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碩士論文

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Master Thesis

正念減壓課程對於情緒調節歷程影響之事件相關電位研究

How does Mindfulness-Based Stress Reduction (MBSR) training influence emotion regulation process: An EEG study

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致謝

這個研究能夠好好地被執行實是得來不易。有時候覺得很神奇，當初一個萌芽的想法能夠因著這麼多人的幫助及投入鋪展開來: 首先要謝謝建德老師，是老師歡心接納做這樣完全沒有接觸過領域的研究，還帶著我去找認識的古慧瑄心理師，最後接觸到華人正念減壓中心。懵懵懂懂什麼都不了解的我，就這樣開啟了跟中心的合作。雖然實體見面的機會不多，但中心的負責人君梅老師以及行政人員 Teresa 是那樣熱情熱心，願意張開雙手溫暖的支援我們，甚至願意在我們經費不足的情況下自己吸收上課的成本以及增加許多行政聯絡的心力。我很難想像自己有這樣的緣分能夠遇到這樣好的合作單位!我也非常感激幫忙上課的瓊月老師，感覺讓老師多了很多教學，謝謝瓊月老師願意接這麼多的課程。

對於我的指導教授建德老師與恩賜老師，我很感激老師們的包容與幫助，他們也總是給我許多建議與思索的引子。在撰寫論文的過程中我才發現要去好好說出來這個故事有多麼困難，也是因為老師們不斷對於論證過程的反饋我才去意識到我原先整個思想的系統有多少漏洞，於是只好於腦中不斷與相互矛盾的想法、尷尬的空白相互糾纏，糾纏了一陣子吐出了東西再被打回然後繼續思考(很謝謝老師打回我才看到原先的架構多麼搖搖欲墜)，雖然我仍然寫得不是很好，但在過程中希望也有不知不覺更精進了思考。我也要謝謝所有在研究中幫助我的朋友，每當我思考論文到打結而忍不住撥通電話或送出訊息，謝謝在電話那頭或訊息那端耐心真摯的你們，謝謝你們讓我在孤獨的過程中感覺被承接，能夠感受到還有人陪我走著這段路，真好。我也很感謝預口試的時候仁和老師、君梅老師從研究以及應用的角度給了我對於正念更清楚的認識，讓我在寫作時能夠拿出來反芻思量。

其實在研究所的這兩三年我是處於有些迷茫迷失的狀態，但也因為這樣讓我好像不得不向內探索，去進行跟自己的對話，去重建自己跟自己的關係。在歷經了那些低潮後回首來時路，我發現我竟然比起以前是能夠在心態上更有餘裕的生活著。雖然要承認自己沒有好好練習正念，但好似有漸漸學會接納自己一些，把那些自己跟自己打架的力氣省下來，能夠更自在的體驗人生。

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中文摘要

研究動機與目的:

正念減壓(Mindfulness Based Stress Reduction, 簡稱 MBSR)是由卡巴金博士 (Dr. Kabat-Zinn)於美國麻州大學醫學院所發展出的結構化課程，已有許多文獻指出其對心理健康、壓力與臨床精神症狀的正面影響並且可以改善個體情緒調節的能力。過往研究提出諸多模組探討正念訓練如何對心理與腦部產生變化進而影響情緒調節機制，但鮮少有實證研究直接量測個體如何透過正念訓練課程在情緒調節的神經歷程上有所變化。本研究旨於探討正念減壓課程如何影響個體情緒調節的神經歷程有關之變化。

研究方法:

27 位受試者於正念減壓課程前後進行相關心理問卷的評估與腦電波情緒調節實驗。受試者運用以自我為焦點的認知再評估（self-focused reappraisal）與開放監控（open monitoring）二種策略來面對正向與負向的情緒圖片，研究進而分析與情緒反應有關的事件關聯電位- 晚期正電位（Late Positive Potential, LPP）來探索在情緒調節過程中的情緒反應與認知資源的投入程度。

研究結果:

本研究顯示正念減壓課程能帶來正念特質與心理健康的提升。在情緒調節作業中此訓練則會使情緒效價（Valence）趨於中性並降低喚起（Arousal）程度。self-focused reappraisal 與 open monitoring 在處理負向圖片上於訓練後皆增進對 centroparietal LPP 的調節效果，降低情緒的強度。而 self-focused reappraisal 在處理負向圖片上於訓練後另也有增加對 frontal LPP 的調節效果，減少認知資源的投入程度。

研究結論：

本研究驗證了正念減壓對心理健康的影響，且顯示短期八周正念減壓課程對於 self-focused reappraisal 在情緒調節程度上於 centroparietal LPP 及 frontal LPP 皆有明顯增進的效果，能降低情緒反應與認知資源的投入。而 open monitoring 則可能需要更長期的正念訓練及練習來促進對情緒反應及認知資源的調節程度。

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ABSTRACT

Objectives

Past studies showed Mindfulness-based Stress Reduction (MBSR), a program focusing on cultivating awareness to the current moment without judgment, has positive influence on mental health and improved emotion regulation capabilities. But few studies unfolded how MBSR leverage the neuropsychological process under emotion regulation. The present study aimed to explore the change during emotion regulation process with an eeg-derived index- Late Positive Potential (LPP) before and after the MBSR training.

Methods

We recruited 27 participants (age = 42.26 (7.81)) who received 8-week MBSR. Training outcomes were evaluated through questionnaires and the LPP responses while performing an emotion regulation task in which participants were required to use either the self-focused reappraisal or the open-monitoring strategy to respond to given emotional pictures. EEGs were recorded when participants were performing the emotion regulation tasks and the LPP over the centroparietal and frontal scalp regions were analyzed.

Results

First, participants showed improved trait mindfulness, subjective well-beings and emotion regulation capabilities after MBSR training. Second, the MBSR training enhanced the neutralization of emotional valences and reduced emotional arousals of emotional stimuli in performing the emotion regulation task. The magnitudes of the centroparietal LPP due to emotional downregulation during self-focused reappraisal and open monitoring strategies were both larger after MBSR training. In contrast, the magnitudes of the frontal LPP due to emotional downregulation decreased only during self-focused reappraisal, but not open monitoring, after MBSR training, potentially reflecting a lower recruitment of cognitive effort.

Conclusions

As an immediate effect following the 8-week MBSR training, the emotional downregulation effect through self-focused reappraisal showed significant improvement, as evidenced by the decreased emotional intensity and reduced cognitive resources in processing negative emotional stimuli. Furthermore, it may take longer periods of MBSR practices to show clear improvement in the emotional downregulation process through the open-monitoring strategy.

