mindfulness training (Quaglia et al., 2015a). Individuals with higher dispositional mindfulness are theorised to engage in mindful states with greater frequency (Brown, Ryan & Creswell, 2007). Mindfulness skills can also be cultivated through training; practices such as breath awareness train attention to focus on a specific object in the present moment (such as the breath) with an open and accepting attitude. In the actual process of mindfulness practice metacognitive skills are employed in monitoring for distractions (could be internal elaborative thoughts or external environmental distractions), and when these distractions are detected, attention is re-directed towards the present moment object again (Dickenson et al., 2012; Hasenkamp et al., 2012). It has been suggested that repeated engagement in mindfulness practices which train these metacognitive and attention abilities may enhance broader self-regulatory skills (Bishop et al., 2004a; Shapiro et al., 2006).

Self-regulation refers broadly to the ability to regulate cognitions, emotions and behaviours in a goal directed way (Lewis & Todd, 2007; Posner et al., 2007); it can be considered as an umbrella term which encapsulates attention control and emotion regulation (Berger et al., 2007; Rueda et al., 2005; Ursache et al., 2012). Pre-adolescence is an important developmental period in which self-regulation skills rapidly develop due to maturational changes within the brain. These brain changes include increasing connectivity between brain regions such as the prefrontal cortex, linked with top down regulation, and brain regions such as amygdalae, which support threat detection and bottom up emotional reactivity (Kelly et al., 2009; Lewis & Todd, 2007; Stevens, 2009). Adaptive self-regulation skills have been related to a variety of socio-emotional outcomes during childhood including greater social competence, school readiness and academic achievements, fewer behavioural problems at home and fewer associations with the police (Blair & Razza, 2007; Buckner et al., 2009; Ursache et al., 2012).

Currently, there is limited understanding of whether higher dispositional mindfulness is associated with greater self-regulation in preadolescence. However, a study with adolescents aged 14 to 18 years found that the dispositional mindfulness facets of non-reactivity and non-judgement significantly moderated the relationship between dysphoric affect (positive and negative affect) and life stress. Whilst this relationship was strong for adolescents lower in dispositional mindfulness, this relationship was reduced for those with higher dispositional mindfulness (Ciesla et al., 2012). Another study found that higher levels of self-reported dispositional mindfulness were linked with lower prevalence of multiple health conditions and poor health related quality of life in adults who had experienced adverse childhood experiences (Whitaker et al., 2014). This suggests that individuals with higher levels of dispositional mindfulness might be more resilient in managing difficult situations encountered during childhood. More broadly, research indicates that the self-regulation skills present during childhood can predict a wide range of socio-emotional outcomes for the individual at 32 years of age (Moffitt et al., 2011), it is therefore possible that a positive association between dispositional mindfulness and self-regulation is already observable in pre-adolescence.

Whilst dispositional mindfulness research with pre-adolescents is currently limited, research on the effects of mindfulness training on aspects of self-regulation with pre-adolescents is more extensive. Cumulatively, the findings suggest that mindfulness training is a potentially effective method of improving self-regulation skills during childhood. For example, a recent systematic review identified that for youths from primary and secondary schools, reductions in behavioural problems and anxiety and improvements in attention were reported after mindfulness training (Felver et al., 2016). In addition, a recent meta-analysis of 24 primary and secondary school based studies found that mindfulness training had a large effect on cognitive performance and small to medium effects on stress and resilience (Zenner et al., 2014). These findings are informative; however, most studies have employed questionnaire-based measures to study the effects of mindfulness training (Felver et al., 2016). A recent review highlighted the advantages of taking an integrative approach where multiple methods (psychophysiological and self-reports for example) are employed to study the effects of mindfulness training on self-regulation with pre-adolescents (Kaunhoven & Dorjee, 2017). A multimethod approach can provide converging evidence which can strengthen the understanding of how mindfulness impacts on self-regulation at behavioural, cognitive and psychophysiological levels. In addition, the use of psychophysiological methods could be particularly advantageous with pre-adolescents as these methods could be more sensitive to changes associated with mindfulness which may not be detected by self-report or informant based reports. This is especially relevant in the context of children’s limited abilities to understand and reliably self-report on their internal states (Zeman et al., 2007).

Heart rate variability (HRV) derived physiological indexes are one of the methods which could further the understanding of the link between mindfulness (dispositional and acquired through training) and self-regulation in preadolescents. HRV is the change in the timing of heart beats which occurs due to changes in the interactions between two branches of the autonomic nervous system - the parasympathetic (PNS) and sympathetic (SNS) nervous systems (Acharya et al., 2006; Sztajzel, 2004). An effective balance between the PNS and SNS is required to facilitate adaptive flexible responding to the environment (Acharya et al., 2006; Sztajzel, 2004). The PNS has a role in restorative functions and pro-social behaviour and is more active during non-threatening situations where the priority is to conserve metabolic resources (Acharya et al., 2006; Porges, 2007). The SNS is involved in the activation of fight or flight behaviours and is more active during stress-inducing situations which require the employment of metabolic resources to respond to a potential threat (Porges, 2007; Thayer et al., 2010). During non-threatening situations, the PNS facilitates the conservation of metabolic resources through slowing down the natural fast pace of the heart via the vagal nerve resulting in a suppression of SNS activity (Porges, 2007). During stressful situations, the inhibitory effect of the PNS on heart rate is reduced and SNS activity is elevated (Porges, 2007).

Respiratory sinus arrhythmia (RSA) is possibly the most researched index of HRV which provides a measure of parasympathetic cardiac control; RSA is the naturally occurring variability in heart rate which occurs at the same ‘fast frequency’ as spontaneous breathing (Allen, 2002; Grossman & Taylor, 2007). Higher RSA during non-threatening situations (resting RSA) is adaptive as it indicates a greater ability to act as a vagal brake on the heart and return the body to metabolic conservation after a stress inducing event (Kennedy, Rubin, Hastings & Maisel, 2004). RSA has been found to negatively correlate with a HRV index of SNS activity called the cardiac sympathetic index (CSI; Toichi, Sugiura, Murai & Sengoku, 1997) both at rest and during a stress inducing task (Allen et al., 2007; Hibbert, Weinberg & Klonsky, 2012). At rest RSA also positively correlates with total HRV (total HRV), this metric is influenced by both PNS and SNS activity, however, at rest PNS has a greater influence over total HRV (Allen et al., 2002; Allen et al., 2007).

Studies with pre-adolescents have found that higher resting RSA levels are associated with more adaptive self-regulation abilities. For instance, higher resting RSA is associated with higher effortful control (the ability to inhibit a pre-potent response) and lower aggression in youths aged 8 to 17 years (Chapman et al., 2010) and better working memory in children aged 6 to 13 years (Staton et al., 2009). A longitudinal study with 8 to 12 year olds which assessed resting RSA over a three-year period, found that increases in resting RSA over the three years were linked with reduced difficulties in self-reports of emotion regulation when assessed at 11 to 15 years (Vasilev, Crowell, Beauchaine, Mead & Gatzke-Kopp, 2009). This suggests that improvements in resting RSA through interventions might improve socio-emotional outcomes in future years.

With regards to the link between dispositional mindfulness and HRV indexes, Burg, Wolf and Michalak (2012) found that when adults with no mindfulness experience underwent a mindful breathing exercise (a behavioural task associated with dispositional mindfulness; Davidson, 2010; Levinson et al., 2014), a positive correlation was found between the ability to stay focused on their breath (rather than engage in mind wandering) and HRV. Another study with adults found that dispositional mindfulness positively correlated with high frequency HRV (a measure of PNS activity) during a recovery period after a stressful autobiographical interview. In the same study, high dispositional mindfulness also negatively correlated with the ratio of low frequency to high frequency HRV (a high ratio is indicative of SNS activity) during the stress recovery period. Overall, these findings suggest that high dispositional mindfulness is linked with greater vagal control (Kadziolka, Di Pierdomenico & Miller, 2016).

Most studies examining the impact of mindfulness training on HRV have included assessments during periods of meditation. For example, after an 8-week mindfulness-based stress reduction course there was a decrease in low frequency HRV and an increase in high frequency HRV during meditation in comparison to a controlled respiration task (Nijjar et al. 2014). Another study assessed HRV indexes for adults who had received 4 weeks of either body scan mindfulness training (where participants mindfully attended to their breath and other parts of their body in the present moment), progressive muscular relaxation training (where participants tensed and relaxed different muscle groups) or engagement in sitting quietly. HRV metrics were recorded whilst participants engaged in their respective training exercises. A greater increase in RSA levels was found between baseline and a body scan meditation for adults who had received the mindfulness training in comparison to the change in RSA levels for individuals who engaged in the relaxation or sitting quietly sessions (Ditto, Eclache & Goldman, 2006).

Changes in HRV indexes have also been observed after much shorter meditation training - Tang et al., (2009) found that after 5 days of integrative body-mind training (meditation training adapted from Chinese medicine which aims to calm the mind and body through breathing and body posture meditation) there was an increase in high frequency HRV during meditation in comparison to an active control group who received relaxation training (which involved consciously inducing relaxation through muscle movements). In contrast, Delgado et al., (2010) found no difference in high frequency HRV at rest between adults who had attended a five-week mindfulness course and adults who had attended a relaxation course. Participants in both groups did, however, show an increase in high frequency HRV during periods of mindfulness meditation/ relaxation respectively. This increase in vagal control could have been due to both training programmes being effective at reducing a range of symptoms linked with maladaptive self-regulation including worry, trait anxiety and depression. Overall, the findings with adults are promising and suggest that HRV metrics are potentially sensitive to both mindfulness disposition and changes in mindfulness after meditation training.

To explore the association between dispositional mindfulness and self-regulation with pre-adolescents (7 to 11 years) as well as the impact of mindfulness training on self-regulation for children in this age group, resting HRV measures and self-reports were employed. Dispositional analysis was expected to reveal higher resting levels of total HRV and RSA and lower resting levels of CSI in pre-adolescents who were higher in dispositional mindfulness. Self-report measures were expected to show greater positive affect and attentional control along with lower levels of self-reported negative affect and difficulties with emotional awareness and expression for pre-adolescents higher in dispositional mindfulness compared to pre-adolescents with lower self-reports of dispositional mindfulness.

Similarly, higher resting levels of total HRV and RSA were expected along with lower resting levels of CSI after mindfulness training, reflecting an enhancement in self-regulatory control. In addition, enhancements in self-reports of mindfulness, positive affect and attentional control along with reductions in negative affect and difficulties with emotional awareness and expression were also expected after mindfulness training in comparison to a wait-list control group.

Method

Participants

This study was approved by Bangor University School of Psychology Ethics committee and the NHS Research Ethics Committee, a small stationary gift was provided to pupils to recompense them for their participation. Four primary schools in North Wales were approached to participate in the study; participants (7 to 11 year olds) were recruited from these schools using convenience sampling. All participants had normal or corrected to normal hearing and vision and no exclusion criteria were applied. Across the four schools informed parental consent and informed pupil verbal assent was gained for 76 pre-adolescents as part of an overarching project on mindfulness and self-regulation; dispositional and longitudinal analysis for this section of the project was conducted for a subset of participants from this sample.

For the dispositional mindfulness analysis 28 participants were removed for the following reasons: incompletion of the testing session (n = 5), excessive artifacts in the RSA data (n = 8) or equipment failures (n = 15). The remaining 48 participants were divided into a high dispositional mindfulness group (n = 27) and a low dispositional mindfulness group (n = 21), based on a median split of scores on the Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011), see *Figure 1*.

No significant difference in age, handedness or gender was found between the groups (all ps > .1), and there was no significant group difference in the number of participants recruited from schools scoring high or low in the socioeconomic criteria of free school meals [$X^2(1, N = 48) = .006$, $p = 1.00$, $V = -.011$]. There was a marginally significant difference in the number of participants who spoke English as a first language [$X^2(1, N = 48) = 4.34$, $p = .059$, $V = -.301$], in the low dispositional mindfulness group all participants spoke English as a first language, in the high dispositional mindfulness group three participants spoke Welsh, one pupil spoke Aramaic and one pupil spoke German as a first language, see Table 1 for participant demographic information.

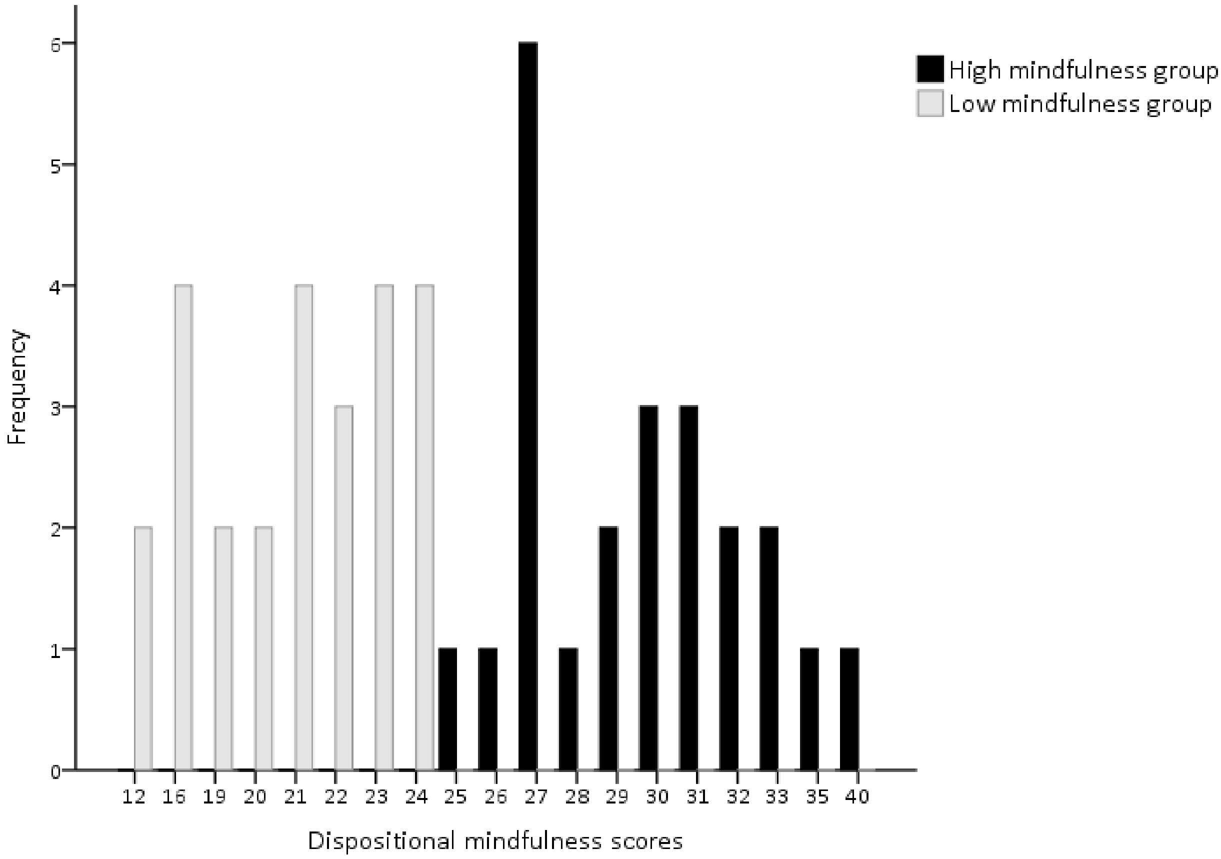


Figure 1. Histogram showing the distribution of dispositional mindfulness scores

Table 1.

A summary of the demographic information for the participants included in the dispositional data analysis (High dispositional mindfulness group n = 27, Low dispositional mindfulness group n = 21).

	Demographic information			
	High mindfulness group		Low mindfulness group	
	(*n*)	(*%*)	(*n*)	(*%*)
Participants	27		21	
Gender: Female	12	44.4	9	42.9
Handedness: Right	22	81.5	16	76.2
First language: English	22	81.5	21	100
First language: Welsh	3	11	0	0
First language: Other	2	7.4	0	0
Age (Year 3)	4	14.8	3	14.3
Age (Year 4)	13	48.1	10	47.6
Age (Year 5)	3	11.1	6	28.6
Age (Year 6)	7	25.9	2	9.5
Age (*M*)	9.39 years		9.39 years	
Age (*SD*)	1.02 years		0.93 years	
Age (Range)	7.58 – 10.92 years		7.75 – 11.25 years	

For the longitudinal analysis, the first two schools to opt in to the study were assigned to the mindfulness training group (*n* = 2 schools), the other two schools were assigned to a wait-list control group (*n* = 2 schools). The socioeconomic criteria of free school meals (national average = 20.8%) was measured for each school, both the training group and wait-list control group included one school which was higher and one which was lower than the national average for free school meals (training group schools: 49.4% and 4.2%; wait-list control group schools: 45.3% and 12.7%). For the longitudinal analysis of the 76 participants for whom informed parental consent and informed pupil verbal assent was gained (training group n = 46; wait-list control group n = 30); a total of 39 participants were removed from the analysis. This was due to the following reasons: incompletion of the testing session at pre-test (training group n = 5) or absence from the testing session at post-test (training group n = 2; control group n = 3), excessive artifacts in the RSA recordings at pre-test (control group n = 8) or post-test (training group n = 2; control group n = 4) or equipment failures at pre-test (training group n = 15). For the remaining 22 participants in the training group (10 female) and 15 participants in the control group (12 female) there were no group differences in age, handedness, gender, English as a first language or the school socioeconomic criteria of free school meals (all ps > .1), see Table 2 for demographic information.

Table 2.

A summary of the demographic information for the participants included in the longitudinal data analysis (Training group n = 22, Wait-list control group n = 15).

	Demographic information			
	Training group		Wait-list control group	
	(*n*)	(*%*)	(*n*)	(*%*)
Participants	22		15	
Gender: Female	10	45.5	12	46.7
Handedness: Right	17	77.3	12	80
First language: English	19	86.4	14	93.3
First language: Welsh	2	9.09	1	6.7
First language: Other	1	4.5	0	0
Age (Year 3)	2	9.1	4	26.7
Age (Year 4)	15	68.2	6	40
Age (Year 5)	1	4.5	4	26.7
Age (Year 6)	4	18.2	1	6.7
Age (*M*)	9.18 years		9.26 years	
Age (*SD*)	0.83 years		0.88 years	
Age (Range)	7.75 – 10.92 years		8.00 – 10.67 years	

Self-report measures

At the start of each session, participants were administered a pre-screening form which detailed demographics, handedness, language skills and brain injury/epilepsy. Then self-report measures were administered.

The Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011) is a 10-

item self-report which evaluates the ability to have non-judgmental awareness and acceptance of present moment experiences. Responses are measured on a 5-point Likert scale (0 = never true to 4 = always true) and all scores are reversed and summed to generate a total mindfulness score. The CAMM is validated for use with children and adolescents aged between 10 and 16 years (Greco et al., 2011), good internal consistency has been reported for children aged between 10 and 12 (α = .71; de Bruin et al., 2014). A recent study with 10 to 12 year olds found that the 10-item CAMM could be divided into two factors; present moment non-judgemental awareness (items 1, 2, 4, 6, 7, 8, 9) which had good internal consistency (α = .72) and suppressing or avoiding thoughts and feelings (items 3, 5, 10) which had poor internal consistency (α = .58; de Bruin et al., 2014). This study will analyse total CAMM scores and scores on the present moment non-judgemental awareness subscale.

The Positive and Negative Affectivity Scale for Children (PANAS-C short version) (Ebesutani et al., 2012) is a 10-item self-report which measures the frequency of positive and negative emotions experienced over the past few weeks. Responses are measured on a five-point Likert scale (1 = very slightly/ not at all, 5 = extremely); items in each subscale are summed to generate total scores. This measure is validated for use with children aged 6 to 18 year olds (Ebesutani et al., 2012). High internal consistency has been found for the negative affect subscale (α = .82) and the positive affect subscale (α = .86) in this age group (Ebesutani et al., 2012).

The Emotion Expression Scale for Children (EESC; Penza-Clyve & Zeman, 2002) is a 16-item self-report which measures poor awareness (reduced emotional awareness) and expressive reluctance (reduced motivation to express negative emotions). Responses are measured on a 5-point Likert scale (1 = not at all true, 5 = very true); items for each subscale are summed to generate total scores. This EESC is validated for use with children aged between 9 and 12 years of age (Penza-Clyve & Zeman, 2002). High internal consistency has been found for the poor awareness subscale (α = .83) and the expressive reluctance subscale (α = 81) in this age group (Penza-Clyve & Zeman, 2002)

The Attentional Control Scale for Children (ACS-C; Muris et al., 2004) is a 20-item self-report which assesses aspects of attentional control including attentional focusing and attentional shifting. Responses are recorded on a 4-point Likert scale (1 = almost never, 4 = always); items for each subscale are summed to calculate total scores. The ACS-C is validated to use with 8 to 13-year-old children (Muris et al., 2004). Acceptable internal consistency has been found for attentional focusing (α = .65) and attentional shifting (α = 71) with this age group (Muris et al., 2004).

Mindfulness (Paws b) curriculum

To assess the impact of mindfulness training on resting measures of HRV, the Paws b mindfulness curriculum (Mindfulness in Schools Project, 2015) was delivered to participants over a 10-week period as part of the usual school curriculum. This curriculum was designed and developed by an experienced mindfulness trainer (Sarah Silverton) and two teachers from a North Wales primary school (Ysgol Pen-Y-Bryn, Colwyn Bay) in collaboration with the Mindfulness in Schools Project. The curriculum aims to promote well-being, resilience and prosocial behaviours through providing children in key stage 2 (7 - 11 year olds) with skills and abilities to respond adaptively to cognitions, emotions and bodily states (Mindfulness in Schools Project, 2015). The 12 half hour sessions of the programme were delivered weekly by the school classroom teacher, except for two weeks where two sessions were delivered.

All the school teachers had no mindfulness training prior to participation in the study. School teachers first attended a four session .b foundations mindfulness course (Mindfulness in Schools Project, 2015; delivered over three months, each session 3 hours 15 minutes in length). Following this the teachers were asked to regularly engage in mindfulness meditation in their daily lives over a 5-month period. An experienced mindfulness trainer decided whether the teachers had developed a sufficient regular mindfulness practice (based on a reflective exercise in which teachers described their mindfulness practice). The teachers then attended a three-day Paws b course where they were trained to deliver the mindfulness curriculum to their class. Of the six teachers who received the initial mindfulness training and the training in the Paws b curriculum, four teachers delivered the curriculum to classes which were assessed as part of this study.

Design and procedure

The dispositional analysis had a cross-sectional design and the longitudinal analysis had a non-randomised pre-post design with a wait-list control group. The dispositional/pre-test data collection was conducted in February/March; in the two weeks prior to the mindfulness curriculum delivery. The post-test sessions for the longitudinal analysis were conducted in June/July in the two weeks after curriculum delivery. For the longitudinal analysis the mindfulness curriculum delivery across the two training schools was staggered by a week to enable testing sessions to be conducted as close as possible to the start and end of curriculum delivery. The training group and wait-list control group had the same time gap between pre-testing and post-testing sessions. Testing sessions took place on school premises in rooms especially designated for the research project. Participants completed the self-report measures with support from a research assistant, who read the questions aloud to facilitate understanding. During the EKG data collection, participants were seated in front of a laptop and a portable EEG system; a 32- electrode channel cap was fitted onto the participant head along with two electrodes which were attached to each forearm to record EKG signal for resting HRV analyses. Participants were instructed to remain still and relaxed for 3 minutes whilst the EKG recording was taken. Participants also completed an emotion oddball task (findings reported in chapters five and seven) and an attention oddball task (findings reported in chapter four). After completion of the research project participants and their parents were debriefed.

Heart rate variability (HRV) analysis

The EKG signal was recorded from two electrodes attached to the forearms which were connected to a 32-channel portable EEG system with NuAmp amplifiers. A paced breathing task was not used during data collection and respiration was not monitored, this is in line with other studies with developmental populations (Chapman et al., 2010; Marcovitch et al., 2010; Obradović et al., 2010). A paced breathing task could be demanding for children and impact on the ecological validity of the measure (Bar-Haim et al., 2000; Grossman & Taylor, 2007). There is debate regarding the importance of using respiratory parameters to quantify RSA, particularly for resting measures of RSA taken during undemanding situations (Bar-Haim et al., 2000; Denver et al., 2007; Grossman & Taylor, 2007; Oveis et al., 2009). Analysis was conducted on a two minute segment of the resting heart rate recording using the ORSTool in CMetX (Allen, 2002; Allen et al., 2007). The heart period (HP) was defined as the millisecond intervals between successive R-wave, errors created by the peri-beat filter were visually inspected and then corrected. The heart rate (HR) was calculated by applying the formula HR5 60,000/HP to the HP. RSA was computed using the formulae power spectral density values/ frequency band associated with respiration for pre-adolescents, between 0.15 and 0.50Hz (Gentzler et al., 2009; Marshall & Stevenson-Hinde, 1998; Schmitz et al., 2011) which was normalised to the natural logarithm. The data analysis focused on three HRV indexes; RSA, total HRV and CSI.

Results

Dispositional Results

For the 48 participants included in the dispositional analysis (high dispositional mindfulness group *n* = 27; low dispositional mindfulness group *n* = 21), group differences in the self-report and HRV data were analysed using independent samples t-tests, Cohen's *d* was calculated to measure the effect sizes. To assess the relationships between self-reports and HRV measures, correlational analyses were also conducted. Missing data for the self-report measures was replaced using multiple imputations and extreme outliers (>3 x interquartile range) were winsorised. To explore whether there was an association between the demographics of age and gender and the HRV indices of RSA, HRV and CSI, correlational analysis was conducted, no significant correlations were found (all *p*s > .1). Additional analysis including age as a factor in the analysis was also conducted. Children were divided into two age categories; older (years 5 and 6; 9.58 – 11.25 years) and younger (years 3 and 4; 7.58 – 9.42 years). Chi square tests revealed no significant group difference for these age categories [$X^2(1, N = 48) = .006, p = 1.00, V = -.011$].

Self-report Results.

Child and Adolescent Mindfulness Measure (CAMM).

No missing data was found for the CAMM. Acceptable internal consistency was found for the 10-item CAMM (α =.655). There were significant group differences in total

CAMM scores [$t(46) = -9.03$, $p < .001$, $d = -2.64$], as expected the high dispositional mindfulness group had significantly higher mindfulness scores, see *Figure 2*.

Acceptable internal consistency was found for the present moment awareness subscale ($\alpha = .659$). There were significant group differences in present moment awareness subscale scores [$t(46) = -8.10$, $p < .001$, $d = -2.33$], as expected the high dispositional mindfulness group had significantly higher scores, see *Figure 2*.

For correlational analysis between total mindfulness scores and the other self-report measures see Table 3.

Table 3.

Correlational analysis between total mindfulness scores and self-report and HRV indices for the dispositional analysis (N = 48).

Dispositional correlation results	
Correlational variables	Correlation coefficient
Mindfulness – positive affect	< .001
Mindfulness – negative affect	-.176
Mindfulness – attentional shifting	.400**
Mindfulness – attentional focusing	.372**
Mindfulness – poor emotional awareness	-.554***
Mindfulness – expressive reluctance	-.450***
Mindfulness – RSA	.409***
Mindfulness – total HRV	.421***
Mindfulness – CSI	-.318*

* Significant $p < .05$ ** Significant $p < .01$ *** Significant $p <.005$

Positive and Negative Affectivity Scale for Children (PANAS-C).

No missing data was found for the PANAS-C. Acceptable internal consistency was found for the negative affect subscale ($\alpha =.657$). There were no significant group differences in negative affect ($p > .1$).

Acceptable internal consistency was found for the positive affect subscale ($\alpha = .682$).

There were no significant group differences in positive affect ($p > .1$), see *Figure 2*.

Emotion Expression Scale for Children (EESC).

No missing data was found for the EESC. Good internal consistency was found for the poor awareness subscale (α = .744). There were significant group differences in the poor awareness subscale [$t(46) = 4.23$, $p < .001$, $d = 1.24$], as expected the high dispositional mindfulness group had significantly lower poor awareness scores.

Good internal consistency was found for the expressive reluctance subscale (α =.746). There were also significant group differences in the expressive reluctance subscale [$t(46) = 2.95$, $p = .005$, $d = 0.87$], as expected the high dispositional mindfulness group had significantly lower expressive reluctance scores, see *Figure 2*.

Attentional Control scale for Children (ACS-C).

No missing data was found for the ACS-C. Acceptable internal consistency was found for the attentional shifting subscale (α =.695). There was a significant group difference in attentional shifting [$t(46) = -3.37$, $p = .002$, $d = -0.99$], as expected the high mindfulness group had significantly higher scores, see *Figure 2*.

Poor internal consistency was found for the attentional focusing subscale (α = .462). There were significant group differences in attentional focusing [$t(46) = -3.24$, $p = .002$, $d = -0.95$], as expected the high dispositional mindfulness group had significantly higher scores, see *Figure 2*.

Age analysis

2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs were conducted to analysed the effects of age on the self-report results.

There was no significant main effect of age and no significant interactions involving age for any of the self-report measures (all *p*s > .1).

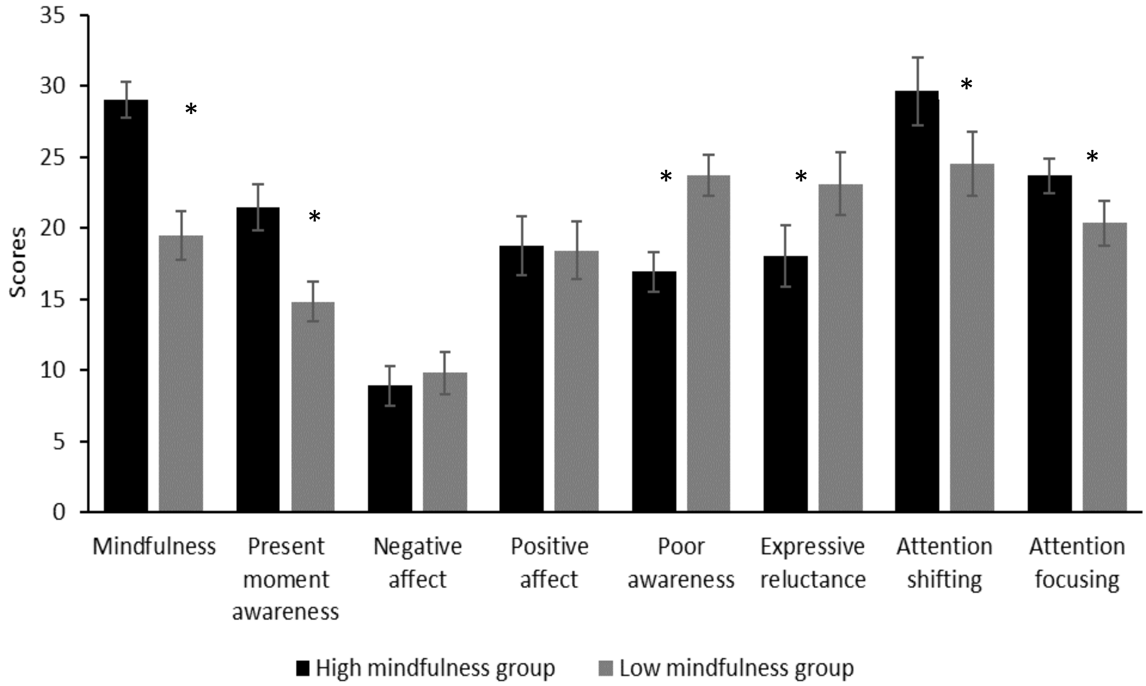


Figure 2. High dispositional mindfulness (*n* = 27) and low dispositional mindfulness (*n* = 21) group differences in total mindfulness scores, present moment non-judgemental awareness scores, PANAS-C negative affect and positive affect scores, EESC poor emotional awareness and expressive reluctance scores, ACS-C attentional shifting and attentional focusing scores. Error bars indicate 95% confidence intervals (CI).

HRV Results.

Resting respiratory sinus arrhythmia (resting RSA).

There was a significant group difference in resting RSA [*t*(46) = -2.05, *p* = .047, *d* = -0.58], as expected the resting RSA was significantly higher for the high dispositional mindfulness group, see *Figure 3*. This difference was confirmed in correlational analyses - total mindfulness scores positively correlated with resting RSA amplitude [*r*(46) = .409, *p* = .004], see Table 3 and *Figure 4*.

Total HRV (HRV).

There was a significant group difference in HRV [$t(46) = -2.15$, $p = .037$, $d = 0.85$], as expected HRV was significantly higher for the high dispositional mindfulness group, see *Figure 3*. Correlational analysis also found that total mindfulness scores positively correlated with total HRV [$r(46) = .421$, $p = .003$], see Table 3 and *Figure 4*.

Cardiac sympathetic index (CSI).

There was a marginally significant group difference in CSI amplitude [$t(46) = 1.85$, $p = .071$, $d = 0.54$], as expected CSI was marginally significantly higher for the low dispositional mindfulness group, see *Figure 3.* This was confirmed through correlational analysis which found that total mindfulness scores negatively correlated with CSI amplitude [$r(46) = -.318$, $p = .028$], see Table 3 and *Figure 4*.

Age analysis

2 (age; older, younger) x 2 (group; high mindfulness, low mindfulness) between subjects ANOVAs were conducted to analysed the effects of age on the HRV results. For total HRV, there was a significant group x age interaction [$F(1, 44) = 4.51$, $p = .039$, $\eta^2 = .08$]. For older children the higher dispositional mindfulness group had higher resting total HRV levels [$t(16) = -2.66$, $p = .017$, $d = 0.94$], for younger children there were no dispositional mindfulness group differences ($p > .1$). For resting RSA levels, there was a significant group x age interaction [$F(1, 44) = 5.46$, $p = .025$, $\eta^2 = .10$]. For older children the higher dispositional mindfulness group had higher resting RSA levels [$t(16) = -2.54$, $p = .022$, $d = -1.16$], for younger children there were no dispositional mindfulness group differences ($p > .1$). For resting CSI levels, there was a significant group x age interaction [$F(1, 44) = 5.95$, $p = .019$, η^2

= .08]. For older children the higher dispositional mindfulness group had lower resting CSI levels [$t(16) = -3.31$, $p = .004$, $d = 1.53$], for younger children there were no dispositional mindfulness group differences ($p > .1$).

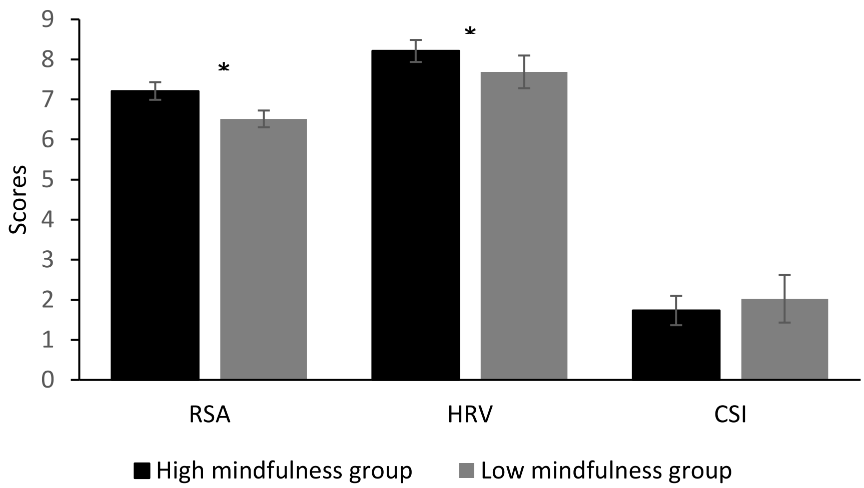


Figure 3. High dispositional mindfulness ($n = 27$) and low dispositional mindfulness ($n = 21$) group differences in respiratory sinus arrhythmia (RSA), total heart rate variability (total HRV) and cardiac sympathetic index (CSI). Error bars indicate 95% confidence intervals (CI).

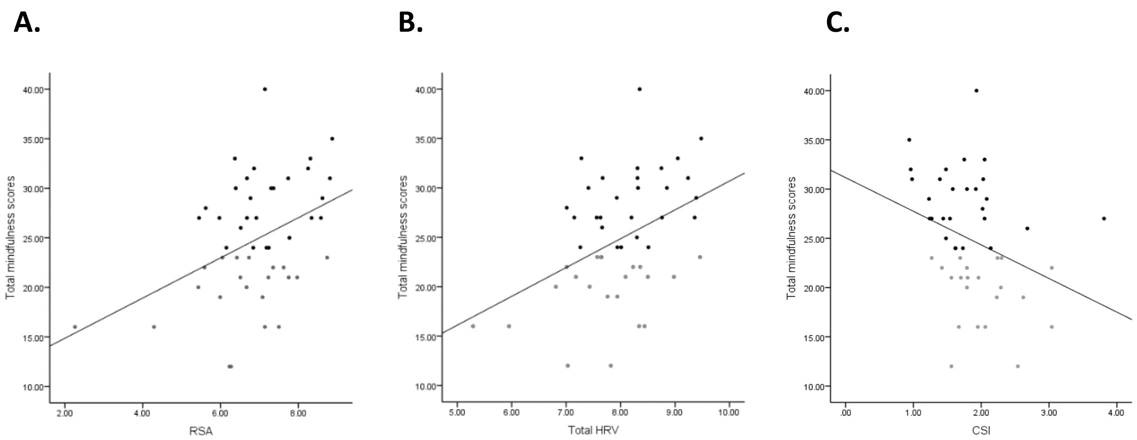


Figure 4. Across the high dispositional mindfulness group ($n = 27$) and low dispositional mindfulness group ($n = 21$), a significant positive correlation between total mindfulness scores and A) respiratory sinus arrhythmia (RSA) and B) total HRV (total HRV) was found. A significant negative correlation between total mindfulness scores and C) cardiac sympathetic index (CSI) was also found.

Longitudinal Results

For the 37 participants included in the longitudinal analysis (training group *n* = 22, wait-list control group *n* = 15), baseline group differences in the self-report and HRV measures were assessed using independent samples t-tests, with Cohen's d providing an estimate of effect size. Longitudinal changes in the self-report and HRV measures were evaluated using 2 (group; training, control) x 2 (time; pre-test, post-test) mixed factorial analysis of variance (ANOVAs) with eta squared (η^2) providing a measure of effect size. Follow-up analysis on significant time x group interactions was conducted using two-tailed paired samples t tests. Missing data for the self-report measures was replaced using multiple imputations and extreme outliers (>3 x interquartile range) were winsorised. To explore whether there was an association between the demographics of age and gender and the change in HRV indices of RSA, HRV and CSI, correlational analysis was conducted, no significant correlations were found (all *p*s > .1). Additional analysis, including age as a factor, was also conducted for the self-reports and HRV data. Children were divided into two age categories; older (years 5 and 6; 9.58 – 10.92 years) and younger (years 3 and 4; 7.75 – 9.42 years). Chi square tests revealed no significant group difference for these age categories [$X^2(1, N = 37) = .509$, $p = .708$, $V = .117$].

Self-report Results.

Child and Adolescent Mindfulness Measure (CAMM).

There was no missing data for this measure and the 10-item CAMM had good internal consistency at pre-test (α = .682) and post-test (α = .740). No baseline differences in the total CAMM scores were found at pre-test (*p* > .1). There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure*

5.

The present moment awareness subscale had good internal consistency at pre-test ($\alpha = .671$) and post-test ($\alpha = .714$). No baseline differences in present moment awareness scores were found at pre-test ($p > .1$). There were no significant main effects and the interaction of time x group was not significant either (all ps > .1), see *Figure 5*.

Positive and Negative Affectivity Scale for Children (PANAS-C).

Missing data on one question at post-test was found for one participant and was replaced using the multiple imputation method. The negative affect subscale had good internal consistency at pre-test ($\alpha = .696$), the internal consistency at post-test was poor ($\alpha = .468$). There was a baseline difference in negative affect [$t(30.5) = 2.68$, $p = .012$, $d = 0.84$] with the training group reporting higher scores. Longitudinally, there was no significant main effect of time or group (all *p*s > .15), but the time x group interaction was significant [$F(1, 35) = 5.25$, $p = .028$, $\eta^2 = .13$]. Follow-up analyses showed no change in negative affect scores for the training group over time [$t(21) = .951$, $p = .352$, $d = 0.20$], however, negative affect scores significantly increased for the control group over time [$t(14) = -3.40$, $p = .004$, $d = -0.88$], see *Figure 5*. To examine whether this time x group interaction was significantly impacted by baseline group differences in negative affect an ANCOVA was conducted on post-test scores with baseline negative scores as a covariate and no significant difference in negative affect scores was found between groups at post-test [$F(1, 34) = .741$, $p = .395$, $\eta^2 = .02$].

The positive affect subscale had acceptable internal consistency at pre-test ($\alpha = .641$) and good internal consistency at post-test ($\alpha = .755$). There were no group differences in positive affect at baseline ($p > .1$). There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure 5.*

Emotion Expression Scale for Children (EESC).

One participant did not complete the EESC. Missing data on one question at post-test was found for one participant and was replaced using the multiple imputation method. The poor awareness subscale had good internal consistency at pre-test (α = .744) and post-test (α = .720). There were no group differences in poor awareness scores at baseline (*p* > .1). There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure 5*.

The expressive reluctance subscale had good internal consistency at pre-test (α = .770) and post-test (α = .623). There were no group differences in expressive reluctance scores at baseline (*p* > .1). There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure 5*.

Attentional Control Scale for Children (ACS-C).

At post-test two participants had missing data for one question and one participant had missing data for two questions, this missing data was replaced using the multiple imputation method. The attentional shifting subscale had good internal consistency at pre-test (α = .724) and post-test (α = .718). There were marginally significant group differences in attention shifting at pre-test [$t(35) = -1.76$, $p = .088$, $d = -0.57$], scores were higher for the control group. There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure 5.*

The attentional focusing subscale had a poor internal consistency at pre-test (α = .412) and at post-test (α = .506). There were no significant group differences in attentional focusing at baseline ($p > .1$). There were no significant main effects and the interaction of time x group was not significant either (all *p*s > .1), see *Figure 5*

Age analysis

2 (age; older, younger) x 2 (time; pre-test, post-test) x 2 (group; training, control) mixed factorial ANOVAs were conducted to analysed the effects of age on the longitudinal self-report results. For attentional shifting there was a marginally significant group x age interaction [$F(1, 33) = 3.01$, $p = .092$, $\eta^2 = .08$], follow up t tests were not significant (all *p*s > .1). For attentional focusing there was a marginally significant time x age interaction [$F(1, 33) = 3.79$, $p = .06$, $\eta^2 = .10$], follow up t tests were not significant (all *p*s > .1). There was a significant group x age interaction [$F(1, 33) = 10.02$, $p = .003$, $\eta^2 = .23$], for younger children attentional focusing scores were higher for the control group [$t(25) = -2.50$, $p = .019$, $d = -0.94$], for the older children attentional focusing scores were higher for the training group [$t(8) = 2.40$, $p = .043$, $d = 1.52$]. There were no age effects for any other self-report measures (all *p*s > .1).