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Chapter 1 Introduction

Mindfulness-based Stress Reduction(MBSR), developed by Jon Kabat-Zinn in 1979, is a structural program focusing on the practice about attending to the current moment with a non-judgmental attitude. This program has been applied to diverse populations like chronic pain, cancer, multiple sclerosis and psychiatric disorders, to improve their psychological well-being and somatic symptoms (Rosenzweig et al., 2010; Lengacher et al., 2009; Kolahkaj & Zargar, 2015; Goldin & Gorss, 2010; Biegel, Brown, Shapiro & Schubert, 2009). Although many psychological and neurobiological models have been proposed to elucidate mindfulness emotion regulatory mechanisms, no studies directly focused on providing empirical evidence in the neural mechanism of how mindfulness training leverage the neural emotion regulation process. The present study aimed to adopt an electroencephalogram (EEG)-derived index, centroparietal and frontal late positive potential (LPP) to shed a light on the MBSR training effect on the neural temporal process of top-down control and emotion reactivity during emotion regulation.

1.1 MBSR improves well-being and emotion regulation

An early meta-analysis (Grossman, Niemann, Schmidt & Walach, 2004) investigating the effect of MBSR have shown that mental health variables (calculated by 771 people for their psychological well-being and symptoms such as depression, anxiety and quality of life) yielded significant Cohen's d effect sizes of 0.56 in patient studies and 0.53 of non-patient studies. A recent study also demonstrated moderate effectiveness of MBSR for healthy individuals in pre-post analyses and in between-group analyses (Khoury, Sharma, Rush & Fournier, 2015), the former showing the effect size of Hedge's g of 0.53 and the latter showing Hedge's g of 0.55. It further suggested that MBSR brought

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a large effect on stress reduction and a medium effect on depression, distress, anxiety and quality of life.

MBSR could promote one's mindfulness disposition (Shapiro, Brown, Thoresen, & Plante, 2011), making one adopt more acceptive and non-reactive awareness on current experience. Some emotion regulation capabilities were reported to mediate between trait mindfulness and mental health outcomes, with rumination mediating the relation between mindfulness and anxiety as well as depression while reappraisal serves as a mediator between mindfulness and depression (Desrosiers, Vine, Klemanski & Nolen-Hoeksema, 2013). Trait mindfulness could also predict the effectiveness of downregulating sad mood in both instructed reappraisal and open-monitoring conditions (Keng, Robins, Smoski, Dagenbach & Leary, 2013). In an fMRI study, an individual's level of trait mindfulness covariate with the degrees of correlation between the dmPFC/amygdala and behavioral success of the cognitive reappraisal process (Modinos, Ormel & Aleman, 2010). the MBSR trainings itself also had empirical evidence on influencing emotion regulation as decreasing difficulty in emotion regulation, reducing maladaptive (like catastrophizing and rumination) and promoting adaptative emotion regulation strategies (like cognitive reappraisal) (Hölzel et al., 2016; Robins, Keng, Ekblad & Brantley, 2012; Shahidi, Akbari & Zargar, 2017; Garland, Gaylord & Fredrickson, 2011; Campbell, Labelle, Bacon, Faris, & Carlson, 2012; Rayan & Ahmad, 2016).

There were some psychological models explaining training effects on Mindfulness-based Interventions (MBIs) (for a review, see Grecucci et al., 2017). For MBSR, the components of the program contents are tied to Shapiro, Carlson, Astin and Freedman (2006) and Baer, Smith, Hopkins, Krietemeyer & Toney (2006) s' models, which focus on intentional practices of directing attention to the present moment with acceptance and through instructing one to put the practices into daily life, practitioners learn to act with

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awareness and discriminate transient mental state. Shapiro et al. (2006) also proposed that a *shift in perspective* would come out as a meta mechanism, in which we don't immerse ourselves in the internal experience and instead adopt a more detached perceiving viewpoint.

1.2 Possible Neural Mechanisms of how the MBSR training influences emotion regulation

From a neurophysiological perspective, MBSR seems to involve both top-down and bottom-up neural systems to modulate emotional response (Tang, Hölzel, & Posner, 2015; Grecucci et al., 2017; Hölzel et al., 2011; Chiesa, Serrett & Jakobsen, 2013). For top-down processing, more activation of cognitive control neural substrates like lateral prefrontal cortex and inferior parietal lobule are recruited after MBSR during emotion processing paradigms such as sad induction or affect labeling (Farb et al., 2010; Hölzel et al., 2013; Allen et al., 2012), serving as explicit emotion regulation (Grecucci et al., 2017). Bottom-up emotion processing after mindfulness-based training included increased activation of interoception and emotion processing with the involvement of insula and the subgenual anterior cingulate cortex(sgACC) in pain and emotion induction or affective Stroop tasks (Allen et al., 2012; Farb et al., 2010; Zeidan et al., 2015) or decreased amygdala activation during affect labeling or emotion induction (Hölzel, 2013; Desbordes et al., 2012). The brain regions related to implicit emotion regulation, such as mPFC were also activated during MBSR (Allen et al., 2012; Farb et al., 2010; Zeidan et al., 2015). Overall, for mindfulness-based training, beginners were reported to lay more on top-down processing routes for they need more cognitive resources to overcome habitual reactions to emotions while experienced practitioners take more bottom-up processing approach for they "automate an accepting stance toward their experience without control efforts" after long-term practice (Chiesa, Serrett & Jakobsen, 2013).

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The change of these brain activity under mindfulness-based training overlapped with the Central Executive Network (CEN), Salience Network (SN) and Default Mode Network (DMN), and thus at a high-cognition level, mindfulness-intervention seemed to influence the within or between intrinsic functional connectivity of these three networks (Doll, Hölzel, Boucard, Wohlschläger & Sorg, 2015; Taylor et al., 2013; Berkovich-Ohana, Glicksohn, & Goldstein A., 2014). Because SN serves as a filter to salient stimuli and passes to CEN and DMN for further goal-directed or self-referential processing (Menon, 2011; Menon, 2015), it seems mindfulness training like MBSR train the CEN to effectively focus on the current moment through breath-focused and open-monitoring practice (Hasenkamp, Wilson-Mendenhall, Duncan & Barsalou, 2012; Farb et al., 2007). Based on gradual cultivation on a non-judgmental glance at the internal experience, one might facilitate SN sensitivity but also change the encoded salience of emotional stimuli to lower level of self-reference and decrease related emotion reactivity (Doll et al., 2015).

1.3 Self-reappraisal and open-monitoring - LPP as a neuromarker

From the studies above, the underlying mechanism of how the MBSR training effect may modulate emotional processing has been demonstrated. However, previous empirical studies usually used emotion processing tasks that did not directly induce emotion regulation processing, such as passive viewing the emotional pictures or labelling the presented emotional stimuli. To capture fine changes on the emotion regulation process through MBSR, the present study aimed to track specific emotion regulation strategy processes before and after the programs. Because MBSR mainly focuses on being aware of human internal experience and may shift in perspective to a more decentering trajectory , it is intriguing to know how this internal-oriented practice changes the emotion

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regulation process that also deploy internal cues. Adaptative emotion regulation strategies seldom focus on internal cues, such as situation-focused reappraisal and distraction seeking external environmental cues to downregulate emotions. But SELF-FOCUSED REAPPRAISAL, on the contrary, intends to break off the relation between oneself and affective stimuli to detach from emotion reactivity, which is consider an internal-focused strategy (Ochsner et al., 2004). This reappraisal approach was seldom reported on its change under the MBSR training. On the other hand, mindfulness itself can also serve as a sort of emotion regulation strategy (Grecucci et al., 2017). Here we focused on a practice form called OPEN-MONITORING (Lutz, Slagter, Dunne & Davidson, 2008), which refers to non-judgmentally observing one's body sensation, emotion and thoughts and ought to fall into the internal-focused genre.

To capture subtle change of transient emotion regulation process, there is an electroencephalogram (EEG)-derived index called centroparietal Late Positive Potential (LPP) that can be utilized to measure the temporal dynamic change of transient emotion regulation process and further reflect emotional salient-related reactivity. LPP was an event-related potential component starting from 300ms to 400ms with an upgoing slow wave located maximally at centroparietal sites after the emotional stimuli onset and lasts until pictures disappear (Cuthbert, Schupp, Bradley & Birbaumer & Lang, 2000). This component represents for motivated attention to emotionally salient stimuli (Schupp, Flaisch, Stockburger & Junghöfer, 2006), showing enhanced amplitudes towards high arousal negative and positive visual stimuli compared to neutral stimuli. The amplification of centroparietal LPPs can be downregulated by some emotion regulation strategies regardless of negative or positive valence (Hajcak, Dunning, Foti & Weinberg, 2014; Thiruchselvam, Blechert, Sheppes, Rydstrom & Gross, 2011; Krompinger, Moser & Simons, 2008). Previous studies showed self-reappraisal LPPs elicited by negative

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pictures would reduce amplitudes compared to passive viewing negative pictures. (Qi et al., 2017; Thiruchselvam et al., 2011). Only one study explored the downregulating effect of reappraisal towards pleasant stimuli (combining self-focused and situation-focused reappraisal, which reinterprets the situation to regulate emotional reactivity) and reduced amplification of LPPs was also exhibited (Krompinger et al., 2008). These findings indicated self-reappraisal could downregulate emotional reactivity in the brain. As to open-monitoring, a study suggested enhanced LPP amplitudes during emotional picture processing in the first session of pictures compared to passive viewing, but this phenomenon decreased in next two sessions of pictures and during re-exposure, which might implicate mindful emotion regulation could enhance salience sensitivity when first exposed to emotional stimuli and through non-judgmental observing one's mental state, LPP activation tended to decrease (Uusberg, Uusberg, Talpsep & Paaver, 2016).

At frontal electoral sites, LPPs are also found with the same latency during emotion regulation process and can be measured as an index of cognitive resources consumption (Moser, Hartwig, Moran, Jendrusina & Kross, 2014; Shafir, Schwartz, Blechert & Sheppes, 2015). Like situation-focused reappraisal were reported to induce higher frontal LPPs than passive viewing the negative pictures in some studies (Moser et al., 2014; Qi et al., 2017), indicating more attentional control in this strategy. As to the strategies we were interested in the current study, only self-focused reappraisal but not mindfulness has been reported in previous research about its frontal LPP characteristics, for a study showed more reduced frontal LPP amplitudes elicited by disgusting pictures compared to passive viewing (Ma et al., 2019) and another study exhibited no frontal LPP difference elicited by negative pictures between self-focused reappraisal and passive viewing (Qi et al., 2017), implicating adopting this strategy wouldn't recruit more cognitive resources than just attending to the emotional stimuli.

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Although little investigation carried out for mindfulness-based training modulation on LPP, there were some studies investigating the relationship between stable trait mindfulness and centroparietal LPP amplification. From studies by Brown, Goodman, & Inzlicht (2013) and Lin, Fisher, Roberts & Moser (2016), the amplitudes of LPP showed a negative correlation with trait mindfulness, indicating lower amplification for higher mindful people. Experienced meditators also demonstrated more reduced LPP amplitudes than controls (Sobolewski, Holt, Kublik, & Wróbel, 2011) when viewing emotional pictures. This implicated the MBSR training may also tend to reduce emotion intensity marked with LPPs. Because 8-week MBSR keeps letting one learn mindful detachment and dereification (not immersed in subjective realism) toward ones' internal experience through different kinds of practice. This training effect might reflect on the process of self-focused reappraisal and open-monitoring as these two strategies both make participants hold a more objective way either toward emotional stimuli or one's own emotions in mind.

In the present study, we aimed to explore the change of emotion regulation process by measuring centroparietal and frontal LPP and one's subjective rating of their arousal and valence state elicited by negative and positive stimuli during self-reappraisal and open-monitoring strategies before and after the MBSR programs to examine the training effects on the negative and positive emotion regulation process of these two strategies. While originally open-monitoring strategy wouldn't show the regulatory effect on centroparietal LPP (Uusberg et al., 2016) and self-reappraisal did modulate the amplification, we hypothesized that after the MBSR training, both open-monitoring and self-reappraisal would display the trend of decreased centroparietal LPPs compared to the pretest. For frontal LPPs, we hypothesized that self-focused reappraisal would show a more reduced frontal LPPs compared to the pretest for MBSR would improve attention-

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related network and make a more effective way to recruit cognitive resources. But for open-monitoring, we hypothesized both before and after the MBSR, it would result in higher frontal LPP amplification since open-monitoring might still rely on cognitive control for the beginners with short term practice. Moreover, we also speculated pre-post regulatory changes centroparietal/ frontal LPPs during open-monitoring and reappraisal would correlate with each other for both might relate to shifting in perspective towards internal experience through MBSR. Also, we hypothesized that trait mindfulness would show a trend of negative correlation with these pre-post regulatory changes centroparietal/ frontal LPPs.

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Chapter 2 Methods

2.1 Participants

The study was approved by the National Taiwan University Hospital (NTUH) Research Ethics Committee (REC). Twenty-seven healthy novice participants (24 females) with a mean age of 42.26 years (SD=7.81; range = 25-56 years) were recruited from 8-week Mindfulness-based Stress Reduction (MBSR) programs at the Chinese MBSR Service Center. The gender ratio of participants was unequal because female members in the MBSR course took up the majority. They all had no prior experience of mindfulness-based training. After entering the laboratory, participants completed an informed consent and received NT$650 dollars for their participation after finishing the experimental procedure. Participants needed to conduct behavioral psychological questionnaires and the EEG recording experiment before and after 8-week MBSR programs. To minimize potential confounding effects from different scanning/evaluation time across participants, all participants would complete all evaluation within 4 weeks. The MBSR course would include an orientation before the first class, 8 weekly classes for the core mindfulness learning and a whole-day practice. The one-day practice would be held during session 6 and session 7. MBSR practices increased the awareness of body sensations, thoughts and emotions and improved the mind and body connection. The MBSR course typically included the following sessions:

- Orientation. In this session, the group leader will provide an introduction about mindfulness, MBSR, a brief history of mindfulness training, the risks of taking this course, and all the logistics.
- Session 1. Introduction to the practices of body scan, awareness of breathing, eating meditation, and 10-15 minutes sitting meditation.