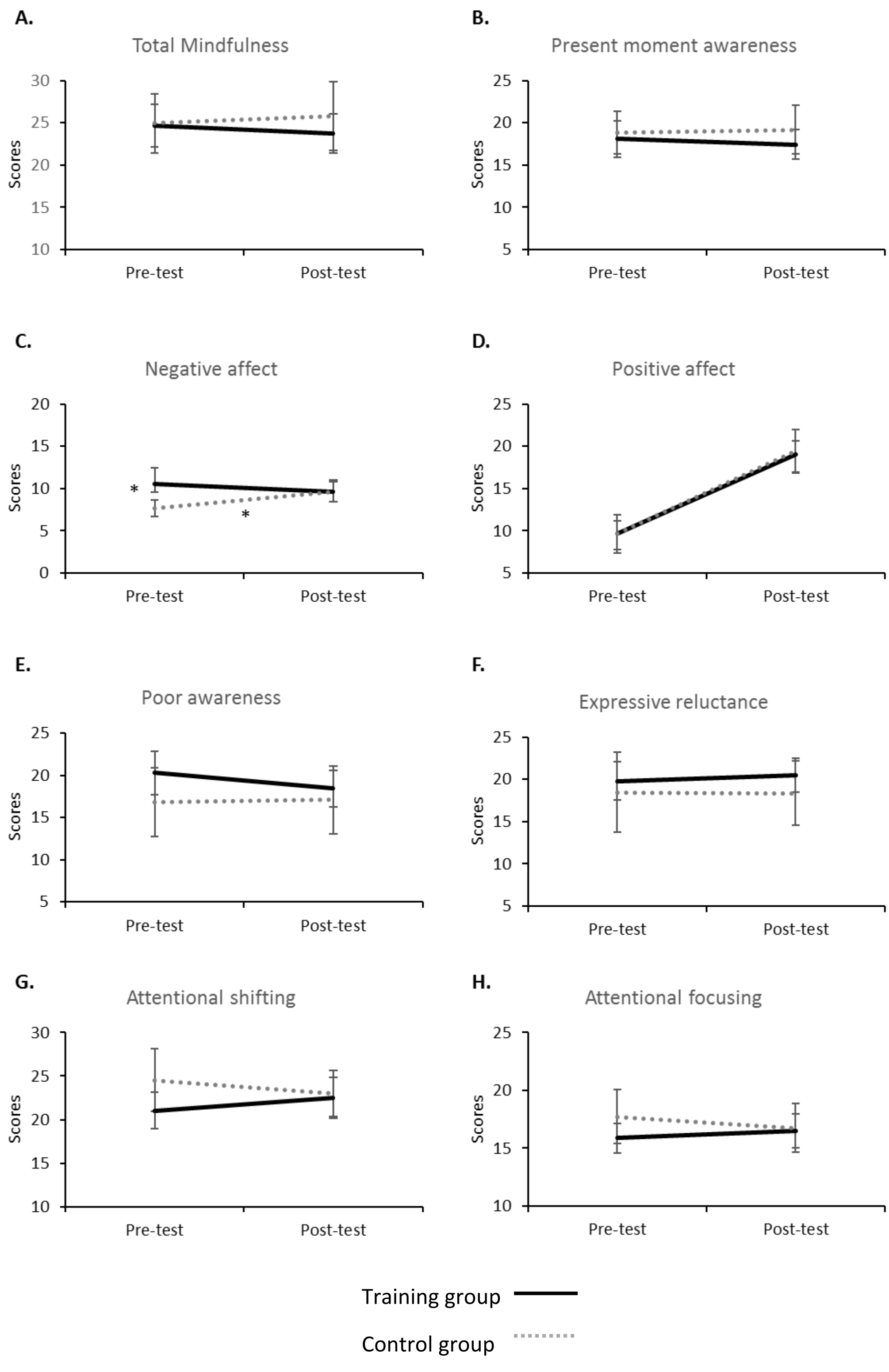


Figure 5. Pre-post changes for the training group (n = 22) and control group (n = 15) for A) total mindfulness scores, B) Present moment non-judgemental awareness scores, C) PANAS-C negative affect scores, D) PANAS-C positive affect scores, E) EESC poor emotional awareness scores, F) EESC expressive reluctance scores, G) ACS-C attentional shifting scores and H) ACS-S attentional focusing scores. Error bars indicate 95% CI.

HRV Results.

Resting respiratory sinus arrhythmia (resting RSA).

There were no significant group differences in resting RSA levels at baseline ($p > .1$). Longitudinally, there was a marginally significant main effect of time [$F(1, 35) = 3.85$, $p = .058$, $\eta^2 = .09$], resting RSA was higher at pre-test. No significant main effect of group was found ($p > .1$). There was a significant time x group interaction [$F(1, 35) = 4.90$, $p = .033$, $\eta^2 = .11$], paired samples t-tests revealed that resting RSA levels decreased for the training group over time [$t(21) = 2.69$, $p = .014$, $d = 0.58$], no change in resting RSA levels for the control group were found [$t(14) = -.317$, $p = .756$, $d = -0.08$], see *Figure 6*.

Total HRV (HRV).

There were no significant group differences in HRV levels at baseline ($p > .1$). Longitudinally, there was a marginally significant main effect of group [$F(1, 35) = 3.47$, $p = .071$, $\eta^2 = .09$], Total HRV was higher for the control group. There was no significant main effect of time and no significant time x group interaction (all *p*s > .1), see *Figure 6.*

Cardiac sympathetic index (CSI).

There were no significant group differences in CSI levels at baseline ($p > .1$). Longitudinally, there was a significant main effect of time [$F(1, 35) = 7.06$, $p = .012$, $\eta^2 = .14$], CSI was marginally higher at pre-test. No significant main effect of group was found ($p > .1$). There was a significant time x group interaction [$F(1, 35) = 7.36$, $p = .010$, $\eta^2 = .15$], paired samples t-tests revealed that CSI levels increased for the training group over time [$t(21) = -3.55$, $p = .002$, $d = -0.75$], no change in resting CSI levels for the control group were found [$t(14) = -.059$, $p = .954$, $d = 0.02$], see *Figure 6*.

Age analysis

2 (age; older, younger) x 2 (time; pre-test, post-test) x 2 (group; training, control) mixed ANOVAs were conducted and revealed that age had no effect on resting total HRV levels, resting RSA levels or resting CSI levels (all *ps* > .1).

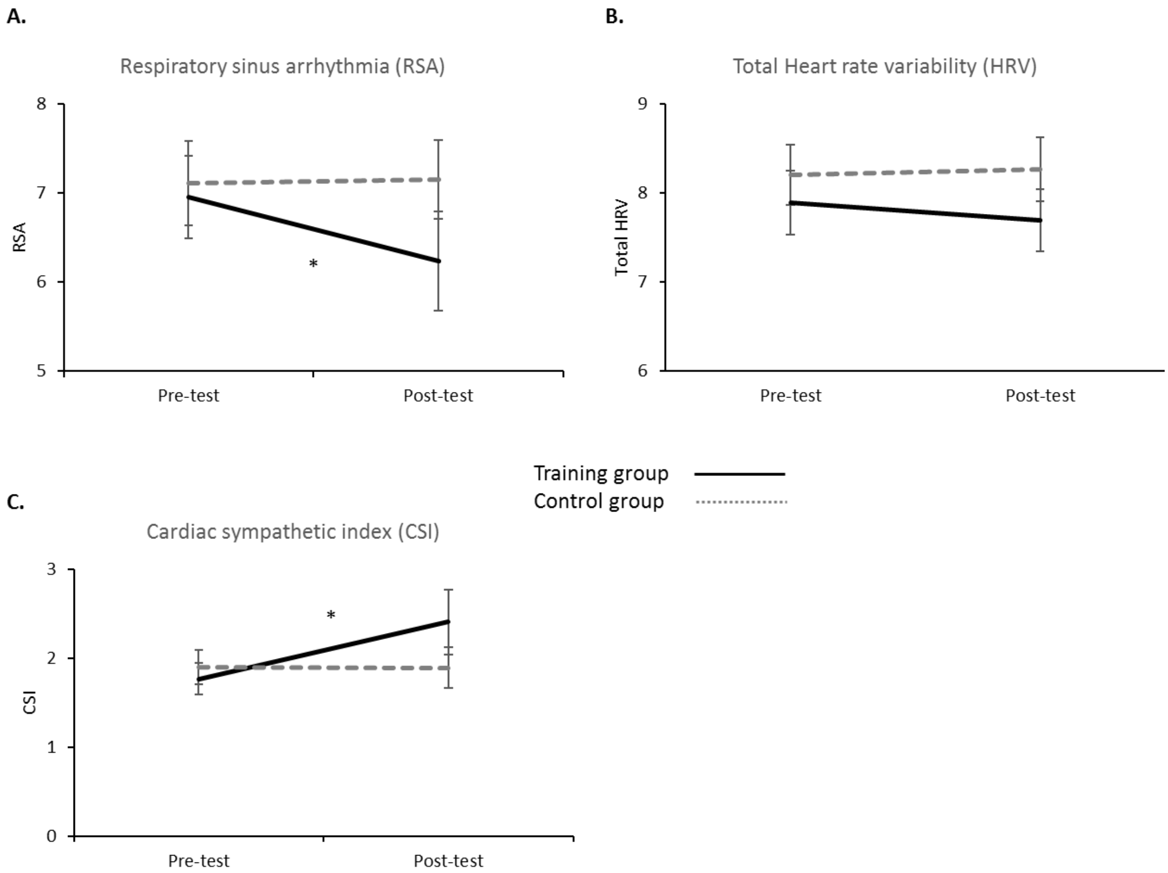


Figure 6. Pre-post changes for the training group (n = 22) and control group (n = 15) for A) respiratory sinus arrhythmia (RSA), B) total heart rate variability (total HRV) and C) cardiac sympathetic index (CSI). Error bars indicate 95% CI.

Discussion

This study aimed to explore whether mindfulness was associated with enhanced self-regulation abilities indexed by psychophysiological measures in pre-adolescents. The associations between self-reported dispositional mindfulness and HRV indices of self-regulation were explored in pre-adolescents aged between 7 and 11 years. HRV and self-report assessments were also employed to measure the impact of mindfulness training on self-regulation in this age group. The dispositional analysis revealed that, as expected, pre-adolescents higher in dispositional mindfulness had higher resting RSA levels and higher total HRV levels in comparison to individuals with lower dispositional mindfulness. In addition, marginally significant group differences in resting CSI levels were found, as expected, the high dispositional mindfulness group had lower levels of resting CSI. In the self-report assessments, pre-adolescents higher in dispositional mindfulness reported having better attentional control on the subscales of attentional shifting and focusing and less difficulties with emotional expressions including poor emotional awareness and expressive reluctance. No group differences on self-reports of positive or negative affect were found. Convergence between the HRV indices and self-report measures was also found, mindfulness scores positively correlated with resting RSA and total HRV levels and negatively correlated with resting CSI amplitudes.

The longitudinal analysis of HRV indices revealed that in contrast to the hypotheses, the resting RSA significantly reduced and the resting CSI levels significantly increased over time for the training group, whilst no change in resting RSA or resting CSI levels was found for the control group over time. Total HRV levels did not change over time for either group. There were no changes in self-reports of mindfulness, positive affect, expressive reluctance, emotional awareness, attentional shifting or attentional focusing after the mindfulness training. There was a significant increase in negative affect scores for the control group and no change in negative affect scores for the training group over time.

The dispositional findings showing higher resting RSA and total HRV levels and lower resting CSI levels in individuals with higher dispositional mindfulness suggests that pre-adolescents higher in mindfulness disposition had greater vagal control over their autonomic system responses. Greater activation of the PNS and lower activation of the SNS at rest has been shown to be adaptive as it indicates a greater ability to conserve metabolic resources and engage in prosocial behaviours during undemanding situations (Porges, 2007). In contrast, lower levels of PNS and higher levels of SNS activity at rest are thought to be maladaptive as they indicate hypervigilance at rest and the excessive consumption of metabolic resources (Thayer et al., 2010). Indeed, whilst high resting RSA is linked with greater emotion regulation abilities (Chapman et al., 2010; Vasilev et al., 2009) and attention control (Staton et al., 2009), low resting RSA is associated with psychopathological difficulties in pre-adolescent children (Graziano & Derefinko, 2013). The self-report findings from the current study showing greater attentional control and fewer difficulties with emotional awareness and expression for pre-adolescents with higher dispositional mindfulness adds further support to the suggestion that individuals with higher dispositional mindfulness have more adaptive self-regulation abilities. To the author’s knowledge, there are no known published studies which have investigated the association between dispositional mindfulness and HRV in pre-adolescents, the findings from the current study are in line with previous studies with adults which also found enhanced HRV for individuals with higher dispositional mindfulness (Burg et al., 2012; Kadziolka et al., 2016). The association between dispositional mindfulness and self-regulation therefore appears to be present relatively early in development.

Interestingly, exploratory analysis on age revealed that this association between dispositional mindfulness and heart rate variability indexes was only present for older pre-adolescents. In line with this finding, Beauchaine, Gatze-Kopp and Mead (2007) also found that the relationship between resting HRV indexes and psychological traits differed across pre-adolescence. Whilst lower baseline RSA was found in children aged 8 to 12 years with aggressive oppositional defiant disorder and conduct disorder in comparison to typically developing children, this group difference in baseline RSA was not found in children aged 4 to 6 years of age. Similarly, Gentzler, Rottenberg, Kovacs, George and Morey (2012) found that resting RSA levels were similar for 4 to 10-year-old children at high and low risk of depression. However, after the age of 10 years, whilst resting RSA levels increased with age for low risk children, it did not increase with age for high risk children. This suggests that the relationship between resting HRV indexes and psychological traits may become more apparent during the middle/later stages of pre-adolescence in line with developmental changes in self-regulatory abilities.

In contrast, the longitudinal findings from the current study were not consistent with the study predictions; the mindfulness training group appeared to decrease in vagal control at rest after mindfulness training. These findings are difficult to interpret, especially as self-reports of mindfulness, attention control, difficulties with emotional expression and awareness and positive and negative affect did not change for the training group after mindfulness training. One possible explanation is that the mindfulness curriculum had a detrimental effect and made children more physiologically reactive in a maladaptive way. Whilst adult programmes can have the potential to induce adverse effects due to participants engaging in in depth explorations of thoughts, feelings and behaviours which may have previously been suppressed, this is not the case with programmes for children. Mindfulness training programmes for pre-adolescents are adapted to be age-appropriate and do not involve an in depth exploration of potentially negative situations, to date no adverse effects have been reported in studies with children. During the mindfulness training pre-adolescents engage in mindfulness practices which bring attention to thoughts, feelings and bodily sensations and provide children with skills to manage them effectively (Mindfulness in Schools Project, 2015). Perhaps receiving training in these practices made children more aware of their sensations during the resting state, and therefore, whilst participants in the control group were partaking in cognitively undemanding processes such as mind wandering, children in the mindfulness group were engaging in bringing their attention to their thoughts, feelings and bodily sensations. Lumma, Kok and Singer (2015) found an increase in SNS activity and decrease in PNS activity during meditation practices such as loving kindness and observing thoughts for adults after mindfulness training. Importantly, this increase in physiological arousal was not linked with decreases in subjective well-being. This increased physiological arousal was suggested to be due to an increased alertness to present moment experiences. An increased awareness of present moment thoughts, feelings and sensations is thought to be an important step in facilitating the early engagement of adaptive regulatory strategies (Teper et al., 2013). Similarly, in the current study the increase in physiological arousal was not found in conjunction with decreased self-reports of attention control and emotion regulation which suggests that the mindfulness training did not negatively impact on subjective self-regulation abilities. This is further supported by the event-related potential assessments of emotion processing which were also taken for a large proportion of participants from this sample - whilst the control group showed enhanced reactivity towards emotional and neutral stimuli (indexed by the LPP amplitude), the training group did not show these decrements (see chapter seven).

To the author's knowledge, no known published studies have investigated the association between mindfulness training and HRV during rest with pre-adolescents. Previous studies with adults predominantly investigated the effects of mindfulness training on HRV indexes in the context of meditation (Delgado et al., 2010; Nijjar et al., 2014). Only a few studies have investigated the impact of mindfulness training on resting HRV, with several of these studies finding no effect of mindfulness training (Delgado et al., 2010; Krygier et al., 2013; Tang et al., 2009). Therefore, the extent to which resting RSA levels can sensitively detect changes after mindfulness training is unclear, further research is needed to assess whether the HRV findings from the current study are replicable.

Furthermore, whilst many studies have found that resting HRV can provide a stable index of self-regulatory abilities in pre-adolescents (El-Sheikh, 2005; Graziano & Derefinko, 2013; Staton et al., 2009), higher resting HRV indexes are not always associated with more adaptive self-regulatory abilities (Calkins et al., 2007). In addition, Hinnant and El-Sheikh (2009) found that resting RSA levels alone did not predict psychopathological abilities in pre-adolescents, however, both resting RSA and RSA measured during a challenging task together did predict psychopathological difficulties. For instance, high resting RSA was adaptive if found in conjunction with RSA withdrawal during a task but high resting RSA was linked with high levels of internalising disorders if found in conjunction with RSA augmentation during a task. Therefore, to provide a more accurate measure of self-regulatory abilities, future research could investigate the impact of mindfulness training on HRV indexes during both resting states and during demanding tasks.

Limitations and future research

Due to equipment failure during the testing sessions the sample size is much smaller than intended, a larger sample size could improve the power of the analysis and improve the generalisability of the findings. In addition, the measuring of respiration rate was not conducted in this study, in line with previous developmental studies (Bar-Haim et al., 2000). Some researchers, however, suggest that respiration rate can impact on HRV (Grossman &

Taylor, 2007), therefore measuring of respiratory rate could have ruled out the influence of respiration on the HRV measures and might have also helped with the interpretation of the reduction in resting RSA and total HRV levels observed after mindfulness training.

Another limitation was that indexes such as weight and fitness level were not assessed for participants. Previous studies suggest that weight can impact on HRV indices (El-Sheikh, 2005; Thayer et al., 2010), a higher body mass index was linked with lower levels of resting RSA in children (Hinnant & El-Sheikh, 2009) and so this is something which should be controlled for in future studies. Furthermore, a measure of the frequency of regular exercise children partake in should also be taken. Nagai and Moritani (2004) found that 6 to 12 year olds who were classified as being physically active (involved in at least three 60-minute after school exercise sessions a week) had higher resting parasympathetic and sympathetic HRV indexes in comparison to obese and physically inactive children. This was suggested to indicate that those who partake in regular exercise have more adaptive autonomic nervous system responses. In addition, an increase in resting HRV levels were found for 7 to 11 year olds who were classified as obese, after receiving 4 months physical training (five 40 minute sessions a week) in comparison to a control group (Gutin, Barbeau, Litaker, Ferguson & Owens, 2000). Another variable which could be controlled for in future studies is the consumption of caffeinated energy drinks, whilst research examining the effect of this on HRV indexes is still in its infancy, caffeinated drinks could impact on both resting HRV and HRV levels after exercise (Wiklund, Karlsson, Öström & Messner, 2009). This could be of relevance for research with children as children’s consumption of caffeinated drinks has increased during recent years and these drinks have even been marketed to children as young as 4 years of age (Temple, 2009).

Another limitation was that the mindfulness curriculum was delivered by four different school teachers and so there could be variations in the effectiveness of curriculum delivery. Due to the small sample size it was not possible to examine whether the outcomes observed for pupils after mindfulness training were impacted by the teacher who had delivered the curriculum. Research suggests that teacher's social and emotional competence can have a significant impact on a range of emotional and social outcomes for students (Baker, 2006; Jennings & Greenberg, 2009). It is therefore possible that the lack of changes in self-report measures of attention and emotion regulation and the increase in resting HRV markers of physiological reactivity observed in the mindfulness training group could have been due to deficiencies in the school teachers' delivery of the mindfulness curriculum. In this study the school teachers were trained for 8 months prior to curriculum delivery and the school teachers were supervised throughout curriculum delivery by two experienced mindfulness teachers who were co-authors of the Paws b curriculum to ensure that the curriculum was delivered to a high standard. This level of training is more extensive than the teacher training provided in other mindfulness training studies with pre-adolescents which found improvements in social and emotional outcomes for pre-adolescents after curriculum delivery (Schonert-Reichl & Lawlor, 2010; Schonert-Reichl et al., 2015). This suggests that it is unlikely that the teachers in our study delivered the curriculum in an ineffective way. To assess this further formal assessment of curriculum delivery effectiveness could be implemented in future studies. For instance, Mendelson et al., (2010) employed focus groups with primary school pupils to assess their experiences of receiving the mindfulness curriculum. Formal observations of mindfulness lessons by experienced mindfulness practitioners could also be conducted. Furthermore, some suggest that mindfulness teachers should have a regular mindfulness practice to deliver the mindfulness training in an effective way (Kabat-Zinn, 2003). Whilst in our study an experienced mindfulness teacher did assess teacher's mindfulness practice using a reflective exercise, it would be informative to also include a self-report measure to assess frequency of mindfulness practice in school teachers.

As mentioned, in future research, it would be interesting to measure RSA withdrawal during a stress inducing task to gain an understanding of how both dispositional mindfulness and mindfulness acquired through training are associated with self-regulation in relation to a stressful life event. For the longitudinal study, it would be interesting to conduct a follow-up to assess long-term changes in HRV. It would be particularly interesting to explore the impact of mindfulness training on HRV indexes for pre-adolescents undergoing a transition between primary and secondary school, especially as this has been found to be a challenging stressful period (Rice, Frederickson & Seymour, 2011; West, Sweeting & Young, 2010).

Conclusion

This study investigated the relationship between mindfulness (dispositional and acquired through training) and psychophysiological measures of self-regulation in pre-adolescents aged between 7 and 11 years. The findings suggest that dispositional mindfulness is associated with better self-regulation for pre-adolescents (based on HRV indices and self-reports). However, in contrast, pre-adolescents became more physiologically reactive after mindfulness training in comparison to a wait-list control group. Further larger scale research is needed to explore these differences in self-regulation observed for dispositional mindfulness and mindfulness training.

Chapter Seven - The impact of mindfulness training on emotion processing in pre-adolescent children: An event related potential study

Abstract

Mindfulness training is a potentially promising method for enhancing emotion processing skills in preadolescents – initial studies suggested improvements in optimism and positive affect along with reductions in anxiety and stress. There is, however, limited research on the neurocognitive mechanisms underlying such positive effects in children. This non-randomised wait-list controlled study explored the impact of a 10-week mindfulness curriculum (Paws b), delivered by primary school teachers, on emotion processing in pre-adolescents aged 7 to 11 years (training group n = 25, control group n = 11). Electrophysiological markers of emotion processing were measured whilst pupils completed an emotion oddball task before and after mindfulness training. The training group self-reported an increase in positive affect (p = .06, d = - 0.40) and elicited a less positive P1 mean amplitude for angry targets after mindfulness training (p = .058, d = 0.40). The control group reported significantly increased negative affect (p = .020, d = -0.84) and elicited enhanced P1 (p = .006, d = -1.04) and LPP mean amplitudes (p = .008, d = -0.99) over time for emotional and neutral faces. No change in the N2 or P3b were found for either group over time. Overall, these findings suggest that the training group became less emotionally reactive to angry faces during the early stages of stimulus processing whilst the control group became more reactive to all stimuli during both early and late stages of stimulus processing. These findings provide one of the first longitudinal insights into the neurodevelopmental changes in emotion processing with mindfulness training in children,

the cultivation of mindfulness skills during pre-adolescents may have protective effects on emotion processing.

During childhood, emotion processing abilities, including the ability to recognise and respond optimally to emotional faces and inhibit the processing of task irrelevant facial expressions, becomes increasingly efficient (Herba et al., 2006; Thomas et al., 2007). This is due to maturational changes within emotion processing networks -- increased connectivity between the amygdalae, which are involved in the detection of salient stimuli and the generation of rapid emotional responses (Fitzgerald, Angstadt, Jelsone, Nathan & Phan, 2006; Pessoa & Adolphs, 2010), and regions involved in top-down regulation of the amygdalae (Gee et al., 2013; Qin et al., 2012). The areas associated with top-down modulation of emotional responses include the medial prefrontal cortex, which is activated during the appraisal of emotions (Etkin, Egner & Kalisch, 2011; Qin et al., 2012), and the anterior cingulate cortex (Kujawa et al., 2016; Perlman & Pelphrey, 2011), which is associated with response inhibition and conflict monitoring (Bush et al., 2000; Etkin, Egner, Peraza, Kandel & Hirsch, 2006).

Emotion processing abilities during pre-adolescence can predict social adjustment and mental wellbeing in later stages of development (Pérez-Edgar et al., 2010; Pérez-Edgar et al., 2011). For example, threat related attention biases were found in adults exposed to environmental stressors during childhood, including poverty (Javanbakht et al., 2015) and childhood maltreatment (Dannlowski et al., 2012; Fonzo et al., 2016). These biases can index the risk or presence of psychopathological disorders including anxiety during both childhood (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & Van Ijzendoorn, 2007; LoBue &

Pérez-Edgar, 2014; Shackman et al., 2007) and adulthood (Bar-Haim et al., 2007; Van Bockstaele et al., 2014). Bolstering adaptive emotion processing abilities could therefore provide children with skills to flexibly respond to the environment and build resilience to protect against the development of psychopathological difficulties in later life (Durlak et al., 2011; McDermott et al., 2013; Wang et al., 2016). Mindfulness training could be one of the possible approaches to fostering adaptive emotion processing abilities during childhood.

Mindfulness training aims to support the development of metacognitive attention skills; these skills enable introspective non-reactive monitoring of mental processes and behaviour and facilitate attention control (Dorjee, 2016). In the secular context of mindfulness-based approaches (Kabat-Zinn, 1990; Segal et al., 2002), these mindfulness skills are applied in a range of practices which support the cultivation of acceptance and other adaptive emotion-regulation strategies (Garland, Farb, Goldin & Fredrickson, 2015). Research on mindfulness training with pre-adolescents has primarily been conducted within school settings; several meta-analyses and systematic reviews with both pre-adolescents and adolescents have revealed improvements in anxiety, depression, stress, resilience and emotional problems after mindfulness training (Felver et al., 2016; Zenner et al., 2014; Zoogman et al., 2015). Mindfulness training seems most effective for clinical populations; however, beneficial outcomes have been found for typically developing children as well (Zoogman et al., 2015), suggesting that mindfulness training may be effective both as a treatment and as a preventative approach.

Developmental studies of mindfulness have so far primarily used questionnaire-based measures when investigating the impact of mindfulness on emotion processing (Felver et al., 2016; Zenner et al., 2014). There are issues surrounding the validity and reliability of questionnaire-based measures, particularly as they require a level of metacognitive abilities which are developing and therefore somewhat limited in this age group (Greenberg & Harris, 2012; Zeman et al., 2007). Hence, employment of experimental response time measures and neuroscientific methods such as event related potential (ERP) assessments can be particularly advantageous in evaluating the effects of mindfulness in pre-adolescents (Kaunhoven & Dorjee, 2017). ERPs measure the brains' neural responses to stimuli with millisecond accuracy (Luck, 2014; Woodman, 2010) and are therefore particularly suited for evaluating the impact of mindfulness training on the time course of emotion processing. Collection of the brain wave signals, from which ERPs are derived, is non-invasive, child-friendly and also more cost-effective than other neuroscientific methods (Banaschewski & Brandeis, 2007; de Haan & Thomas, 2002).

The P1, N2, P3b and LPP are developmentally sensitive ERP markers of emotion processing which can be modulated by mindfulness training (Leutgeb et al., 2010; O'Toole & Dennis, 2012; Willner et al., 2015). These ERP components assess different temporal stages of an emotional response. The P1 is an occipital positivity elicited around 100ms after stimulus presentation (Dennis et al., 2009; Pourtois, Delplanque, Michel & Vuilleumier, 2008). A more positive P1 reflects an increased allocation of attention during early stages of visual processing (O'Toole & Dennis, 2012). The P1 amplitude decreases with age for emotional and non-emotional non-targets (Batty & Taylor, 2006) and targets (MacNamara et al., 2016) suggesting that early visual processes become increasingly more efficient during development. P1 responses can be of clinical significance; for example, an enhanced P1 for angry non-targets was found for children with anxiety (Hum et al., 2013a). In addition, children with a history of physical abuse elicited an enhanced left sided P1 for angry faces in a selective attention paradigm (Pollak & Tolley-Schell, 2003). There are, however, mixed findings with regards to the specificity of the P1 as an index of emotion processing for typically developing children (Dennis et al., 2009; MacNamara et al., 2016; Todd et al., 2008). Mindfulness is considered an antecedent focused regulatory strategy which acts early in emotion processing to enhance the efficient deployment of attention to emotional stimuli (Teper et al., 2013). To date, the P1 has not been used as an index of the impact of mindfulness training on emotion processing. However, an intervention study involving pre-adolescents with anxiety who attended cognitive behavioural therapy (CBT) showed that a greater P1 amplitude to emotional and non-emotional stimuli at baseline predicted non-improvement in anxiety after CBT training (Hum, Manassis & Lewis, 2013b). The effects of mindfulness-based approaches and CBT clearly can't be equated, but this study demonstrates that the P1 can be predictive of and sensitive to a psychological intervention in pre-adolescents.

The N2 is a fronto-central negativity elicited approximately 200 to 400ms after stimulus onset (Lewis et al., 2006b; Folstein & Van Petten, 2008; van Veen & Carter, 2002b). The N2 amplitude is considered a measure of cognitive control processes including conflict monitoring, response inhibition and the detection of distracting or perceptually deviant stimuli; a larger N2 amplitude is found for non-target stimuli after the successful inhibition of a response (Azizian, Freitas, Parvas & Squires, 2006; Buss et al., 2011; Folstein & Van Petten, 2008). The N2 amplitude can also provide a measure of emotion processing in children, for example, a more negative N2 to non-targets during a negative emotion inducing Go/No-go task was found in conjunction with better task performance (Lewis et al., 2006b). This may reflect a better ability to recruit cognitive control resources in emotionally demanding situations. Other studies have found a more negative N2 for both angry and happy non-target faces during Go/No-go tasks in pre-adolescents (Lewis et al., 2007; Todd et al., 2008), suggesting that positive stimuli can place similar demand on attention control resources as negative stimuli. Studies have not examined the impact of mindfulness training on the N2 for emotional faces in pre-adolescents, however, a study with older adolescents found a more negative N2 to standard and distractor non-targets during a non-emotional oddball paradigm after 8-weeks of mindfulness training (Sanger & Dorjee, 2016). This suggests that mindfulness training may enhance cognitive control in adolescence. In addition, a study with adults found that higher dispositional mindfulness was linked with a more negative N2 to neutral, positive and negative non-targets as well as enhanced behavioural performance (Quaglia et al., 2015b). Overall, mindfulness training could improve pre-adolescent's ability to recruit cognitive control resources required to monitor and inhibit processing of both positive and negative salient emotional distractors, leading to a more negative N2 amplitude.

The P3b, a parietal component elicited approximately 300ms after the presentation of infrequent targets in an oddball paradigm (Polich, 2007), indexes voluntary attention allocation typically associated with target detection (Chennu et al., 2013; Polich, 2007). The P3b amplitude is sensitive to emotion processing; a more positive P3b for target angry faces during a modified emotion oddball paradigm mediated the relationship between self-reports of anxiety and physical abuse in children with experience of maternal maltreatment (Shackman et al., 2007). In another study, this time with typically developing children, a more positive P3b for negative images was linked with reduced accuracy rates on non-emotional targets displayed right after the negative images (Kujawa et al., 2013b).

In adult research, mindfulness training has been shown to facilitate more efficient and balanced allocation of attention resources, indexed by the P3b (Moore et al., 2012;

Slagter et al., 2007). Whilst the impact of mindfulness training on the P3b for angry and happy faces has not yet been examined in pre-adolescents or adults, numerous studies have found beneficial effects of mindfulness training on symptoms of anxiety and stress for pre-adolescents (Felver et al., 2016; Zenner et al., 2014; Zoogman et al., 2015). Mindfulness training could facilitate more adaptive processing of negative emotions through disengaging from automatic emotional reactions and reducing the allocation of attention towards negative stimuli, resulting in an attenuation of the P3b (Kaunhoven & Dorjee, 2017).

The LPP is a sustained occipital/parietal positivity elicited between 300ms and 2000ms after stimulus onset (Hajcak et al., 2010; Kujawa et al., 2012b; Kujawa et al., 2013a; Kujawa et al., 2013b). The LPP indexes sustained emotional responses, a more positive LPP is elicited for emotionally arousing stimuli (DeCicco et al., 2012; Hajcak et al., 2010; Solomon et al., 2012). Enhanced LPP for positive pre-target distractors has been linked with decrements in target accuracy for typically developing children (Kujawa et al., 2012b). Pre-adolescents with social anxiety elicit more positive LPPs for angry and fearful faces (Kujawa et al., 2015). Mindfulness training could facilitate a disengagement from maladaptive prolonged emotional responses through fostering a non-reactive attitude towards emotions and thus reducing rumination. Indeed, less positive LPP amplitudes were found during re-exposure to negative images for adults after brief mindfulness inductions in comparison to passive viewing or distraction focused conditions (Uusberg et al., 2016) and less positive LPP amplitudes have also been found for adults with extensive meditation experience (Sobolewski et al., 2011). In contrast, only Sobolewski et al., (2011) examined the relationship between meditation experience and the LPP for positive stimuli, no modulations were found, suggesting that mindfulness training may initially target the processing of negative stimuli. No study so far investigated modulations in the LPP to emotional images in pre-adolescents, but based on the outlined evidence it could be predicted that mindfulness training would result in reductions of the LPP to negative stimuli whereas there doesn't seem to be enough research evidence to make conclusive predictions regarding the LPP changes for positive stimuli.

The current longitudinal pilot study explored the effectiveness of a mindfulness training programme (Paws b), delivered by children's own school teachers, for enhancing emotion processing abilities in pre-adolescents in comparison to the usual school curriculum. This teacher-led method of implementation is in line with educational policies in the United Kingdom which favour a whole school approach targeting the emotional health and wellbeing of both staff and pupils (Public Health England, 2015; Wales Institute for Public Policy, 2016).

ERP indexes of emotion processing (P1, P3b, N2 and LPP) were derived from children's responses in an emotion oddball paradigm which included Go and No-go oddballs. Neutral faces were presented as frequent standards, which did not require a response, and happy and angry faces were presented as infrequent targets (Go oddballs) and non-targets (No-go oddballs). Emotional faces were chosen as they contain relevant information regarding social cues and have previously been used as markers of emotional processing in children (Batty & Taylor, 2006; Todd et al., 2008; Wu et al., 2016). Both angry and happy faces were used to assess the impact of mindfulness training on both positively and negatively valenced stimuli. In this current study an attenuation of the P3b for angry targets was expected after mindfulness training, reflecting an improvement in the efficient deployment of attention resources towards negatively valenced stimuli (Kaunhoven & Dorjee, 2017). In addition, an attenuation of the LPP for both target and non-target angry faces was expected after mindfulness training reflecting an overall decrease in sustained negative emotional responses, as evidenced in adult mindfulness studies which have used the LPP as an index of change (Sobolewski et al., 2012; Uusberg et al., 2016). Whilst clear predictions could be given with regards to the ERP responses to angry faces, exploratory analysis for the P3b and LPP was also conducted to examine the impact of mindfulness training on the processing of positive emotions (happy faces) as this is an interesting yet underexplored question. With regards to the N2, a more negative mean amplitude was expected for happy and angry No-go oddballs, reflecting an enhanced ability to recruit cognitive control resources to monitor and inhibit processing of these emotional distractors. Finally, we examined whether mindfulness training would reduce the attention resources required for stimulus processing during the early stages of attention processing indexed by the P1 amplitude, resulting in a less positive P1 mean amplitudes across all stimuli. As previous studies have not found consistent mindfulness training related modulations on behavioural measures (Sanger & Dorjee, unpublished results; Sanger & Dorjee, 2016; Schonert-Reichl et al., 2015), no specific hypotheses were made for the current study. With regards to self-report assessments, improvements in self-reports of negative and positive affect, emotional awareness and emotional expression and attentional control were expected for pre-adolescents after mindfulness training.

Method

Participants

The study was approved by the Bangor University School of Psychology Ethics Committee and the NHS Research Ethics Committee prior to participant recruitment. At each testing session each child received a small stationary gift (e.g., a pencil) for their participation. Four primary schools in North Wales participated in this study and were assigned to either a mindfulness training group (*n* = 2 schools) or a wait-list control group (*n* = 2 schools) using a first to opt in basis. Both the training group and wait-list control group consisted of one school which was above and one school which was below the national average (20.8%) on the socioeconomic criteria of free school meals (training group schools: 49.4% and 4.2%; wait-list control group schools: 45.3% and 12.7%). The schools were matched on language policy. Pre-adolescents (7 to 11 years of age) were recruited from these schools using convenience sampling. All participants had normal or corrected to normal hearing and vision and the only exclusion was a diagnosis of epilepsy. Informed parental consent and informed pupil assent was gained from 76 pre-adolescents (training group *n* = 46; control group *n* = 30) for a larger study on mindfulness and self-regulation. For this section of the study 39 participants were excluded from the ERP analysis due to the following reasons: incompletion of the testing sessions at either pre-test or post-test (training group *n* = 4; control group *n* = 5), absence from the testing session at post-test (training group *n* = 2; control group *n* = 5), high error rates (> 35%; training group *n* = 11; control group *n* = 7) or excessive artifacts in the ERP data (training group *n* = 4; control group *n* = 2). A complete data set including self-report, behavioural and ERP data for each participant was obtained from a total of 25 participants in the training group (10 female; *M* = 10.05 years, *SD* = 1.01, 8.58 – 11.33 years; 21 right handed) and 11 participants in the wait-list control group (5 female; *M* = 9.70 years, *SD* = 1.01, 8.50 – 10.92 years; 9 right handed). No significant group differences in age, gender or English as the first language learnt were found (all *p*s > .1). No significant group differences in whether participants were from schools high or low in the socioeconomic criteria of free school meals was found (*p* >

.1). One participant in the control group was ambidextrous, no significant group difference in right or left handedness was found ($p > .05$), see Table 1.

Table 1.

A summary of the demographic information for participants (training group n = 25, wait-list control group n = 11).

	Demographic information			
	Training group		Wait list control group	
	(*n*)	(%)	(*n*)	(%)
Participants	25		11	
Gender: Female	10	40	5	45.45
Handedness: Right	21	84	9	81.81
First language: English	21	84	9	81.81
First language: Welsh	3	12	2	18.18
First language: Other	1	4	0	0
Age (Year 3)	0	0	2	18.2
Age (Year 4)	9	36	3	27.3
Age (Year 5)	6	24	3	27.3
Age (Year 6)	10	40	3	27.3
Age (*M*)	10.05 years		9.70 years	
Age (*SD*)	1.01 years		1.01 years	
Age (Range)	8.58 – 11.33 years		8.50 – 10.92 years	

Self-report measures

A form detailing demographics, handedness, language skills and brain injury/epilepsy was administered to pupils.

The Child and Adolescent Mindfulness Measure (CAMM; Greco et al., 2011), a 10 item self-report questionnaire, assessed the ability to non-judgmentally observe and accept internal experiences and act with awareness in the present moment. Responses were recorded on a 5-point Likert scale (0 = never true to 4 = always true) and a total mindfulness score was calculated by reversing and summing all scores. This measure was designed for children and adolescents aged between 10 and 16 years (Greco et al., 2011). Good internal consistency for the ten items has been found for 10-12 year olds (α = .71; de Bruin et al., 2014). In addition, factor analysis revealed that for 10-12 year olds the CAMM could be divided into two components; present moment non-judgemental awareness (items 1, 2, 4, 6, 7, 8, 9) which had good internal consistency (α = .72) and suppressing or avoiding thoughts and feelings (items 3, 5, 10) which had lower internal consistency (α = .58). No gender differences in the CAMM scores have previously been found (de Bruin et al., 2014; Greco et al., 2011). This study analysed total CAMM scores and scores for the present moment non-judgemental awareness subscale.

The Positive and Negative Affectivity Scale for Children (PANAS-C short version; Ebesutani et al., 2012), a 10 item self-report, measured the experience of positive and negative emotions. Responses were recorded on a five-point Likert scale (1 = very slightly/ not at all, 5 = extremely) and total scores were calculated for each subscale by summing scores. The measure was designed for children aged 6 to 18 year olds and high internal consistency was found for the negative affect subscale (α = .82) and the positive affect subscale (α = .86) for this age group (Ebesutani et al., 2012).

The Emotion Expression Scale for Children (EESC; Penza-Clyve & Zeman, 2002), a 16-item self-report, measured poor awareness (lack of emotional awareness) and expressive reluctance (the lack of motivation to express negative emotions). Responses were recorded on a 5-point Likert scale (1 = not at all true, 5 = very true) and total scores were calculated for each subscale by summing scores. This measure was designed for 9-12 year olds, high internal consistency was found for the poor awareness subscale (α = .83) and the expressive reluctance subscale for this age group (α = 81; Penza-Clyve & Zeman, 2002). No gender differences in emotional expression have previously been found (Penza-Clyve & Zeman, 2002).

The Attentional Control Scale for Children (ACS-C; Muris et al., 2004), a 20-item self-report, assessed two forms of attentional control; attentional focusing and attentional shifting. Responses were recorded on a 4-point Likert scale (1 = almost never, 4 = always) and total scores for the two subscales were calculated. This measure was designed for children aged 8 to 13 years of age, acceptable internal consistency was reported for total attentional control (α = .80) and the subscales of attentional focusing (α = .65) and attentional shifting for this age group (α = .71; Muris et al., 2004).

A brief acceptability self-report questionnaire was administered to pupils from the training schools after the mindfulness Paws b curriculum. Specifically, participants were asked to rate how much they liked the mindfulness curriculum using a 7 point Likert scale (1 = not at all; 7 = very much). Participants were also asked how often they practiced mindfulness at home (ranging from never to every day) and whether they would like to carry on practicing mindfulness at school.

Mindfulness (Paws b) curriculum

The Paws b mindfulness curriculum (https://mindfulnessinschools.org/) was developed by Sarah Silverton (an experienced mindfulness trainer), Tabitha Sawyer and

Rhian Roxburgh (teachers from Ysgol Pen-Y-Bryn, Colwyn Bay) in conjunction with the Mindfulness in Schools Project (MISP). It was designed for pupils in Key Stage 2 and focuses on building adaptive skills and knowledge to promote well-being, resilience and adaptive relationships with others. Children also learn about the relationship between their cognitions and emotional and physiological reactions (Mindfulness in Schools Project, 2015). This curriculum was delivered over 10 weeks (between February and June 2015) within a classroom environment as part of the regular school curriculum (in personal, social and health education lessons; PSHE and Science class). The curriculum consisted of 12 half hour sessions which were delivered weekly, except for two of the ten weeks where two sessions were delivered. School teachers (*n* = 4) were required to progress through several stages of training; initially teachers attended a mindfulness course (.b foundations; Mindfulness in Schools Project, 2015) which provided mindfulness training tailored to meet the needs of school staff; this training was delivered over three months in 4 sessions, each 3 hours 15 minutes in length. Following this teachers were given 5 months to develop a regular mindfulness practice and then received three full days of Paws b curriculum training. All pupils in the class received the Paws b curriculum, and participation in the research study was optional. This teacher led delivery of the Paws b curriculum has previously been found feasible and acceptable for implementation in school classrooms (Vickery & Dorjee, 2015). The same initial training in mindfulness followed by training in the Paws b curriculum was offered to teachers from the wait-list control group after completion of the study.

Emotion oddball paradigm

The oddball task involved the presentation of happy, angry and neutral faces taken from the Karolinska faces database (Lundqvist et al., 1998). This database was chosen as it has previously been successfully used in studies on emotion processing with children (Lewis et al., 2007). Neutral faces comprised 70% of total trials (one male face for 176 trials, one female face for 176 trials). Happy faces were presented in 15% of total trials (19 female faces and 19 male faces were presented once as targets for 38 trials and once again as non-targets for 38 trials). Angry faces (from the same actors as the happy faces) were presented in the remaining 15% of total trials (19 female faces and 19 male faces were presented once as targets for 38 trials and once again as non-targets for 38 trials). Each face was presented for 900ms with a gap of 750ms between stimuli. The entire task took approximately 14 minutes.