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- Session 2. Review the practices of session 1 and discussing the home assignments. Introduction to the awareness of perception and 15-20 minutes sitting meditation.
- Session 3. Learning the practices of lying-down yoga, walking meditation, and 20-25 sitting meditation. Introduction to the awareness of body sensation, thoughts and emotion, especially the pleasant ones.
- Session 4. Learning the practices of standing-yoga and 25-30 sitting meditation. Awareness of unpleasant emotions and stress reactions.
- Session 5. Some mindful stretches and longer sitting meditation with the 5 different aspects of awareness: awareness of breathing, awareness of the body as a whole, awareness of listening, awareness of thoughts, and open awareness. Introduction of stress and the differences between reacting to stress and responding to stress.
- Session 6. Sitting mediation with fewer verbal guidance and some mindful stretches. The practice of mindful listening and communication to increase the awareness of interpersonal relationships.
- One-day mediation. A whole day of mindfulness practices and awareness with guidance but in silence, including body scan, standing and lying-down yoga, sitting meditation ,etc.. There are two more practices, mountain meditation and loving-kindness meditation.
- Session 7. A combination of practices like stretches and sitting meditation. Introduction to the practice of changing the seat to improve the awareness of position.
- Session 8. Reviewing all the practices and highlighting the relationship between the practices and moment-to-moment awareness that improves the quality of being, the relationship between mind and body and how they interact, and also the relationship between stress reactions and stress responses.

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2.2 Questionnaires

To make sure the MBSR training accords with previous studies of improved dispositional mindfulness and psychological well-being as well as explores if MBSR promotes emotion regulation capabilities at the behavioral level, related questionnaires were measured in the present study.

Trait Mindfulness

To evaluate participants' dispositional mindfulness, mindfulness-related questionnaires, The Five Factor Mindfulness Questionnaire (FFMQ) and The Mindful Attention Awareness Scale (MAAS), have been included. The Mindful Attention Awareness Scale (MAAS) (Brown & Ryan, 2003) comprises 15 items to assess an individual's awareness of present experience with a 6-point Likert scale. The Chinese version was developed by 張仁和、林以正& 黃金蘭 (2011). The 39-item Five Factor Mindfulness Questionnaire (FFMQ) using a 5-point Likert scale to measure five mindfulness constructs: Observe, Describe, ActAware, Nonjudge and Nonreact (Baer et al., 2006). Each facet is assessed with 8 items except for Nonreact (7iems). FFMQ scores can be calculated for total scores and subscale scores.

Emotion regulation capability

The Response Style Questionnaire (RSQ) (Nolen-Hoeksema, & Morrow,1991). and the Emotion Regulation Questionnaire (ERQ) (Gross and John, 2003) were selected to validate whether mindfulness training could change emotion coping strategies. The Response Style Questionnaire(RSQ) contains 52 items used 4 scale points to measure an individual's tendency to distract or ruminate towards negative emotions. It comprises of two subscales: Rumination and Distraction, the former with 32 items and the latter with

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20 items. The 10-item ERQ using 7 scale points to assess one's habitual tendency to use emotion regulation strategies of cognitive reappraisal and expressive suppression.

Well-being outcomes

To examine one's psychological well-being, the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977) and the Satisfaction with Life Scale (SWLS) (Diener, Emmons, Larsen & Griffin, 1985) has been selected. The Center for Epidemiologic Studies Depression Scale (CES-D) uses 20 items of 4-point scales to measure one's level of depressed feelings over the past 7 days. The Satisfaction with Life Scale (SWLS) consists of 5 items used a 7 Likert scale, assessing one's subjective well-being in life. The Chinese version of the CES-D was developed by Chien and Cheng (1985) and the Chinese version of the SWLS was developed by Wu and Yao (2006).

2.3 Materials

A total of 222 pictures (105 positive/ 117 negative) were selected as experimental stimuli from the International Affective Picture System (IAPS) with positive and negative valence ratings (Valence: 2.25 (0.30) for negative pictures, 7.62 (0.30) for positive pictures; Arousal: 5.92 (0.66) for negative pictures, 4.90 (0.90) for positive pictures). Positive and negative pictures are divided into three sets in random (each set 74 pictures). These three sets were randomly assigned to the Attend, Open-monitoring and Reappraisal condition for respective participants in advance. To separate the neurophysiological effects of visual processing from emotional-related processing, one set of the pictures were replicated and randomized the pixels to build a picture set which didn't contain emotional meaning (Neutral).

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2.4 Procedure

Participants came to the laboratory in the department of occupational therapy at National Taiwan University before and after MBSR programs to complete questionnaires and EEG experiments. They first filled out the questionnaires and were then fitted with 64-channel Quick-cap by Neuroscan. Participants were then informed of the whole experiment procedure briefly. The EEG experiment using the *emotion regulation task (ERT)* paradigm modified from the study by Taylor et al. (2011). **Figure 1** illustrated the task procedures. The task consisted of four condition types with 74 trials for each condition: Neutral , Attend, Open-monitoring and Reappraisal. The task was a block design that always began with the Neutral condition and the Attend condition as the first two blocks, avoiding carry-over influence from the two emotion regulation condition (Open-monitoring and Reappraisal). The order of Open-monitoring and Reappraisal conditions were counterbalanced across participants. In addition, for each participant, the order of Open-monitoring and Reappraisal conditions were switched at the posttest stage. To reduce the influence of fatigue on task performance due to long EEG recordings, trials in the Neutral condition were divided into 4 runs, and trials in the Attend, Open-monitoring and Reappraisal condition were each divided into 6 runs.

Before each block started, instructions for a certain condition type would be presented on the screen and further explanation of that instruction would be played in audio recordings. For the Attend, Open-monitoring and Reappraisal conditions, 8 practice trials were provided to make participants familiar with the strategy. The researcher also interviewed participants to ensure they understood how to apply the strategies. For formal trials, participants fixated a white dot in the center of the screen and each picture was presented for 5 seconds, with inter-trial intervals jittered from 2.5~4 seconds. After pictures disappeared, participants answered if they understood the content of the pictures

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pand rated valence and arousal of their emotion with a 9-point scale. When finishing the whole task at the pretest, participants would additionally receive an email giving them a link to an online form listed all emotional pictures in the task. They would rerate valence and arousal elicited by each picture at home by just attending to the stimuli without any strategy, providing an original rating of each picture to examine if there was a cultural effect.

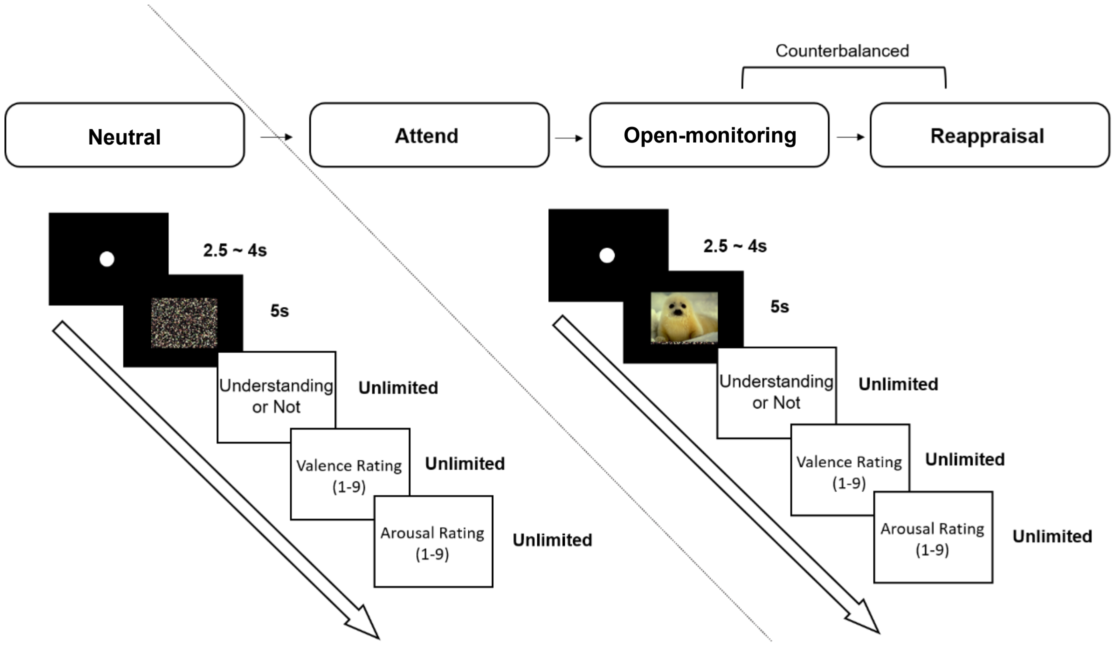

Figure 1 Stimuli sequences for the Neutral, Attend, Open-monitoring and Reappraisal condition.

2.5 Instructions

Before experiment, the instructions of all conditions were debriefed through audio-visual presentation in Mandarin. For the attend condition, participants were asked to just naturally and attentively view pictures and not to try to change their feelings. For the Reappraisal condition, participants were instructed to have a detached, objective mindset that the situation of the pictures has no relation to themselves. For the Open-monitoring

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condition, participants were instructed to observe their current body sensation, emotion and thoughts while viewing pictures of emotional contents with an openness, non-judgmental attitude. They would need to focus on their internal experience at the present moment. They were also told that if somehow they find themselves fall into mind wandering, they could just gently focus back to the current momentary experience

2.6 EEG recordings

EEG activity was collected from 64 Ag/AgCl electrodes using a Neuroscan Quik-cap (Compumedics, Inc., Charlotte, NC) based on a standard 10/ 20 system and intermediate positions. Vertical and horizontal eye movements were recorded as electrooculogram (EOG) signals with four additional electrodes placed on the outer canthus of both eyes as well as above and below the left orbit. The recordings were digitized at 500 Hz and band-pass filtered at 0.1 to 100 Hz to avoid line noise artifacts. Continuous data were online referenced to a reference electrode between CZ and CPZ and offline re-referenced to the average of the left and right mastoids. Electrode impedance was below 5 kOhm.

2.7 Data Analysis

Questionnaires and Subjective Rating

Changes of the averaged item scores from various subscales in the MAAS, FFMQ, RSQ, ERQ, CES-D, and SWLS between the pre-MBSR and post-MBSR stage were analyzed by paired t-tests and Cohen’s d. The correlation of score changes among different questionnaires were further analyzed by the Pearson’s correlation analysis. The subjective valence and arousal ratings for all emotional pictures used in the emotion regulation task was first evaluated within the current participant pool to see whether these

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emotional pictures from IAPS were effective to induce designated emotions. Next, differences of subjective valence and arousal ratings for the negative and positive pictures in the attend, reappraisal and open-monitoring conditions between pre- and post-MBSR training were analyzed in a repeated-measured ANOVA with a 3(Strategy: attend, open-monitoring, reappraisal) × 2(Valence: Positive, Negative) × 2(Time: pretest, posttest) design. Specifically, to quantify how neutralized one experienced for a given picture after emotional regulation, we extract the 'neutral-corrected valence rating' (ncVR) by subtracting the subjective ratings with 5. To be able to directly compare the ncVR between positive and negative pictures, the neutral-corrected valence rating scores for the negative pictures were multiplied by -1.

EEG preprocessing and Event-Related Potential (ERP) Analysis

Offline analysis was conducted using the EEGLAB, ERPLAB and FieldTrip toolbox (Delorme & Makeig, 2004; Lopez-Calderon & Luck, 2014; Oostenveld, Fries, Maris & Schoffelen, 2011). EEG recordings were first preprocessed with EEGLAB and ERPLAB, MATLAB toolboxes. Epochs were generated from 1s before the onset of randomized-pixel/ emotional pictures to 5 s when pictures disappeared, and baseline correction was processed using -500ms to -100ms time window. For artificial signals, the contaminated epochs were selectively screened out by hand. The channels which consisted of continuous noise recordings would also be removed and interpolated by signals at surrounding electrodes. Because holding a stare without blinking for 5s was difficult for participants, we conducted independent component analysis (ICA) and implemented ADJUST, an automatic algorithm to pick out the components related to eye movements or other artificial sources. To more precisely capture manipulation-related data, epoched data were filtered to under 30Hz after cleaning artifacts.

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Event-related potentials (ERP) were constructed by separately averaging 74 epochs in four conditions (neutral, attend, open-monitoring and reappraisal) and time-locked to the onset of pictures. Isolated averages were also built for negative and positive picture epochs in each experimental condition. The ERPs elicited by negative and positive pictures during attend, open-monitoring and reappraisal at the pretest and posttest (total 12 conditions) were first subtracted from the corresponding Neutral condition (negative/positive at the pretest/posttest) to minus visual components and leave emotion-related components. Because ERPs had to confront the multiple comparisons problem due to tremendous statistical analyses of channel and time pairs, pre-planned nonparametric clustered-base permutation t-test had been performed and Monte Carlo significance probability had been estimated for tests of Open-monitoring and Reappraisal compared to Attend condition at the pretest or posttest (ERPs towards negative/positive pictures at pretest or posttest: attend vs. open-monitoring, attend vs. reappraisal, total 8 comparisons). These comparisons would be respectively conducted for centroparietal LPP and frontal LPP. Centroparietal LPPs were averaged across CP1, CPZ, CP2, P1, PZ, P2 channels and frontal LPPs were averaged across F1, FZ, F2 channels as previous studies (Qi et al., 2017).