The task was presented over four blocks with breaks in between, for two consecutive blocks participants were instructed to press the keyboard spacebar in response to happy facial expressions (happy targets) and ignore the angry faces (angry non-targets) and neutral faces (neutral Blocks1&2 non-targets). For the other two consecutive blocks participants were instructed to respond to angry faces (angry targets) and ignore the happy faces (happy non-targets) and neutral faces (neutral Blocks3&4 non-targets). The order of the blocks was counterbalanced and the order of the faces presented within each block was randomised, no difference in the counterbalanced versions of the task were found between both groups ($p < .05$). Happy and angry faces were evenly distributed across the blocks and matched on arousal and intensity between the blocks and across the whole task (all *p*s > .05). The hit rate of happy and angry faces (validation measure from the Karolinska database showing emotion identification accuracy rates, faces with a hit rate above 70% were included as stimuli in the study) was also matched between the blocks and across the whole task (all *p*s > .05). Male and female faces were evenly distributed across the blocks, no differences in arousal, intensity or hit rate were found between male and female faces across the whole task or between the blocks (all *p*s > .05).

Design and procedure

This study followed a non-randomised longitudinal design with a wait-list control group. Participants took part in testing sessions in the two weeks before and after delivery of the 10 week Paws b curriculum. The delivery of the curriculum across the two training schools was staggered by a week to enable the research sessions to be conducted as close as possible to the start and end of curriculum delivery. The wait-list control group had the same time duration between the pre-testing and post-testing as the training group. Each testing session took approximately one hour per participant. The testing sessions were conducted on school premises in a small room designated for testing; all the resources needed for testing, including the EEG equipment, were brought to the school. Participants completed the self-report measures under research assistant supervision who read the questions aloud to aid with understanding.

Participants were seated in front of the computer screen and a 32-channel electrode cap (EasyCap, Brain Products) was fitted. Participants were asked to remain still and focus on the laptop screen throughout the experimental task. In addition to the emotion oddball task, participants in the same session completed an attention oddball task (chapter four) and their resting electrocardiogram data was also collected for further heart-rate variability analyses (chapter six).

Event related potential (ERP) analysis

EEG signal was recorded during the emotion oddball task at a rate of 1kHz using NeuroScan NuAmp amplifiers connected to 32 Ag/AgCl electrodes referenced online to the right mastoid, offline the right and left mastoid channels were averaged together using linear derivation. Two additional electrodes were placed above and below the left eye to record ocular movements. The impedance of all electrodes was kept below 7 kOhms. The EEG signal was filtered online with a bandpass filter range of 0.01 to 200Hz. Offline, the EEG signal was bandpass filtered with a zero shift low pass filter cut off point of 30Hz and a 48dB/Oct slope and a high pass filter cut off point of 0.1Hz. The EEG data was then manually cleaned to reject motor artefacts or irregular ocular artefacts. In the next step of the analysis, eye-blinks were regressed out of the signal to remove ocular artefacts. The data was epoched into 1 second segments and baseline corrected using the first 100ms segment recorded before the onset of the stimulus. Averages were computed for each participant in each condition and then grand averages were computed for each condition and participant group. To define the search intervals for the ERP components, the grand mean global field power across the scalp was used. The P1 was classified as the mean voltage between 100-180ms averaged across electrodes PO7, PO8, O1 and O2, this occipital topography is consistent with previous P1 studies with pre-adolescents (Dennis et al., 2009; Hum et al., 2013a). The N2 was classified as the mean voltage between 340-425ms averaged across electrodes FC1, FC2, FC3, FC4, FCz and Fz, this frontal topography and time window has previously been found in studies with pre-adolescents (Espinet et al., 2012; Lewis et al., 2008; Shackman et al., 2007). The P3b was determined as the mean voltage between 425-620ms averaged across electrode sites P1, P2, P3, P4 and Pz, this parietal topography is in line with previous P3b studies in adults and children (Polich, 2007; Shackman et al., 2007).

The LPP was classified as the mean voltage between 300-700ms averaged across electrodes PO7, PO8, O1 and O2; whilst this topography is more posterior than studies with adults, this topography is consistent with previous LPP studies with pre-adolescents (Kujawa et al., 2012b; Kujawa et al., 2013a, Kujawa et al., 2013b; Kujawa et al., 2015). Latency analysis for the P1 and P3b ERP components was conducted on the maximal electrode; for the P1 waveform this was electrode O1, for the P3b waveform this was electrode P4, for the N2 waveform this was electrode FC1. ERP analysis was only conducted on correct trials.

Results

Self-report, behavioural and ERP data was analysed for the training group (n = 25) and wait-list control group (n = 11). Missing data was identified and replaced using the multiple imputation method. Baseline group differences were assessed using independent samples t-tests or mixed factorial analyses of variance. Changes in the measures over time for the two groups were evaluated using mixed factorial analysis of variance (ANOVA). Eta squared (η^2) was calculated to provide an estimate of effect size. Significant interactions were followed up by two-tailed paired samples t-tests and Cohens *d* was calculated as an estimate of effect size. Results reported below are after extreme outliers (>3 x interquartile range) were winsorised. To explore whether the age of participants impacted on the results, additional analysis was conducted with age as a factor. Children were divided into two age brackets; older (years 5 and 6; 9.58 – 11.33 years) and younger (years 3 and 4; 8.5 – 9.25 years). Chi square tests revealed no significant group difference for these age categories [$X^2(1, N = 36) = .287, p = .716, V = -.089$].

Acceptability Results

Analyses of the acceptability self-report revealed that 76% of participants liked the mindfulness curriculum and only 4% responded that they disliked it. 52% reported practicing mindfulness often at home and 8% recorded that they practiced mindfulness every day. 64% of participants rated that they would like to continue practicing mindfulness in school and 36% that they would maybe like to continue with mindfulness training at school.

Self-report Results

The Child and Adolescent Mindfulness Measure (CAMM), Positive and Negative Affectivity Scale for Children (PANAS-C), Emotion Expression Scale for Children (EESC) and Attentional Control Scale for Children (ACS-C) measures were analysed. For the CAMM and ACS-C there was missing data at post-test (< 5%), missing data was replaced using the multiple imputation method. One participant did not complete the ACS-C and EESC at post-test and was therefore excluded from analysis for these questionnaires. Baseline differences were assessed using independent samples t-tests and longitudinal changes in self-reports were evaluated by 2 (group: training group, control group) x 2 (time: pre-test, post-test) mixed ANOVAs.

The CAMM had poor internal consistency at pre-test ($\alpha = .497$) and good internal consistency at post-test ($\alpha = .719$). At baseline, no difference between groups was found ($p > .1$). Longitudinal analysis revealed a marginally significant main effect of time [$F(1, 34) = 3.58$, $p = .067$, $\eta^2 = .10$], scores decreased over time. There was no significant main effect of group or time x group interaction (all *p*s > .1), see *Figure 1*.

Cronbach's alpha was also calculated for a present-moment non-judgemental awareness subscale of the CAMM, in line with previous research conducted with 10-12 year olds (de Bruin et al., 2014). This subscale had fair internal consistency at pre-test (α = .600) and good internal consistency at post-test (α = .754). At baseline, no difference between groups was found (p > .1). Longitudinal analysis revealed a significant main effect of time [F(1, 34) = 5.27, p = .028, η^2 = .13], scores were higher at pre-test. No significant main effect of group or time x group interaction were found (all ps > .1), see *Figure 1*.

The PANAS-C positive affect subscale had good internal consistency at pre-test (α = .613) and at post-test (α = .716). At baseline there was a marginally significant difference between groups for the positive affect subscale [t(34) = -1.84, p = .075, d = -0.67], scores were higher for the control group. Longitudinal analysis revealed no significant main effect of time or group (all ps > .1), but a marginally significant time x group interaction was found [F(1, 34) = 3.82, p = .059, η^2 = .10] While scores marginally significantly increased for the training group over time [t(24) = -1.98, p = .06, d = - 0.40], no change in scores was found for the control group [t(10) = .96, p = .36, d = 0.29], see *Figure 1*.

The PANAS-C negative affect subscale had good internal consistency at pre-test (α = .651) and post-test (α = .737). Significant baseline differences were found for negative affect scores [t(33.82) = 3.32, p = .002, d = 1.02], the training group was higher in negative affect at baseline. Longitudinal analysis revealed a significant main effect of time [F(1, 34) = 8.79, p = .006, η^2 = .18], scores increased over time. There was no significant main effect of group (p > .1). A significant time x group interaction was also found [F(1, 34) = 5.82, p = .021, η^2 = .12], no change in scores was found for the training group [t(24) = .54, p = .594, d = -0.11], but scores significantly increased over time for the control group [t(10) = -2.78, p = .020, d = -0.84], see *Figure 1*. To examine whether baseline differences in negative affect impacted on the findings, the significant time x group interaction was followed up by conducting an analysis of covariance (ANCOVA) using baseline scores as a covariate. The ANCOVA revealed marginally significant group differences in negative affect at post-test after controlling for baseline differences [$F(1, 33) = 3.25$, $p = .081$, $\eta^2 = .49$].

The EESC poor awareness subscale had good internal consistency at pre-test ($\alpha = .786$) and post-test ($\alpha = .843$). At baseline, no difference between groups was found ($p > .1$). Longitudinal analysis revealed no significant time or group main effects or time x group interaction (all ps > .1), see *Figure 1*.

The EESC expressive reluctance subscale had good internal consistency at pre-test ($\alpha = .787$) and post-test ($\alpha = .775$). At baseline, no difference between groups was found ($p > .1$). Longitudinal analysis revealed no significant time or group main effects or time x group interaction (all ps > .1), see *Figure 1*.

The ACS-C attentional shifting subscale had fair internal consistency at pre-test ($\alpha = .669$) and good internal consistency at post-test ($\alpha = .754$). At baseline, significant differences were found for attention shifting scores [$t(33) = -2.71$, $p = .013$, $d = -0.96$], scores were marginally higher for the control group. Longitudinal analysis revealed no significant main effect of time ($p > .1$), there was a significant main effect of group [$F(1, 33) = 7.16$, $p = .012$, $\eta^2 = .18$], scores were higher for the control group. There was no significant time x group interaction ($p > .1$), see *Figure 1*.

The ACS-C attentional focusing subscale had poor internal consistency at pre-test ($\alpha = .393$) and fair internal consistency at post-test ($\alpha = .576$). At baseline significant group differences were also found for attention focusing [$t(33) = -2.35$, $p = .025$, $d = -0.78$], scores were higher for the control group. Longitudinal analysis revealed no significant main effect of time ($p > .1$), there was a marginally significant main effect of group [$F(1, 33) = 2.94$, $p =

.096, η^2 = .082], scores were marginally higher for the control group. No significant time x group interaction was found (p > .1) see *Figure 1*.

Age analysis

To examine the effects of age on longitudinal changes in the self-report measures, 2 (age; older, younger) x 2 (group; training group, control group) x 2 (time; pre-test, post-test) mixed factorial ANOVAs were conducted. For attentional shifting there was a marginal time x group x age interaction [F(1, 31) = 3.13, p = .087, η^2 = .09], follow up t tests were not significant (all ps > .1). There were no other significant main effects or interactions involving age for attentional shifting (all ps > .1). Age also did not impact on the findings for any of the other self-report measures (all ps > .1).

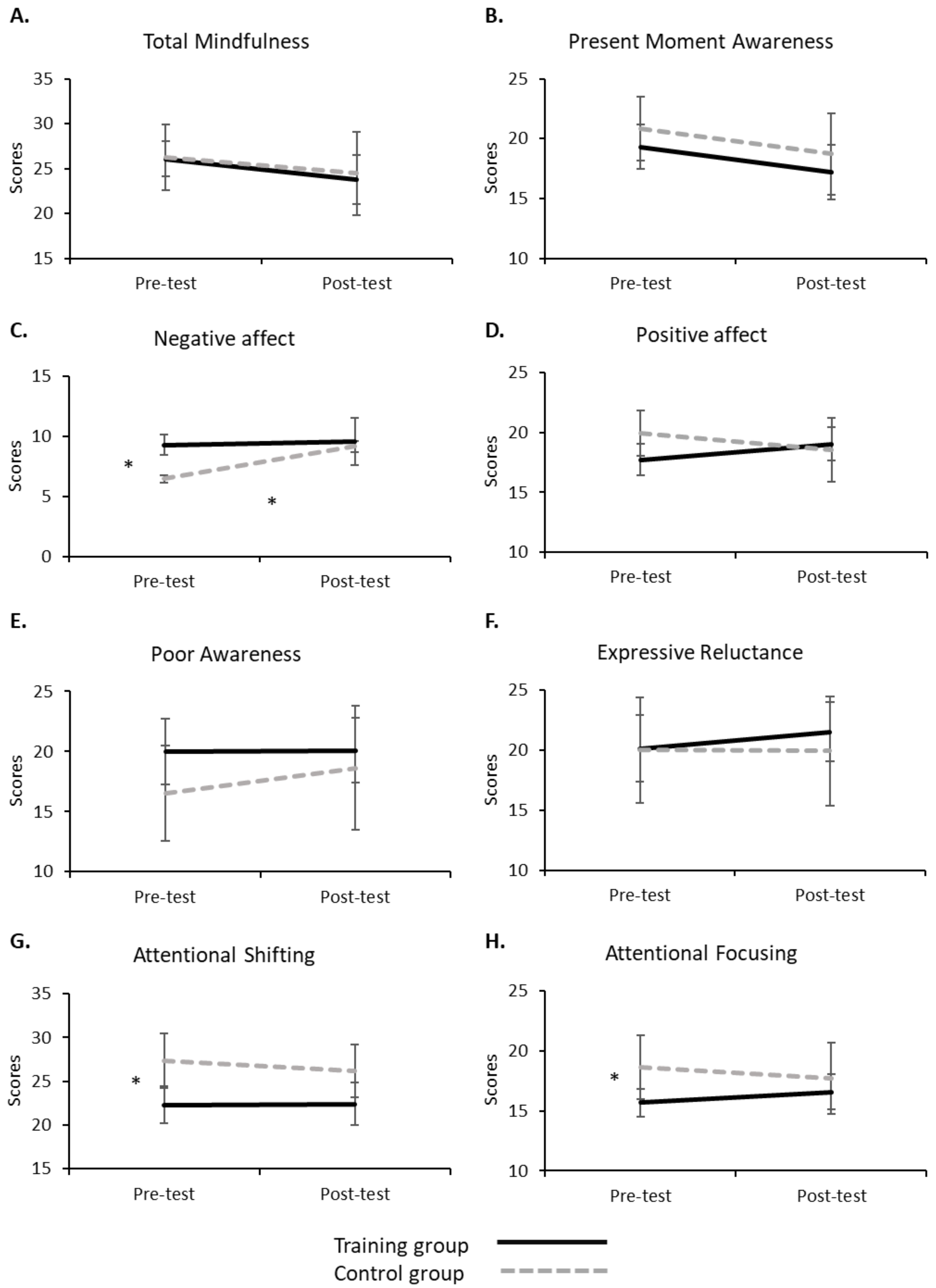


Figure 1. Pre-post changes for the training group (*n* = 25) and control group (*n* = 11) for A) total mindfulness scores, B) Present moment non-judgemental awareness scores, C) PANAS-C negative affect scores, D) PANAS-C positive affect scores, E) EESC poor emotional awareness scores, F) EESC expressive reluctance scores, G) ACS-C attentional shifting scores and H) ACS-S attentional focusing scores. Error bars indicate 95% CI.

Behavioural Results

Accuracy rates (% of correct responses) were computed for happy and angry targets and false alarm rates were recorded for non-targets. Response times were computed for happy and angry correct targets. Response times which were shorter than 199ms and longer than 900ms were excluded from the analysis. There was no missing data. There were no group differences in the proportion of children excluded from data analysis due to poor error rates [$X^2(1, N = 54) = 0.375$, $p = .760$, $V = .083$].

Baseline differences in accuracy rates for targets were assessed using a 2 (group; training, control) x 2 (condition; angry targets, happy targets) mixed factorial ANOVA. There was a marginally significant main effect of group [$F(1, 34) = 3.20$, $p = .082$, $\eta^2 =.09$], accuracy rates were marginally higher for the training group. No significant main effect of condition or group x condition interaction were found (all ps > .1). To assess longitudinal changes in accuracy rates a 2 (group) x 2 (time; pre-test, post-test) x 2 (condition) mixed factorial ANOVA was conducted. There was a significant main effect of group [$F(1, 34) = 6.11$, $p = .019$, $\eta^2 = .15$], accuracy rates were higher for the training group. There were no other significant main effects or interactions (all ps > .1), see *Figure 2*.

Baseline differences in false alarms for non-targets were assessed using a 2 (group; training, control) x 4 (condition; angry non-targets, happy non-targets, neutral-Blocks1&2 non-targets, neutral-Blocks3&4 non-targets) mixed factorial ANOVA. There was a main effect of condition [$F(1.87, 63.66) = 25.06$, $p < .001$, $\eta^2 = .42$], pairwise comparisons revealed that neutral non-targets had significantly fewer false alarms than angry and happy non-targets (all ps < .1). There was no significant main effect of group or group x condition interaction (all ps > .1).

Longitudinal changes in false alarm rates were assessed by a 2 (group) x 2 (time; pre-test, post-test) x 4 (condition) mixed factorial ANOVA. There was a marginally significant main effect of time [$F(1, 34) = 3.53$, $p = .069$, $\eta^2 = .006$], there were fewer false alarms at post-test. There was a significant main effect of condition [$F(2.02, 68.60) = 36.00$, $p < .001$, $\eta^2 = .37$], pairwise comparisons revealed that there were fewer false alarms for neutral non-targets compared to happy and angry non-targets (all *p*s < .1). There were no other significant main effects or interactions (all *p*s > .1), see *Figure 2.*

Baseline differences in response times for the angry and happy targets were assessed using a 2 (group) x 2 (condition; angry targets, happy targets) mixed ANOVA. There was a significant main effect of condition [$F(1, 34) = 8.48$, $p = .006$, $\eta^2 = .19$], response times were faster for happy targets. There was a marginally significant main effect of group [$F(1, 34) = 3.46$, $p = .072$, $\eta^2 =.09$], response times were faster for the training group. There was no significant group x condition interaction (*p*s > .1).

Longitudinal changes in response times were assessed by a 2 (group) x 2 (time) x 2 (condition) mixed ANOVA. There was a significant main effect of group [$F(1, 34) = 7.43$, $p = .010$, $\eta^2 = .18$], response times were faster for the training group, and a significant main effect of condition [$F(1, 34) = 11.94$, $p = .001$, $\eta^2 = .11$], response times were faster for happy targets. There was no significant main effect of time ($p > .1$). There was also a marginally significant time x condition x group interaction [$F(1, 34) = 3.92$, $p = .056$, $\eta^2 = .02$], paired samples t tests revealed that for happy faces the control group got slower over time [*t*10) = -2.07, $p = .066$, $d = -0.62$], the response times to angry faces did not change over time ($p > .1$). For the training group, the response times for happy and angry faces did not significantly change across time (all *p*s > .1) see *Figure 2*.

Age analysis

To examine whether the age of participants impacted on longitudinal changes in target accuracy, target response times and non-target false alarm rates, additional time x condition x group x age mixed factorial ANOVAs were conducted. For false alarm rates there was a significant main effect of age [$F(1, 32) = 4.36$, $p = .045$, $\eta^2 = .11$], false alarm rates were higher for younger children. There was also a significant condition x age interaction [$F(3, 96) = 3.66$, $p = .015$, $\eta^2 = .03$], false alarm rates for happy non-targets were higher for younger children [$t(34) = 3.15$, $p = .003$, $d = 1.03$]. There were no other significant main effects or interactions (all *p*s > .1). For target accuracy and response times, age had no effect on the findings (all *p*s > .1).

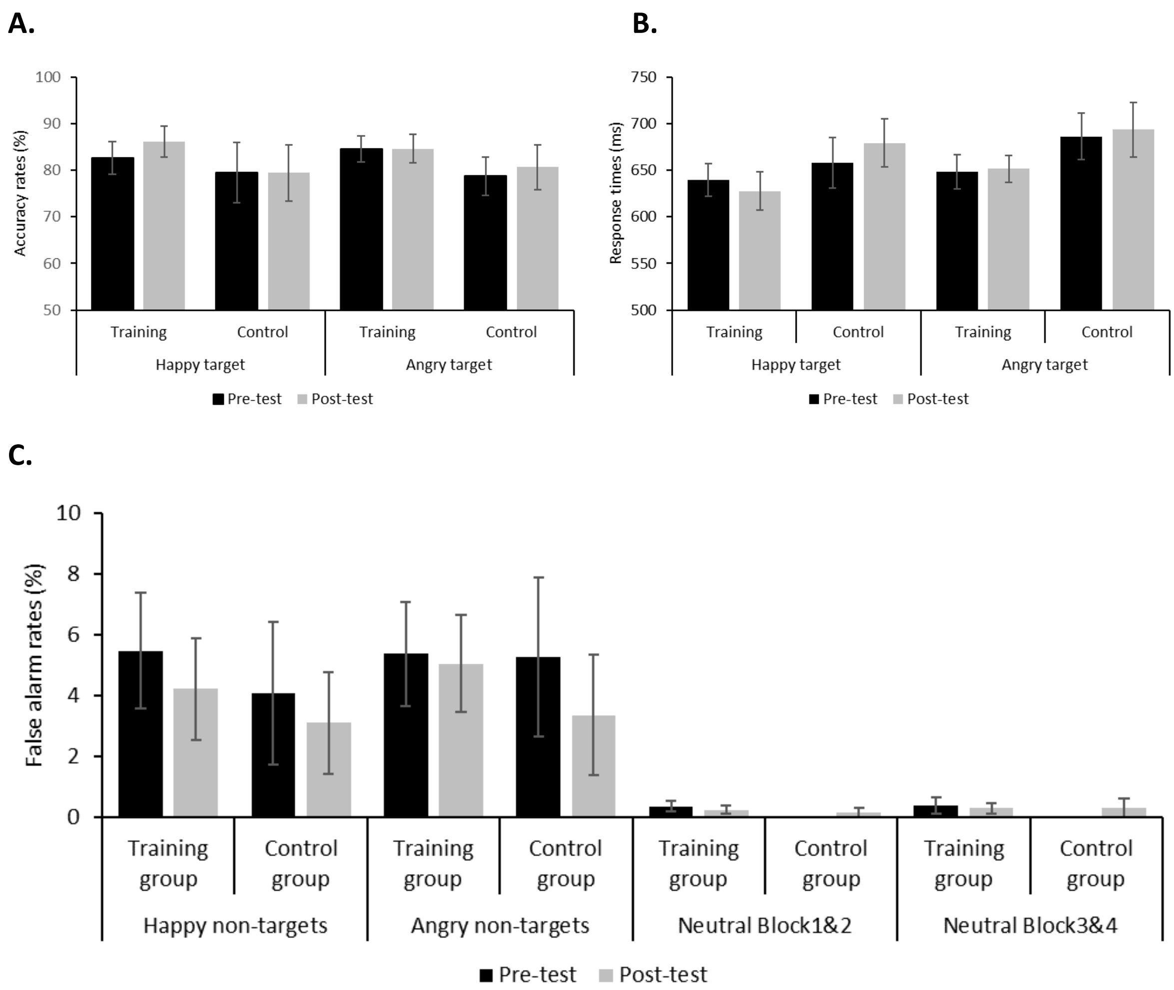


Figure 2. Pre-post changes for the training group (n = 25) and control group (n = 11) for A) happy and angry target accuracy rates (%) B) happy and angry target response times (ms) C) happy, angry and neutral non-target false alarm rates (%). Error bars indicate 95% confidence intervals (CI).

ERP Results

ERP analysis was conducted for the P1 component, P3b component and LPP component. The minimum number of trials per condition was 23 trials. If the assumption of sphericity was violated for any of the comparisons, Greenhouse-Geisser correction was applied. There was missing data on one electrode (FCz) for one participant at pre-test, this was replaced using multiple imputation.

P1 component

Baseline differences in mean P1 amplitude were assessed by a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Blocks3&4 non-target) mixed factorial ANOVA. There was a marginally significant main effect of group [$F(1, 34) = 3.21$, $p = .082$, $\eta^2 = .09$], the P1 mean amplitude was more positive for the training group. No significant main effect of condition or group x condition interaction was found ($p > .1$).

Longitudinal differences in mean P1 amplitude were assessed by a mixed ANOVA: 2 (group; training, control) x 2 (time; pre-test, post-test) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Blocks1&2 non-target, neutral Blocks3&4 non-target). There was a significant main effect of condition [$F(3.70, 125.81) = 2.71$, $p = .037$, $\eta^2 = .018$], pairwise comparisons revealed that the P1 mean amplitude for happy targets was significantly more positive than for happy non-targets and neutral non-targets and marginally more positive than angry non-targets (all ps <.1), no difference between happy targets and angry targets was found (p >.1). In addition, the P1 mean amplitude for angry targets was significantly more positive than neutral Block3&4 non-targets ($p < .1$) and marginally more positive than neutral-Block1&2 non-targets ($p = .051$). There were no other significant main effects (all ps > .1). There was also a significant time x group interaction [$F(1, 34) = 10.46$, $p = .003$, $\eta^2 = .12$], paired samples t tests revealed no significant attenuation of the P1 mean amplitude for the training group over time [$t(24) = 1.53$, $p = .138$, $d = 0.31$], but the P1 mean amplitude became more positive for the control group over time [$t(10) = -3.46$, $p = .006$, $d = -1.04$]. In addition, there was a marginally significant time x condition x group interaction [$F(5, 170) = 2.12$, $p = .065$, $\eta^2 = .012$], the paired samples t-tests indicated that for the training group the P1 mean amplitude for angry targets became marginally less positive over time [$t(24) = 2.00$, $p = .058$, $d = 0.40$]. For the control group the P1 mean amplitude became more positive for angry non-targets [$t(10) = -2.33$, $p = .042$, $d = -0.70$], angry targets [$t(10) = -3.49$, $p = .006$ $d = -1.05$], happy non-targets [$t(10) = -2.45$, $p = .034$, $d = -0.74$], happy targets [$t(10) = -2.24$, $p = .049$, $d = -0.67$] and neutral Block1&2 non-targets [$t(10) = -3.01$, $p = .013$, $d = -0.91$] and marginally more positive for neutral Block3&4 non-target [$t(10) = -2.17$, $p = .056$, $d = -0.65$] over time, see *Figure 3*.

Baseline differences in the P1 latency were analysed using a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was no significant main effect of condition or group and no significant condition x group interaction (all *p*s > .1). Longitudinal differences in P1 latency were analysed using a 2 (group; training, control) x 2 (time; pre-test, post-test) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There were no significant main effects or interactions (all *p*s > .1).

N2 component

Baseline differences in N2 mean amplitude were assessed by a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Blocks3&4 non-target) mixed factorial ANOVA. There was a significant main effect of condition [$F(3.93, 133.67) = 5.95$, $p < .001$, $\eta^2 = .15$]. Pairwise comparisons revealed the N2 for angry-non-targets was significantly more negative than happy targets and neutral non-targets and marginally more negative than for happy non-targets. The N2 for angry targets was significantly more negative than happy targets and neutral non-targets. The N2 mean amplitude for happy non-targets was significantly more positive than neutral non-targets (all *ps* < .1). There was no significant main effect of group or condition x group interaction (all *p*s > .1).

Longitudinal differences in mean N2 amplitude were assessed for happy and angry non-targets by conducting a mixed ANOVA: 2 (group; training, control) x 2 (time; pre-test, post-test) x 2 (condition; angry non-target, happy non-target). There was a marginally significant time x condition interaction [$F(1, 34) = 3.98$. $p = .054$, $\eta^2 = .03$], paired samples t tests were not significant. There was no other significant main effects or interactions (all *p*s > .1), see *Figure 4*.

Baseline differences in the N2 latency were analysed using a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was no significant main effect of condition or group and no significant condition x group interaction (all *p*s > .1). Longitudinal differences in N2 latency were analysed using a 2 (group; training, control) x 2 (time; pre-test, post-test) x 2 (condition; angry non-target, happy non-target) mixed factorial ANOVA. There were no significant main effects or interactions (all *p*s > .1).

P3b component

Baseline differences were assessed by a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was a significant main effect of condition [$F(3.97, 134.89) = 44.24$, $p < .001$, $\eta^2 = .56$], pairwise comparisons revealed that as expected the P3b mean amplitude for angry and happy targets was significantly more positive than for angry and happy non-targets and neutral non-targets. In addition, P3b mean amplitudes for angry and happy non-targets were significantly more positive than for neutral stimuli (all *p*s < .1). There was no significant main effect of group or significant group x condition interaction (all *p*s > .1).

The longitudinal analysis focused on the P3b mean amplitude for angry and happy targets. A 2 (group; training, control) x 2 (time; pre-test, post-test) x 2 (condition; angry targets, happy targets) mixed factorial ANOVA was conducted. There was a marginally significant main effect of condition [$F(1, 34) = 3.70$, $p = .063$, $\eta^2 = .04$], the P3b mean amplitude was more significant for angry targets. There were no significant main effects or interactions (all *p*s > .1), see *Figure 5*.

Baseline differences in the P3b latency were analysed using a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was a significant main effect of condition [$F(5, 170) = 16.43$, $p < .001$, $\eta^2 = .32$], pairwise comparisons revealed that the latencies for neutral non-targets were significantly earlier than for angry and happy targets and non-targets. The latency for angry-non-targets was marginally earlier than happy non-targets and targets. The latency for angry targets was marginally earlier than happy non-targets (all *p*s < .1). There was no significant main effect of group and no significant condition x group interaction (all *p*s > .1).

Longitudinal differences in P3b latency were analysed using a 2 (group; training, control) x 2 (time; pre-test, post-test) x 2 (condition; angry target, happy target) mixed factorial ANOVA. There were no significant main effects or interactions (all *p*s > .1).

LPP component

At baseline a 2 (group; training, control) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA was conducted. There was a main effect of condition [$F(3.64, 123.81) = 17.43$, $p < .001$, $\eta^2 = .33$]; pairwise comparisons revealed that the LPP mean amplitude for angry targets was significantly more positive than for angry and happy non-targets and neutral non-targets (all *p*s < .1). No difference between angry and happy targets was found ($p > .1$). The LPP mean amplitude for happy targets was significantly more positive than neutral non-targets and marginally more positive than angry and happy non-targets. Finally, the LPP for angry and happy non-targets was significantly more positive than neutral non-targets (all *p*s < .1). There was no significant main effect of group and no significant group x condition interaction (all *ps* > .1).

Longitudinal group differences in the LPP mean amplitudes were assessed using a 2 (group; training, control) x 2 (time; pre-test, post-test) x 6 (condition; angry non-target, happy non-target, angry target, happy target, neutral Block1&2 non-target, neutral Block3&4 non-target) mixed factorial ANOVA. There was a main effect of time [$F(1, 34) = 4.60$, $p = .039$, $\eta^2 = .02$], the LPP mean amplitude was more positive at post-test. There was also a significant main effect of group [$F(1, 34) = 6.70$, $p = .014$, $\eta^2 = .16$], the LPP mean amplitude was more positive for the control group. In addition, there was a significant main effect of condition [$F(3.42, 116.27) = 29.89$, $p < .001$, $\eta^2 = .24$], pairwise comparisons revealed that the LPP mean amplitude for happy and angry targets was significantly more positive than for angry and happy non-targets and neutral non-targets (all *p*s < .1). No significant difference between angry and happy targets was found (*p* >.1). Finally, the LPP mean amplitude for angry and happy non-targets was significantly more positive than neutral non-targets (all *p*s < .1). There was also a significant time x group interaction [*F*(1, 34) = 16.20, *p* = .001, η^2 = .06]; the LPP mean amplitude became marginally less positive over time for the training group [*t*(24) = 1.80, *p* = .084, *d* = 0.36], the LPP mean amplitude became more positive for the control group [*t*(10) = -3.29, *p* = .008, *d* = -0.99]. There were no other significant interactions (all *p*s > .1), see *Figure 6.*

Age analysis

To examine whether the age of participants impacted on longitudinal changes in the mean amplitudes of the P1, N2, P3b and LPP mean amplitudes, additional time x condition x group x age mixed factorial ANOVAs were conducted.

For the P1 mean amplitude, there was a marginally significant time x group x age interaction [*F*(1, 32) = 3.74, *p* = .062, η^2 = .04], follow up t tests revealed that in the training group, the younger children elicited a marginally less positive P1 mean amplitude across all conditions over time [*t*(8) = 2.30, *p* = .051, *d* = 0.77]. For the control group the P1 mean amplitude across all conditions became more positive for younger [*t*(4) = -2.28, *p* = .084, *d* = -1.02] and older children [*t*(5) = -2.68, *p* = .044, *d* = -1.09]. There were no other significant main effects or interactions (all *p*s > .1),

For the N2 mean amplitude, there was a significant time x age interaction [*F*(1, 32) = 4.48, *p* = .042, η^2 = .05], and a significant condition x age interaction [*F*(1, 32) = 7.66, *p* = .009, η^2 = .05], follow up t tests were not significant (all *p*s > .1). There was a significant time x group x age interaction [$F(1, 32) = 5.40$, $p = .027$, $\eta^2 = .06$], for the control group the N2 mean amplitude became marginally more negative over time for older children [$t(5) = 2.52$, $p = .053$, $d = 1.03$]. There were no other significant main effects or interactions (all *p*s > .1).

For the P3b and LPP mean amplitude, age had no effect on the findings (all *ps* > .1).

[insert Figure 3, see additional document]

[insert Figure 4, see additional document]

[insert Figure 5, see additional document]

[insert Figure 6, see additional document]

Discussion

This longitudinal study explored the impact of a mindfulness curriculum (Paws b) delivered by pupil's regular school teachers on self-report, behavioural and electrophysiological measures of emotion processing for pre-adolescents aged between 7 and 11 years of age. The mindfulness curriculum was highly acceptable based on the percentage of participants in the training group who reported liking it (76%) and reported a wish to continue with the mindfulness curriculum in school in the future (64%).

Improvements in emotion processing of children were expected for the training group after completion of the mindfulness training in comparison to the wait-list control group who received the curriculum as usual. As expected, self-report findings showed a marginal improvement in positive affect for the training group after the mindfulness training. Contrary to our hypothesis, negative affect scores did not change for the training group, but they increased for the control group. In addition, no changes in self-reports of emotional expression and awareness, attentional control or mindfulness were found for either group over time. The behavioural findings showed no change in accuracy or false alarm rates over time for either group, whilst the response time analyses revealed that the response times for happy targets became marginally slower for the control group over time.

With regards to changes in ERP indexes of emotions processing, a less positive P3b mean amplitude for angry targets was expected for the training group after mindfulness training, but no change in the P3b mean amplitude was found for either group over time. More negative N2 mean amplitudes for angry and happy non-targets were also expected after mindfulness training, no change in the N2 mean amplitudes were found for the training or control group over time. An attenuation of the LPP mean amplitude for angry targets and non-targets was also expected for the training group after mindfulness training, however, the LPP mean amplitude did not change for the training group over time, but did become more positive for the control group across all stimuli. Finally, exploratory analysis of the P1 mean amplitude revealed a marginally less positive P1 mean amplitude for angry targets in the training group at post-test in contrast to a more positive P1 mean amplitude for the control group across all stimuli.

The high acceptability ratings found for this current study replicate findings from a previous study where school teachers delivered the same curriculum to children aged 7 to 9 years (Vickery & Dorjee, 2015). In both these studies school teachers had at least 8 months of mindfulness practice experience by the time they delivered the mindfulness training to their pupils - they were rigorously trained first in a standard mindfulness-based programme (.b Foundations in this case; Mindfulness in Schools Project, 2015) and then trained to deliver the mindfulness curriculum to pupils. Only the teachers who developed sufficient continuous personal experience in mindfulness during the .b foundations course and the 5 month period after were invited to train in and deliver the mindfulness curriculum. This suggests that mindfulness curricula can be effectively delivered within a school environment by school teachers without extensive mindfulness experience.

With regards to the enhancement in self-reports of negative affect found for the control group, the Tripartite model (Clark & Watson, 1991) suggests that there are clinical implications associated with changes in negative and positive affect assessed by the PANAS-C. Specifically, increases in negative affect have been associated with enhanced anxiety (Hughes & Kendall, 2009; Lonigan, Phillips & Hooe, 2003; Phillips, Lonigan, Driscoll & Hooe, 2002). There were, however, no group differences in negative affect at post-test once baseline differences were controlled for and therefore it is possible that the control group's negative affect levels simply regressed to the mean.

The lack of effects in the CAMM measure is particularly relevant to the debate considering whether mindfulness self-report assessments can accurately capture changes in mindfulness resulting from mindfulness training (Bergomi et al., 2013; Grossman, 2011; Quaglia et al., 2015a). Whilst this debate has focused on adult research, it also seems to be relevant to research with children as no changes in self-reports of mindfulness were found in previous training studies with pre-adolescents (Britton et al., 2014; Vickery & Dorjee, 2015) and many studies with children do not include a self-report of mindfulness (Flook et al., 2010; Mendelson et al., 2010; Schonert-Reichl & Lawlor, 2010), possibly for these reasons.

The response time findings also suggest that the control group decreased in their ability to respond adaptively to happy faces; slower response times to happy stimuli and no difference in responses to angry stimuli have previously been found for individuals with maladaptive emotion processing abilities, including adolescents with behavioural inhibition (Pérez -Edgar et al., 2010), a temperament associated with negative affectivity, social withdrawal and anxiety (LoBue & Pérez-Edgar et al., 2013) and adults with social anxiety (Silvia, Allan, Beauchamp, Maschauer & Workman, 2006). This finding suggests that whilst there was a decline in the control group's ability to respond effectively to happy faces over time, the mindfulness training may have protected children in the training group from emotion processing decrements.

In contrast to the study predictions, no change in the N2 for angry and happy non-targets was found after mindfulness training, this suggests that mindfulness did not impact on the ability to monitor for and inhibit salient emotional distractors. One potential reason for the lack of findings could be due to some parameters of the particular task which was employed. In the modified oddball task non-responses were more frequent than responses, therefore the happy and angry non-targets (No-go oddballs) may not have required extensive conflict monitoring and response inhibition skills. This is because these skills are usually engaged to override a pre-potent tendency to respond (Folstein & Van Petten, 2008). Azizian et al., (2006) found that the inhibition of No-go oddballs during a Go/No-go oddball task can require some conflict monitoring and response inhibition skills, especially when No-go oddballs shares perceptual similarities with the Go-oddballs (as was the case in this current study as both Go and No-go oddballs were emotional faces in comparison to repeated neutral non-targets). However, these skills are not required as extensively as tasks such as the Go/No-go task, where Go responses are more frequent than No-go responses (Folstein & Van Petten, 2008). Therefore, future studies could examine the N2 during a traditional Go/No-go task in order to assess the impact of mindfulness training on executive attention abilities.

The lack of change in P3b mean amplitude for both groups over time was contrary to our predictions, the P3b mean amplitude indexes attention resource allocation and a more positive P3b to emotional stimuli has been linked with less effective emotion processing abilities in children (Kujawa et al., 2013b; Pollak et al., 1997, Shackman et al., 2007). However, the P3b amplitude is not always sensitive to individual differences in emotion processing (Campanella et al., 2010; Rossignol et al., 2005), therefore the P3b mean amplitude may not have detected the changes in emotion processing which were observed in the LPP and P1 modulations for the control group. This suggests that the P3b may be a less suitable marker of longitudinal changes in emotion processing after mindfulness training in pre-adolescents.

The LPP findings showing no change in LPP mean amplitude for the training group over time and an increase in the LPP mean amplitude for all stimuli for the control group over time, did not support our hypothesis. A more positive LPP amplitude to emotional stimuli can indicate increased emotional reactivity and has been associated with elevated levels of anxiety (Kujawa et al., 2015) as well as detriments in task performance (Kujawa et al., 2012b). Anxiety has also been linked with an enhanced processing of non-emotional stimuli (Bar-Haim et al., 2007; Sylvester et al., 2012; Waters, Neuman, Henry, Craske & Ornitz, 2008b). Mühlberger et al., (2009) found that in comparison to adults with low social anxiety, the LPP elicited for individuals with high social anxiety showed no differentiation between emotional and neutral faces, perhaps suggesting that these individuals remained vigilant to all facial expressions. The fact that the LPP mean amplitude was more positive at post-test for happy, angry and neutral faces could suggest that the control group became more vigilant and possibly also more reactive to all face stimuli. This pattern is similar to the self-report and behavioural findings and suggests that whilst the control group showed less adaptive emotion processing abilities over time, the training group did not show such declines in emotion processing abilities.

The exploratory P1 findings add further support to the suggestion that the mindfulness training protected the training group from the decline in emotion processing abilities experienced by the control group. A less positive P1 amplitude is thought to index enhanced efficiency during early stages of stimulus processing (Batty & Taylor, 2006; MacNamara et al., 2016), whilst a more positive P1 amplitude has been found for both emotional and non-emotional stimuli in adults and children with anxiety, possibly reflecting an enhancement in initial reactivity and vigilance towards all facial expressions (Hum et al., 2013b; Mühlberger et al., 2009). In the context of this previous evidence, the current finding of reduced P1 to angry faces in the training group after mindfulness training may indicate more efficient and possibly less reactive processing of negative emotional stimuli. In contrast, it seems that the control group became more reactive and less effective at allocating attention resources during these initial stimulus processing stages.

Overall, the findings were not as expected and not in line with previous reports that mindfulness training can improve emotional wellbeing in pre-adolescents (Mendelson et al., 2010; Saltzman & Goldin, 2008; Schonert-Reichl & Lawlor, 2010; Schonert-Reichl et al., 2015). The mindfulness training instead appeared to have a protective effect on children in the training group in comparison to the children in the control group who showed less effective emotion processing on self-report, behavioural and ERP measures over time. We can only speculate at why the control group's emotion processing abilities declined over time, the time of testing could have been a factor for the year 6 pupils given that they were undergoing a time of transition where preparations were being made for secondary school. This transition from primary to secondary school can have a detrimental impact on well-being (Rice et al., 2011; West et al., 2010) and mindfulness training could have a particularly protective effect during this time. Indeed, mindfulness training has been found to provide adaptive skills which enable children to respond with resilience to stress inducing situations (Zenner et al., 2014). Perhaps this period of transition also impacted negatively on the school environment as a whole and therefore impacted on the other age groups included in the study.

Limitations and Future directions

The study had several limitations. Firstly, the groups were not randomised into the training and control groups. This was due to the significant time commitment required from the schools and school teachers for enabling school teachers to attend both a standard mindfulness training course of 4 sessions plus three days of curriculum training within 8 months of a school year. Therefore, schools which could accommodate these requirements and were first to opt into the training group were allocated accordingly. It could be that the schools which were more motivated to provide mindfulness training to their pupils were faster to opt into the training group which could reflect differences in baseline intentions of the teachers at the training and control schools. Secondly, the final sample for the control group was smaller than expected due to unpredictably high school absences and dropout rates of pupils in this group at post-test. This imbalance limits the generalisability of the study's findings. Future studies can address these two shortcomings in larger-scale randomised controlled trials**.**

The oddball task included the use of emotional faces to measure the impact of mindfulness training on emotion processing. Emotional faces have been used extensively in research with children and are considered motivationally salient because they contain relevant information regarding social cues (Batty & Taylor, 2006; Pollak & Kistler, 2002; Todd et al., 2008; Wu et al., 2016). Emotional faces are also less emotionally arousing than alternative stimuli such as IAPs images and so there are fewer ethical implications when working with children (Kujawa et al., 2012b). It is possible, however, that the lack of changes in behavioural and ERP measures of emotion processing after mindfulness training were due to the task not being of a sufficiently emotionally arousing nature. Indeed, Kujawa et al., (2012b) found no differences in LPP or behavioural measures between emotional and neutral faces, whilst in comparison, emotional IAPs images did induce more positive LPP amplitudes and greater impairments in task performance in comparison to neutral IAPs images. As well as using stimuli of a more emotionally arousing nature, it would also be interesting to examine whether mindfulness training could modulate emotion processing in different experimental paradigms. Emotional dot probe tasks for example, which can provide a measure of attention biases, have previously been found to be modulated by mindfulness training in adults (Garland, Gaylord, Boettiger & Howard, 2010; Vago & Nakamura, 2011) and have been used extensively to study the impact of interventions such as attention training on anxiety in children (Bar-Haim, Morag & Glickman, 2011; Eldar et al., 2012; Eldar, Ricon & Bar-Haim, 2008). Whilst the oddball task used in the current study provided a measure of the attention resources allocated towards the stimulus, the dot probe task can measure both whether there is a bias in the attention resources allocated towards a stimulus and whether children have difficulties disengaging from the stimulus, both these indexes are markers of emotion processing difficulties (Salemink, van den Hout & Kindt, 2007) and may therefore provide a more sensitive measure of the impact of mindfulness training on emotion processing**.**

The high error rates in the emotion oddball task can be considered another limitation. Due to the time constraints of testing in a school environment the task was shorter than similar lab-based tasks. Lengthening of the stimulus presentation could possibly reduce error rates and improve the retention of participant data sets in the data analyses. Finally, poor internal consistency was found for the mindfulness and attention focusing self-report measures, suggesting that pupils may have found it difficult to understand the questions. Future studies could also include informant-based (parent and teacher) questionnaires to complement the children's self-report findings.