To explore the pre-post changes of the regulatory effects, (Open-monitoring minus Attend) and (Reappraisal minus Attend), difference waves of LPPs at pretest and posttest were also conducted on permutation t-tests respectively for positive and negative pictures at centroparietal and frontal electrode sites. One-tail Pearson's r correlation analyses were conducted based on hypotheses between centroparietal/frontal LPPs averaged by the amplification in respective significant time windows of pre-post (Reappraisal -Attend) difference wave and pre-post (Open-monitoring -Attend) difference wave towards positive/ negative stimuli and among these pre-post significant average LPPs and pre-

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post change on trait mindfulness questionnaires to examine if the regulation effect during open-monitoring and reappraisal were correlated with each other and if the regulation effect on LPPs correlated with trait mindfulness change.

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Chapter 3 Results

3.1 Questionnaires

Table 1 summarized mean, standard deviation, t value and Cohen's d of subject's questionnaire item score at the pretest and at the posttest to examine the MBSR training effect. Paired sample t-tests showed that trait mindfulness improved over the training course, for total and each facet of FFMQ and MAAS scores all showed a significant increase. In well-being related variables, SWLS significantly increased while CES-D significantly decreased. For coping capability, Reappraisal subscale scores of ERQ and Distraction subscale scores of RSQ exhibited significant increase and Rumination subscale score of RSQ showed a significant decrease. **Table 2** described Pearson's r correlation between pre-post score differences in questionnaires. Adjusted one-tailed comparisons (Holm, 1979) showed significant correlation between MAAS and SWLS ($r = 0.74$, $p < 0.05$) and CES-D and SWLS ($r = - 0.75$, $p < 0.05$) and for total scores and the Describe and Observe subscale of the FFMQ ($r = 0.73$, $p < 0.05$; $r = 0.74$, $p < 0.05$).

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Table 1 A result summary for the questionnaires before and after the MBSR training

Scale	N	pre-MBSR Mean	pre-MBSR *SD*	post-MBSR Mean	post-MBSR *SD*	t	Cohen's d
FFMQ							
Total	19	3.12	0.47	3.67	0.32	7.21***	1.65
Observe	20	2.85	0.66	3.52	0.39	5.59***	1.25
Describe	20	3.29	0.58	3.63	0.56	2.84*	0.63
ActAware	20	3.35	0.79	3.85	0.50	3.33**	0.75
NonJudge	20	3.49	0.85	4.00	0.69	3.86**	0.86
NonReact	19	2.65	0.34	3.22	0.48	5.61***	1.29
ERQ							
Reappraisal	26	5.16	0.82	5.58	1.07	2.12*	0.42
Suppression	26	3.66	1.27	3.27	1.10	-1.96	-0.38
MAAS	27	3.46	0.81	4.12	0.81	4.11***	0.79
CES-D	21	1.61	0.34	1.42	0.26	-2.86**	-0.63
SWLS	21	3.86	1.17	4.49	1.14	2.87**	0.63
RSQ							
Distraction	26	2.48	0.41	2.64	0.44	2.12*	0.42
Rumination	26	2.03	0.35	1.87	0.40	-2.17*	-0.43

Note. FFMQ: Five Facet Mindfulness Questionnaire; ERQ: Emotion Regulation Questionnaire; MAAS: The Mindful Attention Awareness Scale; CES-D: The Center for Epidemiologic Studies Depression Scale' SWLS: Satisfaction With Life Scale; RSQ: Response Style Questionnaire

*$p < 0.05$; **$p<0.01$; ***$p<0.001$

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Table 2 Pearson's r correlation between questionnaires

	RA	SP	MAAS	DR	RM	CES-D	SWLS	FFMQ_ Describe	FFMQ_ Observe	FFMQ_ ActAware	FFMQ_ NonJudge	FFMQ_ NonReact	FFMQ_ all
ERQ _RA	1.00												
ERQ _SP	-0.31	1.00											
MAAS	0.31	-0.33	1.00										
RSQ _DR	0.42	-0.08	0.41	1.00									
RSQ _RM	0.34	0.05	-0.43	0.19	1.00								
CES-D	-0.19	-0.15	-0.31	-0.36	0.29	1.00							
SWLS	0.22	-0.11	**0.74***	0.40	-0.43	**-0.75***	1.00						
FFMQ_ Describe	0.24	-0.37	0.46	0.30	-0.41	-0.58	0.69	1.00					
FFMQ_ Observe	0.05	-0.47	0.27	0.26	-0.18	-0.24	0.29	0.60	1.00				
FFMQ_ ActAware	0.20	-0.03	0.66	0.18	-0.42	-0.31	0.44	0.01	0.02	1.00			
FFMQ_ NonJudge	0.02	-0.03	0.20	-0.35	-0.43	-0.45	0.28	0.21	0.10	0.48	1.00		
FFMQ_ NonReact	0.15	-0.50	0.21	0.23	0.20	-0.09	0.21	0.47	0.63	-0.28	-0.11	1.00	
FFMQ _all	0.24	-0.44	0.64	0.20	-0.45	-0.57	0.66	**0.73***	**0.74***	0.49	0.59	0.49	1.00

Note. FFMQ: Five Facet Mindfulness Questionnaire; ERQ_RA: Reappraisal subscale of the Emotion Regulation Questionnaire; ERQ_SP: Suppression subscale of the Emotion Regulation Questionnaire; MAAS: The Mindful Attention Awareness Scale; CES-D: The Center for Epidemiologic Studies Depression Scale' SWLS: Satisfaction With Life Scale; RSQ_DR: Distraction subscale of the Response Style Questionnaire; RSQ_RM: Rumination subscale of the Response Style Questionnaire
$^*p < 0.05$; $^{**}p<0.01$; $^{***}p<0.001$

3.2 Subjective Valence/Arousal Rating

Based on participants' valence and arousal rating scores on online forms conducted after the pretest experiment, we calculated the averaged baseline emotional rating of the stimuli we used in the task (Valence: 3.53 (1.10) in negative pictures, 4.54 (0.95) in positive pictures; Arousal: 4.79 (1.49) in negative pictures, 4.24 (1.48) in positive pictures). In terms of the valence rating deviation from neutral valence, the 3-way repeated-measure ANOVA revealed significant main effects of Strategy ($F(2,52) = 34.2$,

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$p < 0.001$), Valence ($F(1,26) = 71.41$, $p < 0.001$) and Time ($F(1,26) = 4.636$, $p < 0.05$) but no interaction effects. FDR-adjusted simple comparisons revealed that for the strategy factor, the valence rating level was closer to neutral during Reappraisal than Open-monitoring ($p < 0.001$) and Attend ($p < 0.001$) conditions, and closer during Open-monitoring than Attend condition ($p < 0.01$). For the picture valence factor, negative pictures showed a significantly larger valence deviation than positive pictures ($p < 0.001$). As for Time factors, valence was closer to neutral at the posttest than at the pretest ($p < 0.001$).

The ANOVA analysis in arousal rating on the other hand showed significant main effects of Strategy ($F(2,52) = 33.92$, $p < 0.001$), Valence ($F(1,26) = 47.95$, $p < 0.001$) and Time ($F(1,26) = 7.994$, $p < 0.01$). The interaction effects displayed significance in Strategy × Time ($F(2,52) = 5.314$, $p < 0.01$) and in Strategy × Valence ($F(2,52) = 8.606$, $p < 0.01$). FDR-adjusted simple comparisons revealed that in Strategy × Valence interaction effect, arousal rating was significantly lower in Reappraisal than in Attend and Open-monitoring both towards negative and positive pictures (Reappraisal vs. Attend: $p < 0.001$; Reappraisal vs. Open-monitoring: $p < 0.001$ both for positive and negative pictures). Open-monitoring also showed lower arousal than Attend both for positive and negative pictures (positive pictures: $p < 0.05$; negative pictures: $p < 0.01$). For all strategies, Attend, Open-monitoring and Reappraisal, negative pictures were rated higher arousal level than positive pictures ($p < 0.001$).

Additionally, in Strategy × Time interaction effect, arousal rating was significantly lower in Reappraisal than in Attend ($p < 0.001$) and Open-monitoring ($p < 0.001$) at the pretest and the posttest (Reappraisal vs. Attend: $p < 0.001$; Reappraisal vs. Open-monitoring: $p < 0.001$ both at the pretest and the posttest). Open-monitoring showed lower arousal than Attend at the pretest ($p < 0.05$) but not at the posttest. From the pretest

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to the posttest, Open-monitoring and Attend but not Reappraisal showed a more decreased arousal level (Attend: $p < 0.001$; Open-monitoring: $p < 0.001$). **Figure 2** showed valence to neutral and arousal rating level of their main effects or interaction effects. **Table 3** and **Table 4** described the mean rating for neutral-corrected valence to and arousal.

Table 3 The subjective neutral-corrected valence rating in each condition

		Pretest		Posttest	
Strategy	Picture Valence	Mean	*SD*	Mean	*SD*
Attend	Positive	1.42	0.60	0.97	0.84
Open-monitoring	Positive	1.17	0.56	0.92	0.62
Reappraisal	Positive	0.70	0.55	0.55	0.58
Attend	Negative	2.26	0.77	1.68	1.04
Open-monitoring	Negative	1.94	0.79	1.55	0.72
Reappraisal	Negative	1.48	0.84	1.15	0.92

Table 4 Subjective Rating of arousal during each condition

		Pretest		Posttest	
Strategy	Picture Valence	Mean	*SD*	Mean	*SD*
Attend	Positive	3.95	1.55	2.56	1.44
Open-monitoring	Positive	3.45	1.66	2.35	1.31
Reappraisal	Positive	2.43	1.51	1.96	1.22
Attend	Negative	5.13	1.78	3.54	1.75
Open-monitoring	Negative	4.34	2.04	3.02	1.51
Reappraisal	Negative	3.14	1.74	2.49	1.43

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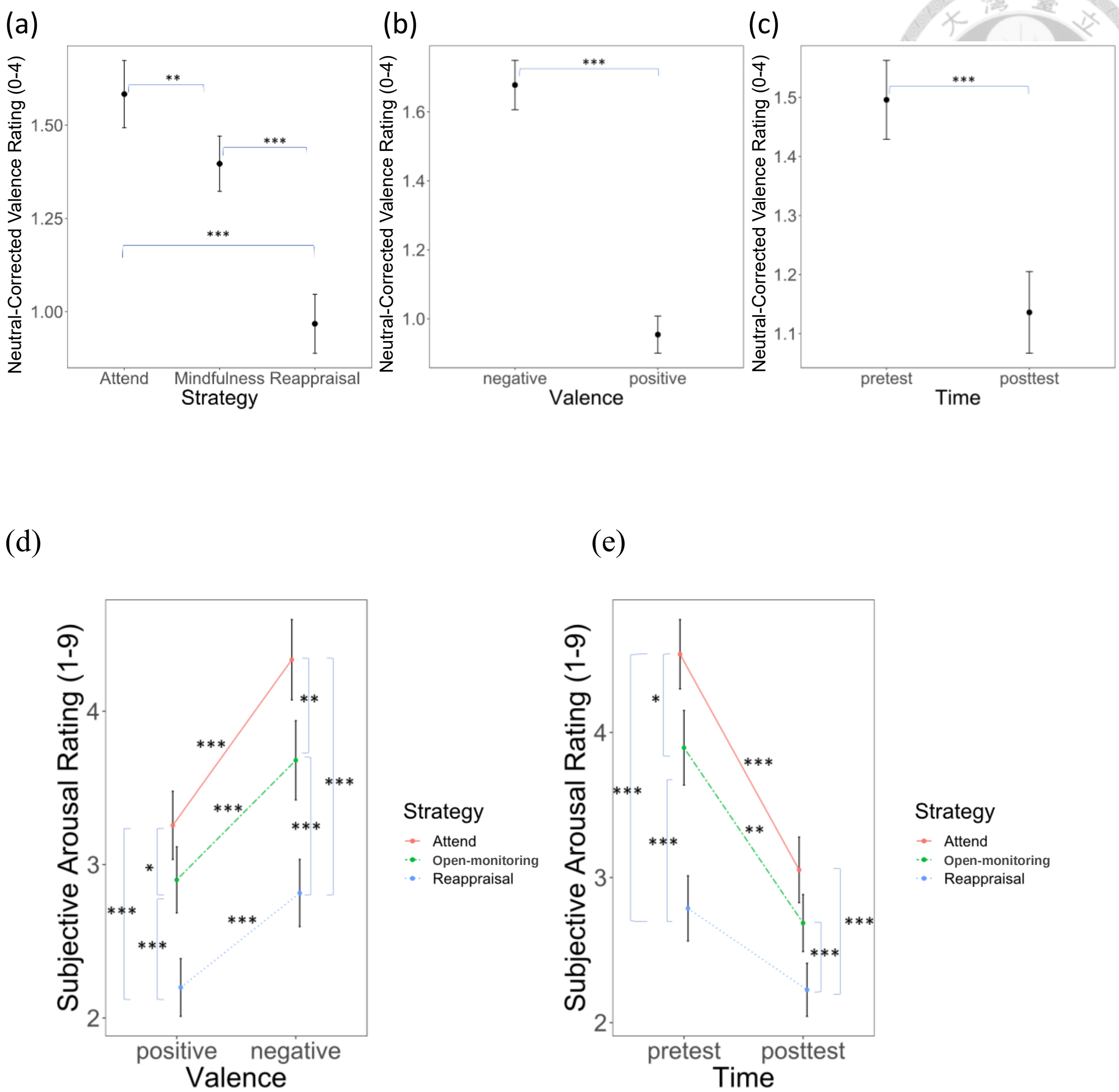