The relationship between teachers and their pupils can have a significant impact on a student's ability to foster adaptive social and emotional abilities whilst at school (Baker, 2006; Jennings & Greenberg, 2009). Therefore, if the mindfulness curriculum was delivered in an ineffective way then this could have contributed to the lack of self-report, behavioural and ERP modulations after mindfulness training. Most mindfulness training studies with pre-adolescents have used an external mindfulness trainer to deliver mindfulness curricula (Felver et al., 2016), however, previous studies have found beneficial outcomes for pupils who received the mindfulness curriculum from their teachers (Schonert-Reichl & Lawlor, 2010; Schonert-Reichl et al., 2015). Our study involved a teacher training programme which was more extensive than these previous studies and the high acceptability ratings which were reported by pupils in the training group suggests that the mindfulness curriculum was delivered in an effective way. However, to assess the impact of variations in the effectiveness of curriculum delivery on student's outcomes, future larger scale trials could include the teacher as a factor in the analysis. More in depth information on teaching experience and frequency of the teacher's mindfulness practice would also be important to include.

It is also possible that whilst the mindfulness curriculum was delivered in an effective way, the lack of self-report, behavioural and ERP modulations for the training group could be due to the mindfulness curriculum itself being ineffective at modulating attention and emotion processing. Whilst previous meta-analyses and systematic reviews have found that mindfulness training can effectively modulate self-regulatory processes in pre-adolescents

(Felver et al., 2016; Klingbeil et al., 2017; Zenner et al., 2014; Zoogman et al., 2015), there are currently a broad range of mindfulness programmes available for pre-adolescents (Kaunhoven & Dorjee, 2017). Therefore, unlike adult research which focuses primarily on examining the effectiveness of two core standardised programmes; MBSR and MBCT, research with children is much more diverse. As a result, studies examining the effectiveness of the Paws b curriculum are still in their infancy. One study examining the effects of Paws b with pre-adolescents found improvements in metacognition on teacher reports but not on parent reports. It is therefore difficult to rule out that these improvements were due to teacher bias, especially as the teachers were delivering the curriculum. Furthermore, decreases in negative affect were only observed at a three-month follow-up, suggesting that perhaps mindfulness training of a longer duration is needed to effectively modulate emotion processing.

Conclusion:

The current study was one of the first to investigate longitudinal changes in brain indexes of emotion processing after mindfulness training in pre-adolescents. The findings suggest that cultivation of mindfulness skills may have resulted in protective effects on emotion processing of children trained in mindfulness in comparison to the control group which showed decreases in adaptive emotion processing across ERP, behavioural and self-report measures. We did not find evidence of actual improvements in the emotion processing in the training group in any of the measures, except for marginally significant decreases in the positivity of the P1 mean amplitudes to angry face targets which possibly reflects more efficient non-reactive emotion processing. Overall, the findings from this study highlight the value and importance of multi-method integrative approaches in investigating effects of mindfulness training on emotion processing in pre-adolescents.

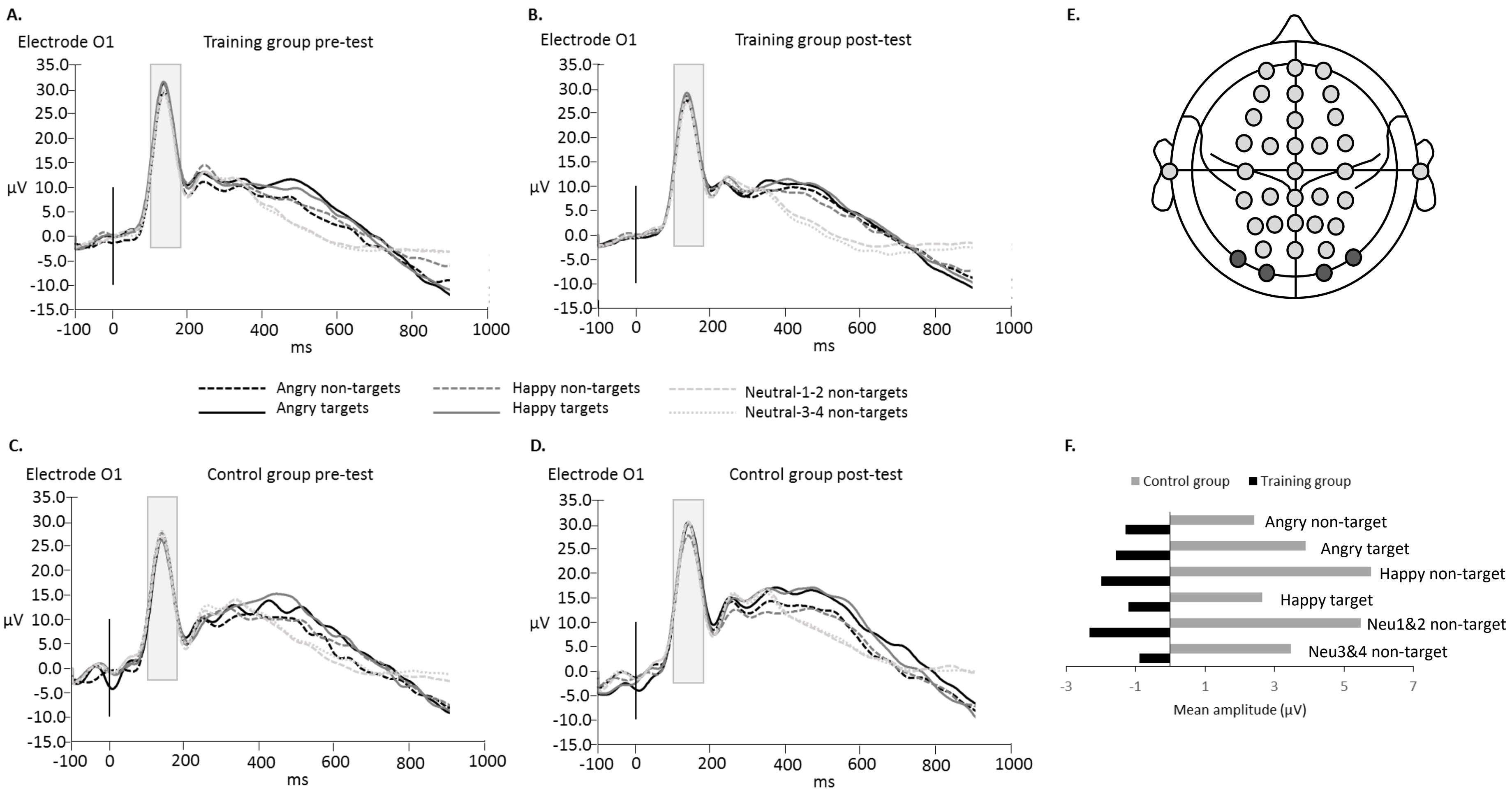


Figure 3. The P1 mean amplitude (100-180ms) for angry and happy targets and non-targets and neutral non-targets at maximal electrode O1 for the mindfulness training group (n = 25) at A) pre-test and B) post-test; and for the control group (n = 11) at C) pre-test and D) post-test. E) shows the position of the electrodes the P1 mean amplitude was averaged across, and F) is a bar chart displaying the marginally significant time x group x condition interaction. A filter of 16Hz was applied for display purposes only.

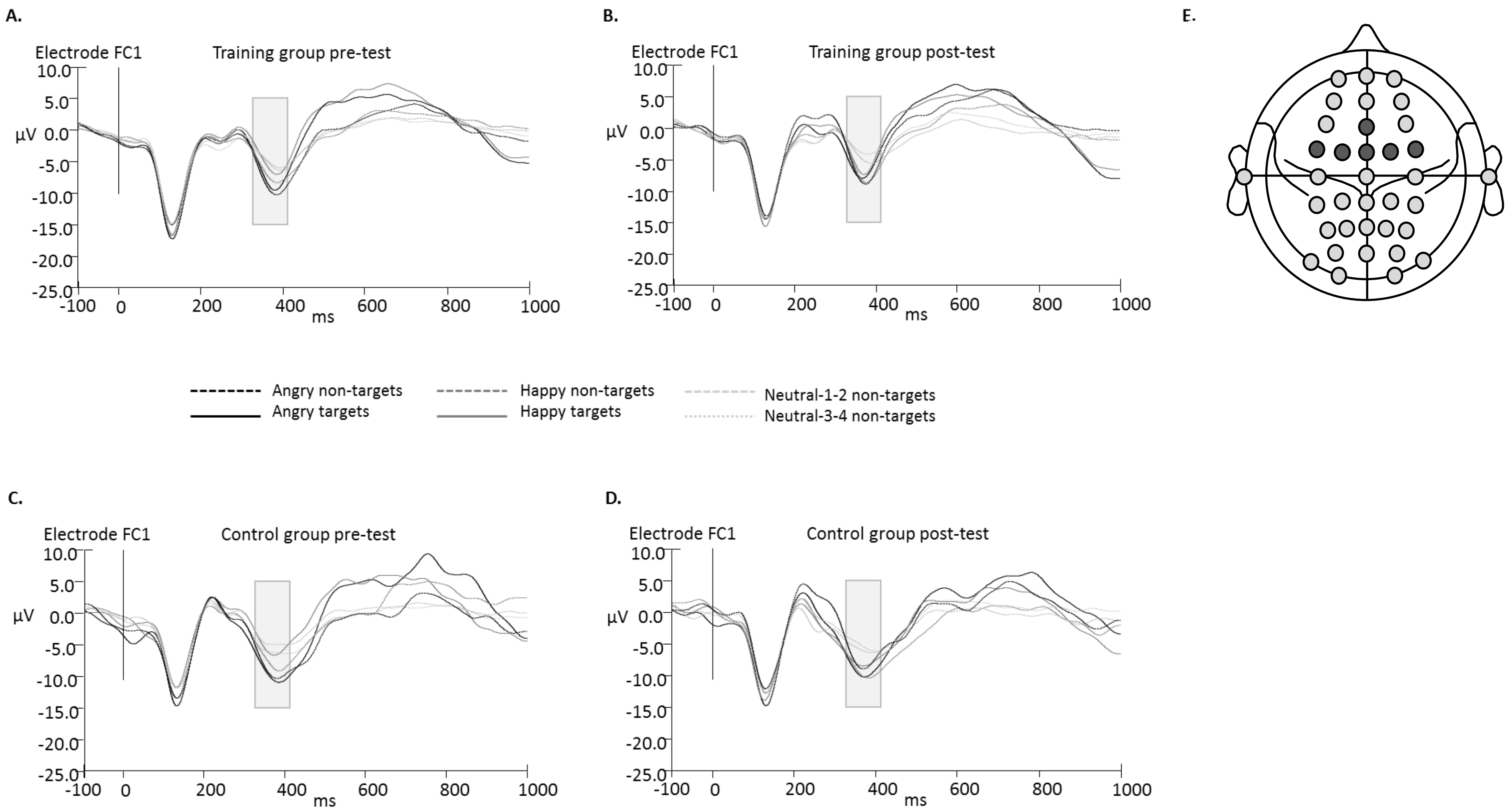


Figure 4. The N2 mean amplitude (340-425ms) for angry and happy targets and non-targets and neutral non-targets at maximal electrode FC1 for the mindfulness training group (n = 25) at A) pre-test and B) post-test; and for the control group (n = 11) at C) pre-test and D) post-test. E) shows the position of the electrodes the N2 mean amplitude was averaged across. A filter of 16Hz was applied for display purposes only.

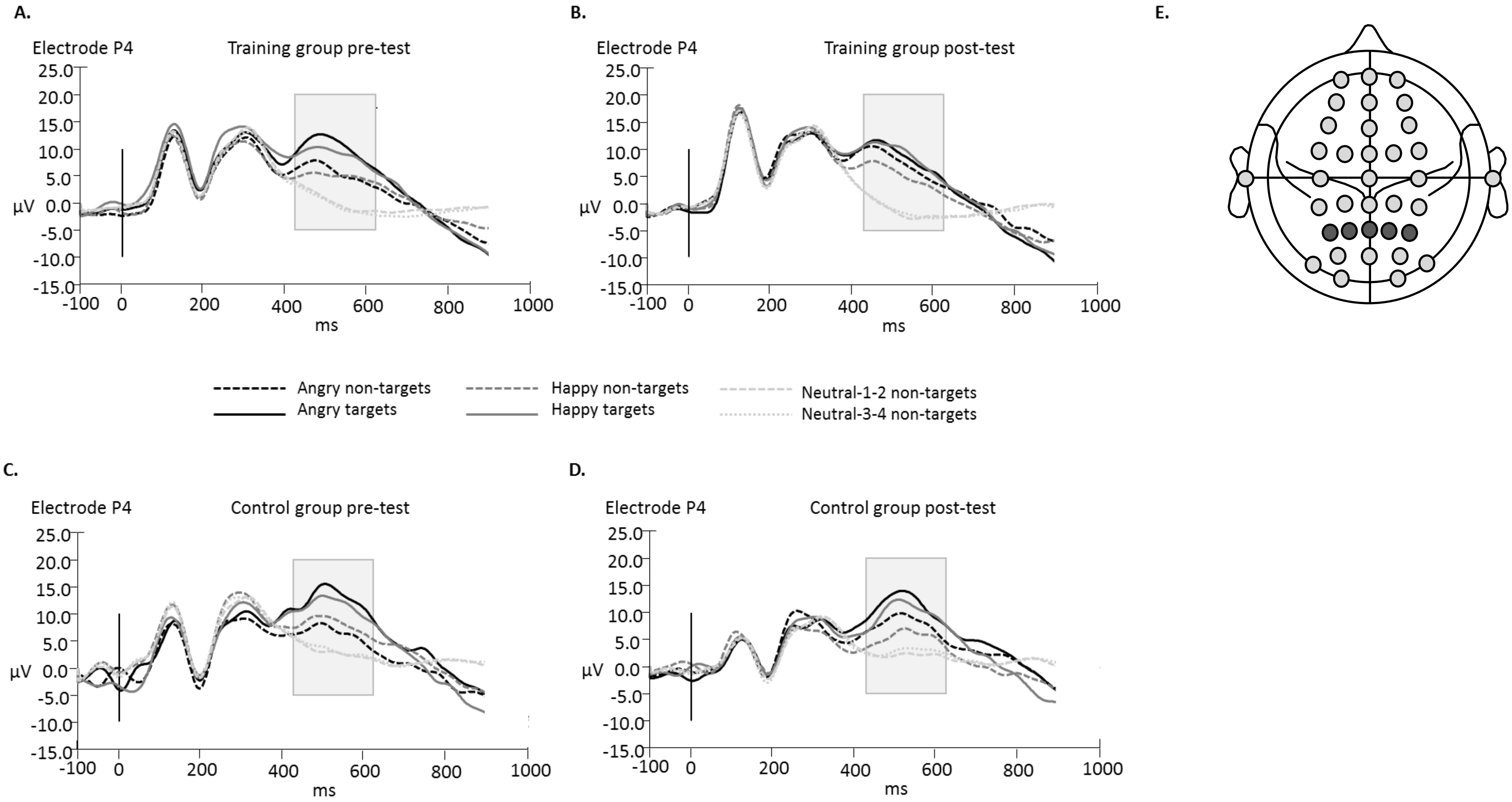


Figure 5. The P3b mean amplitude (425-620ms) for angry, happy targets and non-targets and neutral non-targets at maximal electrode P4 for the mindfulness training group (n = 25) at A) pre-test and B) post-test; and for the control group (n = 11) at C) pre-test and D) post-test. E) shows the position of the electrodes the P3b mean amplitude was averaged across. A filter of 16Hz was applied for display purposes only.

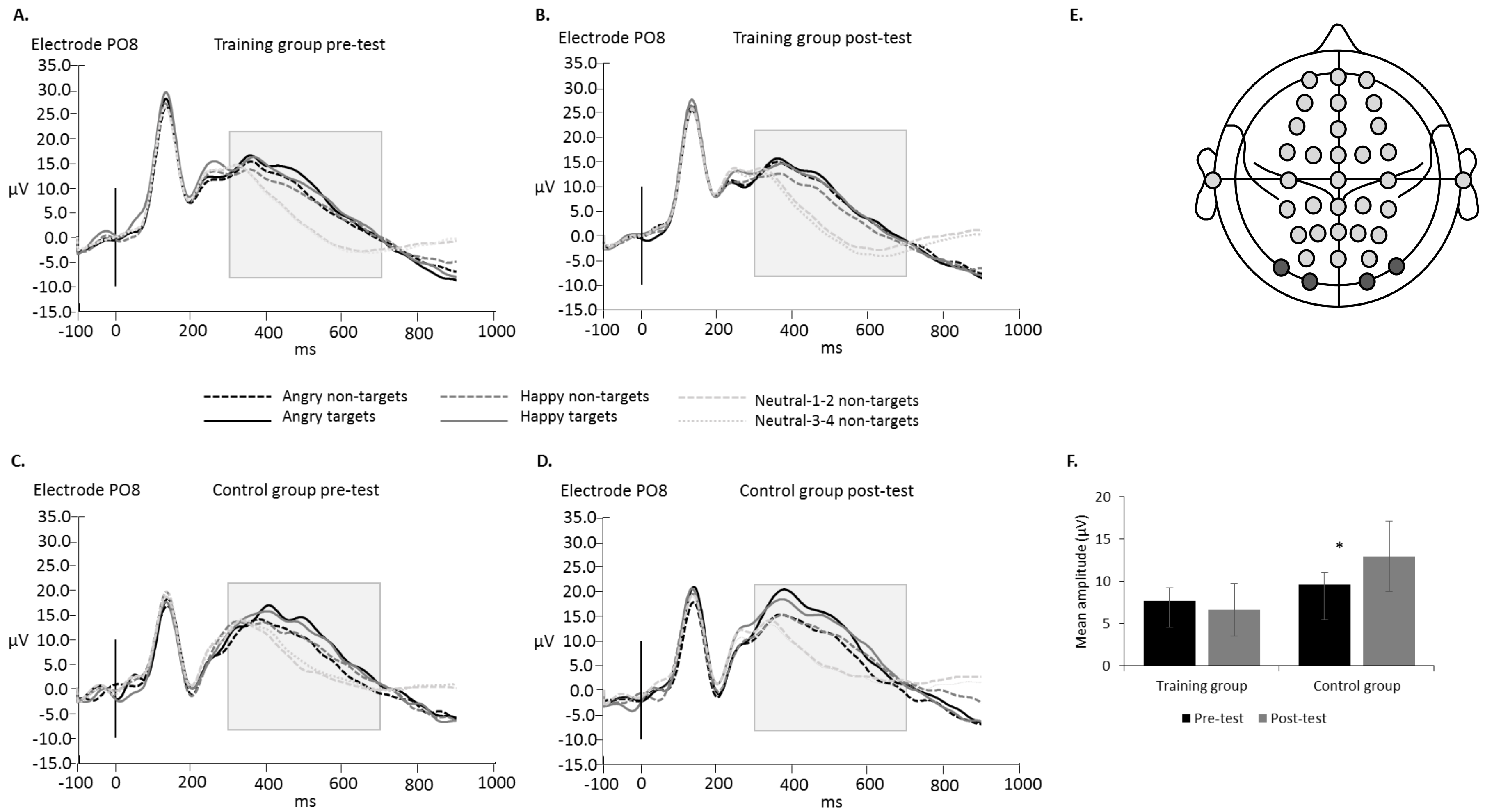


Figure 6. The LPP mean amplitude (300-700ms) for angry and happy targets and non-targets and neutral non-targets at maximal electrode PO8 for the mindfulness training group (n = 25) at A) pre-test and B) post-test; and for the control group (n = 11) at C) pre-test and D) post-test. E) shows the position of the electrodes the LPP mean amplitude was averaged across, and F) is a bar chart displaying the significant time x group interaction. A filter of 16Hz was applied for display purposes only.

Chapter Eight - Discussion

The current research project aimed to study possible neurocognitive changes in self-regulatory processes after mindfulness training in pre-adolescents. In addition, the relationship between dispositional mindfulness and neurocognitive measures of self-regulatory processes was examined in this age group. The research project recruited 76 pre-adolescents aged 7 to 11 years from four primary schools in North Wales to investigate possible converging dispositional patterns and longitudinal changes using self-report, behavioural, electrophysiological and psychophysiological measures.

Chapter two provided an overview of event-related potential (ERP) and heart rate variability (HRV) measures and discussed the methodological considerations underlying the current research project when employing these measures with pre-adolescent children. Chapter three (Kaunhoven & Dorjee, 2017) was an analytical review which outlined how mindfulness training could impact aspects of self-regulation including attention control and emotion processing in pre-adolescents aged 7 to 12 years. The paper discussed developmental changes in the neural brain networks underlying self-regulation which occur during pre-adolescence and then provided clear theory driven, developmentally specific predictions for how ERP components including the N2, ERN, Pe, P3a, P3b and the LPP, could index possible changes in self-regulation after mindfulness training.

Chapter four studied the association between dispositional mindfulness and ERP, self-report and behavioural measures of attention control in primary school children. A three-stimulus auditory oddball task, which involved the presentation of a frequent non-target sound, infrequent distractor sound and an infrequent target sound, was used to assess attention resource allocation efficiency. Self-reports of mind wandering during the task were also measured. This study found that pre-adolescents with higher dispositional mindfulness self-reported significantly higher levels of attention control, no group differences in self-reports of mind wandering were found. In addition, no group differences in response times or accuracy rates and no group differences in the mean amplitude of the P3b and No-go P300 ERP measures of attention control were observed.

Chapter five employed a cross sectional design to assess the relationship between dispositional mindfulness and ERP as well as self-report measures of emotion processing in primary school children. EEG signal was recorded during an emotion oddball task which involved the presentation of frequent neutral non-targets, infrequent happy and angry targets which required a response (Go oddballs) and infrequent happy and angry non-targets which did not require a response (No-go oddballs). Pre-adolescents with higher dispositional mindfulness elicited a significantly less positive LPP mean amplitudes across neutral, angry and happy stimuli, after controlling for self-reported attentional control. In addition, significantly higher self-report scores of attention shifting and attention focusing and lower self-report scores of negative affect, poor emotional awareness and expressive reluctance were found for the high dispositional mindfulness group. No group difference in positive affect was observed. There were no differences in response times or accuracy rates between the high and low dispositional groups and no group differences in the N2, P3b or P1 mean amplitudes were found.

Chapter six used resting HRV measures and self-report assessments to explore both the association between dispositional mindfulness and self-regulation and the impact of a 10-week teacher delivered mindfulness curriculum on self-regulation in pre-adolescent children. Overall, the dispositional analysis showed that pre-adolescents with higher dispositional mindfulness had more effective self-regulation as indexed by significantly higher levels of resting respiratory sinus arrhythmia (RSA), higher total heart rate variability (total HRV) and marginally significantly lower cardiac sympathetic index (CSI) levels in comparison to the low dispositional mindfulness group. In addition, pre-adolescents with higher dispositional mindfulness had significantly better self-reports of attention shifting and attention focusing and fewer difficulties with emotional awareness and emotional expression. No significant differences in negative or positive affect were found. The longitudinal analysis showed that resting RSA became significantly lower after mindfulness training and CSI levels became significantly higher, no change in HRV indices was found for the control group over time. Furthermore, no change in self-reports of attention control, positive affect, emotional awareness or expressive reluctance were found for either group over time, however, the control group did significantly increase in negative affect over time.

Finally, chapter seven employed a non-randomised pre-post design with a wait-list control group to examine changes in emotion processing for pre-adolescents after a 10-week teacher delivered mindfulness curriculum (Paws b). ERP (P1, P3b, N2, LPP) components were analysed from the EEG signal which was recorded during an emotion oddball paradigm, in addition, self-reports were also used to assess the impact of mindfulness training on emotion processing. The mindfulness curriculum was found to be highly acceptable, 74% of children in the training group reported liking the curriculum and 64% reported that they would like to continue with mindfulness training in school. A marginally significant less positive P1 mean amplitude was found for angry targets for the training group after mindfulness training and the P1 mean amplitude became significantly more positive across all stimuli for the control group over time. Whilst the LPP mean amplitude did not significantly change for the training group after the Paws b curriculum, the LPP mean amplitude became significantly more positive across all stimuli (happy, angry and neutral faces) for the control group over time. No changes in the P3b or N2 mean amplitudes were found for either group over time. The control group's self-reported negative affect significantly increased over time. No change in negative affect was found for the training group but a marginally significant improvement in positive affect was observed. For the control group, response times to happy faces became marginally significantly slower over time, no change was found for the training group. No change in accuracy rates were found for either group over time.

The findings from the dispositional studies (chapters four, five and six) suggest that there is an association between higher dispositional mindfulness and lower emotional reactivity in pre-adolescents. This is supported firstly by the finding that pre-adolescents in the high dispositional mindfulness group elicited a less positive LPP mean amplitude for angry, happy and neutral faces during an emotion oddball task in comparison to the low dispositional mindfulness group. The LPP amplitude is a broad sustained positivity ERP component which is sensitive both to the emotional valence and intensity of stimuli (Hajcak et al., 2010; Schupp et al., 2010); a more positive LPP amplitude is thought to index greater emotional reactivity (Hajcak & Dennis, 2009). In pre-adolescents, a more positive LPP was found in those with emotion processing difficulties including the presence of greater fearful behaviours (Solomon et al., 2012) and social anxiety (Kujawa et al., 2015). The results of chapter five therefore suggest that pre-adolescents with higher dispositional mindfulness may have lower emotional reactivity to emotional and neutral stimuli.

Secondly, pre-adolescents with higher dispositional mindfulness also had significantly lower resting CSI and significantly higher resting RSA levels in comparison to the low dispositional mindfulness group. Resting HRV indices can provide a trait measure of the balance between top-down attention control processes, which underlie volitional goal directed behaviour and bottom-up emotional reactivity processes, which underlie non-volitional salience driven behaviour (Park & Thayer, 2014; Thayer et al., 2012); an optimal balance between these processes is required to enable the individual to respond adaptively to situational demands (Blair & Dennis, 2010; Lewis & Todd, 2007). CSI is an index of a branch of the autonomic nervous system (ANS) called the sympathetic nervous system (SNS), which is more active during the stress response to mobilise metabolic resources (Allen et al., 2007; Hibbert et al., 2012) and RSA is a measure of the other branch of the ANS called the parasympathetic nervous system (PNS), which is more active during non-stressful situations to prioritise the conservation of metabolic resources (Allen, 2002; Grossman & Taylor, 2007).

Bidirectional links between the prefrontal cortex, including the orbitofrontal cortex and medial prefrontal cortex, which enable top-down regulatory control, and the ANS, which underlies bottom-up psychophysiological reactivity, has been found (Park & Thayer, 2014; Thayer et al., 2012). At rest, the prefrontal cortex can exert an inhibitory influence over the ANS through decreasing SNS activity and increasing PNS activity, this is adaptive as it prioritises the conservation of metabolic resources during non-stressful situations (Park & Thayer, 2014; Thayer et al., 2012). Higher RSA levels and lower CSI levels are therefore indexes of adaptive self-regulation. In contrast, if individuals have less adaptive top-down regulatory control then SNS activity at rest can be higher and PNS activity can be lower than those with more effective top-down regulatory control (Park & Thayer, 2014; Thayer et al., 2012). In this situation, rather than conserving metabolic resources there is a greater hypervigilance to threat during non-stressful situations, this can lead to psychopathological and physiological difficulties in pre-adolescents and adults (Beauchaine et al., 2007; Gorman & Sloan, 2000; Park & Thayer, 2014; Schmitz, Tuschen-Caffier, Wilhelm & Blechert, 2013; Thayer et al., 2009). Higher CSI levels and lower RSA levels at rest are therefore indicative of less effective self-regulation. Based on the findings in chapter six pre-adolescents with higher dispositional mindfulness seem to be less physiologically reactive during non-stressful situations, perhaps due to more efficient connections between top-down and bottom-up regulatory mechanisms.

Interestingly, however, whilst the above findings suggested reduced emotional reactivity indexed by HRV and ERP indices, no group differences in ERP indices of top-down attention control processes were found across the dispositional studies. The P3b, a parietal positivity elicited 300-500ms after stimulus onset, is considered a measure of attention resource availability (Hajcak et al., 2010; Polich, 2007). A more positive P3b amplitude suggests a greater endogenous allocation of attention resources towards task relevant stimuli (Chennu et al., 2013; Hillman et al., 2005; Willner et al., 2015) and has been linked with a reduction in task irrelevant mind wandering (Barron et al., 2011). The lack of differences in the P3b amplitude across the emotion oddball and auditory oddball tasks suggests that pre-adolescents with higher dispositional mindfulness do not show enhanced endogenous attention control efficiency during emotional or non-emotional situations. It is also possible that the P3b is not a developmentally sensitive measure of such changes. Several studies for example, have found that the P3b is not always sensitive to individual differences in emotion processing between healthy adults and adults with anxiety (Rossignol et al., 2005) and comorbid anxiety and depression (Campanella et al., 2010).

The N2, a frontal negativity elicited approximately 200 to 400ms after stimulus onset, indexes top-down attention control abilities including conflict monitoring and response inhibition in adults and children (Chapman et al., 2010; Falkenstein et al., 1999; van Veen & Carter, 2002b). The lack of group differences in this ERP component during the emotion oddball task contrasts with the dispositional mindfulness findings in adults (Quaglia et al., 2015b) and suggests that higher dispositional mindfulness is not associated with enhancements in these top-down regulatory abilities for pre-adolescents during emotionally demanding tasks. As mentioned previously, dispositional mindfulness group differences in executive attention abilities such as conflict monitoring and response inhibition may have been present in a traditional Go/No-go task which could tax these skills to a greater extent compared with the Go/No-go oddball task which was used in this study (Folstein & Van Petten, 2008). Indeed, the association between dispositional mindfulness and the N2 amplitude which was found previously for adults was during a Go/No-go task (Quaglia et al., 2015b).

The No-go P300, a central parietal positivity elicited approximately 300ms after stimulus onset, is observed for stimuli which do not require a response and is thought to index response inhibition (Polich, 2007). The lack of group differences in this component also suggests that pre-adolescents higher in dispositional mindfulness do not have better response inhibition abilities. In chapter three it was theorised that as pre-adolescent's top-down regulatory abilities are less developed in comparison to adults (Fair et al., 2007; Farrant & Uddin, 2015), mindfulness training may preferentially modulate bottom-up regulatory processes linked with sensory awareness during pre-adolescence (Kaunhoven & Dorjee, 2017). Perhaps this also extends to dispositional mindfulness, pre-adolescents with a naturally more advanced ability to attend to experiences in a mindful way may be less reactive during rest and during emotionally demanding situations without having to engage top-down regulatory control mechanisms (indexed by the N2 and P3b and No-go P300).

The findings across the mindfulness training studies in this current research project are not as consistent as the dispositional findings. Modulations of HRV indices linked with physiological reactivity were found after mindfulness training, however, rather than pre-adolescents becoming less physiologically reactive after mindfulness training, resting RSA levels decreased and resting CSI levels increased, indicating a trait increase in physiologically reactivity. This suggests that the balance between top-down and bottom-up regulatory processes shifted towards an increase in bottom-up physiological reactivity whilst at rest. This finding contrasts with the initial study predictions and it is unclear why this effect was observed. Perhaps, the enhancements in physiological reactivity which were observed after mindfulness training could reflect an increase in bottom-up sensory awareness of thoughts, feelings and sensations due the training of these skills over the course of the Paws b curriculum (Mindfulness in schools, 2015). This increased awareness is thought to be an important first step in reducing automatic maladaptive modes of self-regulation (Bishop et al., 2004a; Goldin & Gross, 2010). Whilst this increased awareness may have led to an increase in physiological reactivity, it is possible that with further training, children will become more effective at employing a non-reactive, non-judgemental approach to experiences and as such a trait decrease in physiological reactivity may occur. Mindfulness training has previously been found to enhance initial emotional reactivity (indexed by a spike in amygdala activity) followed by a subsequent drop in emotional reactivity in response to negative stimuli during a breath focused task in comparison to a distraction focused task for adults with social anxiety (Goldin & Gross, 2010). Importantly, these individuals also reported a decrease in depression and anxiety, suggesting that an initial increase in reactivity after mindfulness training can be adaptive (Goldin & Gross, 2010).

During the emotion oddball task, however, pre-adolescents did not show enhanced reactivity to emotional and neutral stimuli after mindfulness training as indexed by ERP components P1 and LPP. A marginal decrease in the P1 amplitude for angry faces was observed after mindfulness training. The P1 ERP component is a positivity elicited approximately 100ms after stimulus onset which is considered as an index of early orienting of attention resources (Eldar & Bar-Haim, 2010) – a less positive P1 amplitude occurs during development due to an increase in attention resource efficiency (Batty & Taylor, 2006). This suggests that in the current study pre-adolescents allocated less attention resources towards angry stimuli during the early stages of stimulus processing after mindfulness training, perhaps due to a reduction in emotional reactivity. In addition, the LPP mean amplitude across emotional and neutral stimuli became more positive for the wait-list control group along with increases in negative affect, whilst no modulation of the LPP mean amplitude was found for the training group. This suggests that rather than improving emotion processing abilities, as previous developmental studies have shown (Mendelson et al., 2010; Schonert-Reichl et al., 2015), in this study the mindfulness curriculum had a potentially protective effect on the later stages of emotion processing in comparison to the control group who received the curriculum as usual.

It is not clear why after mindfulness training pre-adolescents showed enhanced physiological reactivity indexed by lower RSA and higher CSI levels at rest in contrast to a reduction or no change in emotional reactivity during the different stages of an emotional response to affective faces indexed by the P1 and LPP. Whilst previous studies have found that resting RSA is a reliable trait measure of self-regulation (Chapman et al., 2010; Staton et al., 2009), Hinnant and El-Sheikh (2009) found that resting RSA only predicted psychopathological disorders when measured in conjunction with RSA during a stress inducing task. As expected they found that children with high resting RSA along with moderate to high RSA withdrawal during a stressful task scored below average on internalising symptoms. But interestingly, children with low resting RSA along with RSA augmentation during the task also had low scores on internalising symptoms. Therefore, further research is needed to explore the impact of mindfulness training on trait and state measures of emotional reactivity during pre-adolescence to further the understanding of whether an individual can respond adaptively to situational demands.

Interestingly, in contrast to studies with adults and older adolescents which have found modulations in the N2 and P3b ERP indices of attention control after mindfulness training (Moore et al., 2012; Sanger & Dorjee, 2016), no modulations of these ERP components were found during the emotion oddball task for either the control or training group. This suggests that after mindfulness training no group differences in top-down attention control abilities were present. These findings contrast with prevailing mindfulness theories on self-regulation with adults which suggest that in inexperienced meditators an increase in top-down regulation can reduce emotional reactivity after attending a mindfulness course (Chiesa et al., 2013; Tang et al., 2015). Then with extensive training, the development of a non-reactive non-judgemental awareness towards experiences may facilitate a shift away from top-down regulation towards modulations of bottom-up processes linked with sensory awareness (Chiesa et al., 2013; Tang et al., 2015). Perhaps in individuals with less effective top-down regulation abilities, such as pre-adolescents, mindfulness training may not solely target top-down regulatory control mechanisms, but also modulate processes linked with bottom-up sensory awareness (Kaunhoven & Dorjee, 2017). Indeed, in adults experiencing social anxiety, a disorder also characterised by deficits in top-down regulatory control, a reduction in amygdala activity during a breath focused task in comparison to a distraction focused task was found after mindfulness training which was not driven by an increase in prefrontal cortex activity. This suggests that mindfulness training did not modulate emotion processing through the enhancement of top-down attention control (Goldin & Gross, 2010). However, as noted above when discussing the dispositional findings, it is also possible that an N2 elicited during this oddball task did not tax conflict monitoring and response inhibition skills to the same degree as a task such as the Go/No-go task. Therefore, it is not clear whether these group differences in top down attention control abilities would become apparent using a different task. Whilst these explanations are currently speculative, further research using an integration of electrophysiological, psychophysiological and self-report measures is needed to further examine whether the patterns reported in this study are consistently found in pre-adolescents.

The high acceptability ratings observed for the teacher delivered Paws b curriculum are encouraging and suggest that the model of mindfulness training implemented in the current research project is both feasible and acceptable. The teacher training involved school teachers (*n* = 19) first attending a mindfulness training course (.b foundations; Mindfulness in Schools.org) which was delivered over three months (May – July) in four sessions (each 3 hours 15 minutes in length) and following this, teachers were given several months (July- November) to develop and sustain their mindfulness practice. Five school teachers developed sufficient mindfulness practice and decided to train in delivery of the Paws b curriculum (three full days of training). Four of these teachers then delivered the curriculum as part of the research project. The depth of their mindfulness practice was assessed through a reflective exercise with an experienced mindfulness trainer and co-author of the Paws b curriculum. This was an important step in ensuring the fidelity of the curriculum delivery as the development of an in depth personal practice is considered a key pre-requisite for effectively delivering mindfulness training (Crane, Kuyken, Hastings, Rothwell & Williams, 2010; Kabat-Zinn, 2003). During curriculum delivery (March – June), supervision from the same experienced mindfulness trainer and two primary school teachers who have extensive personal practice of mindfulness and are co-authors of the Paws b curriculum, also provided support to ensure the curriculum was delivered in an effective way.

A recent systematic review of 28 primary and secondary school based studies of mindfulness-based interventions for children and adolescents found that more studies were conducted with the use of an outside mindfulness trainer in comparison to the school teacher based model (Felver et al., 2016). Training school teachers to deliver the mindfulness curriculum could be advantageous for several reasons - first, it is potentially more cost effective and sustainable than having external trainers deliver the mindfulness training. The teacher-led delivery could also meet Government policies pertaining to the need to improve primary school children's mental health and well-being through the development of a whole school approach (Public Health England, 2015; Banerjee et al., 2016). Improving the mental health and well-being of both teachers and pupils is a central aspect of the whole school approach, previous studies have found that 8 weeks of mindfulness training can improve stress, depression, and occupational burnout in primary and secondary school teachers (Flook, Goldberg, Pinger, Bonus & Davidson, 2013; Gold et al., 2010; Roeser et al., 2013). In addition, school teacher delivered mindfulness curricula have been found to increase optimism, socio-emotional competence, emotional control and metacognition and decrease negative affect and depression in primary school aged pupils (Schonert-Reichl & Lawlor, 2010; Schonert-Reichl et al., 2015; Vickery & Dorjee, 2015). The current research project adds further support to the potential effectiveness of this teacher led-style of delivery.

Limitations and future research

The research project employed a non-randomised pre-post design with a wait-list control group to assess the impact of mindfulness training. Randomised controlled trials (RCTs), which involve the random allocation of participants into groups, are the most rigorous method of determining whether a cause and effect relationship exists between an intervention and an outcome (Sibbald, 1998). In non-randomised designs, it is possible that biases in how participants were allocated to a group could impact on the results observed. For example, participants who are more motivated to improve their mental health and well-being may be more likely to opt into the intervention group in comparison to a control group and these participants may show greater improvements over time due to their higher intrinsic motivation. RCTs can minimise these biases as there is the same probability of a participant being allocated to the intervention or control group (Sedgwick, 2013).

Accordingly, in the current study, several potential sources of bias could have impacted on the findings obtained. It is possible that there were group differences in the motivation levels of the school teachers and parents who provided informed consent for their children to participate. If this is the case, then it is possible that the differences which emerged between the training group and control group for some measures in the current study were due to baseline group differences in motivation levels. Furthermore, it is possible that these findings would not have been observed if the mindfulness curriculum was delivered by other schools with less motivation and confidence in the potential of mindfulness training. As these sources of bias cannot be ruled out caution is needed when considering the generalisability of the results. In the current study, it was not possible to randomise schools due to the considerable time commitments which were required from the school teachers in the training group in terms of the initial mindfulness training and mindfulness curriculum training they undertook. Therefore, it was necessary to allocate schools using a first to opt in basis to ensure that the schools which could accommodate these study requirements were allocated to the training group. The current study was a pilot study and whilst interesting findings have been observed which contribute to the understanding of the link between mindfulness and self-regulation in pre-adolescents, further large scale RCTs are needed to replicate and expand the findings from this study.

The current study compared the impact of a mindfulness curriculum with a wait-list control group who received the curriculum as usual. The lack of an active control group could be considered another potential limitation of the study. With wait-list control groups it is not possible to determine whether the effects observed after the intervention are due to the intervention itself or due to other factors including the novelty of receiving a new curriculum. Active control groups can eliminate these factors and improve confidence that the findings observed are due to the actual intervention (Karlsson & Bergmark, 2015). For example, an RCT with sixth-grade students which compared the impact of six weeks of mindfulness training with a novel African history course found that both groups showed improvements in positive affect and reductions in internalising and externalising problems and attention problems (Britton et al., 2014). This shows that some of the beneficial effects observed after the implementation of a mindfulness curriculum could be due to the introduction of a novel, engaging curriculum rather than due specifically to the training of mindfulness skills. An active control intervention should ideally match the targeted intervention in terms of its duration, frequency, format and instructor experience to minimise the influence of these factors on the intervention related outcomes. As the school teachers were trained in mindfulness, developed mindfulness practice and were trained in the mindfulness curriculum delivery over an 8-month period, it was not logistically feasible to train the control teachers in an equivalent way for another intervention. Therefore, whilst the current project cannot rule out the potential contribution the novel didactic elements of the mindfulness curriculum could have had on the outcomes, it can provide information regarding whether the mindfulness curriculum can improve mental health and well-being beyond the usual curriculum which is routinely implemented in primary schools in the UK.

Another limitation of the current research project was that some of the self-report questionnaires completed by the children had low internal consistency. This suggests that children struggled to understand some of the items included in the questionnaires. As has been previously explored throughout the thesis, the use of self-report questionnaires can be problematic with developmental populations (Campbell & Rapee, 1996) as they require a level of metacognitive awareness of thoughts and feelings which children can lack (Adrian, Zeman & Veits, 2011). This is a particular limitation of investigating dispositional mindfulness with pre-adolescents as currently self-report measures are the only approach for measuring dispositional mindfulness in both developmental and adult's samples (Brown et al., 2011a; Goodman et al., 2017). Whilst initial research suggests that a behavioural measure of mindfulness in the form of a breath counting task could provide an index of dispositional mindfulness (Levinson et al., 2014), validation of this measure (or other similar measures) with pre-adolescents is needed.

The sample size for the control group in the studies was also smaller than expected. This was due to higher than expected participant dropout rates and lower than expected accuracy rates of participants. As discussed in previous chapters, there are ways to address this in future studies, for example, accuracy rates could be improved through lengthening stimulus presentation time. This smaller sample size restricts the generalisability of findings from this study and further highlights the need for future larger scale trials.

Larger scale trials would also enable more group comparisons to be made, for example, it would be possible to establish whether the outcomes observed after the mindfulness training were impacted by the teacher who delivered the curriculum. In addition, the current research project was a naturalistic study which recruited schools from North Wales rated both low and high in the socioeconomic criteria of free school meals. The schools included in the training group and control group were matched on this socioeconomic criterion, however, it would be interesting to compare whether the outcomes observed after mindfulness training were different for participants from low socioeconomic areas in comparison to high socioeconomic areas. Additional measures of socioeconomic criteria, such as household income (Côté, Gyurak, & Levenson, 2014), parental occupation and the family affluence scale (which assesses family circumstances such as number of cars, computers, bedrooms etc.; Currie, Elton, Todd & Platt, 1997; Currie et al., 2008), could be particularly informative to use here to gain an accurate assessment of the socioeconomic levels of the pupils.

Larger scale trials would also make it possible to evaluate whether baseline differences in dispositional mindfulness modulate the effectiveness of mindfulness training programmes for pre-adolescents. Research with adults suggests that those with higher dispositional mindfulness prior to mindfulness training showed greater well-being and lower perceived stress after mindfulness training (Shapiro et al., 2011). It would be informative to explore whether this is the case with children, a mindfulness training study with pre-adolescents suggested that mindfulness training may be more effective for children who have lower levels of self-regulatory abilities at baseline (Flook et al., 2010). Given that higher dispositional mindfulness has been linked with more adaptive self-regulatory abilities in pre-adolescents (Oberle et al., 2012; Riggs et al., 2015), it could be the case that mindfulness training may be more effective for pre-adolescents with lower dispositional mindfulness.

Mindfulness studies should also assess the impact of mindfulness training on self-regulatory abilities over a longer time scale. This is important for several reasons, firstly, studies with pre-adolescents have found that the beneficial effects of mindfulness training on outcomes such as negative affect were only present at a three-month follow-up and not immediately after the mindfulness course (Vickery & Dorjee, 2015). A meta-analysis also revealed that treatment effects were larger at a follow-up in comparison to post-test (Klingbeil et al., 2017), however, few studies have included a follow-up session and so the long-term potential benefits of mindfulness training are still unclear. Secondly, pre-adolescents undergo several important transitions during this developmental period, including the transition from primary to secondary school. This can negatively impact on well-being (Rice et al., 2011; West et al., 2010) and so it would be interesting to explore whether mindfulness training can have protective effects during this time. Thirdly, as highlighted throughout the thesis, adult studies suggest that mindfulness training modulates self-regulatory processes through first targeting top-down regulatory processes linked with attention and cognitive control and then with more meditation experience modulations of bottom-up regulatory processes linked with sensory awareness occur (Chiesa et al., 2013;

Tang et al., 2015). Little is known about the neurocognitive impact of mindfulness training on self-regulatory processes in pre-adolescents, however, as chapter three (Kaunhoven & Dorjee, 2015) highlights, ERP markers of attention control and emotion processing could provide useful markers of the impact of mindfulness training on top-down and bottom-up regulatory processes. Through combining ERP measures with behavioural tasks and self-report measures it would be possible to explore whether extensive mindfulness training modulates self-regulatory processes in pre-adolescents in a similar way to adults.

This research project recruited children from a broad age bracket (7 to 11 years), and exploratory analysis has revealed that the association between dispositional mindfulness and self-regulation can change as a function of age. For example, dispositional mindfulness group differences in the P3b mean amplitude were only present for younger children (chapter five), whilst dispositional mindfulness group differences on heart rate variability indexes were only present for older children (chapter six). There are still very few studies which have examined the association between dispositional mindfulness and aspects of self-regulation in pre-adolescents. All known studies have been conducted with older pre-adolescents (Oberle et al., 2012; Riggs et al., 2015) and this is the first known study which has explored this association in children as young as 7 years of age. As self-regulatory abilities undergo substantial maturational changes during pre-adolescence (Rothbart et al., 2011), it is not surprising that these age differences emerged. Due to the small sample size included in the current research project it was only possible to run exploratory analysis on the factor of age. However, this project highlights the importance of taking age into account when designing studies exploring mindfulness and self-regulation.

This research project employed self-report, behavioural, ERP and psychophysiological measures to investigate mindfulness (dispositional and acquired through training) and self-regulation in pre-adolescents. An integration of different methods can be advantageous in providing a multilevel understanding of the mechanisms underlying the relationship between mindfulness and self-regulation in pre-adolescents, which would not be apparent through self-report or informant reports alone (Kaunhoven & Dorjee, 2017). In addition, converging evidence across these different assessments can provide a more in depth understanding of this relationship. As this current research project has shown, often the same pattern of effects is not obtained across these different measures and this raises some important questions which can be explored in future research. Further research utilising these different research measures is needed to examine the sensitivity of these markers for measuring the group differences in dispositional mindfulness and the effects of mindfulness training on self-regulation in pre-adolescence. Most research studies on mindfulness with pre-adolescents have employed self-reports (Felver et al., 2016) and whilst these studies have provided useful information regarding the potential beneficial effects of mindfulness, they have not progressed the understanding of how mindfulness impacts on self-regulation during pre-adolescence. To build an understanding of the mechanisms underlying dispositional mindfulness and mindfulness training, research which employs neurocognitive measures is needed.

Conclusions

Despite the potential limitations outlined above, this study made an important contribution to the literature on developmental neuroscience of mindfulness. Most developmental studies of mindfulness training have so far employed self-reports and informant reports (Felver et al., 2016). Aside from the potential limitations of using self-reports, informant reports also require the informant to have an accurate awareness of the internal state of others and these reports can be prone to bias (Adrian et al., 2011; De Los Reyes & Kazdin, 2005), especially if the parent or teacher has a personal interest in the outcome of the study. The current study is one of the first developmental studies to investigate the impact of mindfulness training using self-report, behavioural, neural and psychophysiological measures. Overall, the current research project suggests that pre-adolescents with higher mindfulness disposition have greater self-regulation abilities. In addition, the fostering of mindfulness skills through a school teacher delivered mindfulness curriculum can potentially have protective effects on emotion processing abilities during childhood. Mindfulness skills could have an important role in the development of self-regulation development during pre-adolescence which could impact on children’s long term developmental trajectories. These findings can be built upon in the development of future long-term large scale RCTs.

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How does mindfulness modulate self-regulation in pre-adolescent children? An integrative neurocognitive review

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ABSTRACT

Pre-adolescence is a key developmental period in which complex intrinsic volitional methods of self-regulation are acquired as a result of rapid maturation within the brain networks underlying the self-regulatory processes of attention control and emotion regulation. Fostering adaptive self-regulation skills during this stage of development has strong implications for physical health, emotional and socio-economic outcomes during adulthood. There is a growing interest in mindfulness-based programmes for pre-adolescents with initial findings suggesting self-regulation improvements, however, neurodevelopmental studies on mindfulness with pre-adolescents are scarce. This analytical review outlines an integrative neuro-developmental approach, which combines self-report and behavioural assessments with event related brain potentials (ERPs) to provide a systemic multilevel understanding of the neurocognitive mechanisms of mindfulness in pre-adolescence. We specifically focus on the N2, error related negativity (ERN), error positivity (Pe), P3a, P3b and late positive potential (LPP) ERP components as indexes of mindfulness related modulations in non-volitional bottom-up self-regulatory processes (salience detection, stimulus driven orienting and mind wandering) and volitional top-down self-regulatory processes (endogenous orienting and executive attention).

Contents

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1. Introduction

Early and middle childhood has been highlighted as a key developmental period in which skills in self-regulation are fostered (Berger et al., 2007; Fjell et al., 2012; Marsh et al., 2009; Posner and Rothbart, 2009). Self-regulation skills facilitate goal oriented behaviour and optimal responding to emotionally and cognitively demanding stimuli through the effective regulation of cognitions, feelings and behaviours (Fjell et al., 2012; Posner et al., 2007; Zelazo and Lyons, 2012). There are two key processes of self-regulation: attention control as the capacity to resolve conflicts, inhibit processes and shift the focus of attention (Muris et al., 2007; Rueda et al., 2004a, 2005), and emotion regulation, the ability to modify how emotions are experienced and expressed (Gross and Thompson, 2007; Lewis and Todd, 2007; Thompson, 1994).

Self-regulation has a pivotal impact on developmental outcomes including social and emotional wellbeing and academic functioning (Blair and Razza, 2007; Gross and John, 2003; Liew, 2012; Ursache et al., 2012); children who exhibit ineffective self-regulation skills are at increased risk of physical and mental health disorders as adults (Althoff et al., 2010). Indeed, self-regulation abilities present during childhood predict adult health problems, substance dependence, socioeconomic position and the likelihood of committing a criminal offence in adulthood (Moffitt et al., 2011). Higher levels of self-regulation are associated with enhanced well-being including better mental health, the ability to maintain effective social relationships and global adaptive functioning in home and school life (Buckner et al., 2009; Checa et al., 2008; Graziano et al., 2007).

Effective self-regulation hinges upon an optimal balance between "bottom-up" emotional reactivity (ventral system; involving brain regions lower down the neuroaxis including the limbic areas) and "top-down" cognitive and attention control (dorsal system; involving brain regions higher up the neuroaxis including the prefrontal cortex; PFC; Blair and Dennis, 2010; Blair and Ursache, 2011; Lewis and Todd, 2007; Zelazo and Lyons, 2012). Bottom-up regulation involves unconscious, non-volitional processes which are driven by the salient behaviourally relevant properties of stimuli (i.e. novel, unexpected or emotionally arousing; Buschman and Miller, 2007; Lewis and Todd, 2007). Bottom-up self-regulatory processes can be externally directed, i.e. the rapid detection and re-orientation of attention resources to salient stimuli within the environment (Buschman and Miller, 2007; Corbetta and Shulman, 2002) or internally directed, i.e. the automatic orientation of attention away from a goal towards task irrelevant internal thoughts (mind wandering; Smallwood and Schooler, 2006). Top-down regulation involves the conscious, volitional goal oriented regulation of cognitions and emotions (Corbetta and Shulman, 2002; Lewis and Todd, 2007). Endogenous orienting is a top-down process which involves the orienting of attention towards goal relevant stimuli (Corbetta and Shulman, 2002). Top-down executive attention abilities include conflict monitoring and resolution – the detection of behaviour which is incongruent to a goal, the resulting modification of behaviour to align it with a goal and the inhibition of goal-irrelevant stimuli (Berger et al., 2007; González et al., 2001; Mezzacappa, 2004; Posner and Rothbart, 2007; Rueda et al., 2005). The connection between top-down and bottom-up neural systems is mediated by the anterior cingulate cortex (ACC); the dorsal caudal ACC increases attention control when conflicts between competing stimuli are detected and the ventral rostral ACC assesses the emotional salience of a stimulus to aid the formation of regulatory responses (Bush et al., 2000; Dennis, 2010; Yeung et al., 2004). Inefficient interactions between these neural systems are associated with psychopathological disorders such as anxiety, depression, aggression and impulsivity (Lewis et al., 2008; Pagliaccio et al., 2014).

During pre-adolescence the brain networks underlying self-regulation undergo considerable maturation (Berger et al., 2007; Posner et al., 2007). Bottom-up self-regulatory processes develop earlier in childhood than top-down self-regulatory processes due to the protracted development of the PFC (Lewis and Todd, 2007; McRae et al., 2012; Qin et al., 2012). Accordingly, the self-regulatory strategies employed by children are often more short term and inflexible compared with adults (Decicco et al., 2012; Rothbart et al., 2011). During pre-adolescence considerable maturational brain changes occur including synaptic pruning of ineffective local neural connections and neuronal myelination of longer range neural connections (Kelly et al., 2009; Stevens, 2009). This enables the top-down regulatory regions of the PFC and the bottom-up sensory areas of the parietal cortex to become increasingly connected (Fair et al., 2007; Kelly et al., 2009; Rothbart et al., 2011; Stevens, 2009), facilitating the ability to employ complex, long term strategic methods of self-regulation (Rothbart et al., 2011).

These maturational developments are strongly shaped by childhood experiences (Blair and Diamond, 2008; Evans and Kim, 2013; Fonagy and Target, 2002). For instance, exposure to cumulative environmental stressors, such as being raised in socially and emotionally deprived home environments, can heighten stress reactivity through impairing the stress regulatory response formulated by the hypothalamic-adrenal stress axis (Blair, 2010; Evans and Kim, 2013; Fonagy and Target, 2002). This increased sensitivity to stress can have a maladaptive impact on development within brain regions underlying top-down self-regulation including reduced efficiency of the executive attention network (Kishiyama et al., 2009; Kolb et al., 2012; Loman et al., 2013; McDermott et al., 2012) and over activation of the amygdala (Arnsten, 2009; Noble et al., 2012; Tottenham et al., 2010). Some consequences which have been documented include an increased vulnerability to internalising and externalising psychopathological disorders (Blair and Raver, 2012; Davidson and McEwen, 2012; Gunnar and Fisher, 2006; Leve et al., 2005), heightened negativity biases (Pollak et al., 1997), a reduced ability to effectively cognitively reappraise situations (Kim et al., 2013), and impairments in response inhibition (Evans and Kim, 2013). However, bolstering self-regulation skills during childhood may potentially ameliorate adverse outcomes during adulthood (Durlak et al., 2011; Greenberg et al., 2003; Greenberg et al., 2001). Hence not surprisingly, promotion of self-regulation during childhood is high on educational policy agendas (e.g. in the United Kingdom: Connolly et al., 2011; Department of Education Northern Ireland, 2007; Hyland, 2014; Public Health England, 2015; The Scottish Government, 2013; Welsh Assembly Government, 2010).

Initial evidence suggests that mindfulness training can improve well-being and nurture a wide range of effective self-regulatory skills in pre-adolescents with and without clinical disorders (Harnett and Dawe, 2012; Meiklejohn et al., 2012; Schonert-Reichl et al., 2015; Tang et al., 2012). Mindfulness is, within the Buddhist context where it originated, often described as a technique or a neutral mental faculty supporting the development of introspective awareness and attention stability (Dorjee, 2010; Thera, 1962). The construct of mindfulness seems more encompassing within the secular context (Kabat-Zinn, 2003) where it is described as an awareness of experiences arising in the present moment whilst attending to them in an open and accepting way without judgement or evaluation (Bishop et al., 2004a; Shapiro et al., 2006). Secular conceptualisations of mindfulness are adopted in the majority of mindfulness-based interventions with pre-adolescents. Mindfulness is conceptualised as both a state and trait, and accordingly, levels of mindfulness can vary both between and within individuals (Brown and Ryan, 2003; Cahn and Polich, 2006). State mindfulness is a mind-set which occurs during mindfulness meditation and fluctuates over time; trait mindfulness is a relatively stable disposition which is present outside of actual meditation practice (Brown and Ryan, 2003; Cahn and Polich, 2006).

To date, schools have been the most frequent setting for studies investigating the impact of mindfulness training in pre-adolescents aged between 7 and 12 years (Black et al., 2009; Burke, 2010; Felver et al., 2016; Felver and Jennings, 2016; Harnett and Dawe, 2012; Zenner et al., 2014); 16 studies have been conducted within a classroom setting (for a full review of these studies see Felver et al., 2016; Felver and Jennings, 2016). A recent meta-analysis of 24 school based mindfulness studies conducted across both pre-adolescent and adolescent years reported large effect sizes on measures of cognitive performance and small to medium effect sizes on stress reduction and resilience (Zenner et al., 2014). Interestingly, a study with pre-adolescents found that the largest improvements in executive functions after mindfulness training were found in children who initially had the poorest skills (Flook et al., 2010). This is important because physical and psychological outcomes during adulthood are better than expected for those children who show self-regulatory improvements over the course of development (Moffitt et al., 2011).

A recent analytical review of adult imaging literature highlighted enhancement in self-regulation as the main mechanism of change with mindfulness training (Tang et al., 2015). It has been proposed that the extent to which mindfulness training modulates top-down and bottom-up regulatory processes depends on the amount of mindfulness experience, with initial changes first observed for top-down regulatory abilities followed by bottom-up modulations after extensive mindfulness experience (Chiesa et al., 2013). In comparison to mindfulness research with adults, investigation of the neurocognitive self-regulatory mechanisms of change underlying the effects of mindfulness in pre-adolescents greatly lags behind and there is no developmentally specific theoretical framework to guide further systematic investigation of how mindfulness training modifies self-regulation in children.

This review aims to contribute to the theoretical foundations of neurodevelopmental research on mindfulness training by examining possible neurocognitive mechanisms of change in attention control and emotion regulation of pre-adolescents aged between 7 and 12 years. The review will primarily focus on stable trait shifts in attention control and emotion regulation resulting from mindfulness training with pre-adolescents. Studies investigating brief inductions of mindfulness associated with state effects will only be discussed where trait-related research on mindfulness is limited. In what follows, we will first summarise the current mindfulness training programmes for pre-adolescents. We will then discuss the importance of adopting an integrative neurodevelopmental approach in research on mindfulness with pre-adolescents; this involves the integration of self-report, behavioural and neural assessments. We will then outline the brain networks underlying self-regulation processes in pre-adolescents and review current findings on the impact of mindfulness training on these. Finally, we will highlight the advantages of using event-related potential methodology to study the neurocognitive impact of mindfulness training on self-regulation processes in pre-adolescents (for a review of the neuropsychological impact of mindfulness with adolescents see Sanger and Dorjee, 2015).

2. Mindfulness training for pre-adolescents

An array of mindfulness training programmes has been investigated in studies with pre-adolescents aged between 7 and 12 years (Meiklejohn et al., 2012; Zoogman et al., 2015). These include the Attention Academy program (Napoli et al., 2005), Inner Kids program (Flook et al., 2010; Greenland, 2010), Integrative contemplative pedagogy (Britton et al., 2014; Roth, 2014), Integrative Body-Mind Training (IBMT; Tang et al., 2012; Tang and Posner, 2009), Mindful Education (ME) (Schonert-Reichl and Lawlor, 2010), Mindfulness-Based Cognitive Therapy for children (MBCT-C; Semple et al., 2010), Mindful Family Stress Reduction (MFSR; Felver and Tipsord, 2011; Felver et al., 2014a), Mindful Schools (MS; Black and Fernando, 2014; Liehr and Diaz, 2010; Mindful Schools, 2012), MindUP (Hawn Foundation, 2011; Schonert-Reichl et al., 2015), Move-Into-Learning (Klatt et al., 2013), Paws b (Mindfulness in Schools Project, 2015; Vickery and Dorjee, 2015), Soles of the Feet (Felver et al., 2014b; Singh et al., 2003), Still Quiet Place (Saltzman and Goldin, 2008), and a yoga-based mindfulness curriculum (Mendelson et al., 2010).

Mindfulness programmes for pre-adolescents vary in format, content and length, for instance, programmes range from 3 to 12 min daily sessions over 6 weeks (Britton et al., 2014) to 45 min fortnightly sessions over 24 weeks (Napoli et al., 2005). The experience of the mindfulness teacher also varies greatly; some programmes are delivered by experienced mindfulness trainers (Felver et al., 2014a; Flook et al., 2010; Klatt et al., 2013; Mendelson et al., 2010) whilst others are delivered by school teachers with different levels of training in mindfulness (Britton et al., 2014; Schonert-Reichl and Lawlor, 2010; Schonert-Reichl et al., 2015; Vickery and Dorjee, 2015). Overall, a meta-analysis of mindfulness studies with youths aged between 6 and 18 years found that the clinical nature of samples and types of outcome measures (not mindfulness training format or other variables) were the only aspect of the studies' design which significantly moderated the effect sizes of outcomes (Zoogman et al., 2015).

Many mindfulness programmes for pre-adolescents include practices adapted from secular standardised mindfulness courses for adults including mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990) and mindfulness-based cognitive therapy (MBCT; Segal et al., 2002). Both of these programmes have a strong evidence base in the treatment of anxiety, depression and well-being enhancement in adults (Chiesa and Serretti, 2010; Hofmann et al., 2010; Keng et al., 2011). In programmes with pre-adolescents, the practices are adapted to be age appropriate, for example, there is less depth of inquiry and shorter time spent in mindfulness meditation (Meiklejohn et al., 2012; Thompson and Gauntlett-Gilbert, 2008; Zelazo and Lyons, 2012). This is due to developmental differences in the ability to focus and sustain attention on the present moment (Mezzacappa, 2004; Rueda et al., 2004b) and the capacity for metacognitive awareness of mental phenomena (Davis et al., 2011; Dignath and Büttner, 2008; Greenberg and Harris, 2012).

However, similarly to MBSR and MBCT (Kabat-Zinn, 1990; Segal et al., 2002), mindfulness courses for pre-adolescents include practices which train aspects of self-regulation including attention control and emotion regulation. Breath awareness practices guide attention to focus on a stimulus such as an object or the breath to anchor attention in the present moment. Learning to reengage attention on the stimulus after recognising that attention has drifted away from the present moment towards a distraction (a habitual process called mind wandering), is another skill cultivated during practices (Britton et al., 2014; Felver et al., 2014a; Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015; Thompson and Gauntlett-Gilbert, 2008). Mindfulness programmes also often include practices which enhance awareness of thoughts, emotions and bodily sensations and involve observing that these states are transient and change over time (Flook et al., 2010; Mindfulness in Schools Project, 2015; Saltzman and Goldin, 2008), as well as practices such as guided visualisation which promote an attitude of kindness and compassion to the self and others (Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015). This suggests that despite the diverse range of mindfulness programmes available for pre-adolescents, similar mechanisms may underlie the impact of mindfulness on self-regulatory abilities.

3. An integrative neurodevelopmental framework for research on mindfulness

As developmental studies of mindfulness are a relatively new emerging area of research in comparison to adult research, many studies have methodological limitations including lack of active control groups and limited sample sizes (Felver et al., 2016; Greenberg and Harris, 2012; Rempel, 2012). And whilst we can assume similar underlying mechanisms across mindfulness interventions with pre-adolescents, the overall lack of standardisation across programmes may make it difficult to isolate and compare the effective active ingredients of mindfulness programmes for pre-adolescents. In addition, most studies on mindfulness with children have used questionnaire-based measures including child, parent and teacher reports, which makes the challenge of isolating active ingredients and underlying mechanisms even more difficult (Flook et al., 2010; Greco et al., 2011; Schonert-Reichl and Lawlor, 2010; Semple et al., 2010). Whilst questionnaire measures clearly have their merits, their limitations include reliance on the individual having an accurate awareness of their own or others' internal and external states, which can be changeable over time and with mindfulness training (Brown and Ryan, 2003), particularly in children (Boekaerts and Corno, 2005). This highlights the need to employ an array of research methodologies in developmental research on mindfulness, particularly methods not reliant on self-reports.

Experimental paradigms measuring reaction time, neurocognitive changes and psychophysiological changes, can usefully broaden the spectrum of currently used techniques (Greenberg and Harris, 2012). Only a few mindfulness studies with children aged between 7 and 12 years have employed experimental tasks (Felver et al., 2014a; Napoli et al., 2005; Schonert-Reichl et al., 2015) and no published studies with this age group have so far used neuroscientific methods. Neurocognitive approaches may provide insights into the neurodevelopmental mechanisms underlying mindfulness and measure changes in pre-adolescents which may not be detected by self-reports and behavioural assessments alone (Banaschewski and Brandeis, 2007). More importantly, concurrent employment of self-report, other-report, behavioural, neural and physiological measures may enhance our understanding of multi-level (cognitive, social, neural and psychophysiological) developmental changes relevant to self-regulation. Such an approach can provide converging evidence and result in a more complete understanding of how mindfulness impacts development at different levels. Theory driven research hypotheses and converging evidence obtained from integrating different research methodologies could reduce the incidences of problematic reverse inferences (inaccurately inferring the engagement of cognitive processes from neural activity) (Hutzler, 2014; Plassmann et al., 2015; Poldrack, 2006). This approach could also be particularly helpful in disambiguating conflicting inferences about modulations of neurocognitive markers with mindfulness training (for example, see the discussion about contradictory ERP findings in Sections 5.1, 5.2 and 5.4). Such understanding can help further improve the efficacy of mindfulness interventions for pre-adolescents and maximise possible long-term preventative effects of mindfulness through the enhancement of specific neurocognitive processes which underlie self-regulation, such as attention control and emotion regulation.

Event-related brain potentials (ERPs), a non-invasive measure of the post synaptic activity from populations of synchronised neurons time locked to the onset of specific stimuli (Luck, 2014), could be particularly useful when measuring neurodevelopmental changes with mindfulness. ERPs are cost-effective compared with other neuroscientific methodologies (Luck, 2014) and can provide a measure of the time course of neurocognitive processes underlying self-regulation with millisecond accuracy (Hajcak et al., 2010; Sur and Sinha, 2009). Whilst ERPs have excellent temporal resolution, they do not have the spatial resolution of neuroimaging techniques such as fMRI (Luck, 2014; Woodman, 2010). Locating the neural source of ERPs can be difficult as it is possible that the signal is generated by multiple undetermined neural generators. Therefore, the scalp topography of the ERP does not necessarily reflect activity from the brain regions directly underneath (Burle et al., 2015; Woodman, 2010; Zani and Proverbio, 2003). It is, however, possible to provide an estimate of the likely neural generators underlying ERPs using post-hoc techniques such as dipole source modelling (Grech et al., 2008; Hallez et al., 2007; Swick et al., 1994). ERPs are also a valuable tool for tracking developmental brain changes and detecting potential self-regulatory difficulties which may arise during childhood (Dennis et al., 2009; Lewis et al., 2008; Stieben et al., 2007). Whilst there are a variety of ERP components which can index attention control and emotion regulation, this review will focus on ERP markers which are modulated by developmental changes in attention and emotion regulation and have previously been sensitive to mindfulness-induced changes in adults or adolescents. Several ERP components meet this criteria (see Table 1) including the N2, error related negativity (ERN), error positivity (Pe), P3a, P3b and the late positive potential (LPP) ERP components (e.g. Brown et al., 2013; Cahn and Polich, 2009; Larson et al., 2013; Moore et al., 2012; Teper and Inzlicht, 2013).

The following sections will consider how mindfulness training could potentially improve self-regulation during pre-adolescence via the modulation of bottom-up and top-down neurocognitive self-regulatory processes. Bottom-up processes include salience detection, stimulus driven orienting of attention and mind wandering, top-down processes include volitional endogenous orienting and executive attention. Due to the absence of experimental neurocognitive studies on mechanisms of mindfulness in children, we will explore possible changes with mindfulness training in pre-adolescents by considering theories of self-regulation development in childhood, findings from adult mindfulness studies, and initial behavioural and self-report evidence from mindfulness intervention research with children. Following this, we outline how ERP components could be used to index mindfulness induced modulations of these self-regulatory processes in order to stimulate further experimental research within an integrative neurodevelopmental framework.

4. Possible modulation of neurocognitive self-regulation by mindfulness practice in pre-adolescence

4.1. Bottom-up and top-down self-regulatory processes

Due to the limited capacity of attention; bottom-up stimulus driven attention processes compete with top-down goal oriented attention processes for cognitive resources (Berger et al., 2005). An effective balance between these processes is needed to enable flexible responding to the environment (Bishop et al., 2004b; Corbetta et al., 2008; Seeley et al., 2007; Sylvester et al., 2012; Vossel et al., 2014). Salient, novel or unexpected stimuli outside the field of awareness can activate bottom-up stimulus driven processes as they have the potential to be behaviourally relevant (Corbetta et al., 2008; Corbetta and Shulman, 2002; Farrant and Uddin, 2015; Schupp et al., 2007). Detection of these stimuli disrupts the top-down task related endogenous focus of attention and rapidly diverts these attention resources to the salient event (Carretié, 2014; Corbetta et al., 2008; Corbetta and Shulman, 2002; Vossel et al., 2014). For behaviourally relevant stimuli, this can

Table 1
A summary of how event related potential (ERP) measures can provide an index of the impact of mindfulness training on top down and bottom up aspects of self-regulation in pre-adolescents.

ERP components	Aspects of self-regulation	Neural generators	Developmental ERP trends	Predictions for changes in self-regulation for pre-adolescents after mindfulness training
N2				
Fronto-central negativity elicited between approximately 200 and 400ms after stimulus onset (Lewis et al., 2006a).	**Executive attention** A more negative N2 is found after the successful inhibition of a pre-potent response during a Go/No-Go task (Falkenstein et al., 1999).	Dorsal caudal ACC (Lewis et al., 2006a; van Veen and Carter, 2002a), which is a node of the cingulo-opercular network (Fair et al., 2007).	During development the N2 amplitude becomes less negative, the latency decreases and the N2 topography becomes more anterior, reflecting an increase in neural efficiency within the executive attention network (Chapman et al., 2010; Lewis et al., 2006a). Mixed developmental patterns have been found with regards to the N2 elicited for No-Go stimuli during an emotionally demanding task; some studies have found a less negative N2 (Chapman et al., 2010) and others have found a more negative N2 with development (Lewis et al., 2006a).	A less negative N2 for No-Go stimuli during a neutral Go/No-Go task after mindfulness training would index more efficient executive attention skills. For an emotionally demanding Go/No-Go task a more negative N2 alongside improvements in self-reports of emotion regulation would index an increased ability to inhibit emotional distractions. For children with self-regulatory difficulties a reduction in the N2 amplitude for No-Go stimuli along with decreases in reports of anxiety would reflect an aligning of their regulatory performance with that of children without regulatory difficulties.
Error related negativity (ERN) and Error positivity (Pe)				
The ERN is a fronto-central negativity elicited approximately 50ms after an error response (Hajcak, 2012). The Pe is a parietal positivity elicited between 200 and 400 ms after an error response (Olvet and Hajcak, 2012).	**Executive attention and error processing**. The ERN reflects the monitoring for and detection of errors (van Veen and Carter, 2002b). A more negative ERN reflects increased error processing efficiency (Segalowitz and Davies, 2004). The Pe indexes the conscious detection and emotional response to errors (Endrass et al., 2007). The Pe is more positive when the emotional salience of an error is high (Endrass et al., 2007).	Several likely neural sources of the ERN include the dorsal caudal ACC (adouceur et al., 2006; van Veen and Carter, 2002b) and rostral ACC (Mathalon et al., 2003). The Pe is linked to the rostral ACC and parietal cortex (Herrmann et al., 2004; van Veen and Carter, 2000b).	The ERN amplitude becomes more negative reflecting increased error processing efficiency (Segalowitz and Davies, 2004). The Pe does not significantly change during development (Davies et al., 2004).	For the ERN more negative ERN along with enhancements in self-reports of empathy and acceptance after mindfulness training could reflect improvements in executive attention abilities, specifically error processing. Modulations of the ERN would be greater after longer durations of mindfulness training. After a short duration of mindfulness training an attenuation of the Pe could reflect a reduction in the emotional reaction to errors. For children with ADHD, who show a reduced ability to recognise and respond to errors, a more positive Pe after mindfulness training along with increases in self-reports of acting with awareness would reflect a more adaptive response to errors.
P3a				
Fronto-medial positivity found approximately 300 to 400 ms after stimulus onset (Bush et al., 2000).	**Stimulus driven orienting** A more positive P3a for infrequent distractor stimuli in an oddball paradigm reflects increased automatic orienting of attention resources (Polich, 2007; Wetzel et al., 2006).	Medial and superior frontal gyrus, the right parietal lobe and the ACC (Volpe et al., 2007). Activations in the ventral attention network and dorsal attention network have been found for oddball distractors (Bledowski, et al., 2004; Kim, 2014).	An anterior shift in topography from central to frontal sites (Gumenyuk et al., 2001; Lewis et al., 2006a) and an attenuation of the P3a amplitude (Stige et al., 2007) reflects reductions in the automatic orientation of attention during development.	A less positive P3a for distractor oddballs during an active oddball task after mindfulness training would index a reduction in exogenous attention. The elicitation of a less positive P3a for emotional distractors after mindfulness training could reflect reduced emotional reactivity towards emotional non-targets.

Table 1 (*Continued*)

ERP components	Aspects of self-regulation	Neural generators	Developmental ERP trends	Predictions for changes in self-regulation for pre-adolescents after mindfulness training
P3b Parietal positivity found approximately 300 to 500 ms after stimulus onset (Hajcak et al., 2010; Polich, 2007).	**Endogenous orienting**, mind wandering and context updating A more positive P3b to target oddballs during an oddball task reflects a greater ability to focus and allocate attention resources in a goal directed way (Polich, 2007). A less positive P3b is linked with increased mind wandering and reduced availability of attention resources (Smallwood et al., 2008).	Right temporo-parietal junction (Linden, 2005), which is a node of the ventral attention network (Bledowski et al., 2004).	The P3b latency decreases (van Dinteren et al., 2014) in conjunction with faster reaction times and increased accuracy rates during development, reflecting more efficient stimulus evaluation (Hillman et al., 2005).	A more positive P3b to targets during a demanding oddball task along with faster reaction times and increased accuracy rates would reflect an improvement in the ability to focus on task relevant stimuli. During less demanding tasks a less positive P3b along with no decrement in accuracy rates or reaction time after mindfulness training would reflect attention resource efficiency. After mindfulness training a more positive P3b together with higher target accuracy during the SART task would reflect reductions in episodes of mind wandering after mindfulness training. Reductions in the P3b to negative stimuli after mindfulness training would reflect a greater ability to disengage from negative affect. These modulations would be expected to be greater for children exposed to environmental stressors.
Late positive potential (LPP) Sustained centro-parietal positivity elicited approximately 300 ms after stimulus onset and sustained up to 2000 ms after stimulus onset (Hajcak et al., 2010).	**Top-down and bottom-up emotion regulation** During passive picture paradigms a more positive LPP reflects increased emotional reactivity to emotional stimuli (Hajcak and Dennis, 2009). During active emotion regulation tasks, an attenuation of the LPP reflects successful top-down regulation of an emotional response (Dennis and Hajcak, 2009).		The LPP topography shifts from occipital to parietal sites reflecting an increase in connectivity between frontal and parietal brain regions during development (Wessing et al., 2015). The ability to regulate emotions using top-down regulatory strategies such as cognitive reappraisal increases during pre-adolescence, resulting in a greater attenuation of the LPP to emotional stimuli (Dennis and Hajcak, 2009).	During passive picture paradigms an attenuation of the LPP to emotional stimuli would reflect reduced emotional reactivity after mindfulness training. During an active emotion regulation task which involves employing mindfulness to regulate emotions, an attenuation of the LPP amplitude for negative stimuli, in conjunction with self-reported reductions in state anxiety and depression would reflect improvements in emotion regulation after mindfulness training.

enhance perceptual clarity, interoceptive awareness and goal oriented behaviour through prioritising the attention focus towards important aspects of an environment (Corbetta and Shulman, 2002; Seeley et al., 2007; Vossel et al., 2014). At times, attention can be also inappropriately distracted (exogenously oriented) away from a task towards salient external stimuli or task unrelated thoughts (mind wandering), leading to interference with cognitive processes (Carretié, 2014; Dennis and Chen, 2007; Gross and Thompson, 2007; Smallwood and Schooler, 2006).

Top-down attention control processes such as endogenous orienting can reduce the detection of and re-orienting towards task irrelevant stimuli through sending top-down filtering signals which bias stimulus driven processes towards stimuli which are behaviourally relevant (Corbetta et al., 2008; Vossel et al., 2014). Top-down executive attention skills including conflict monitoring and resolution together with response inhibition can modulate attention deployment through monitoring the stream of consciousness for conflicts and inhibiting the influence of distracting salient stimuli (Berger et al., 2007; González et al., 2001; Mezzacappa, 2004; Rueda et al., 2005; Wadlinger and Isaacowitz, 2010). Deficits in these top-down attention control abilities including response inhibition and updating of working memory are linked with greater mind wandering (Kam and Handy, 2014) due to an inadequate ability to monitor and filter task unrelated thoughts (McVay and Kane, 2012).

Several models have been proposed to explain the neural networks underling the bottom-up stimulus driven processes of salience detection, stimulus driven orienting and mind wandering and top-down attention control processes of endogenous orienting and executive attention. One prominent approach is the three network model of attention (Posner and Rothbart, 2007, 2009) which suggests that alerting, orienting and executive attention networks underlie the different facets of attention. The alerting network is involved in bottom-up vigilance and stimulus detection. The orienting attention network underlies top-down orienting of attention towards or away from salient or goal relevant stimuli and the executive attention network underlies the top-down monitoring for and resolution of conflicts and response inhibition (Posner and Rothbart, 2007, 2009).

Other models further elaborated on the three network model of attention, a model by Corbetta and Shulman (2002) includes a dorsal and ventral attention network. The dorsal attention network has a similar role to the orienting attention network (Kim, 2014) and is involved in top-down volitional orienting of attention in relation to a goal (Corbetta and Shulman, 2002; Farrant and Uddin, 2015). The ventral attention network, which shares similarities with the alerting attention network (Corbetta et al., 2008; Kim, 2014), underlies the bottom-up detection of and reorientation towards salient behaviourally relevant stimuli (Corbetta and Shulman, 2002; Farrant and Uddin, 2015; Sylvester et al., 2012). Regarding the executive attention network, a model by Dosenbach et al. (2008) divided this into a fronto-parietal network, which is activated for rapid top-down strategic control and a cingulo-opercular network which is responsible for sustained top-down regulation (Dosenbach et al., 2008; Fair et al., 2007; Power and Petersen, 2013; Voss et al., 2011).

Finally, another model (Seeley et al., 2007) suggests that the salience network, which shares similar neural underpinnings to the cingulo-opercular network (Uddin et al., 2011) plays a key role in bottom-up processes such as salience detection. This network acts as a circuit breaker between the default mode network and central executive network (Menon and Uddin, 2010). The default mode network is activated during periods in which the mind is engaged in internal task irrelevant thoughts (i.e. mind wandering) (Christoff et al., 2009; Menon and Uddin, 2010; Sridharan et al., 2008). The central executive network, which has similarities to the fronto-parietal network (Sridharan et al., 2008), underlies top-down goal directed behaviour (Menon and Uddin, 2010; Seeley et al., 2007). Whilst there is some debate regarding the overlap between the neural networks discussed in the different models (Uddin et al., 2011; Uddin, 2015), Power and Petersen (2013) made clear distinctions between the ventral attention, dorsal attention, salience, default mode, fronto-parietal and cingulo-opercular networks.

The ventral attention network, comprised of the right lateralised temporo-parietal junction (TPJ), right ventral frontal cortex and middle and superior temporal gyrus (Corbetta and Shulman, 2002; Sylvester et al., 2012), has a role in bottom-up salience detection. This network disrupts the volitional endogenous goal oriented focus of attention subserved by the dorsal attention network (consisting of the bilateral frontal eye fields and bilateral intraparietal sulcus; Corbetta and Shulman, 2002; Farrant and Uddin, 2015). The ventral attention network, in collaboration with the dorsal attention network, facilitates the re-orientation of attention resources towards unexpected behaviourally relevant stimuli outside the field of awareness (Corbetta et al., 2008; Corbetta and Shulman, 2002; Farrant and Uddin, 2015; Vossel et al., 2014). Greater activation of the ventral attention network has been found for task relevant target oddballs compared to task irrelevant distractor oddballs in an oddball paradigm (Kim, 2014). This suggests that the ventral attention network is sensitive to the influence of top-down factors such as task relevance (Kim, 2014). Indeed, the dorsal attention network has been proposed to act as a filtering system which sends biasing signals to the ventral attention network to prioritise the processing of behaviourally relevant stimuli (Corbetta et al., 2008; Vossel et al., 2014).

The extent to which the ventral attention network is activated for task irrelevant distractors depends on task demands. Nodes of the ventral attention network such as the TPJ are suppressed during demanding tasks in order to reduce distractibility and increase the attention resources allocated towards the task; this is linked with improvements in behavioural performance (Corbetta et al., 2008; Frank and Sabatinelli, 2012). In contrast, during passive tasks the ventral attention network is activated for salient irrelevant stimuli (exogenous attention) in addition to behaviourally relevant stimuli. This suggests that distractibility increases when task demands are lower (Corbetta et al., 2008; Frank and Sabatinelli, 2012). In addition, the right TPJ of the ventral attention network was found to be involved in later stages of stimulus processing, specifically context updating (the updating the internal representation of the environment based on the incoming external stimulus; Geng and Vossel, 2013; Vossel et al., 2014).

Heightened sensitivity to salient stimuli during the early bottom-up stages of stimulus processing and a reduced ability to effectively employ attention control during the later top-down stages of stimulus processing has been reported in individuals with anxiety who display a threat bias (Bar-Haim et al., 2007; Mogg et al., 1997; Pérez-Edgar et al., 2007; Sylvester et al., 2016). This bias can be towards threat related stimuli and neutral stimuli (which they perceive as threat related due to their biased perception of the environment) and can contribute to the severity and maintenance of anxiety disorders (Bar-Haim et al., 2007; Sylvester et al., 2012; Waters et al., 2010). In terms of bottom-up stimulus detection; this heightened sensitivity to threat may be due to over activation of the salience network (Eckert et al., 2009; Menon, 2011) and ventral attention network and increased engagement between the ventral attention network and amygdala (Sylvester et al., 2012). Interventions which target bottom-up stimuli processing could reduce the initial reactivity to salient stimuli and enable more adaptive engagement with the environment.

The salience network (Seeley et al., 2007) and the ventral attention network (Corbetta and Shulman, 2002), likely have a similar role in bottom-up salience detection (Farrant and Uddin, 2015).

The salience network consists of the fronto- insular cortex (FIC) and ACC (Menon and Uddin, 2010; Seeley et al., 2007; Sridharan et al., 2008). The right FIC of the salience network is involved in the detection of salient stimuli and also acts as a task switcher which along with the ACC facilitates task relevant responses during a cognitively demanding task (Menon and Uddin, 2010). This occurs through reduced activation in the default mode network coupled with increased activation within the fronto-parietal network (also known as the central executive network; Menon and Uddin, 2010; Seeley et al., 2007; Sridharan et al., 2008). Specialised von Economo neurons present within the FIC and ACC of the salience network facilitate the ability to rapidly switch between the salience network, fronto-parietal network and the default mode network (Uddin, 2015; Watson et al., 2006).

The default mode network consists of the posterior cingulate cortex (PCC) and ventromedial PFC and is activated during episodes of mind wandering (Christoff et al., 2009; Hasenkamp et al., 2012; Uddin et al., 2009). This network is most active during situations in which the brain can engage in internally focused self-referential processing such as self-monitoring and reflection in the absence of a demanding cognitive task or at rest (Gruberger et al., 2011). Ineffective deactivation of the default mode network has been linked with a decrement in task performance (Weissman et al., 2006) and higher self-reports of mind wandering (Mason et al., 2007).

The fronto-parietal network consists of the dorsolateral PFC, intraparietal sulcus, inferior parietal lobule, precuneus, midcingulate gyrus and dorsal frontal cortex (Dosenbach et al., 2008; Fair et al., 2007). This network is activated for rapid short term flexible self-regulation including the initiation of regulatory control in task switching and rapid behavioural adjustment in response to performance feedback such as error related information (Dosenbach et al., 2008; Fair et al., 2007; Petersen and Posner, 2012; Power and Petersen, 2013). The fronto-parietal network has a collaborative role in self-regulation alongside the cingulo-opercular network (Dosenbach et al., 2008; Voss et al., 2011) which is comprised of the dorsal ACC, anterior PFC, medial superior frontal cortex, bilateral anterior insula, frontal operculum and thalamus (Dosenbach et al., 2008; Fair et al., 2007; Power and Petersen, 2013; Voss et al., 2011). This network is activated during situations requiring long term self-regulation including stable maintenance of goal focused behaviour over the course of a task (Dosenbach et al., 2008) through the detection of distracting conflicts or errors (Sylvester et al., 2012). Once a potential conflict is detected, the cingulo-opercular network signals the need to increase regulatory control to the fronto-parietal network which then adjusts regulation levels (Sylvester et al., 2012). Inefficient interactions between the fronto-parietal and cingulo-opercular network are associated with psychological disorders such as anxiety and major depression (Sylvester et al., 2012). For example, over activation of the cingulo-opercular network could lead to a heightened sensitivity to the need to exert control, such as when an error is made. Under activation of the fronto-parietal network could reduce the ability to initiate an increase in control (Sylvester et al., 2012).

4.2. Self-regulation development during pre-adolescence

Pre-adolescence is a key developmental period in which the brain networks underlying self-regulation undergo substantial maturational development (Fair et al., 2007; Farrant and Uddin, 2015). During development self-regulatory strategies progress from being short-term and inflexible to being increasingly strategic and complex due to an increase in efficient connectivity between bottom-up stimulus driven processes and top-down attention control processes (Fair et al., 2007; Farrant and Uddin, 2015; Rothbart et al., 2011). During early infancy self-regulatory strategies are short-term and inflexible and involve the orienting of attention towards goal relevant stimuli and away from task irrelevant salient stimuli (Corbetta and Shulman, 2002; Posner et al., 2014; Rueda et al., 2004b). In comparison to other forms of top-down regulation involving executive attention, orienting attention skills have an early prominent role in self-regulation as these skills develop sooner (Rothbart et al., 2011; Rueda et al., 2004b; Ishigami and Klein, 2011).

The dorsal and ventral attention networks underlying orienting attention skills show the same topography for pre-adolescents and adults (Farrant and Uddin, 2015). However, whilst the dorsal and ventral networks are formed by pre-adolescence, maturational development of these networks continues beyond pre-adolescence (Farrant and Uddin, 2015). In comparison to adults, pre-adolescents have increased connectivity between the ventral attention network and salience network, which underlies bottom-up salience detection. In addition, less efficient connectivity within the dorsal attention network which underlies top-down endogenous attention was found in pre-adolescents (Farrant and Uddin, 2015; Uddin et al., 2011). This imbalance reflects a disproportionately larger capacity for bottom-up salience detection in comparison to top-down attention control during pre-adolescence (Farrant and Uddin, 2015). Whilst orienting attention can offer effective short term regulation, this strategy has limited long-term effectiveness (Petersen and Posner, 2012) and is too reactive and inflexible as the primary form of self-regulation (Posner et al., 2014; Rothbart et al., 2011). As more complex self-regulatory abilities develop, orienting attention takes on an important supporting role (Rothbart et al., 2011).

During pre-adolescence, complex and strategic self-regulatory abilities, which involve executive attention skills such as conflict monitoring, resolution and response inhibition, play an increasingly prominent role in top-down self-regulation (Rothbart et al., 2011). This is due to maturational changes within the fronto-parietal and cingulo-opercular network. The fronto-parietal network supporting short-term regulation develops earlier than the cingulo-opercular network, which is involved in more sustained regulatory responses (Fair et al., 2007). Short-term self-regulation strategies are more prominently used during childhood due to the greater overlap between the fronto-parietal network and the dorsal attention network (Fair et al., 2007; Petersen and Posner, 2012). During development, the increased integration between the fronto-parietal network and the cingulo-opercular network (Fair et al., 2007) and segregation between the fronto-parietal network and dorsal attention network (Petersen and Posner, 2012) facilitates the progression from reactive and short term self-regulation to the ability to implement long-terms strategic control (Voss et al., 2011).

The connections between the right FIC of the salience network, fronto-parietal network and nodes of the default mode network strengthen with development (Uddin et al., 2011). This facilitates the task switching abilities of the salience network to flexibly respond to environmental demands by reducing mind wandering and initiating top-down goal oriented behaviour. Mind wandering is pertinent for pre-adolescence as it has a strong relevance to educational learning (Smallwood et al., 2007). Indeed, it has been suggested that mind wandering can interfere with memory processes supporting encoding (Smallwood et al., 2007) as well as consolidation of information (Smallwood and Andrews-Hanna, 2013) and has been linked with higher levels of negative affect (Mrazek et al., 2012). Mind wandering can, however, also contribute to creativity and problem solving, when it occurs during relatively low cognitively demanding tasks (Baird et al., 2012). This suggests that mind wandering can be both adaptive and maladaptive depending on the context, the task at hand and the content of thoughts during mind wandering (Smallwood and Andrews-Hanna, 2013). Interventions which strengthen the connectivity between the salience network and the default mode network could enable flexible engagement and disengagement from mind wandering. Pre-adolescents aged between 7 and 9 years have less mature structural and functional connectivity between the PCC and medial PFC regions of the default mode network compared with adults (Fair et al., 2008; Supekar et al., 2010), indicating that the ability for self-monitoring and reflection improves with development.

From a cognitive perspective, the formation of complex forms of self-regulation during development increasingly provides pre-adolescents with strategic skills for regulating emotions (Rothbart et al., 2011). The process model of emotion regulation (Gross, 2002; Gross and John, 2003) suggests that emotion regulatory strategies can have an impact during several stages of an emotional response. Regulatory strategies which impact the early stages of emotion processing are effective as they act before full activation of the emotional response and are therefore able to modulate how emotions are perceived and expressed. These strategies are called antecedent focused strategies (Gross, 2002; Gross and John, 2003).

Orienting attention abilities can have a regulatory impact during the early antecedent stages of emotion processing, at the attention deployment stage (Wadlinger and Isaacowitz, 2010). This involves regulation of emotions through the orienting of attention towards or away from emotionally arousing stimuli (Posner et al., 2014; Rothbart et al., 2011; Waters et al., 2010). Strategies which adaptively modulate the attention deployment stage of emotion processing can act as a gateway to facilitate later cognitive forms of regulation (Wadlinger and Isaacowitz, 2010). Efficiency within the orienting attention network may influence the recruitment of the executive attention network which underlies complex self-regulation strategies (Callejas et al., 2005; Posner et al., 2014). Therefore, training these orienting attention skills could facilitate the development of adaptive short term and long term self-regulatory skills.

In comparison to orienting skills, executive attention skills are involved in the formation of intrinsically motivated, complex "top-down" emotion regulation (Rothbart et al., 2011; Simonds et al., 2007; Thompson et al., 2008) and can modify emotions during several antecedent focused stages of emotion processing. This includes modulating attention deployment through monitoring for and inhibiting distracting emotional stimuli (Teper et al., 2013; Wadlinger and Isaacowitz, 2010), and through cognitive change by reappraising emotion related thoughts in line with intrinsic goals (Gross and Thompson, 2007; McRae et al., 2012).

4.3. *Mindfulness training and self-regulatory processes in pre-adolescents*

During mindfulness training, self-regulatory abilities are trained through practices with internal attention focus such as breath awareness or external object focus such as sound. In both types of practices attention is anchored with emphasis on the present moment experience (Dickenson et al., 2012; Hasenkamp et al., 2012) and with a non-judgemental attitude towards thoughts, feelings and behaviours (Shapiro et al., 2006; Zeidan et al., 2010). During mindfulness practice attention can drift away from the present moment towards task irrelevant thoughts resulting in mind wandering (Hasenkamp et al., 2012). The ability to detect when the focus of attention has diverted towards a distractor is a key skill which is trained during mindfulness practice (Malinowski, 2013).

Literature on mindfulness with adults suggests that the salience network plays a significant role in the recognition of these episodes of mind wandering. This network signals the need to return the focus of attention to the present moment using top-down executive attention networks such as the fronto-parietal network and nodes of the cingulo-opercular network (Hasenkamp et al., 2012; Malinowski, 2013). This helps to maintain goal oriented behaviour through recognising and inhibiting task irrelevant distractors (Dosenbach et al., 2008). Volitional endogenous orienting skills of the dorsal attention network are involved in the act of re-engaging with the object of mindfulness practice after recognising that the mind has wandered towards a task irrelevant distractor (Jha et al., 2007; Malinowski, 2013; van den Hurk et al., 2010). The TPJ of the ventral attention network is also active during focused mindfulness practice (e.g., breath focus) and enables the re-orientation of attention away from the distractor and back to the meditation object (Dickenson et al., 2012). With continuous mindfulness training, self-regulatory skills are refined and the ability to effortlessly sustain attention in the present moment whilst disengaging from distractions increases (Brefczynski-Lewis et al., 2007; Jha et al., 2007; Malinowski, 2013). Overall, based on these findings from adults, mindfulness training facilitates a state of moment-by-moment monitoring and cognitive flexibility by the adaptive regulation of attention and emotions based on current mental content and situational context, associated with effective self-regulation (Moore and Malinowski, 2009).

To date, no neurocognitive studies have examined the impact of mindfulness training on the brain networks that underlie self-regulatory abilities in pre-adolescents. However, some improvements have been seen in cognitive studies (Felver et al., 2014a; Napoli et al., 2005; Schonert-Reichl et al., 2015). Specifically, mindfulness studies with pre-adolescents have found improvements in orienting attention on the selective attention subscale of the test of everyday attention (Tea-Ch) for children aged between 6 and 9 years after a twelve session mindfulness program delivered over 24 weeks (Napoli et al., 2005). Furthermore, a marginal improvement in orienting attention performance for the Attention network test (ANT) (Fan et al., 2002; Rueda et al., 2004b) was found for 9–12 year olds after 8 weeks of mindfulness family stress reduction (MFSR), an adapted version of MBSR suitable for children and their parents (Felver et al., 2014a).

With regards to the impact of mindfulness training on complex top-down executive attention abilities with pre-adolescents, children aged between 9 and 12 years showed enhanced performance on the executive attention trials of the ANT (Felver et al., 2014a). In another study, mindfulness training was more effective at improving aspects of executive attention including inhibitory control and cognitive flexibility on the Flanker task and Hearts and Flowers task for pre-adolescents aged between 9 and 11 years compared with a social responsibility curriculum (Schonert-Reichl et al., 2015). Training these abilities during pre-adolescence is of great importance as adaptive executive attention skills are needed for school readiness and academic performance (Checa et al., 2008; Posner and Rothbart, 2014; Razza et al., 2010; Rueda et al., 2012; Steinmayr et al., 2010). Executive attention deficiencies are found in children with anxiety disorders (Mogg et al., 2015) and linked with academic difficulties (Blair and Diamond, 2008; Checa and Rueda, 2011).

During mindfulness training for pre-adolescents, emotional flexibility that allows emotions to be attended to or inhibited depending on the task requirements is improved with the use of executive attention skills and an attitude of acceptance and non-judgement to experiences (De Raedt et al., 2012; Schonert-Reichl et al., 2015). Improvements in executive attention may also enable emotions to be adaptively regulated earlier in the time course of emotion processing through promoting an earlier awareness of emotional thoughts (Quaglia et al., 2015; Teper et al., 2013). The inhibition of automatic maladaptive regulatory responses (De Raedt et al., 2012; Ortner et al., 2007; Quaglia et al., 2015; Wadlinger and Isaacowitz, 2010) increases the ability to experience emotions without the filter of avoidance or rumination (De Raedt et al., 2012; Wadlinger and Isaacowitz, 2010). While studies investigating these mechanisms with pre-adolescents are lacking, in adults an increased ability to rapidly inhibit emotional distractor stimuli has been linked with reduced emotional interference during a task following mindfulness training (De Raedt et al., 2012; Ortner et al., 2007) and in individuals with high dispositional mindfulness (Quaglia et al., 2015). It is to be seen whether similar effects will be observed in pre-adolescents.

Pre-adolescent mindfulness programmes guide attention towards noticing the transient nature of emotions (Flook et al., 2010; Mindfulness in Schools Project, 2015; Saltzman and Goldin, 2008). This metacognitive awareness of emotions as fluctuating states rather than inherent self-traits could positively impact on how experiences are cognitively appraised (Garland et al., 2011). Young pre-adolescents are not always able to regulate emotions using complex top-down regulatory strategies such as cognitive reappraisal due to maturational limitations within the PFC (Decicco et al., 2012; McRae et al., 2012; Qin et al., 2012). In adults, both mindfulness and cognitive reappraisal strategies recruit brain areas involved in attention and cognitive control including the dorsal medial, dorsal lateral and ventromedial PFC, to exert a “top-down” inhibition of the amygdala (Goldin et al., 2008; Modinos et al., 2010; Opialla et al., 2014). However, in contrast to cognitive reappraisal, mindfulness acts earlier in the emotion generation process (Gross and John, 2003; Quaglia et al., 2015; Teper et al., 2013 Quaglia et al., 2015; Teper et al., 2013). An earlier regulatory strategy can have a more efficient impact, as it requires less effort and resources (Sheppes and Gross, 2011). Indeed, mindfulness is associated with lower cognitive costs than cognitive reappraisal (Kaunhoven & Dorjee, unpublished results; Keng et al., 2013). This suggests that mindfulness training may enable more efficient modulation of emotions via top-down mechanisms in pre-adolescents since it might be less effortful than cognitive reappraisal, thus more readily implementable by this age group.

Mindfulness training can also modulate the intensity and duration of an emotional response to an environmental stressor in the absence of top-down regulatory engagement (Carthy et al., 2010; Chiesa et al., 2013), This is of particular importance for pre-adolescence due to the diminished top-down regulatory capacity observed in this developmental period. This involves modulation of “bottom-up” brain responses associated with sensory awareness including the ACC, insula and somatosensory cortex (Chiesa et al., 2013; Farb et al., 2012; Goldin and Gross, 2010). In adults, modulations of top-down regulatory processes have been found after short term mindfulness training, whereas bottom-up modulations of emotion processing generally occur after more extensive mindfulness practice (Chiesa et al., 2013). For example, a reduction in PFC activation has been found for experienced meditators during emotion processing compared to novice meditators (Taylor et al., 2012). This suggests that with mindfulness training, self-regulatory skills are refined and the ability to effortlessly sustain attention in the present moment whilst disengaging from distractions increases (Brefczynski-Lewis et al., 2007; Jha et al., 2007; Malinowski, 2013). It is not clear whether the recruitment of the bottom-up regulatory capacities in this type of emotion regulation needs to be preceded by a progression from an initial top-down pattern of regulation. This is particularly relevant to the pre-adolescent bias towards the recruitment of bottom-up regulatory strategies and raises the possibility that bottom up pathways may be preferentially engaged when pre-adolescents are trained in mindfulness.

Indeed, initial research suggests that for individuals with deficits in top-down control, it is possible that mindfulness may regulate emotions via bottom-up mechanisms linked with sensory awareness. For example, adults with social anxiety, a disorder associated with reduced cognitive and attention control abilities, showed modulations of emotion processing via bottom-up regulation after only 8 weeks of MBSR. Specifically, the findings reported increased activity in visual attention areas including the middle occipital gyrus, superior and inferior parietal lobules, cuneus and pre-cuneus areas, alongside a reduction in amygdala activity (Goldin and Gross, 2010). This could have important implications for pre-adolescents with immature cognitive control processes (Luna and Sweeney, 2004; Rothbart et al., 2011) as mindfulness training may support adaptive emotional responding without strong involvement of brain networks linked with top-down attention control.

Importantly, mindfulness training aims to foster metacognitive awareness of thoughts, feelings and behaviours with a kind and curious attitude (Shapiro et al., 2006; Zeidan et al., 2010). Enhancements in metacognitive awareness have previously been found after mindfulness training for pre-adolescents based on teacher reports (Vickery and Dorjee, 2015) and for children with the lowest baseline levels on parent and teacher reports (Flook et al., 2010). A lack of metacognitive awareness can be indicative of mind wandering (Smallwood et al., 2007), interestingly, a negative correlation between mind wandering and mindfulness was found in a study with adolescents aged between 12 and 18 years (Luo et al., 2016). Reductions in mind wandering were found to mediate the effects of mindfulness on task performance during a working memory task and a GRE reading comprehension task in adults with a high tendency to mind wander prior to mindfulness training (Mrazek et al., 2013). The development of metacognitive monitoring skills combined with attention control and a non-judgmental attitude towards thoughts through mindfulness training, may enable flexible disengagement or engagement in mind wandering based on the requirements of the academic context.

In the following section we will consider how ERPs can provide a measure of the potential impact of mindfulness training on attention control and emotion regulation with pre-adolescents.

5. ERP measures of mindfulness on attention and emotion processing

5.1. N2

The N2 ERP component indexes the executive attention processes of conflict monitoring and response inhibition (Buss et al., 2011; Dennis and Chen, 2007; Stieben et al., 2007). The N2 is a fronto-central negativity elicited approximately between 200 and 400 ms after stimulus onset which is associated with neural generators in the dorsal caudal ACC (Lewis et al., 2006a; van Veen and Carter, 2002b), a node of the cingulo-opercular network (Dosenbach et al., 2008; Fair et al., 2007). A more negative N2 is elicited after the successful inhibition of a pre-potent response (Bokura et al., 2001; Falkenstein et al., 1999) and in situations which require increased inhibitory control, such as performing an executive attention task under negative emotional demands (Dennis and Chen, 2007; Lewis et al., 2006a; Lewis and Stieben, 2004). The N2 component is measured during tasks targeting conflict monitoring and response inhibition including the Go/No-Go tasks, Stroop tasks and the executive attention trials of the ANT (Espinet et al., 2012; Jha et al., 2007; Lewis et al., 2006a; Lewis et al., 2007).

During childhood the N2 latency decreases and the amplitude becomes less negative, reflecting a developmental increase in neural efficiency within the executive attention networks (Chapman et al., 2010; Espinet et al., 2012; Lewis et al., 2006a; Lamm et al., 2006). The N2 topography also shifts during development from centromedial sites with likely neural generators in the PCC to frontal sites with proposed generators in the dorsal ACC (Lewis et al., 2006a), and this shift is linked with the enhancement of executive attention abilities in pre-adolescents (Lamm et al., 2006). For 3–5 year olds who showed an increased ability to solve conflicts and adapt to new rules during a dimensional change card sort task, less negative N2 amplitudes were elicited compared with children unable to effectively task switch (Espinet et al., 2012). In addition, enhanced performance on the Iowa gambling task and Stroop task predicted a less negative N2 amplitude for children aged 7–16 years with age effects controlled for (Lamm et al., 2006).

These developmental findings suggest that for pre-adolescents, who are undergoing a rapid maturation within the fronto-parietal and cingulo-opercular networks underlying executive attention (Fair et al., 2007; Kelly et al., 2009; Posner et al., 2014; Rothbart et al., 2011), a less positive N2 amplitude after mindfulness training would reflect increased cortical efficiency. Interestingly, the opposite pattern was found for older adolescents after mindfulness training, a more negative frontal N2 amplitudes for distractor and frequent stimuli in an oddball paradigm was associated with improvements in mental uncontrollability and cognitive confidence after mindfulness training (Sanger and Dorjee, 2016). Older adolescents have more advanced conflict monitoring and response inhibition skills compared with pre-adolescents (Chapman et al., 2010; Lewis et al., 2006a; Luna and Sweeney, 2004). Therefore, the more negative N2 observed may be more in line with findings from adults, where a more negative N2 indexes increased executive attention abilities (Falkenstein et al., 1999; Schmajuk et al., 2006). To deconstruct the developmental patterns of N2 modulation further future studies need to measure ERP amplitudes in conjunction with self-reports and behavioural performance.

The emotion regulation improvements which accompany the maturational changes in executive attention during pre-adolescents can also be measured using the N2 (Lewis et al., 2007; Lewis et al., 2008). The patterns of N2 modulation can be impacted by individual differences and task performance (Dennis, 2010). Two studies examined N2 modulations for non-clinical samples of children during emotion inducing and non-emotion inducing blocks of a Go/No-Go task (Chapman et al., 2010; Lewis et al., 2006a). During non-emotion inducing trials the N2 amplitude for No-Go trials became less negative with development (suggesting increased cortical efficiency) (Chapman et al., 2010; Lewis et al., 2006a). Different patterns of N2 modulations were found across the two studies for the negative emotion-inducing blocks. Specifically, Chapman et al. (2010) found that for 8–17 year olds a less negative N2 for No-Go trials and greater accuracy rates across Go and No-Go trials was linked with more adaptive physiological emotion regulation abilities (measured by reactive respiratory sinus arrhythmia; RSA). This suggests that a less negative N2 indexes more efficient emotion regulation abilities. In comparison, Lewis et al. (2006a) found that the N2 amplitudes for 7–16 year olds did not follow a linear developmental trajectory. Adolescents showed a more negative N2 for No-Go trials and this was associated with more frontal generators in the right orbitofrontal cortex, temporal pole and PCC. Younger pre-adolescents showed no emotion induced N2 modulations and this was linked with generators in the PCC. Adolescents in this study also showed higher performance abilities, suggesting that those with the capacity to enhance executive attention resources during emotionally demanding situations (more negative N2) had more adaptive emotion regulation abilities (enhanced behavioural performance).

N2 modulations during the negative emotion inducing Go/No-Go task has also been used to index emotion regulatory difficulties in pre-adolescents aged between 8 and 12 years. Stieben et al. (2007) found that healthy controls showed a similar N2 amplitude for No-Go trials across emotion inducing and non-emotion inducing blocks of the Go/No-Go task. Children with self-regulatory difficulties (comorbid externalising and internalising disorders) showed a similar N2 amplitude to healthy controls for non-emotion inducing blocks. The N2 amplitude did, however, became more negative during negative emotion induction. This was attributed to an increased need to recruit executive attention abilities in children with self-regulatory difficulties who may have found the task more demanding. Similarly, Lewis et al. (2006b) found that for children aged between 8 and 12 years with self-regulatory problems, an enhanced and more frontal N2 during an emotion inducing task was linked with greater behavioural flexibility. This reflected an increased ability to formulate complex regulatory strategies through recruitment of brain areas underlying executive attention such as the ACC (Lewis et al., 2006b). These studies suggest that for children with self-regulatory difficulties, more cognitive resources are required in order to effectively regulate emotions and this is reflected in an enhanced N2 amplitude.

The outlined discrepancies in developmental patterns suggest that any predictions regarding how mindfulness training could modulate the N2 for pre-adolescents need to take into account task demand, the emotional or non-emotional nature of the stimuli and the pre-existing self-regulatory abilities of children. A decreased N2 in healthy children in emotionally neutral tasks could be predicted, but more a negative N2 would be expected in emotionally demanding tasks, reflecting an increased ability to recruit executive attention resources. This pattern should be coupled with improvements in behavioural performance and self-reported or physiological measures of emotion regulation. Indeed, higher levels of dispositional mindfulness were found to predict higher N2 amplitudes alongside fasters reaction times (without a decrement in accuracy) during an emotional Go/No-Go task in adults (Quaglia et al., 2015). In children with self-regulatory difficulties, mindfulness training could enhance executive control and emotion regulation, resulting in a pattern of less negative N2 amplitudes which would be more aligned with the performance of healthy children. Such reductions in N2 should be associated with decreases in anxiety and other clinical symptoms as well as improved behavioural performance.

5.2. Error related negativity (ERN) and error positivity (Pe)

Another ERP marker associated with executive attention is the ERN, a fronto-central negativity elicited 50 ms after an error response (Hajcak, 2012). The ERN is thought to reflect the monitoring for, and, detection of errors (van Veen and Carter, 2002a,b; Yeung et al., 2004). A more negative ERN is elicited when the consequence of committing an error is meaningful (Hajcak, 2012; Teper and Inzlicht, 2013). Debate remains regarding whether the N2 and ERN share the same dorsal caudal ACC neural source (Ladouceur et al., 2006; Lewis and Stieben, 2004; van Veen and Carter, 2002a) or whether the ERN reflects ventral rostral ACC activity (Mathalon et al., 2003). This is of functional significance since the dorsal caudal ACC is linked with attention control (Bush et al., 2000; Yeung et al., 2004) whilst the ventral rostral ACC is linked with emotional appraisal of errors (Mathalon et al., 2003). Another ERP component which is linked with error processing is the error positivity (Pe), a parietal positivity elicited approximately between 200 and 400 ms after an error response (ERN) (Olvet and Hajcak, 2012). The Pe indexes the conscious detection of, and emotional reactivity to an error; the amplitude is more positive when the emotional salience of an error is high (Endrass et al., 2007; Santesso et al., 2006). The Pe is linked with neural sources in the rostral ACC and parietal cortex (Herrmann et al., 2004; van Veen and Carter, 2000a).

The Pe component is observed early in childhood and does not significantly vary over the course of development (Davies et al., 2004; Meyer et al., 2012), the ERN, however, does undergo maturational changes. During middle childhood the ERN becomes more negative, reflecting an increase in error processing efficiency resulting from maturation within the ACC (Meyer et al., 2012; Segalowitz and Davies, 2004; Segalowitz and Dywan, 2009; Wiersema et al., 2007). However, this developmental trend is affected by individual differences, task complexity and motivation (Davies et al., 2004; Kim et al., 2007). Abnormal ERNs can index the presence or risk of self-regulatory disorders which arise from impairments in executive attention (Meyer et al., 2012; Olvet and Hajcak, 2008; Torpey et al., 2013). A less negative ERN was associated with more externalising ADHD behaviours and academic performance deficits for children raised in foster care (McDermott et al., 2013). Interestingly, these deficits were not exhibited for foster care children who elicited a more negative ERN, suggesting that the development of attention control during childhood may have a protective effect for children raised in adverse environments (McDermott et al., 2013). Whilst a more negative ERN can be adaptive, it is also found in individuals with anxiety (Moser et al., 2013; Olvet and Hajcak, 2008). This is possibly due to an increased sensitivity to errors alongside a reduced ability to effectively respond to this performance feedback due to ineffective interactions between the cingulo-opercular and fronto-parietal network (Sylvester et al., 2012; Voss et al., 2011). Only converging evidence from assessments of anxiety and ERN can discern maladaptive from adaptive ERN responses of similar patterns.

A link between error processing abilities indexed by the ERN and empathy (prosocial behaviour which involves the ability to understand and respond to others emotional experiences) has also been previously found (Larson et al., 2010; Thoma and Bellebaum, 2012). For adults higher self-reported trait empathy was linked with a more negative ERN during a Stroop task (Larson et al., 2010) and Flanker task (Santesso and Segalowitz, 2009). Mindfulness programmes for pre-adolescents include practices aimed at increasing kindness and compassion to the self and others (Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015) and self-reported improvement in empathy has been reported for pre-adolescents after mindfulness training (Schonert-Reichl et al., 2015). Correlational analysis between the ERN and self-reports of empathy could provide a marker of the impact of mindfulness training on empathy and error processing with pre-adolescents.

The ERN is thought to reflect a disposition which is not consistently modulated by state changes (Moser et al., 2005; Riesel et al., 2013), the Pe is however, sensitive to changes in emotional states (Moser et al., 2005). The impact of mindfulness training on the different stages of error processing indexed by the ERN and Pe may therefore change depending on the duration of mindfulness training (shorter versus longer term mindfulness training). For experienced meditators, an enhancement in the detection of errors (more negative ERN), was not accompanied by an increase in emotional reaction to errors (no change in Pe amplitude) during a Stroop task (Teper and Inzlicht, 2013). Also emotional acceptance in conjunction with ERN amplitude was found to be the mediating link between mindfulness experience and Stroop test performance (Teper and Inzlicht, 2013). An accepting attitude may enable pleasant, neutral and negative experiences to be attended to without engaging in rumination (Inzlicht et al., 2014); this in turn can increase the attention resources available to actively monitor for errors whilst disengaging from the emotional reaction associated with the error (Teper and Inzlicht, 2013). In contrast, after a brief induction of mindful breathing an attenuation of the Pe was found but no ERN modulation was observed during a modified Flanker (Larson et al., 2013). This suggests that whilst modulations in emotional appraisal of errors (indexed by the Pe) could occur after brief inductions of mindfulness, trait changes in error processing (indexed by the ERN) occur after extensive mindfulness training.

Whilst the duration of mindfulness training is an important factor to consider, the type of mindfulness meditation (thought focused versus emotion focused) is also important when considering the role of mindfulness training on error processing. Saunders et al. (2016) compared the impact of brief inductions of thought focused and emotion focused mindfulness practices on ERN and Pe modulations. An enhanced ERN followed by no Pe modulation was found after the emotion focused practices, in contrast, no ERN or Pe modulations were observed after the thought focused practice during a Go/No-Go task. This suggests that having a mindful acceptance of emotions can modulate early stages of error processing, even after brief inductions of mindfulness. Whilst similar ERN/Pe modulations were found for experienced meditators (Teper and Inzlicht, 2013) and participants who received the brief mindfulness induction (Saunders et al., 2016), improvements in behavioural performance were only observed for experienced meditators (Teper and Inzlicht, 2013). This indicates that longer duration practices are required to improve error processing performance. For pre-adolescents introspective practices which involve bringing attention to emotional experiences are often introduced gradually during mindfulness training (Flook et al., 2010; Mindfulness in Schools Project, 2015) and therefore it would be expected that ERN modulations for pre-adolescents would be observed after longer durations of mindfulness training.

The ERN and Pe may be useful in the assessment of clinically relevant shifts in emotional responses which directly impact on attention efficacy. For instance, for children with ADHD who error frequently the ERN is less negative and the Pe is attenuated in comparison to heathy controls (Senderecka et al., 2012). A deficiency in the ability to emotionally appraise errors may underlie their limited error sensitivity and resulting high error rates (Wiersema et al., 2007). Mindfulness training was found to modulate the Pe in adults with ADHD; an enhancement in the Pe amplitude after mindfulness training correlated with a decrease in hyperactivity and impulsivity and an increase in acting with awareness (Schoenberg et al., 2014). Mindfulness training may therefore encourage adaptive emotional appraisal of errors for pre-adolescents who have attention deficits and this would be associated with a more positive Pe. No ERN modulations were found after mindfulness training, medication status was proposed to be a confound and further research is needed to assess the ERN's sensitivity to changes in error processing for clinical samples after mindfulness training.

With regards to mindfulness research with pre-adolescents, the ERN could be a potentially useful marker of changes in executive attention abilities and their impact on academic performance since the ERN has been linked to these in previous non-intervention research (McDermott et al., 2013). The research with pre-adolescents could assess possible links between an enhancement in ERN and improvements in empathy and acceptance resulting from sustained mindfulness training. Assessing whether the duration of mindfulness training or the type of mindfulness training employed changes the interplay of ERN and Pe modulations for pre-adolescents could hence also provide new insights into the interactions between neurocognitive shifts specific to emotional appraisal (Pe) and attention control (ERN).

5.3. *P3a*

The P3a ERP component can provide a measure of the later stages of exogenous attention (Bledowski et al., 2004; Carretié, 2014; Linden, 2005), particularly the reorienting of attention to salient stimuli (Bledowski et al., 2004; Volpe et al., 2007; Wetzel and Schröger, 2007). The P3a is a frontal medial positivity which is usually elicited between 300 and 400 ms after stimulus presentation (Bush et al., 2000) for infrequent distractor stimuli during an oddball paradigm (Polich, 2007). A more positive P3a amplitude is found for salient stimuli which are novel or of an emotional nature (Delplanque et al., 2005; Thierry and Roberts, 2007) reflecting increased automatic allocation of attention resources to these stimuli (Polich, 2007). Activations in both the ventral attention network (linked with salience detection) and dorsal attention network (linked with reorienting of attention resources) have been found for oddball distractors (Bledowski et al., 2004; Kim, 2014). Specific neural generators associated with the P3a include the medial and superior frontal gyrus, the right parietal lobe (Volpe et al., 2007) and the ACC (Liotti et al., 2005; Volpe et al., 2007).

Developmental changes in P3a amplitude have been found; an anterior shift in topography from central to frontal sites (Gumenyuk et al., 2001; Lewis et al., 2006a) and an attenuation of the P3a amplitude (Stige et al., 2007) occurs with development, reflecting a reduction in the automatic orientation of attention towards distracting stimuli. Pre-adolescents aged between 7 and 10 years who elicited a more positive P3a to novel distractor sounds preceding a visual target exhibited greater distractibility in the form of longer reaction times to the proceeding target (Gumenyuk et al., 2001). In comparison with pre-adolescents, adults were better able to reduce automatic orientation of attention towards auditory sounds when instructed to change from attending to ignoring the auditory sounds, resulting in an attenuation of the P3a (Wetzel et al., 2006).

Modulations of the P3a amplitude for distractor stimuli in an oddball task is a marker of the vulnerability to, or presence of, psychopathological disorders in adults. A more positive P3a to distractor stimuli was found for adults with anxiety (Bruder et al., 2002) and a less positive P3a to novel distractors was found for adults with depression (Bruder et al., 2009). However, research has not established whether the P3a can index psychopathological disorders in pre-adolescents, with some suggesting no relationship between trait anxiety and the P3a (Hogan et al., 2007).

In relation to mindfulness research, to date, the P3a has only been used to study state meditation effects in experienced meditators. Specifically, when experienced Vipassana practitioners were asked to meditate (instructed to adopt a non-reactive detached observation towards the environment) during a passive oddball task with frequent and infrequent distractor tones, an attenuated P3a was elicited in response to distractor stimuli in comparison to a mind-wandering state (instructed to freely think of non-emotional thoughts; Cahn and Polich, 2009). This suggests that the non-reactive attitude adopted during the meditative state may facilitate the reduction in attention resources automatically oriented towards distractor stimuli (attenuated P3a) in comparison to a state of mind-wandering. Regarding pre-adolescents, it would be a methodological challenge to use the P3a as an index of state effects during a meditative state given that meditation practices for pre-adolescents are short in duration (Thompson and Gauntlett-Gilbert, 2008). Mindfulness training programmes for pre-adolescents aim to reduce distractibility by training attention to stabilise in the present moment through breath or object focused mindfulness practices (Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015). The P3a could potentially provide a developmental marker of trait changes in exogenous orienting to distracting stimuli after mindfulness training during tasks which do not require a meditative state. For example, during an active oddball task, which requires participants to respond to targets whilst inhibiting responses to distractors, an attenuation of the P3a for distractor oddballs after mindfulness training would index a reduction in exogenous attention. The elicitation of a less positive P3a for emotional distractors after mindfulness training could reflect reduced emotional reactivity towards salient non-targets.

5.4. P3b

The P3b, a positive peak with a parietal distribution elicited between 300 and 500 ms after stimulus onset (Hajcak et al., 2010; Polich, 2007), can provide a measure of top-down attentional control abilities including the endogenous allocation of attention resources towards task relevant stimuli (Chennu et al., 2013; Linden, 2005; Moser et al., 2005), attention resource availability (Hajcak et al., 2010; Moser et al., 2005; Polich, 2007; Delplanque et al., 2005; Hillman et al., 2005; St-Louis-Deschênes et al., 2015; Willner et al., 2015) and context updating (Geng and Vossel, 2013; Polich, 2007). The P3b is often elicited in an oddball paradigm for infrequent target stimuli requiring a response (Kok, 1997; Polich, 2007). A more positive P3b to task relevant stimuli has been linked with a greater availability of attention resources to allocate during a task (Hillman et al., 2005; Willner et al., 2015). The allocation of attention towards task relevant stimuli can be depleted by the presentation of distracting task irrelevant stimuli and this results in an attenuation of the P3b (Hajcak et al., 2010; Moser et al., 2005). For example, a less positive P3b has been linked with greater mind wandering during a sustained attention to response task (Smallwood et al., 2008), an oddball task (Barron et al., 2011), and a time estimation task (Kam et al., 2012). This reflects a reduction in the attention resources available for task relevant processing due to the reorienting of attention resources towards task irrelevant thoughts.

A recent meta-analysis found that whilst the dorsal attention network was active throughout an oddball task, for all stimuli, the ventral attention network was strongly linked with target oddball detection (Kim, 2014). The P3b is often associated with neural generators in the right TPJ (Linden, 2005), a node of the ventral attention network which is more active for task relevant stimuli (Bledowski et al., 2004) and has a role in post perceptual context updating (DiQuattro et al., 2014; Geng and Vossel, 2013).

During child development the P3b latency decreases (Hillman et al., 2005; Ridderinkhof and van der Stelt, 2000; van Dinteren et al., 2014) in conjunction with faster reaction times and increased accuracy rates for targets, reflecting more efficient stimulus evaluation (Hillman et al., 2005; Ridderinkhof and van der Stelt, 2000). No consistent age-related developmental changes in P3b amplitude have however been reported; studies argue for amplitude modulation in either direction or no modulation at all (Hillman et al., 2005; Segalowitz and Davies, 2004; Willner et al., 2015).

The P3b amplitude has not been used as a marker of the impact of mindfulness on attention resource efficiency in pre-adolescents so far. In adults, this component was sensitive to varying levels of mindfulness training in adults, however, inconsistent trends have been found. A less positive P3b has been reported as an index of increased attention efficiency (Moore et al., 2012) and reduced attention engagement (Jo et al., 2016). There are possible explanations for the differential modulations of the P3b amplitude in these two studies including differences in the intensity of mindfulness training and differences in task design. Due to the cross sectional design of the Jo et al. (2016) study, baseline group differences other than meditation training cannot be ruled out as having an impact. One potential explanation for the differences in P3b modulation is that as the P3b amplitude is sensitive to task difficulty (Polich, 2007), mindfulness training may increase attention flexibility and adjust attention resource allocation depending on the task demands. Specifically, Moore et al. (2012) found a reduced P3b for incongruent stimuli on a Stroop test after 16 weeks of brief mindfulness practice, this could index an increase in attention efficiency given that no deficit in behavioural performance accompanied the P3b attenuation. In contrast, Jo et al. (2016) found no difference in P3b responses between incongruent and congruent stimuli of the ANT task in experienced meditators, whereas non-meditators showed less positive P3b amplitudes to incongruent trials in comparison to congruent trials in the same task. This pattern of findings was associated with higher accuracy rates for incongruent stimuli in meditators. Therefore, overall, when a task is difficult and requires enhanced attention control the elicitation of a more positive P3b is adaptive and linked with increased behavioural performance. In tasks of a lower difficulty a decreased P3b together with no decrement in attention performance could reflect increased task efficiency. Indeed, in an attention blink paradigm Slagter et al. (2007) found decreased P3b to the first target (less attention demand) coupled with increased P3b and greater accuracy to the second (higher attention demand) in practitioners after 3 months of intensive focused attention Vipassana training. The P3b modulations found after 16 weeks of brief mindful breathing practices (Moore et al., 2012) are encouraging for research with pre-adolescents. The mindfulness practices included in training courses for pre-adolescents are often brief in duration (several min) and mindful breathing is included as a core practice (Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015).

When considering the impact of mindfulness training on the P3b in pre-adolescents, developmental differences in attention control skills need to be taken into account. For instance, a study comparing the impact of fitness levels on attention control in adults and pre-adolescents found that for pre-adolescents' better task performance was accompanied by an enhanced P3b (suggesting greater need to recruit task relevant attention resources), whilst for adults better task performance did not elicit a more positive P3b (suggesting greater attention resource efficiency) (Hillman et al., 2005). It would be expected that in pre-adolescents, whose attention controls skills are still undergoing some development (Farrant and Uddin, 2015; Rueda et al., 2004b), the elicitation of a more positive P3b to targets during a demanding oddball task after mindfulness training would reflect an increased ability to focus on task relevant stimuli. This would be expected to be accompanied by faster P3b latencies, enhanced accuracy rates and faster reaction times. This prediction would support previous intervention findings for 5–7 year olds from socioeconomically disadvantaged backgrounds who were enrolled on a PATHS to success programme (Willner et al., 2015). During this study a more positive P3b to correct targets in a Go/No-Go task was linked with less false alarms and longer reaction times to targets (this contradictory finding of longer reaction times might be due to more demand on impulse control in this particular group). The enhanced P3b was also associated with greater teacher and experimenter rated learning engagement which in turn predicted greater academic performance a year later. In addition to these trait changes in attention control, a more positive P3b for correct targets in a visual oddball task was found for pre-adolescents aged 8–12 years after 30 min of exercise compared with rest (St-Louis-Deschênes et al., 2015), suggesting the P3b is sensitive to both state and trait changes in attention control. These previous findings suggest that a similar modulation, i.e., enhanced P3b, would be expected during a demanding task in pre-adolescents after mindfulness training.

The P3b has not been used to index the impact of mindfulness training on mind wandering in pre-adolescents, however, for adult Vipassana meditators a more positive P3b to target stimuli was found during a state of meditation compared with episodes of mind wandering during an auditory oddball paradigm (Delgado-Pastor et al., 2013). This suggests that meditation can improve the ability to sustain attention in the present moment and reduce episodes of mind wandering (Delgado-Pastor et al., 2013). In addition, adults with ADHD, a disorder characterised by deficiencies in attention control, showed an increased parietal positivity for target trials together with increased target accuracy in a continuous performance task after mindfulness training. This increase in amplitude was correlated with an increase in mindfulness scores (Schoenberg et al., 2014). Hence, in future studies the P3b could provide a marker of the impact of mindfulness training on mind wandering for pre-adolescents with clinical levels of regulatory difficulties in attention control. Incidences of mind wandering are higher during tasks which are low in cognitive demands (Mason et al., 2007) and therefore continuous performance tasks which require long periods of repetitive low demanding responses or oddball tasks which involve long periods of non-responses are likely to induce episodes of mind wandering (Cahn and Polich, 2009; Smallwood et al., 2008). For pre-adolescents it could be expected that mindfulness training would result in higher P3b coupled with higher target accuracy in tasks such as the SART, reflecting less mind wandering and better sustained attention.

The P3b could also provide a possible index of how mindfulness impacts on a child's deployment of attention towards affective stimuli. For non-clinical samples of children, the P3b amplitude is similar for happy, angry and sad faces (Kujawa et al., 2013b; Pollak et al., 1997; Shackman et al., 2007). This is because they don't have an attention bias towards threat related stimuli (Bar-Haim et al., 2007; Waters et al., 2008). In comparison, for children with a history of maternal maltreatment an attenuated P3b to happy target stimuli (Pollak et al., 1997) and an enhanced P3b for angry targets (Shackman et al., 2007) during oddball tasks was found. This enhanced P3b for angry targets mediated the relationship between experiences of abuse and anxiety (Shackman et al., 2007) suggesting that the P3b amplitude can index unhealthy engagement with emotional stimuli (Pollak et al., 1997; Shackman et al., 2007). For adults after a brief mindfulness induction of mindful breathing a greater attenuation of the P3b to angry images relative to neutral images during a passive picture paradigm was linked with higher levels of state decentering (ability to observe emotional states and choose how to respond to them) (Eddy et al., 2015). Hence, increasing attention control through mindfulness training could enhance the ability to adaptively regulate deployment of attention towards negative stimuli (and attenuate the P3b for such target stimuli) during pre-adolescence. We could expect these P3b modulations after mindfulness training to be associated with reductions in anxiety symptomatology, especially for children exposed to adverse social stressors.

5.5. Late positive potential (LPP)

The LPP, a broad sustained central parietal positivity elicited between 300 and 2000 ms after stimulus onset can provide a developmentally sensitive marker of bottom-up non-volitional emotional reactivity (Decicco et al., 2012; Hajcak et al., 2010; Solomon et al., 2012) and top-down volitional emotion regulation in pre-adolescents (DeCicco et al., 2014; Decicco et al., 2012; Dennis and Hajcak, 2009). Tasks such as passive picture paradigms, where participants passively attend to the emotional features of affective images without actively regulating their response, have been associated with bottom up emotional reactivity (Carthy et al., 2010; Domes et al., 2010; Hajcak and Dennis, 2009; Ochsner et al., 2009; Solomon et al., 2012). In these tasks, a more positive LPP is found for emotionally arousing positive and negatively valenced stimuli (Hajcak and Dennis, 2009; Hajcak et al., 2006; Schupp et al., 2004; Solomon et al., 2012). In comparison, tasks which involve explicit instructions to implement emotion regulation strategies when viewing emotional stimuli are linked with top-down volitional regulation. Greater activation of the PFC has been found during the implementation of top-down regulatory strategies in comparison to passive viewing tasks (Domes et al., 2010; Ochsner et al., 2009). Successful regulation of the emotional response to negative stimuli is associated with an attenuation of the LPP amplitude for pre-adolescents (Dennis and Hajcak, 2009; Hua et al., 2015).

Developmentally sensitive modulations of the LPP have also been found during active tasks assessing emotional reactivity including the emotional interrupt task. This task involves participants responding to a non-emotional target stimulus preceded and followed by a non-target emotional stimulus (Kujawa et al., 2012b). For pre-adolescents aged between 8 and 13 years, an enhanced LPP for positive pre-target distractors was linked with slower reaction times to targets (Kujawa et al., 2013a) and lower target accuracy (Kujawa et al., 2012b). Similarly, an enhanced LPP for negative pre-target distractors was associated with reduced accuracy (Kujawa et al., 2013a). This suggests that enhanced emotional reactivity towards the pre-target distractor (indexed by a heightened LPP) can interfere with the attention resources available for subsequent target processing resulting in a decrement in task performance.

The LPP amplitude can reflect individual differences in emotional reactivity, for instance a reduced differentiation between the LPP elicited for emotional and neutral faces during a passive faces paradigm was found for 6-year-old children with a maternal history of depression (Kujawa et al., 2012a), this is consistent with findings that depression is associated with reduced processing of emotional stimuli (Bylsma et al., 2008). In addition, children aged 5–7 years who were rated as exhibiting higher fearful behaviour, had prolonged emotional reactivity to negative stimuli (more positive LPP for negative versus neutral stimuli during the later LPP time window 1200–2000 ms) (Solomon et al., 2012). Mixed results have been found with regards to anxiety, Solomon et al. (2012) found the LPP was not associated with maternal reports of fear and anxiety. In contrast Kujawa et al. (2015) found that children with a current diagnosis of social anxiety elicited a heightened LPP between 1000 and 2000 ms to angry and fearful faces in an emotional face matching task.

Developmental changes in top-down volitional regulation have also been found for pre-adolescents asked to regulate their responses to negative pictures using cognitive reappraisal during an affective picture paradigm. Greater attenuation of the LPP to negative stimuli was linked with lower maternal reports of anxiety and depression in children aged 5–10 years (Dennis and Hajcak, 2009) and lower self-reported anxiety in children aged 7–9 years (DeCicco et al., 2014). This suggests the LPP is a stable index of emotion regulation in older pre-adolescence and the ability to effectively implement complex volitional strategies such as cognitive reappraisal increases between 7 and 9 years (DeCicco et al., 2014). The LPP is not always modulated by cognitive reappraisal for younger children aged between 5 and 7 years (Decicco et al., 2012; Dennis and Hajcak, 2009). This possibly reflects an inability to consistently employ complex regulatory strategies in younger pre-adolescents as a result of immature development of the PFC (McRae et al., 2012; Qin et al., 2012). Hua et al. (2015) found that the LPP was sensitive to cognitive reappraisal in children aged 4–5 years of age when the regulation instructions were simplified and made age appropriate. This highlights that children can effectively employ top-down regulatory strategies when the cognitive costs associated with these strategies is reduced.

During childhood a shift in the LPP topography from occipital to parietal sites may reflect a maturational change in the response to emotional stimuli. Increasing connectivity between top-down frontal brain regions and bottom-up parietal brain regions during development may reduce the reliance on bottom-up occipital areas (Kujawa et al., 2012b; Kujawa et al., 2013a,b). Correspondingly, for children aged 8–14 years, occipital cortex activity decreased during development. In addition, increased occipital activity and reduced dorsal PFC activity was linked with higher self-reported trait anxiety and a reduced ability to adaptive regulate emotional responses (Wessing et al., 2015).

Modulations in the LPP have been found to index changes in emotion processing resulting from psychosocial interventions in adults (Gootjes et al., 2011) and in adolescents (Pincham et al., 2016). The LPP has not been used to document changes in emotional reactivity after mindfulness training for pre-adolescents, however, findings from mindfulness studies with adult suggest the LPP could be a suitable marker. Less positive LPP amplitudes for negative stimuli were found during a passive picture paradigm after a brief induction of open monitoring mindfulness practice (bringing mindful awareness to all experiences in the present moment) (Uusberg et al., 2016). This was also found for Buddhist meditators with extensive meditation experience (Sobolewski et al., 2011). In addition, individuals with high dispositional levels of mindfulness (acting with awareness subscale of five facet of mindfulness questionnaire) also elicited a less positive LPP (Brown et al., 2013; Lin et al., 2016). Whilst mindfulness practices for pre-adolescents are often brief in duration, the LPP modulations observed after short inductions of mindfulness suggest the LPP may be sensitive to mindfulness related changes with pre-adolescents. It should be noted that no LPP modulations were observed after a brief induction of mindful breathing (Eddy et al., 2015), perhaps training in mindful emotional awareness is needed to modulate LPP indexes of emotional reactivity.

Mindfulness based programmes for pre-adolescence often have practices which involve mindfully attending to emotional experiences in a kind and accepting way (Flook et al., 2010; Mindfulness in Schools Project, 2015; Schonert-Reichl et al., 2015). For pre-adolescents, attenuations of the LPP amplitude to emotional stimuli during a passive picture paradigm could be expected after mindfulness training, reflecting a reduction in emotional reactivity. Along with using the amplitude of the LPP as a measure of emotion processing, the rise time to peak measurement and recovery time (Hajcak et al., 2010) can also provide a measure of how mindfulness impacts upon the trajectory of an emotional response.

Much of the LPP research with pre-adolescents has focused on the impact of cognitive reappraisal as a volitional emotion regulation strategy, this strategy aims to induce changes in thoughts through reappraising the interpretation of experiences (Decicco et al., 2012; Dennis and Hajcak, 2009). LPP modulations were also found for pre-adolescents aged 8–13 year olds with spider phobias after attending a 4-h Cognitive behavioural therapy (CBT) session (Leutgeb et al., 2010). CBT involves changing the thoughts and behaviours associated with a situation (Arch and Craske, 2008). Prior to CBT training the LPP elicited for spider pictures in a passive picture paradigm was attenuated compared to neutral pictures, reflecting increased avoidance of spider imagery. After a 4 h CBT session a week later the LPP for spider pictures increased in comparison to a spider phobic control group suggesting increased exposure to the fear inducing stimuli.

Mindfulness training has been proposed to facilitate the reinterpretations of experiences through enabling the disengagement from initial emotional appraisals (Garland et al., 2011; Garland et al., 2009). In adults, improvements in trait mindfulness were associated with improvements in cognitive reappraisal after 8 weeks of mindfulness training (Garland et al., 2011). There are also similarities in the brain regions recruited by these strategies (Opialla et al., 2014). However, the distinct difference is that rather than changing thoughts and feelings associated with an emotional experience, mindfulness modulates the relationship to them by cultivating a non-judgemental and accepting perspective (Chambers et al., 2009; Farb et al., 2012). A comparison between cognitive reappraisal and mindfulness in adults found that the cognitive costs for a Stroop task were lower after regulating emotions using mindfulness compared to cognitive reappraisal (Keng et al., 2013). Similarly, Kaunhoven and Dorjee (unpublished results) found less positive LPP amplitudes when adults were implementing a mindful (non-judgemental and non-evaluative) approach to the emotional experience (in comparison to cognitive reappraisal) to regulate their emotional responses to negative and neutral pictures. The lower cognitive costs associated with mindfulness may possibly make this a regulatory strategy which pre-adolescents can implement more easily than cognitive reappraisal. Overall, these findings suggest that the LPP modulations resulting from mindfulness training are likely non-specific to cognitive conditioning. Further research should consider a direct comparison between CBT and mindfulness to further the understanding of how these interventions impact emotion processing abilities as indexed by the LPP.

With regards to the ability to volitionally implement mindfulness as a regulatory strategy, Lin et al. (2016) found in adults that a brief induction of mindfulness did not modulate the ability to implement mindfulness as a regulatory strategy. Longer periods of mindfulness training may therefore be required for such abilities to arise. An improvement in volitional mindful emotion regulation for pre-adolescents could be indexed by less positive LPP for negative stimuli during active emotion regulation tasks. These LPP modulations should be found in conjunction with self-reported reductions in state anxiety, depression and negative affect.

6. Conclusions

Initial evidence suggests that mindfulness training can beneficially impact on a range of self-regulatory abilities in pre-adolescents (Flook et al., 2010; Schonert-Reichl et al., 2015; Tang et al., 2012). However, our understanding of the underlying neurodevelopmental modulations is virtually absent. To stimulate further systematic, theory-driven investigations, this review proposed an integrative neurodevelopmental framework for examining mindfulness-related changes in pre-adolescence. This framework integrates self-report and other-report assessments with evaluations of neurocognitive markers of self-regulation elicited in established cognitive paradigms. We specifically considered how mindfulness could improve self-regulation in pre-adolescents through modulating both top-down volitional self-regulatory processes including endogenous orienting of attention and executive attention and bottom-up automatic self-regulatory processes of stimulus driven orienting of attention, salience detection and mind wandering.

We hope that the clear predictions regarding modulations in ERP markers, self-report, and behavioural measures of self-regulation will help guide further research on mindfulness with pre-adolescents. The potential for mindfulness training to modulate both top-down and bottom-up self-regulatory processes highlights that mindfulness could be an adaptive and flexible self-regulation strategy. This has important implications for groups with reduced self-regulation capacity due to maturation (e.g., pre-adolescents) or pathology. Overall, we suggest that neurocognitive research on mindfulness can not only enrich our limited understanding of the neurodevelopmental changes associated with mindfulness, but also help tailor mindfulness training to developmental trajectories and needs. This in turn, has strong implications for implementation efforts targeting enhancements in self-regulation and educational attainment in children.

Conflict of interest

The authors do not have any conflict of interest to declare, this includes any financial or personal relationships or any other relationships with other people or organisations within a three-year period of beginning the submitted work which could inappropriately influence or be perceived to influence this work.

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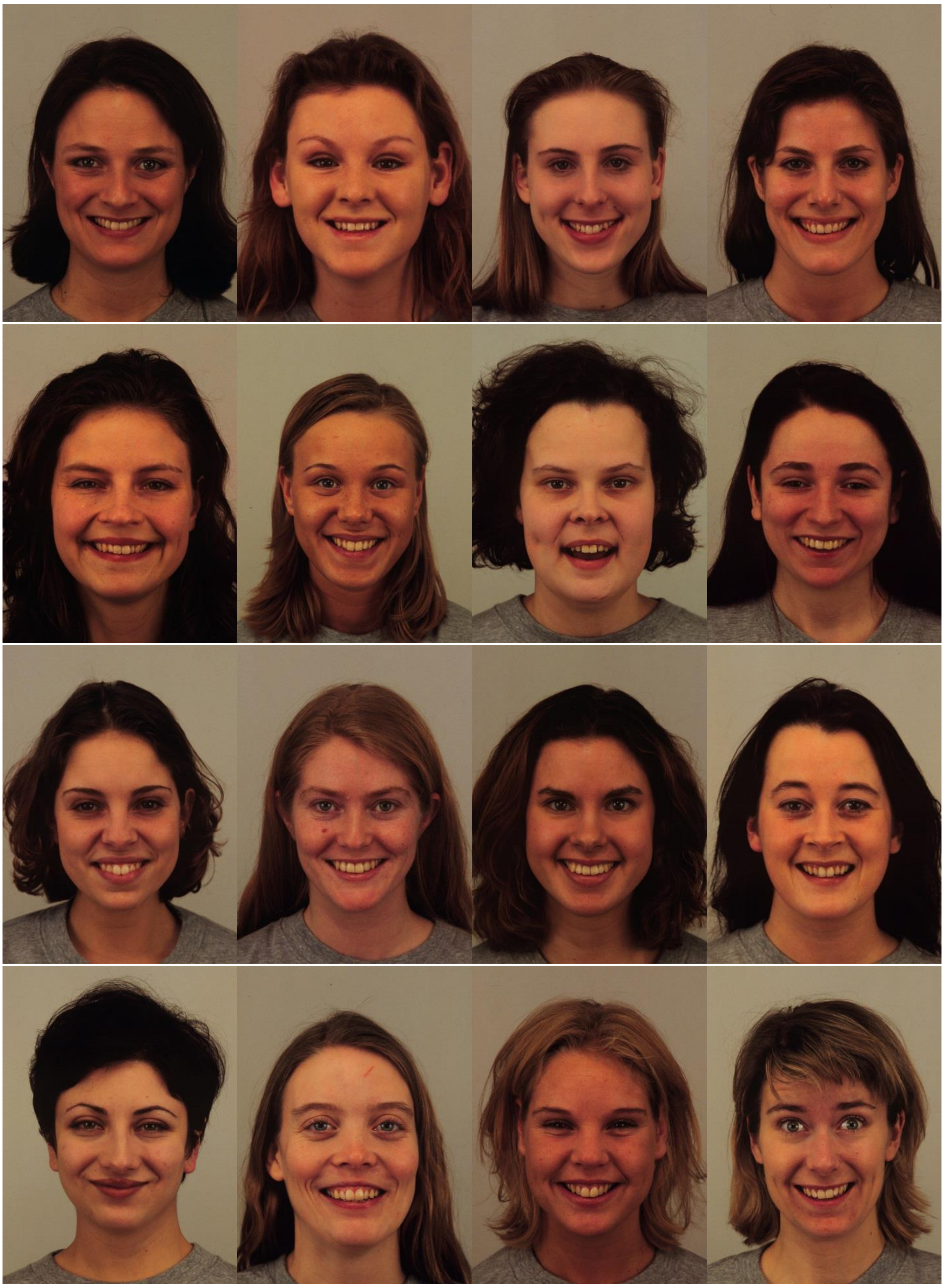

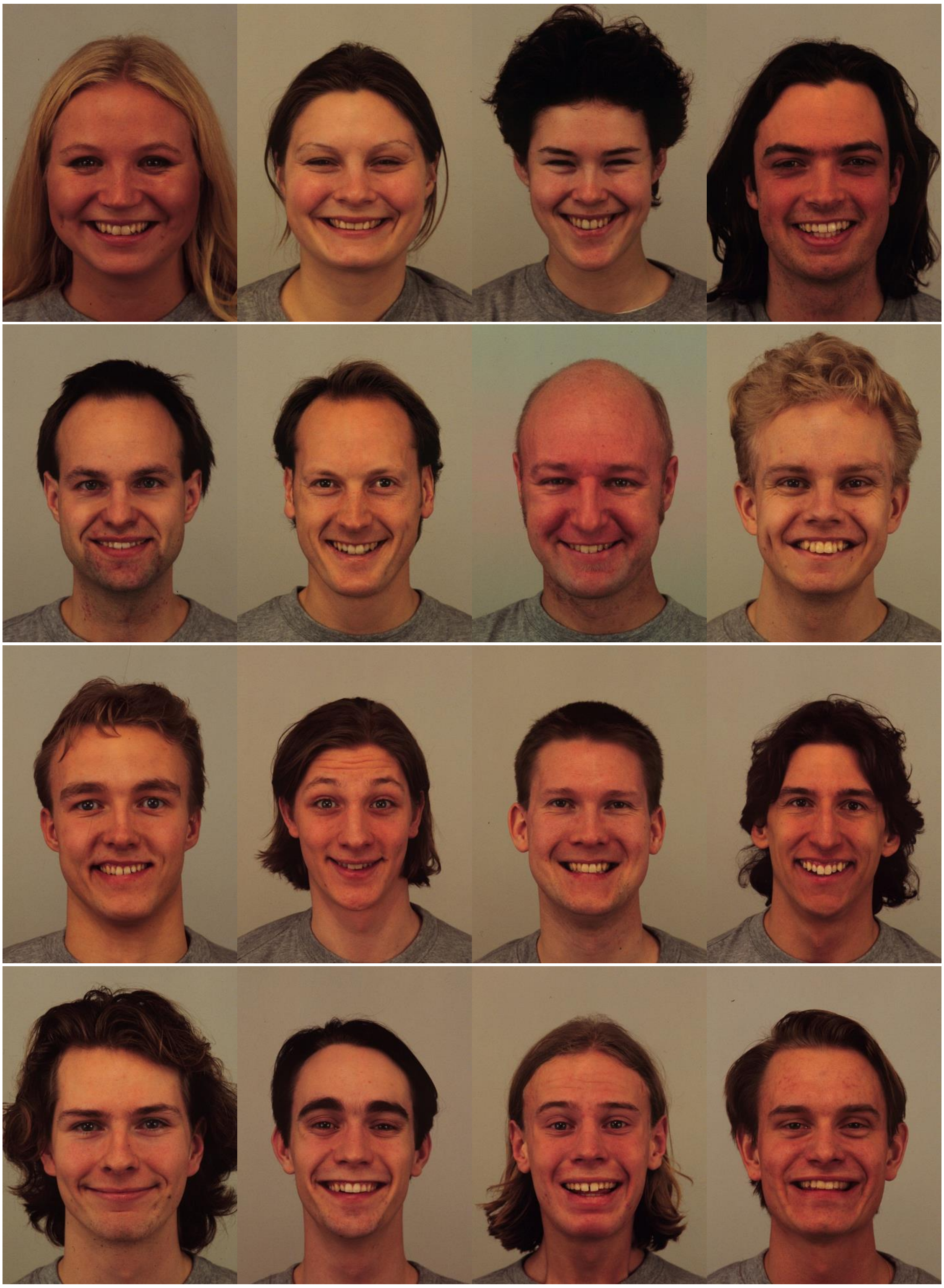

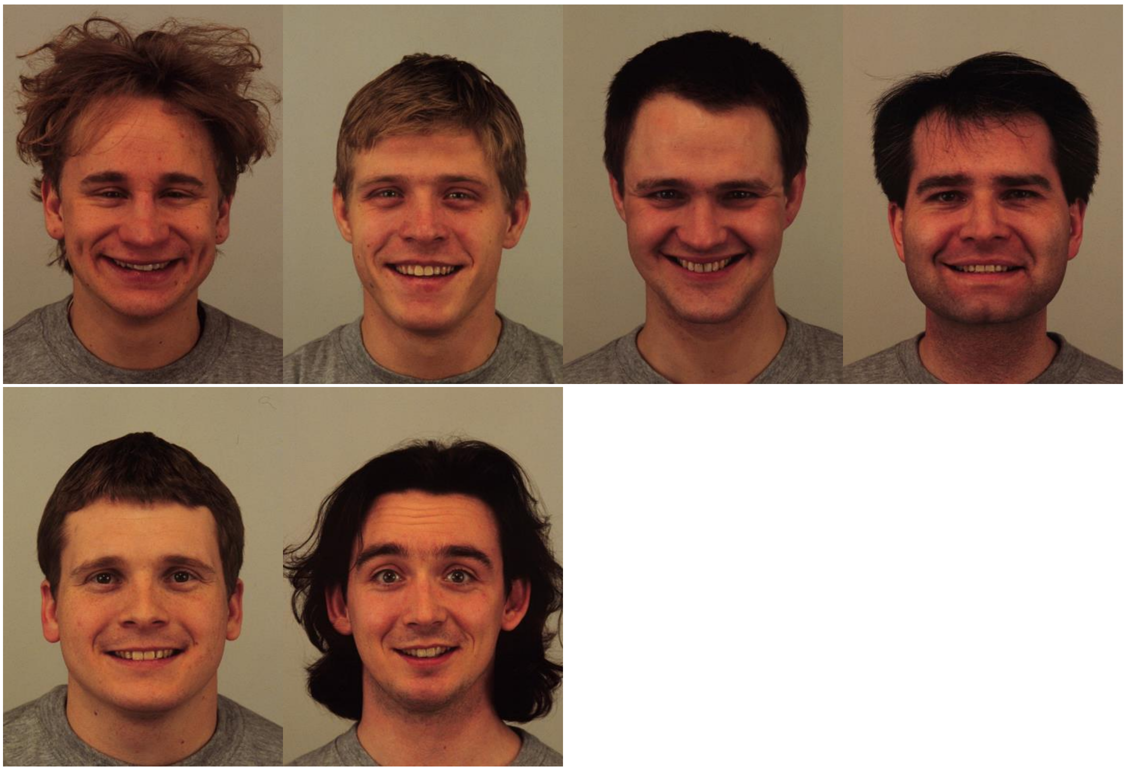

Part of the research infrastructure for Wales funded by the National Institute for Social Care and Health Research, Welsh Government.
Yn rhan o seilwaith ymchwil Cymru a ariannir gan y Sefydliad Cenedlaethol ar gyfer Ymchwil Gofal Cymdeithasol ac Iechyd, Llywodraeth Cymru

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Pwyllgor Moeseg Ymchwil Cymru 5
Wales Research Ethics Committee 5
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20 January 2015

Dear Miss Kaunhoven,

Study title:	**Mindfulness in Primary schools: Assessment of attention and emotion regulation related changes in pupils**
REC reference:	**14/WA/1249**
IRAS project ID:	**167691**

Thank you for your letter of 04 January 2015, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact the REC Manager, Dr Rossela Roberts, rossela.roberts@wales.nhs.uk. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.</u>

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database. This should be before the first participant is recruited but no later than 6 weeks after recruitment of the first participant.

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g. when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non-clinical trials this is not currently mandatory.

If a sponsor wishes to request a deferral for study registration within the required timeframe, they should contact hra.studyregistration@nhs.net. The expectation is that all clinical trials will be registered, however, in exceptional circumstances non registration may be permissible with prior agreement from NRES. Guidance on where to register is provided on the HRA website.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
REC Application Form [REC_Form_02122014]		02 December 2014
Research protocol or project proposal [Research Proposal]	2	04 January 2015
Referee's report or other scientific critique report [Bangor University Ethical Review email]	-	10 November 2014
Participant information sheet [Information sheet for Parents and Guardians]	2	04 January 2015
Participant information sheet [Information sheet for Parents and Guardians]	2	04 January 2015
Participant consent form [Informed Consent Form for Parent and Guardian]	1	14 October 2014
Participant consent form [Informed Consent Form for Parent and Guardian]	1	14 October 2014
Other [Debrief form]	1	14 October 2014
Other [Debrief form]	1	14 October 2014
Non-validated questionnaire [Mind wandering Questionnaire]	1	14 October 2014
Non-validated questionnaire [Child Acceptability form]	1	14 October 2014
Non-validated questionnaire [Language and Handedness Questionnaire]	1	14 October 2014
Validated questionnaire [Attentional Control Scale]	-	-
Validated questionnaire [Emotion Expression Scale]	-	-
Validated questionnaire [Cognitive Emotion Regulation Questionnaire]	-	-
Validated questionnaire [Child and Adolescent Mindfulness Measure]	-	-
Validated questionnaire [Positive and Negative Affectivity Scale]	-	-
Summary CV for Chief Investigator /Student [Miss Rebekah Haunhoven]	-	-
Summary CV for Academic Supervisor [Dr Dusana Dorjee]	-	-
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Bangor University Insurance Certificate]	-	01 August 2014
Response to Request for Further Information		04 January 2015

(end of list)

Please note that the list above reflects the actual documents received by the REC, not the titles /version numbers/dates as uploaded to the IRAS checklist, which is incorrect.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document *"After ethical review – guidance for researchers"* gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website: http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

HRA Training

We are pleased to welcome researchers and R&D staff at our training days – see details at http://www.hra.nhs.uk/hra-training/

14/WA/1249	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project.

Yours sincerely

Rossela Roberts

p.p.
Mr Derek James Crawford, MBChB, FRCS
Chair
E-mail: rossela.roberts@wales.nhs.uk

Enclosure: "After ethical review – guidance for researchers"

SL-AR2 After ethical review - research oth

Copy: Sponsor: Mr Hefin Francis
School Manager
School of Psychology, Bangor University
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Academic Supervisor: Dr Dusana Dorjee
School of Psychology, Bangor University
Brigantia Building, Penrallt Rd
Bangor, Gwynedd, LL57 2AS d.dorjee@bangor.ac.uk

Application for Ethical Approval

Project Title: Electrophysiological investigation of mindfulness with students and primary school children

Principal investigator: Kaunhoven, Rebekah

Other researchers: Dorjee,Dusana, Sanger,Kevanne, Thierry,Guillaume, De Meulenaere,Shelby, Byrne,Adam, Nichols,Brianne

Pre-screen Questions

Type of Project
PhD

What is the broad area of research
Clinical/Health. Language/Development. Vision/Brain
Further details: Cognitive neuroscience of mindfulness

Funding body
Internally Funded

Type of application (check all that apply)
A new application that does not require sponsorship or scrutiny from an outside body?

Proposed methodology (check all that apply)
EEG/MEG. Other type of research, please specify. Questionnaires and Interviews. Standard behavioural tasks such as computer-based reaction time, standardised tests, picture pointing, eye-tracking, etc.
Further details: Respiratory sinus arrhythmia measure, self report measures, event related potentials, reaction times and error rates on behavioural tasks.

Do you plan to include any of the following groups in your study?
Children
Further details: Primary school aged children from key stage 2 (7-11 years).

If your research requires any of the following facilities MRI, TMS/ tCS, Neurology Panel, has the protocol been reviewed by the appropriate expert/safety panel?
Not applicable (the research does not require special safety panel approval)

Connection to Psychology, (i.e. why Psychology should sponsor the question)
Investigator is a student in Psychology (including the North Wales Clinical Psychology Programme)

Does the research involve NHS patients? (NB: If you are conducting research that requires NHS ethics approval make sure to consult the Psychology Guidelines as you may not need to complete all sections of the Psychology online application)
No

Has this proposal been reviewed by another Bangor University Ethics committee?
No

NHS checklist. Does your study involve any of the following?

Part 1: Ethical Considerations

Will you describe the main experimental procedures to participants in advance, so that they are informed about what to expect?
Yes

Will you tell participants that their participation is voluntary?
Yes

Will you obtain written consent for participation?
Yes

If the research is observational, will you ask participants for their consent to being observed?
N/A

Will you tell participants that they may withdraw from the research at any time and for any reason?
Yes

With questionnaires, will you give participants the option of omitting questions they do not want to answer?
Yes

Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?
Yes

Will you debrief participants at the end of their participation (i.e. give them a brief explanation of the study)?
Yes

Will your project involve deliberately misleading participants in any way?
No

Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort? If *Yes* , give details and state what you will tell them to do should they experience any problems (e.g., who they can contact for help)
Yes
Further details: The mindfulness curriculum has previously been delivered in Ysgol Pen-Y-Bryn, Ysgol Hen Golwyn and Ysgol Sant Elfod to children in key stage 2. The mindfulness intervention was found to be both feasible and acceptable and had a beneficial impact on measures of well being. The mindfulness programs developed for adults can enhance an individual’s awareness of emotions which may previously have been unacknowledged and this can lead to some distress. In this case the individual would be advised to talk with their mindfulness trainer who would if needed, direct them to a GP. However the mindfulness intervention for primary school aged children is age appropriate and is designed for implementation in a classroom environment. The intervention should not feasibly pose a risk of psychological distress or discomfort as it does not involve in depth exploration of potentially negative emotions. Prior to the delivery of the intervention, a risk management strategy will be discussed with the teachers who are delivering the intervention. In the unlikely case that a child should feel discomfort, the teacher would provide support to the child. If further support is needed the child's parent and the school well being officer will be informed to manage the situation and contact the child's GP if needed. The self report measures which are used in this study are age appropriate and children will be informed that they can omit any questions they are not comfortable answering. During the event related potential (ERP) testing

sessions at times temporary reddening of the scalp can occur where the electrolyte gel has been applied as it contains a gentle abrasive. This is an infrequent occurrence; the researchers who are conducting the sessions are experienced in ERP testing and so know to not apply too much pressure onto the skin. The children will be asked regularly whether they are in any discomfort and if they are then testing will be stopped.

Is there any realistic risk of any participants experiencing discomfort or risk to health, subsequent illness or injury that might require medical or psychological treatment as a result of the procedures?
No

Does your project involve work with animals? If *Yes* please complete Part 2: B
No

Does your project involve payment to participants that differs from the normal rates? Is there significant concern that the level of payment you offer for this study will unduly influence participants to agree to procedures they may otherwise find unacceptable? If *Yes* please complete Part 2: B and explain in point 5 of the full protocol
No

If your study involves children under 18 years of age have you made adequate provision for child protection issues in your protocol?
Yes
Further details: The researchers who will be conducting the self report and ERP testing sessions with children have valid DBS certificates. A letter detailing information about the testing sessions will be sent to the children's parents so that they are aware of what is involved prior to providing informed consent. All testing sessions will take place on school premises during school hours. Teachers will be aware of the room in which the testing sessions will be conducted.

If your study involves people with learning difficulties have you made adequate provision to manage distress?
Yes
Further details: The mindfulness curriculum is not aimed specifically at children with learning difficulties, however it will be delivered by the school teacher in a classroom environment. The teacher will have prior awareness of any children who have learning difficulties and will manage this situation in the same way as they would in a routine classroom situation. During the testing sessions, the researcher will read out the questions on the self report measures and check that the child knows what the questions are asking and is comfortable completing the forms.

If your study involves participants covered by the Mental Capacity Act (i.e. adults over 16 years of age who lack the mental capacity to make specific decisions for themselves) do you have appropriate consent procedures in place? NB Some research involving participants who lack capacity will require review by an NHS REC. If you are unsure about whether this applies to your study, please contact the Ethics Administrator in the first instance
N/A

If your study involves patients have you made adequate provision to manage distress?
N/A

Does your study involve people in custody?
No

If your study involves participants recruited from one of the Neurology Patient Panels or the Psychiatry Patient Panel then has the protocol been reviewed by the appropriate

expert/safety panel?
N/A

If your study includes physically vulnerable adults have you ensured that there will be a person trained in CPR and seizure management at hand at all times during testing?
N/A

Is there significant potential risk to investigator(s) of allegations being made against the investigator(s). (e.g., through work with vulnerable populations or context of research)?
No

Is there significant potential risk to the institution in any way? (e.g., controversiality or potential for misuse of research findings.)
No

Part 3: Risk Assessment

Is there significant potential risk to participants of adverse effects?
No
Further details: No further potential risks then those detailed in previous sections

Is there significant potential risk to participants of distress?
No
Further details: No further potential risks then those detailed in previous sections

Is there significant potential risk to participants for persisting or subsequent illness or injury that might require medical or psychological treatment?
No

Is there significant potential risk to investigator(s) of violence or other harm to the investigator(s) (e.g., through work with particular populations or through context of research)?
No

Is there significant potential risk to other members of staff or students at the institution? (e.g., reception or other staff required to deal with violent or vulnerable populations.)
No

Does the research involve the investigator(s) working under any of the following conditions: alone; away from the School; after-hours; or on weekends?
Yes
Further details: The research will involve conducting testing sessions in local primary schools, in the situation where one researcher is working alone, lone worker policy will be adhered to. When researchers are conducting testing sessions, Dr Dusana Dorjee will be informed at all times and the researchers will be contactable by phone at all times. The schools and the children's teachers will also be aware of which room the testing sessions will be taking place in.

Does the experimental procedure involve touching participants?
Yes
Further details: The study involves conducting testing sessions with children from key stage 2, this will involve using ERP and RSA measures. With ERP testing, this involves fitting an EEG cap containing electrodes onto the participant's head, this is fitted with a chin strap and an elastic belt which goes under the arms around the chest. Participants will be asked to secure the chin strap and chest belt themselves. Two electrodes will be applied above and below the eye using stickers. A small amount of alcohol gel will be applied to the skin under the electrodes to cleanse it using a cotton bud and then a small amount of electrolyte gel will be applied. The RSA measure involves attaching an electrode onto both forearms to measure the heart rate. After the testing sessions participants will be given their own personal brush and hair towel to get the gel out of their hair. At times a small amount of reddening of the scalp can occur where the gel has been applied as it contains a gentle abrasive. If this occurs it is temporary and an infrequent occurence as the researchers who are conducting the sessions are experienced in ERP testing and so know to not apply too much pressure onto the skin. The children will be asked regularly whether they are in any discomfort and if they are then testing will be stopped.

Does the research involve disabled participants or children visiting the School?
No

Declaration

Declaration of ethical compliance: This research project will be carried out in accordance with the guidelines laid down by the British Psychological Society and the procedures determined by the School of Psychology at Bangor. I understand that I am responsible for the ethical conduct of the research. I confirm that I am aware of the requirements of the Data Protection Act and the University's Data Protection Policy, and that this research will comply with them.
Yes

Declaration of risk assessment The potential risks to the investigator(s) for this research project have been fully reviewed and discussed. As an investigator, I understand that I am responsible for managing my safety and that of participants throughout this research. I will immediately report any adverse events that occur as a consequence of this research.
Yes

Declaration of conflict of interest: To my knowledge, there is no conflict of interest on my part in carrying out this research.
Yes

Part 2: A

The potential value of addressing this issue

Hypotheses

Participants recruitment. Please attach consent and debrief forms with supporitng documents

Research methodology

Estimated start date and duration of the study.

For studies recruiting via SONA or advertising for participants in any way please provide a summary of how participants will be informed about the study in the advertisement. N.B. This should be a brief factual description of the study and what participants will be required to do.

Part 2: B

Brief background to the study

Further details: The development of ineffective attention and emotion regulation skills during childhood can increase the risk of academic problems and mental health disorders (Althoff, Verhulst Rettew, Hudziak van der Ede, 2010; Blair, Zelazo Greenberg 2007; Graziano et al., 2007). Interventions which foster these skills can therefore provide children with adaptive coping strategies to successfully manage adverse situations in the future. Mindfulness based interventions have been shown to beneficially impact upon attention and emotion regulation in primary school aged children, including the improvement of concentration skills and emotional resilience and the reduction of anxiety, aggression and oppositional behaviour (Burke, 2009; Harnett Dawe, 2012). Mindfulness interventions have been successfully implemented in school classrooms and have proved to be both feasible and acceptable (Zenner, Herrnleben, Kurtz Walach, 2014). Whilst these findings are promising, there is currently a limited understanding of the neural mechanisms underlying the impact of mindfulness in developmental populations. The aim of this study is to use electrophysiological, psychophysiological and behavioural measures to provide an insight into how mindfulness impacts upon attention and emotion regulation in children from key stage 2 (7-11 years). This study has a longitudinal non randomised design and involves the delivery of the paws.b mindfulness curriculum into four local primary schools, two intervention schools will receive the intervention in January 2015 and two wait list control schools will receive the intervention after completion of the study. The paws.b mindfulness curriculum was designed by Sarah Silverton from the Centre of mindfulness research and practice (CMRP), Bangor; teachers from Ysgol Pen-Y-Bryn, Colwyn Bay, and the mindfulness in schools project (MISP)). This curriculum will be delivered by school teachers with support from a mindfulness trainer (the teachers received mindfulness training as part of a separate ethically approved study). This curriculum has previously been delivered by mindfulness trained primary school teachers in four local schools with success. Measures of attention and emotion regulation will be assessed at three time points; pre-intervention, post-intervention and a three to six month follow up. Children in the intervention and wait list control group will take part in the testing sessions at the same time. Testing sessions will involve the use of four measures; self-reports, behavioural task performance, event related potentials (ERPs) and respiratory sinus arrhythmia (RSA). Self report questionnaires will be completed by the children to gain a subjective measure of changes in mindfulness, attention and emotion regulation. A measure of the children's satisfaction with the curriculum will also be taken. ERP measures will be recorded using a portable EEG system and will provide a measure of how mindfulness impacts upon neural mechanisms of attention and emotion regulation. Two ERP components will be of particular interest, the P3a and P3b. These components have been found to be sensitive to developmental changes in attention and emotion regulation (Lewis et al., 2006) and have previously been used to document the impact of mindfulness on the neural mechanisms of attention with adults (Moore, Gruber, Derose Malinowski, 2012; Slagter et al., 2007). The ERP measures will be taken whilst children complete two behavioural tasks; an auditory oddball task which will assess the impact of mindfulness training on attentional control and an emotion inducing GO NO GO task which will assess the impact of mindfulness on emotion regulation. Respiratory sinus arrhythmia (RSA), a measure of cardiac vagal tone, will also be recorded to provide a psychophysiological measure of the impact of mindfulness on emotion regulation. Higher RSA is linked with more effective emotion regulation in children (Chapman, Woltering, Lamm Lewis, 2010), increases in RSA have been found after mindfulness training (Ditto, Eclache Goldman, 2006). The methodology which is detailed above will be piloted with adults prior to the testing sessions with children. The adults in the pilot testing will not receive a mindfulness intervention and instead a measure of dispositional mindfulness will be used. (dispositional mindfulness can be measured using the mindfulness self report questionnaire)

The hypotheses

Further details: Improvements in self report measures of mindfulness, attentional control and emotional awareness are expected along with reductions in anxiety and mind wandering in children after the paws.b mindfulness curriculum compared with children in the wait list control group. These improvements are expected to be sustained at the three to six month follow up. Improvements in reaction times and accuracy rates are expected on the auditory oddball task after the mindfulness training, this will reflect an improvement in attentional control. Along with behavioural improvements in this task, a less positive P3b is expected on correct targets indicating a more efficient allocation of attention resources. A less positive P3a is expected for distracter stimuli, indicating a reduction in the automatic allocation of attention to unexpected stimuli. Improvements in the accuracy rates of detecting emotional faces are expected after mindfulness training on the emotional GO NO GO task as a result of increased response inhibition abilities. Along with behavioural improvements on this task, a less positive P3b is expected to be elicited for angry faces reflecting a more accepting attitude when processing negatively valenced stimuli. An increase in levels of RSA is expected in children after receiving the paws.b mindfulness curriculum, this is thought to reflect improvements in emotion regulation.

Participants: recruitment methods, age, gender, exclusion/inclusion criteria
Further details: The first stage of the project is to pilot measures (ERP, self report, behavioural tasks) with approximately 15 adults. Participants will be recruited using SONA and will be paid with course credits and printer credits. If an adequate number of participants cannot be recruited using this method then participants will be recruited through displaying posters in public areas around the university (see supporting documents), through advertising on the Bangor University discussion forum and facebook and word of mouth. Participants recruited in this way will be paid for their participation. This stage of the project will not involve the implementation of a mindfulness intervention. Participants will be excluded if they have epilepsy, other inclusion/ exclusion criteria will not be applied for participants from SONA, only data from individuals aged between 18 and 40 with no psychological, neurological problems or current use of medication which could influence performance and no previous mindfulness experience will be analysed. Participants should also have normal or corrected to normal vision and hearing. This criteria will be assessed using a pre-screening questionnaire (see supporting documents). This criteria will be applied if participants are recruited outside of SONA. For the main study, children from key stage 2 (aged between 7 and 11 years) will be recruited from four schools in North Wales; two intervention schools, Ysgol Glanwydden, Ysgol Emmanuel and two wait list control schools, Ysgol Christchurch and Ysgol Cae Top. These schools are matched on size and socioeconomic status. Some teachers from these schools have previously received mindfulness training as part of a prior study looking at the impact of mindfulness on teacher's well being (Ethically approved by Bangor University). The year groups included in this current study will depend on which teachers express an interest in delivering the mindfulness curriculum to the children. The aim is to recruit approximately 60 children for ERP testing sessions (30 intervention, 30 wait list control). For children who want to take part in the study but do not want to take part in the ERP testing sessions, self report measures will be taken. An information sheet and consent form (see supporting documents) will be sent out to children and their parents to invite them to consent for the children to take part in the study. Where possible the parents will also be invited to an information session at the school to explain what the testing sessions will involve and answer questions parents may have. If parents give informed consent then they are asked to complete and sign the consent form and return it to the school. The intervention will be implemented between January and April 2015 and testing sessions with the children will be conducted before and after the course. The wait list control schools will receive the intervention after completion of the study but the children from these schools will take part in the testing sessions at the same time as the intervention schools. Participants will be invited to take part regardless of age/ gender, socio-economic status or ethnicity. The exclusion criteria will be children with epilepsy. The schools, children and parents will be informed that they can withdraw without penalty at any time.

Research design
Further details: A longitudinal feasibility pilot with two intervention schools and two wait list control schools. The study is non-randomised and recruitment is based on the schools availability and then on a first come basis. Intervention and control schools are matched on socioeconomic status of the school children, classroom size and language policy.

Procedures employed

Further details: Primary school teachers will be delivering the paws.b mindfulness curriculum to pupils in two of the four schools (Ysgol Emmanuel and Ysgol Glanwydden). Two wait list control schools will receive the training after completion of the study. The curriculum will be delivered between January and April 2015. The training will be delivered by teachers previously trained in delivery of the paws.b mindfulness curriculum with support from a trainer from the Centre for Mindfulness Research and Practice (Sarah Silverton) and a teacher from Ysgol Pen-Y-Bryn who co-authored and piloted the paws.b program (Tabitha Sawyer). The curriculum will be delivered by teachers who are in the process of receiving training as part of a previous ethically approved study. Participation in this current study with children will be voluntary for the teachers and so not all the teachers recruited for the last project will volunteer for this one. Data from pupils (training and control schools), will be collected prior to delivery of the curriculum (in January), after completion of the curriculum (April/May), and at three to six month follow up (either July or September 2015). The paws.b mindfulness curriculum further develops the pilot work carried out over the last three years in Ysgol Pen-Y-Bryn in Colwyn Bay, Ysgol Hen Golwyn, Colwyn Bay, and Ysgol Sant Elfod, Abergele, North Wales. This curriculum draws on good practice programmes such as Susan Kaiser-Greenland's (USA) and Mindfulness in Schools Project (secondary schools). The paws.b curriculum (developed by Sarah Silverton and teachers from Ysgol Pen-Y-Bryn in collaboration with the Mindfulness in Schools project) involves 12 half-hour taught classes which will be delivered during PSE classes and the integration of "informal" mindfulness practices within the existing curriculum activities (5-10 minutes daily) including art, sport and music. This curriculum aims to develop knowledge and skills to facilitate adaptive responding to difficult experiences, concentration, meta-cognition, and emotion regulation. During the testing sessions children will be given some self report measures (see measures section). The researcher will read the questions to the participants to ensure that the pupils understand the questions and are comfortable answering them. EEG data and psychophysiological data will be collected using a portable EEG system. Testing sessions will take approximately one hour. Testing sessions will take place on school premises in a room allocated for the research. Participants will be seated comfortably and fitted with an EEG cap containing 32 Ag/AgCl electrodes with right mastoid selected as the site of reference. The data will be obtained with Neuroscan SynAmp1 amplifiers, utilizing a sampling rate of 1kHz. Two electrodes, situated above and below the left eye, will be placed to record ocular movements. The impedance of all electrodes will be kept at less than 7kOhms. After the cap is placed on the head the skin under each electrode will be gently cleaned with alcohol and then electrolyte gel will be applied at each electrode site to ensure good conductivity between each electrode and the participant's scalp. The experimenter will gently move the hair away from the electrode opening and clean the skin with a disposable cotton bud dipped in medical isopropyl alcohol, electrolyte gel will then be placed in the opening. The electrolyte gel contains an abrasive agent (sterile sand). The scalp will be then scrubbed gently using a disposable cotton bud to enhance contact. The gel, which contains sodium, water and a gentle abrasive, is chloride free and non-allergenic. In very rare cases, in participants with sensitive skin, slight abrasion of the skin can occur and participants (and their parents) will be alerted to this in the information sheet before they consent to participate in the study. Since participants will be tested in schools, there will be no requirement to wash hair before the start of the experiment. Rather, participants will be invited to brush their hair with a disposable hair brush, each child will receive their own brush which can be taken home after completion of the study. At the end of each session, the cap will be swiftly removed and washed in soap. Participants will be invited to clean their hair with a wet towel and then with a dry towel. As described, the only temporary effect that can occur relates to the use of a gentle abrasive component. In some participants, even gentle abrasion can induce temporary local reddening of the skin. Participants will be asked on a regular basis whether the procedure causes them any discomfort, and should they report that it does, the session will be terminated. All researchers are experienced in EEG testing with children and know not to put too much pressure on participants' skin during setup procedures and to check their comfort levels regularly Online, the EEG signal will be filtered with a bandpass filter range of 0.01 to 200Hz. Offline, the EEG signal will be filtered with a zero shift low pass of 30Hz, with a 48dB/Oct slope. Initially the EEG data will be cleaned manually by rejecting any motor and irregular occular artefacts; an algorithm will then applied to the remaining data to remove any residual occular and other artefacts. The data will be epoched by its division into 1100ms segments, epochs will be baseline corrected using data 100 ms before the onset of the stimulus. For the three stimulus auditory oddball task there will be 40 epochs for each condition for each participant (35 in the face task); this number may be reduced if data is rejected during the cleaning process. Averages per condition and participant will be computed first and consequently grand averages across conditions will be produced. Participants will also have their respiratory sinus arrhythmia measured at rest (3 minutes) and during a paced breathing task (3 minutes) in which they will receive a tone cue to breathe in a natural paced fashion (9 breathing cycles per minutes). The EKG signal will be measured by attaching two miniature electrodes to the right and left forearms. The heart period (HP) will be obtained through the millisecond interval between successive R-waves, after being corrected or interpolated for outliers due to ectopic activity. Heart rate (HR) will then be calculated by converting HP using the formula: HR5 60,000/HP. RSA measures will be calculated by using customized computer software. The RSA measures are computed by the formula power spectral density values/ the frequency band associated with respiration, which had to be between 0.15 and 0.50 Hz, these are then normalized using the natural logarithm. The emotional GO NO GO task will take the form of an oddball paradigm, two neutral faces (one male and one female) will be presented for 70% of the time and 15% of the time happy faces will be presented, for 15% of the time angry faces will be presented. The instructions in each block will change. In one block the happy faces will be the GO targets and participants will be instructed to press a button when they see a happy face and refrain from pressing a button when angry or neutral faces are displayed (NO GO). For the next block the instructions will be reversed and angry faces will be the GO and neutral and happy faces will be the NO GO. The order of the blocks will be counterbalanced. The task will take approximately 13 minutes and contain 35 targets per block. The happy, angry and neutral emotional faces will be taken from the NimStim faces database (Tottenham et al., 2009) and the Karolinska database (Lundqvist et al., 1998). The faces from these studies have been used with children in previous studies. The three stimulus auditory oddball task will involve three blocks. A frequent neutral sound will be presented for 70% of the time and for 15% of the time a neutral target will be played and for 15% of the time non target distracter animal sounds will be played. Participants will be told to press a button when a target is heard and refrain from pressing a button when either the neutral frequent sound or distracter animal sound is played. This task will take approximately 13 minutes. In between each block a mind wandering self report measure will be given to measure how often the mind wanders during the task. The testing session procedures will be piloted with students aged between 18 and 30 years.

Measures employed
Further details: The child and adolescent mindfulness measure (CAMM) (Greco, 2011) is a 10 item self report measure which will be administered to children to assess the impact of the paws.b mindfulness curriculum on levels of mindfulness. The ability to observe and accept internal experiences and act with awareness will be measured on a five point likert scale (0= never true, 4= always true). This scale is designed for children aged 8 years and older The attentional control scale for children (ACS-C) (Muris, De Jong Engelen, 2004) is a child version of the attentional control scale (Derryberry Reed, 2002). This 20 item self report measure will be administered to children to assess the impact of the paws.b mindfulness curriculum on attention control. The ability to orient and shift the focus of attention is measured on a 4 point likert scale (1= almost never, 4= always). This scale is designed for children aged 8 years and older. The emotion expression scale for children (EESC) (Penza-Clyve, 2002) is a 16 item self report measure which will be administered to children assess the impact of the paws.b mindfulness curriculum on emotional awareness. Emotional awareness and the motivation to express negative emotions will be measured on a 5 point likert scale (1= not at all true, 5= very very true). This scale is designed for children aged between 9 and 12 years. The 10 item positive and negative affectivity scale for children (PANAS-C short version) (Ebesutani et al., 2012) is a 10 item version of the PANAS-C (Laurent et al., 1999) which will be used to assess the impact of the mindfulness paws.b curriculum on feelings and emotions. This scale can also be used to assess anxiety and depression. A five point likert scale is used (1= very slightly/ not at all, 5= extremely). This scale is designed for children aged between 9 and 17 years. A form detailing demographics, handedness, language skills and brain injury/epilepsy will be also administered to children. A brief acceptability self report will be administered after the mindfulness paws.b curriculum to measure the extent to which the child enjoyed the course and amount of home practice completed. A self report measuring mind

wandering will also be administered to children between each of the three blocks of the auditory attention task. This will measure mind wandering on a six point likert scale (1=never, 6= always)

Qualifications of the investigators to use the measures (Where working with children or vulnerable adults, please include information on investigators' CRB disclosures here.)
Further details: Rebekah Kaunhoven and Kevanne Sanger will be involved in research testing sessions and have current CRB certificates and have received in house EEG training and have experience of conducting EEG testing sessions with primary school aged children. Both PhD students also have prior experience of collecting self report data and respiratory sinus arrythmia recordings with primary school aged children. If Dr Dorjee's masters students become involved in data collection with children then they will be supervised at all times and will receive EEG training during the piloting stage of the project.

Venue for investigation
Further details: The research will take place in four North Wales primary schools, the two wait list control schools are Ysgol Cae Top and Ysgol Christchurch, the two intervention schools are Ysgol Emmanuel and Ysgol Glanwydden. All equipment needed for the testing sessions with children, including the portable EEG system will be taken to the schools. Research testing will take place in a small quiet room on school premises.

Estimated start date and duration of the study (N.B. If you know that the research is likely to continue for more than three years, please indicate this here).
Further details: Piloting with adults will take place in November 2014. Pre-intervention testing with children will take place in January 2015, post intervention testing will take place in April-May 2015 and follow up testing will take place in September 2015

Data analysis
Further details: Self report and ERP data from students and primary school children will be analysed using multi-factorial analysis of variance (ANOVA). For example the ANOVA for the ERP data will have a between subjects factor of group and within subjects factors of time, electrode and valence. The ANOVA of the self report data will follow a similar analysis design. To examine the relationship between ERP amplitudes and latencies and self reports, correlational analysis will be conducted.

Potential offence/distress to participants
Further details: As mentioned in section 1: The mindfulness curriculum has previously been delivered in primary schools including Ysgol Pen-Y-Bryn, Ysgol Hen Golwyn and Ysgol Sant Elfod to children in key stage 2. The mindfulness intervention was found to be both feasible and acceptable and had a beneficial impact on measures of well being. The mindfulness programs developed for adults can enhance an individual’s awareness of emotions which may previously have been unacknowledged and this can lead to some distress. In this case the individual would be advised to talk with their mindfulness trainer who would if needed, direct them to a GP. However the mindfulness intervention for primary school aged children is age appropriate and is designed for implementation in a classroom environment. The intervention should not feasibly pose a risk of psychological distress or discomfort as it does not involve in depth exploration of potentially negative emotions. Prior to the delivery of the intervention, a risk management strategy will be discussed with the teachers who are delivering the intervention. In the unlikely case that a child should feel discomfort, the teacher would provide support to the child. If further support is needed the child's parent and the school well being officer will be informed to manage the situation and contact the child's GP if needed. The self report measures which are used in this study are age appropriate and children will be informed that they can omit any questions they are not comfortable answering. During the Event related potential (ERP) testing sessions at times temporary reddening of the scalp can occur where the electrolyte gel has been applied as it contains a gentle abrasive. This is an infrequent occurrence; the researchers who are conducting the sessions are experienced in ERP testing and so know to not apply too much pressure onto the skin. The children will be asked regularly whether they are in any discomfort and if they are then testing will

be stopped.

Procedures to ensure confidentiality and data protection
Further details: To ensure data is kept confidentially, a code will be assigned to each participant in place of their name. A 'linking sheet' containing information about which code is linked with which name will be used to link the data from pre, post follow up. The linking sheet will only be accessible by the PI on the project and stored in a password protected file. A printed version will be stored in a locked filing cabinet away from the rest of the data. All data, including self report measures, behavioural data including accuracy and reaction time data (E-prime output files), EEG/heart rate data files, and data analysis files will be stored on password protected computers. Original measures (self report measures and external drives/DVDs with the psychophysiological data) will be stored in a locked filing cabinet at Bangor University under a random code. Data from individual participants will not be identifiable in reports, only group data will be reported.

****How consent is to be obtained (see BPS Guidelines and ensure consent forms are expressed bilingually where appropriate. The University has its own Welsh translations facilities on extension 2036)***
Further details: The researcher will be working with the schools and parents to provide information about the study and to ensure a full informed consent process. Information sheets and consent forms will be sent to parents with contact information of the researchers if the parents/pupils wish to ask questions about the project. The information sheets contain information about the study and detailed information about participant involvement so that parents/guardians and children can make fully informed decisions about consent. All correspondence will be provided in English and Welsh. Both parents and the child will be informed that the child can withdraw from the assessment at any time. This will be clearly stated in the information sheet. In addition, the researcher will verbally ask children if they wish to participate in the study, only if a clear positive answer is provided will the researcher continue. Where possible, the researchers will also attempt to organize parent information sessions and in class demonstrations of EEG data collection for pupils prior to the start of the project. For the piloting stage, participants will be asked to sign a consent form if they wish to participate. The information sheet and consent form will be provided in Welsh and English.

Information for participants (provide actual consent forms and information sheets) including if appropriate, the summary of the study that will appear on SONA to inform participants about the study. N.B. This should be a brief factual description of the study and what participants will be required to do.
Further details: Description of the pilot study on SONA: This study aims to investigate the links between dispositional mindfulness and brain markers of attention and emotion processing. For this study, you will be asked you to complete some questionnaires assessing mindfulness, emotion regulation and attention skills followed by participation in two computerised tasks whilst EEG recordings are taken. In preparation for the EEG recording, we will ask you to wash your hair using baby shampoo in the washroom of the EEG lab. We will provide the towels, shampoo and hairdryer. After this we will fit a cap containing electrodes onto your head and apply some gel (a hypo-allergenic mix of water, fine sand and jellifying agent) at different points on your scalp. The activity from the surface of your head will be measured whilst you complete the two computerised experiments in which you will be required to make keyboard responses to sounds and emotional face expressions. As the stimuli used in the study are sounds and images, if you require glasses or hearing aids then please come prepared. Each task will take about twelve minutes. There will also be a short resting/breathing task where we will be measuring your heart rate for three minutes. We can not take participants with epilepsy. The experiment will take place in Deniol building (next to Brigantia) and will be accessible for participants who are wheelchair users. The experimental session will take a maximum of 1 hour 30 minutes and you will be rewarded 4 course credits and £6 printer credits.

Approval of relevant professionals (e.g., GPs, Consultants, Teachers, parents etc.)
Further details: The schools were made aware of this research project with children during participation in a previous ethically approved study investigating the effectiveness of mindfulness

on teachers well being. During this previous study, expressions of interest were gained from the schools and their teachers to take part in this study subject to ethical approval. The teachers and schools participation in this current study is voluntary and was not a requirement of the participation in the previous ethically approved study. Informed consent will be gained from the headteacher in the form of an email and parents and teachers will complete consent forms to take part in delivering the curriculum.

Payment to: participants, investigators, departments/institutions
Further details: For the piloting: Participants will be paid according to the rates given for an EEG study on SONA (4 course credits and £6 printer credits, study will take maximum of 1.5 hours). If an adequate number of participants can not be obtained in this way then participants will be paid £12 for their participation. The entire testing sessions (including washing hair) will take a maximum of 1.5 hours. Schools project: The schools are receiving free training in the paws.b mindfulness curriculum, the cost of training a teacher in this curriculum would usually cost approximately £700 per person (£200 for an introductory mindfulness course and £500 for the paws.b curriculum training). Children taking part in the EEG testing sessions will receive a small reward for taking part such as stationary.

Equipment required and its availability
Further details: All the measures attached are free to use and permission has been obtained by the authors of these measures. The EEG portable system consisting of two laptops and amplifier and two EEG caps will be used for the research testing sessions. This equipment was obtained for this project and has previously been used for similar projects in Dr Dorjee's lab. Dr Dorjee has already checked on insurance related issues with regard to use of the system in schools.

If students will be engaged a project involving children, vulnerable adults, one of the neurology patient panels or the psychiatric patient panel, specify on a separate sheet the arrangements for training and supervision of students. (See guidance notes)
Further details: The testing will be conducted under the supervision of PhD students who have prior experience of EEG testing with children of this age group. If masters students are involved in the research testing sessions then these students will always be fully supported and supervised by experienced PhD students and will not undertake testing sessions alone.

If students will be engaged in a project involving use of MRI or TMS, specify on a separate sheet the arrangements for training and supervision of students. (See guidance notes)
Further details: N/A

What arrangements are you making to give feedback to participants? The responsibility is yours to provide it, not participants' to request it.
Further details: A Debriefing form (see supporting documents) will be given to parents and teachers at the end of this longitudinal study. This will explain the purpose of the study and the expected results. The option is given on the consent form for teachers and parents to receive a summary of the results, an initial in the appropriate box is required to receive this.

Finally, check your proposal conforms to BPS Guidelines on Ethical Standards in research and sign the declaration. If you have any doubts about this, please outline them.

Part 4: Research Insurance

Is the research to be conducted in the UK?
Yes

Research that is based solely upon certain typical methods or paradigms is less problematic from an insurance and risk perspective. Is your research based solely upon one or more of these methodologies? Standard behavioural methods such as questionnaires or interviews, computer-based reaction time measures, standardised tests, eye-tracking, picture-pointing, etc; Measurements of physiological processes such as EEG, MEG, MRI, EMG, heart-rate, GSR (not TMS or tCS as they involve more than simple 'measurement'); Collections of body secretions by non-invasive methods, venepuncture (taking of a blood sample), or asking participants to consume foods and/or nutrients (not including the use of drugs or other food supplements or caffine).
Yes

Ysgol Seicoleg
Canolfan Ymchwil ac Ymarfer Ymwybyddiaeth Ofalgar
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Mindfulness in Primary Schools: Assessment of attention and emotion regulation related changes in pupils

<u>Information Sheet for Parents and Guardians</u>

Please keep this information sheet and a signed copy of the consent form for your records

Investigators:

Ms. Rebekah Kaunhoven, Ph.D. student, School of Psychology, Bangor University

Dr. Dusana Dorjee, Lecturer and Research Lead, Centre for Mindfulness Research and Practice, School of Psychology, Bangor University

Prof. Guillaume Thierry; Professor of Cognitive Neuroscience, School of Psychology, Bangor University

Ms. Kevanne Sanger, Ph.D. student, School of Psychology, Bangor University

Ms. Shelby DeMeulenaere; PhD student, School of Psychology, Bangor University

Ms. Thy Thi Uyen Nguyen; MSc student, School of Psychology, Bangor University

You are invited to consider your child's participation in a research project. This information sheet will include details about what the research will involve and why it is being carried out. Please read the following information carefully before deciding whether you would like your child to take part in the project. If you are unclear about anything in the information sheet then please feel free to contact us on the details included at the end of the letter.

Thank you for reading this information sheet.

What is the project?

This research project aims to investigate whether a mindfulness curriculum (called paws.b), which will be taught as part of the regular school curriculum by school teachers, can improve children's attention and emotion regulation skills. We know from previous research that mindfulness practice can reduce stress, improve wellbeing and help develop the experience of positive emotions, this is important as children nowadays are facing increasing levels of stress. This project aims to gain a more complete picture of how mindfulness practice could be useful for primary school children in key stage 2, through examining its' impact on the brain functions and body functions underlying concentration and emotion management skills. We would like to evaluate the effectiveness of mindfulness using self-report questionnaires, computer tasks and a brain wave measure called event related potentials, and compare findings with pupils from your child's school, who have not received the mindfulness curriculum. We would like to take measures at three time points; before the curriculum (February, 2015), after the curriculum (May, 2015) and at a three to six month follow up (September or December 2015).

Mindfulness is a secular practice which helps us to take notice of the present moment and see our experiences clearly through developing the ability to choose what we focus on. Through discovering more about our present moment experiences we can find friendly and appropriate ways to respond and develop the skills to manage challenges that present themselves in life.

Who can take part?

Children aged between 7 and 11 years of age from four local schools will be invited to take part in this study; any child in your child's class can take part, however as a precautionary measure, children with epilepsy will not be able to take part.

What will I have to do and when?

About half of the children participating in the project will be learning simple mindfulness practices taught be their teachers. The other half of children, including those in your school, will not be learning mindfulness practices this year. We would like to ask your child to take part in research to measure the impact of the mindfulness curriculum on children's attention and emotion regulation abilities. The findings from children receiving the mindfulness curriculum will be compared with pupils from your child's school who have not learned mindfulness, at three time points, before the mindfulness curriculum (February 2015), after the mindfulness curriculum (May 2015) and at a three to six month follow up (September or December 2015). The experimental sessions with the researchers will take approximately 1 hour each time and will take place during school hours in a small room outside of the classroom on school premises. Before the start of each of the research sessions we will always ask each child whether they would like to participate in the research and respect their wishes if they would prefer not to participate.

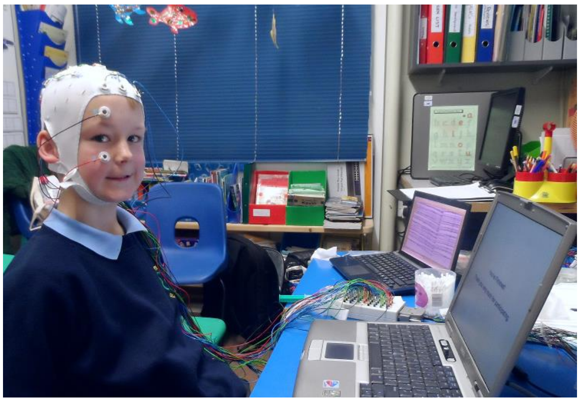
The experimental sessions will involve the following:

1. Self report questionnaires

The pupils will be asked to complete questionnaires about attention control skills, mindfulness, the experience of positive and negative emotions, emotion management and some background information including age, whether they are left or right-handed, language abilities and whether they have epilepsy or have had a brain injury in the past. It will take about 15 minutes to fill in the forms each time. The questionnaires will be completed in small groups or individually in school with support from the researchers (questions will be read aloud). Children will be told that they can leave out any questions which they don't want to answer. If in the unlikely event that your child becomes uncomfortable for any reason during the testing sessions then school policy will be followed, this will involve informing the child's school teacher who will then take the further appropriate steps.

2. Brain and body function measures

Along with the questionnaires, we would also like to measure how mindfulness impacts upon the brain functions and body functions related to attention control and wellbeing using a portable EEG (electroencephalography) system. This system measures brain waves using a stretchy cap containing sensors (electrodes) which is placed on the head; this measures the brain signal which is naturally present on the surface of the scalp all the time. Your child will be asked to brush their hair with a hairbrush which we will provide (each child will receive their own which can be kept after completion of the project). The cap will be fitted and some medical alcohol will be applied at different points on the scalp as a cleanser, followed by a hypoallergenic gel (consisting of water, sterilised fine sand and jellifying agent). Two sensors (electrodes) will be placed above and below one eye to monitor the eye blinks during the experiment. Brain wave measures will be taken whilst the pupils complete two computerised tasks (similar to simple computer games). These tasks will involve making keyboard responses to the presentation of some happy, angry and neutral faces and some environmental sounds. Each of the two tasks will take about thirteen minutes. Two sensors (electrodes) will also be placed on the forearms to measure the pupils' heart rate whilst they complete a short three minute resting task; this has been found to be a physiological indicator of wellbeing. After completion of the session, the pupils will have a chance to remove some of the gel from their hair using a wet towel. The remainder of the gel can be easily removed at home



during hair washing. These procedures are safe and have been conducted on hundreds of adults and children at the School of Psychology, Bangor University. In rare cases, even a gentle use of the electrolyte gel can result in a slight abrasion and temporary reddening of the skin on scalp. For this reason we frequently ask for feedback from our participants during the cap setup. If your child experiences any discomfort during the cap setup procedures, the testing will be stopped and the cap removed immediately. The EEG brain wave measures are taken for research purposes and the researchers are not trained to detect or interpret any disorders such as epilepsy using these measures.

What are the benefits for me?

We hope that the research participation will be a useful educational experience for your child and provide them with initial first hand insight into neuroscience research. This project will also enable teachers from the participating schools, where children are currently not taught mindfulness, to learn how to teach mindfulness to their pupils next year. Your child's participation in this study will also help us to understand whether mindfulness can be used to support primary school children in managing their wellbeing skilfully. Your child will receive a small reward for their participation (stationary) after each research session. Those pupils who will not have an opportunity to learn mindfulness this year will be invited together with their class to visit our electrophysiology lab in the School of Psychology at Bangor University to learn more about neuroscience and ways to measure brain activity with EEG.

Do I have to complete the study once I've started?

Your child's participation in the study is completely voluntary and your child is free to withdraw from participation at any time. If at some point during the project you decide that your child should not continue their participation in the research then please contact the researchers. We will always ask each child if they want to participate in the research at the start of each research session, if they indicate they do not wish to continue their participation at the beginning or during the testing session then the child can withdraw immediately.

Will my information be safe?

All data will be kept safe and confidential and will only be accessible to the researchers conducting this study. Questionnaires will be stored in a locked filing cabinet at Bangor University and data from the experimental tasks (brain waves, heart rate, reaction time and accuracy rates) will be stored on a password protected computer at Bangor University. A randomly assigned code will be assigned to the questionnaires and electronic records in place of your child's name. A linking sheet will be used to link your child's name and code to keep track of the records across the three research sessions. The linking sheet will be stored separately from the questionnaires and will only be accessible by the Principal Investigator (PI) of the project. Only group data will be reported in the publications resulting from this study, and no individual participants will be identifiable. If you would be interested in hearing more about the results of this study after it's been completed (about nine months from now), please indicate this on your consent form. Standard safeguarding procedures will be followed in line with school policy if a child confides in a researcher about any disclosure of abuse. This will involve informing the child's school teacher who will then take the further appropriate steps.

Is there a complaints procedure?

This study has been reviewed by the Bangor University ethics committee and the Research Ethics Committee, Bangor. In the event of complaints arising from the research; please address them to Mr. Hefin Francis, School Manager, School of Psychology, Bangor University, Gwynedd, LL57 2AS (h.francis@bangor.ac.uk).

If you have any further questions regarding the research project, please contact:

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Mindfulness in Primary Schools: Assessment of attention and emotion regulation related changes in pupils

Information Sheet for Parents and Guardians

Please keep this information sheet and a signed copy of the consent form for your records

Investigators:

Ms. Rebekah Kaunhoven, Ph.D. student, School of Psychology, Bangor University

Dr. Dusana Dorjee, Lecturer and Research Lead, Centre for Mindfulness Research and Practice, School of Psychology, Bangor University

Prof. Guillaume Thierry; Professor of Cognitive Neuroscience, School of Psychology, Bangor University

Ms. Kevanne Sanger, Ph.D. student, School of Psychology, Bangor University

Ms. Shelby DeMeulenaere; PhD student, School of Psychology, Bangor University

Ms. Thy Thi Uyen Nguyen; MSc student, School of Psychology, Bangor University

You are invited to consider your child's participation in a research project. This information sheet will include details about what the research will involve and why it is being carried out. Please read the following information carefully before deciding whether you would like your child to take part in the project. If you are unclear about anything in the information sheet then please feel free to contact us on the details included at the end of the letter.

Thank you for reading this information sheet.

What is the project?

This research project aims to investigate whether a mindfulness curriculum (called paws.b), which will be taught as part of the regular school curriculum by your child's class teacher, can improve children's attention and emotion regulation skills. We know from previous research that mindfulness practice can reduce stress, improve wellbeing and help develop the experience of positive emotions, this is important as children nowadays are facing increasing levels of stress. This project aims to gain a more complete picture of how mindfulness practice could be useful for primary school children in key stage 2, through examining its' impact on the brain functions and body functions underlying concentration and emotion management skills. We would like to evaluate the effectiveness of mindfulness using self-report questionnaires, computer tasks and a brain wave measure called event related potentials, and compare findings with pupils who have not received the mindfulness curriculum. We would like to take measures at three time points; before the curriculum (February, 2015), after the curriculum (May, 2015) and at a three to six month follow up (September or December 2015).

What is the paws.b mindfulness curriculum?

Mindfulness is a secular practice which helps us to take notice of the present moment and see our experiences clearly through developing the ability to choose what we focus on. Through discovering more about our present moment experiences we can find friendly and appropriate ways to respond and develop the skills to manage challenges that present themselves in life.

The **paws.b mindfulness curriculum** is designed to be an enjoyable educational course which will provide children with mindfulness practices and techniques aimed to improve concentration, awareness and wellbeing. As part of this curriculum, pupils will also learn about different functions within the brain. The curriculum will be delivered weekly in twelve 30 minute sessions by school teachers as part of the regular school curriculum, short mindfulness practices will also be delivered throughout the day. Participation in the research project is optional and if you decide that you do not want your child to take part in the research then the child will still be able to receive the mindfulness curriculum provided by the class teacher.

Who can take part?

Children aged between 7 and 11 years of age from four local schools will be invited to take part in this study; any child in your child's class can take part, however as a precautionary measure, children with epilepsy will not be able to take part.

What will I have to do and when?

Children from your school will be taught the mindfulness curriculum by their teachers between February and May 2015 as part of the regular school curriculum. We would like to ask your child to take part in research to measure the impact of the mindfulness curriculum on children's attention and emotion regulation abilities. These findings will be compared with pupils who have not learned mindfulness at three time points, before the mindfulness curriculum (February 2015), after the mindfulness curriculum (May 2015) and at a three to six month follow up (September or December 2015). The experimental sessions with the researchers will take approximately 1 hour each time and will take place during school hours in a small room outside of the classroom on school premises. Before the start of each of the research sessions we will always ask each child whether they would like to participate in the research and respect their wishes if they would prefer not to participate.

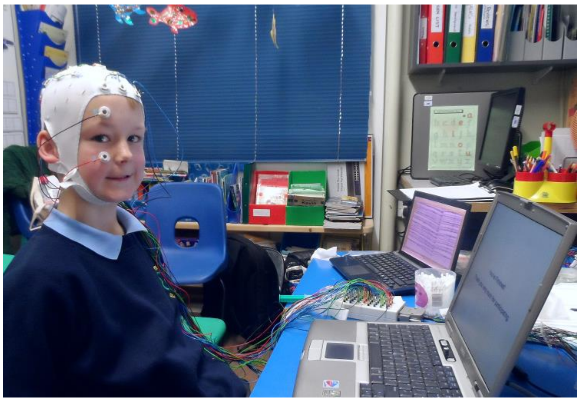
The experimental sessions will involve the following:

1. **Self report questionnaires**

The pupils will be asked to complete questionnaires about attention control skills, mindfulness, the experience of positive and negative emotions, emotion management and some background information including age, whether they are left or right-handed, language abilities and whether they have epilepsy or have had a brain injury in the past. After completion of the curriculum the pupils will be asked to fill in a form about how enjoyable they found the mindfulness curriculum. It will take about 15 minutes to fill in the forms each time. Pupils will be told that they can leave out any questions which they don't want to answer. The questionnaires will be completed in small groups or individually in school with support from the researchers (questions will be read aloud). Pupils will most likely keep a log about their mindfulness practice; we would like to ask for you and your child's permission to copy the log so that we can relate the amount of practice to possible changes in wellbeing. If in the unlikely event that your child becomes uncomfortable for any reason during the testing sessions then school policy will be followed, this will involve informing the child's school teacher who will then take the further appropriate steps.

2. **Brain and body function measures**

Along with the questionnaires, we would also like to measure how mindfulness impacts upon the brain functions and body functions related to attention control and wellbeing using a portable EEG (electroencephalography) system. This system measures brain waves using a stretchy cap containing sensors (electrodes) which is placed on the head; this measures the brain signal which is naturally present on the surface of the scalp all the time. Your child will be asked to brush their hair with a hairbrush which we will provide (each child will receive their own which can be kept after completion of the project). The cap will be fitted and some medical alcohol will be



applied at different points on the scalp as a cleanser, followed by a hypoallergenic gel (consisting of water, sterilised fine sand and jellifying agent). Two sensors (electrodes) will be placed above and below one eye to monitor the eye blinks during the experiment. Brain wave measures will be taken whilst the pupils complete two computerised tasks (similar to simple computer games). These tasks will involve making keyboard responses to the presentation of some happy, angry and neutral faces and some environmental sounds. Each of the two tasks will take about thirteen minutes. Two sensors (electrodes) will also be placed on the forearms to measure the pupils' heart rate whilst they complete a short three minute resting task; this has been found to be a physiological indicator of wellbeing. After completion of the session, the pupils will have a chance to remove some of the gel from their hair using a wet towel. The remainder of the gel can be easily removed at home during hair washing.

These procedures are safe and have been conducted on hundreds of adults and children at the School of Psychology, Bangor University. In rare cases, even a gentle use of the electrolyte gel can result in a slight abrasion and temporary reddening of the skin on scalp. For this reason we frequently ask for feedback from our participants during the cap setup. If your child experiences any discomfort during the cap setup procedures, the testing will be stopped and the cap removed immediately. The EEG brain wave measures are taken for research purposes and the researchers are not trained to detect or interpret any disorders such as epilepsy using these measures.

What are the benefits for me?

The project offers the opportunity for pupils from your school to learn mindfulness practices from their teachers this year. We also hope that the research participation will be a useful educational experience for your child and provide them with initial first hand insight into neuroscience research. This project will also enable teachers from the participating schools, where children are currently not taught mindfulness, to learn how to teach mindfulness to their pupils next year. Your child's participation in this study will also help us to understand whether mindfulness can be used to support primary school children in managing their wellbeing skilfully. Your child will receive a small reward for their participation (stationary) after each research session.

Do I have to complete the study once I've started?

Your child's participation in the study is completely voluntary and your child is free to withdraw from participation at any time. Participation in this research project is in addition to receiving the mindfulness curriculum. Therefore the choice to decline participation in the research and withdrawal from the research will not have an impact on your child receiving the mindfulness curriculum or your child's status in the school. If at some point during the project you decide that your child should not continue their participation in the research then please contact the researchers. We will always ask each child if they want to participate in the research at the start of each research session, if they indicate they do not wish to continue their participation at the beginning or during the testing session then the child can withdraw immediately.

Will my information be safe?

All data will be kept safe and confidential and will only be accessible to the researchers conducting this study. Questionnaires will be stored in a locked filing cabinet at Bangor University and data from the experimental tasks (brain waves, heart rate, reaction time and accuracy rates) will be stored on a password protected computer at Bangor University. A randomly assigned code will be assigned to the questionnaires and electronic records in place of your child's name. A linking sheet will be used to link your child's name and code to keep track of the records across the three research sessions. The linking sheet will be stored separately from the questionnaires and will only be accessible by the Principal Investigator (PI) of the project. Only group data will be reported in the publications resulting from this study, and no individual participants will be identifiable. If you would be interested in hearing more about the results of this study after it's been completed (about nine months from now), please indicate this on your consent form. Standard safeguarding procedures will be followed in line with the school policy if a child confides in a researcher about any disclosure of abuse. This will involve informing the child's school teacher who will then take the further appropriate steps.

Is there a complaints procedure?

This study has been reviewed by the Bangor University ethics committee and the Research Ethics Committee, Bangor. In the event of complaints arising from the research; please address them to Mr. Hefin Francis, School Manager, School of Psychology, Bangor University, Gwynedd, LL57 2AS (h.francis@bangor.ac.uk).

If you have any further questions regarding the research project, please contact:

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Parent and Guardian Informed Consent Form

PLEASE KEEP A SIGNED COPY OF THIS CONSENT FORM AND THE INFORMATION SHEET FOR YOUR RECORDS.

Title of project:
Mindfulness in Primary Schools:
Assessment of attention and emotion regulation related changes in pupils

Investigators:

Ms. Rebekah Kaunhoven, Ph.D. student, School of Psychology, Bangor University
Dr. Dusana Dorjee, Lecturer and Research Lead, Centre for Mindfulness Research and Practice, School of Psychology
Prof. Guillaume Thierry; Professor of Cognitive Neuroscience, School of Psychology, Bangor University
Ms. Kevanne Sanger, Ph.D. student, School of Psychology, Bangor University
Ms. Shelby DeMeulenaere; PhD student, School of Psychology, Bangor University
Ms. Thy Thi Uyen Nguyen; MSc student, School of Psychology, Bangor University

This is to certify that I, ……………………………..………….…………….., hereby agree for my child, ………………………………………………….. (print child's name), to participate as a volunteer in a scientific investigation conducted as an authorised part of the research ventures within the School of Psychology at Bangor University, under the supervision of Dr. Dusana Dorjee.

Items for your consent	Please initial below if you consent to the following statements
I understand the explanation of the investigation and my child's part in it as described in the information sheet. I understand that I can contact the researchers if I have further questions.	
The procedures of this investigation and any questions about risk to my child have been answered to my satisfaction.	
I understand that my child will have a cap with electrodes fitted on their head.	

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I know of no medical condition (epilepsy), which may cause adverse effects to my child if they participate in this experiment	
I understand that I am free to withdraw the consent for my child to participate and terminate my child's participation at any time without any adverse consequences.	
I understand that my child is free to not answer specific items on questionnaires without explanation.	
I understand that all data will be stored, analysed and published in a confidential manner with regard to my and my child's identity.	
I understand that I may request a summary of the results once this study has been completed.	
I agree for data from my child to be used in related future research, provided that the data is handled securely, respectfully, and confidentially.	

	Yes	No
It is often helpful to present photos and short videos of children practicing mindfulness and/or participating in research at research conferences, impact events about our research to audiences such as health-care professionals, policy makers and general public, and in publications reporting on our research. We would also like to illustrate our research with pictures and short videos on our Bangor University research website. Please indicate whether you agree for photos and short videos of your child to be used in these research-related activities.		

	Yes	No
Please indicate if you would like a summary of research results once the study has been completed? If, Yes, please also provide an email address where the information can be sent. ……………………………………………………………………………… ………………………………………………………………………………		

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Parent/ Guardian Consent

Signature ______________________________ Date ________________

Child's full name and provide attending school

Print child's full name ___________________________ School ______________

Investigator Consent

I, the undersigned, have fully explained the investigation to the above individual.

Signature ______________________________ Date ________________

In the event of complaints arising from this research, please address them to Mr. Hefin Francis, School Manager, School of Psychology, Bangor University, Gwynedd, LL57 2AS (h.francis@bangor.ac.uk).

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Title of project:
Mindfulness in Primary Schools:
Assessment of attention and emotion regulation related changes in pupils

Investigators:

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Ms. Thy Thi Uyen Nguyen; MSc student, School of Psychology, Bangor University
Ms. Ana Cristina Atanes; MSc student, School of Psychology, Bangor University

Purpose and background of this study:

This research project aimed to investigate the impact of mindfulness practice on well-being in pupils from key stage 2. Specifically, we looked at how mindfulness training influenced domains of well-being including emotion expression, positive and negative affect, anxiety, stress, reactivity/awareness, attention control and the ability to self-regulate. Previous research with adults has shown that practicing mindfulness can decrease stress, encourage positive emotions, and improve well-being. We investigated whether similar effects were experienced by children participating in a mindfulness program as part of the regular school curriculum in comparison to children who did not receive the mindfulness training. We also investigatedwhether the effects of mindfulness were similar or different across boys and girls, and collected children's views on using mindfulness in school.

The brain measures enabled us to investigate in more depth whether mindfulness practice resulted in some positive changes in brain areas involved in mind wandering and regulation of attention and emotions. The heart rate derived measures aimed to investigate whether any changes reported on questionnaires and changes in brain function also impacted on body physiology involved in stress responses and regulation of emotions.

Questions:

If you provided your e-mail address when agreeing for you and your child to participate in the study, you will be sent a summary of the research results when data analysis is complete. If you did not provide contact details but would like to receive a research summary, please contact us via e-mail or phone using the contact information below.

If you have further questions about how or why this research was conducted or would like more information about mindfulness research in general, please contact:

Rebekah Kaunhoven – psp233@bangor.ac.uk or 01248 382663
Dr. Dusana Dorjee – d.dorjee@bangor.ac.uk or 01248-383858

Thank you again for taking part in this research

PARTICIPANT LANGUAGE AND HANDEDNESS QUESTIONNAIRE

Please answer following questions. Your name will NOT appear on the questionnaire to assure confidentiality.

Participant Code: ________________ Date: __________________

1. How old are you? ___________________

2. I am a ☐ Girl ☐ Boy

3. Was English the first language you learned? ☐ YES ☐ NO
   If no, what is your first language?

   ____

4. Do you speak well any other languages? ☐ YES ☐ NO
   If yes, what are they?

   ____

5. Are you right or left-handed? ☐ Right Handed ☐ Left Handed ☐ Ambidextrous

6. Do you have epilepsy? ☐ YES ☐ NO

7. Did you have had a brain injury or a brain operation in the past?

   ☐ YES ☐ NO

THANK YOU!!!

Child and Adolescent Mindfulness Measure

We want to know more about what you think, how you feel, and what you do. **Read** each sentence. Then, circle the number that tells **how often each sentence is true for you.**

	Never True	Rarely True	Some-times True	Often True	Always True
1. I get upset with myself for having feelings that don't make sense.	0	1	2	3	4
2. At school, I walk from class to class without noticing what I'm doing.	0	1	2	3	4
3. I keep myself busy so I don't notice my thoughts or feelings.	0	1	2	3	4
4. I tell myself that I shouldn't feel the way I'm feeling.	0	1	2	3	4
5. I push away thoughts that I don't like.	0	1	2	3	4
6. It's hard for me to pay attention to only one thing at a time.	0	1	2	3	4
7. I get upset with myself for having certain thoughts.	0	1	2	3	4
8. I think about things that have happened in the past instead of thinking about things that are happening right now.	0	1	2	3	4
9. I think that some of my feelings are bad and that I shouldn't have them.	0	1	2	3	4
10. I stop myself from having feelings that I don't like.	0	1	2	3	4

Scoring Instructions: Compute total score on the CAMM by reverse scoring and summing all items.

PANAS-C (short version)

This scale has a number of words that describe different feelings and emotions. Read each item and then circle the best answer next to that word. Indicate to what extent you have felt this way during the past few weeks. There are no right or wrong answers.

		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
1.	Sad	1	2	3	4	5
2.	Happy	1	2	3	4	5
3.	Scared	1	2	3	4	5
4.	Miserable	1	2	3	4	5
5.	Cheerful	1	2	3	4	5
6.	Proud	1	2	3	4	5
7.	Afraid	1	2	3	4	5
8.	Joyful	1	2	3	4	5
9.	Mad	1	2	3	4	5
10.	Lively	1	2	3	4	5

Pre Post Follow up

Participant Code   Date

EESC

Here are some sentences which describe feelings. Think about how you felt over the last two weeks. Read each one and tick the best answer. There are no right or wrong answers

		Not true	**A little bit true**	**A bit true**	**Very true**	**Very very true**
1.	I prefer to keep my feelings to myself.					
2.	I do not like to talk about how I feel.					
3.	When something bad happens, I feel like exploding.					
4.	I don't show how I really feel in order not to hurt others' feelings					
5.	I have feelings that I can't figure out.					
6.	. I usually do not talk to people until they talk to me first.					
7.	When I get upset, I am afraid to show it.					

		Not true	A little bit true	A bit true	Very true	Very very true
8.	When I feel upset, I do not know how to talk about it					
9.	I often do not know how I am feeling					
10.	People tell me I should talk about my feelings more often.					
11.	Sometimes I just don't have words to describe how I feel.					
12.	When I'm sad, I try not to show it.					
13.	Other people don't like it when you show how you really feel.					
14.	I know I should show my feelings, but it is too hard.					
15.	I often do not know why I am angry.					
16.	It is hard for me to show how I feel about somebody.					

Mind Wandering questionnaire

(administered verbally by the experimenter after each block of the mind wandering task)

1. Did you find yourself mind wandering during this part of the task (**block 1**)?

☐ Never

☐ Very rarely

☐ Rarely

☐ Often

☐ Very often

☐ Always

2. Did you find yourself mind wandering during this part of the task (**block 2**)?

☐ Never

☐ Very rarely

☐ Rarely

☐ Often

☐ Very often

☐ Always

3. Did you find yourself mind wandering during this part of the task (**block 3**)?

☐ Never

☐ Very rarely

☐ Rarely

☐ Often

☐ Very often

☐ Always

Attentional Control Scale for Children (ACS-C)

		1 Almost never	2 Sometimes	3 Often	4 Always
1.	It's very hard for me to concentrate on a difficult lesson, if there is a lot of noise in the class	○	○	○	○
2.	If I have to concentrate and solve a difficult maths problem, I have trouble focusing my attention	○	○	○	○
3.	When I am working hard on something, I still get distracted by things going on around me	○	○	○	○
4.	My concentration is good, even when somebody turns the music on*	○	○	○	○
5.	When I concentrate, I do not notice what is happening in the room around me*	○	○	○	○
6.	When I am reading in the classroom, I am easily disturbed by other children talking to each other	○	○	○	○
7.	When I try to concentrate, I find it difficult not to think about other things	○	○	○	○
8.	I find it difficult to concentrate when I am excited about something	○	○	○	○
9.	When I am concentrating, I do not notice when I am hungry or thirsty	○	○	○	○
10.	When I am doing something, I can easily stop and switch to another task*	○	○	○	○
11.	When I have to start a new task, it takes me a while to get really involved in it	○	○	○	○

		1 Almost never	2 Sometimes	3 Often	4 Always
12.	When the teacher explains something, I find it difficult to understand it and write it down at the same time.	○	○	○	○
13.	When it is necessary, I can become interested in a new topic very quickly*	○	○	○	○
14.	It is easy for me to read or write, while I am also talking to someone on the telephone*	○	○	○	○
15.	I have trouble having two conversations at the same time	○	○	○	○
16.	I find it difficult to come up with new ideas quickly	○	○	○	○
17.	After being interrupted or distracted, I can easily shift my attention back to what I was doing before*	○	○	○	○
18.	When I am daydreaming or having distracting thoughts, it is easy for me to switch back to the work I have to do*	○	○	○	○
19.	It is easy for me to switch back and forth between two different tasks*	○	○	○	○
20.	I find it difficult to let go of my own way of thinking about something, and look at it in a different way.	○	○	○	○

Scoring

*Reversed items.
A total attentional control score can be obtained by summing across all items (after recoding reversed items). Higher scores are indicative of lower levels of attentional control.
Items 1, 2, 3, 4 (R), 5 (R), 6, 7, 8, and 9 (R) = Attentional focusing
Items 10 (R), 11, 12, 13 (R), 14 (R), 15, 16, 17 (R), 18 (R), 19 (R), and 20 = Attentional shifting

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Note

The ACS-C is an age-downward version of the Attentional Control Scale. See: Derryberry, D., & Reed, M.A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, *111*, 225-236.

Post

Participant Code
Date

A - Questions

---

1. Did you like doing mindfulness in school?
   Please tick one box

Not at all — Very much

1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

2. How often did you practice mindfulness outside of the school lessons (at home)?

- ☐ Never
- ☐ Rarely
- ☐ Often
- ☐ Every day

3. Would you like to carry on doing mindfulness in school?
   Please circle your answer?

   Yes Maybe No

4. Can you tell us what you liked about doing mindfulness?

…………………………………………………………………………………………..

…………………………………………………………………………………………..

5. Can you tell us what you didn't like about doing mindfulness?

…………………………………………………………………………………………..

…………………………………………………………………………………………..

Appendix Contents

Appendix 1

Kaunhoven, R. J., & Dorjee, D. (2017). How does mindfulness modulate self-regulation in pre-adolescent children? An integrative neurocognitive review. *Neuroscience & Biobehavioral Reviews, 74,* 163-184. doi: 10.1016/j.neubiorev.2017.01.007.

Appendix 2

Happy, angry and neutral face stimuli taken from the Karolinska faces data base

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces (KDEF). *CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet*, 91-630.

Appendix 3

NHS ethics approval letter

Appendix 4

Approved ethics application from the School of Psychology, Bangor University

Appendix 5

Parent information sheets, consent forms and debrief forms

Appendix 6

Self-report assessments administered during the project

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