Figure 2

Simple comparisons of main effects of (a) Strategy (b) Valence (c) Time on rating of neutral-corrected valence and interaction effects of (d) Valence × Strategy (e) Time × Strategy on arousal rating

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3.3 Event-Related Potentials (ERP)

Planned 12 permutation t-tests of centroparietal and frontal LPP were conducted within negative or positive LPPs during open-monitoring and reappraisal compared to during the attend condition at pretest or posttest (negative/positive at pretest/posttest: attend vs. open-monitoring, attend vs. reappraisal, open-monitoring vs. reappraisal) as well as (Open-monitoring minus Attend) and (Reappraisal minus Attend) elicited by negative and positive pictures. The results were depicted in **Figure 3** and described in below.

Centroparietal LPP

At pretest, no significant differences of centroparietal LPP amplitudes elicited by negative or positive pictures were found between open-monitoring vs. attend or reappraisal vs. attend ($p > 0.05$). At posttest, as predicted, open-monitoring and reappraisal significantly reduced LPPs elicited by negative pictures compared to attend condition ($p < 0.05$) in certain time windows (Open-monitoring vs. Attend: 854-1054ms, 1062- 1138ms, 1170-1270ms, 1276-1448ms, 1662-2000ms; Reappraisal vs. Attend: 430-578ms, 608-1452ms, 1578-2000ms). There was no significant difference in LPPs elicited by positive pictures during open-monitoring and reappraisal as compared to the attend condition. For pre-post change, both ERPs of reappraisal and open-monitoring minus attend condition showed significant reduction during time windows of 440-1464, 1666-1744,1756-1836ms and 856-1018, 1066-1268ms.

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Frontal LPP

At pretest, frontal LPP amplitudes elicited by negative or positive pictures did not differ among attend, open-monitoring and reappraisal ($p > 0.05$). At posttest, reappraisal and open-monitoring both showed reduced frontal LPPs elicited by negative pictures compared to attend condition ($p < 0.05$) (Open-monitoring vs. Attend: 1366-1444ms, 1660-1946ms; Reappraisal vs. Attend: 400-1430ms, 1458-1566ms, 1582-2000ms). For the pre-post comparisons of the regulation related effect (i.e., Reappraisal minus Attend vs. Open-monitoring minus Attend), only ERPs of the regulation related effect for the reappraisal condition showed a significant decrease from pretest to posttest, during time windows of 440-730ms, 738-1346ms, 1636-1850ms and1868-1962ms.

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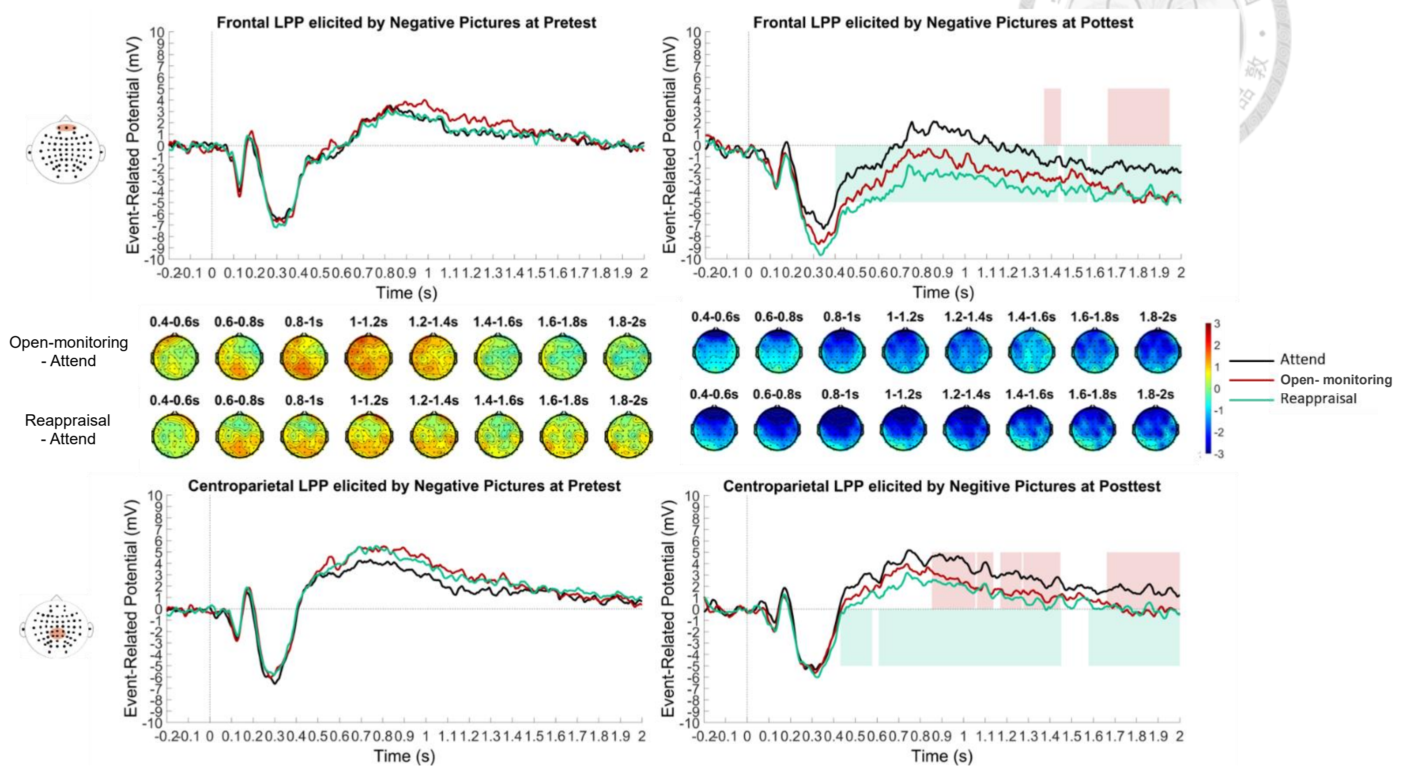
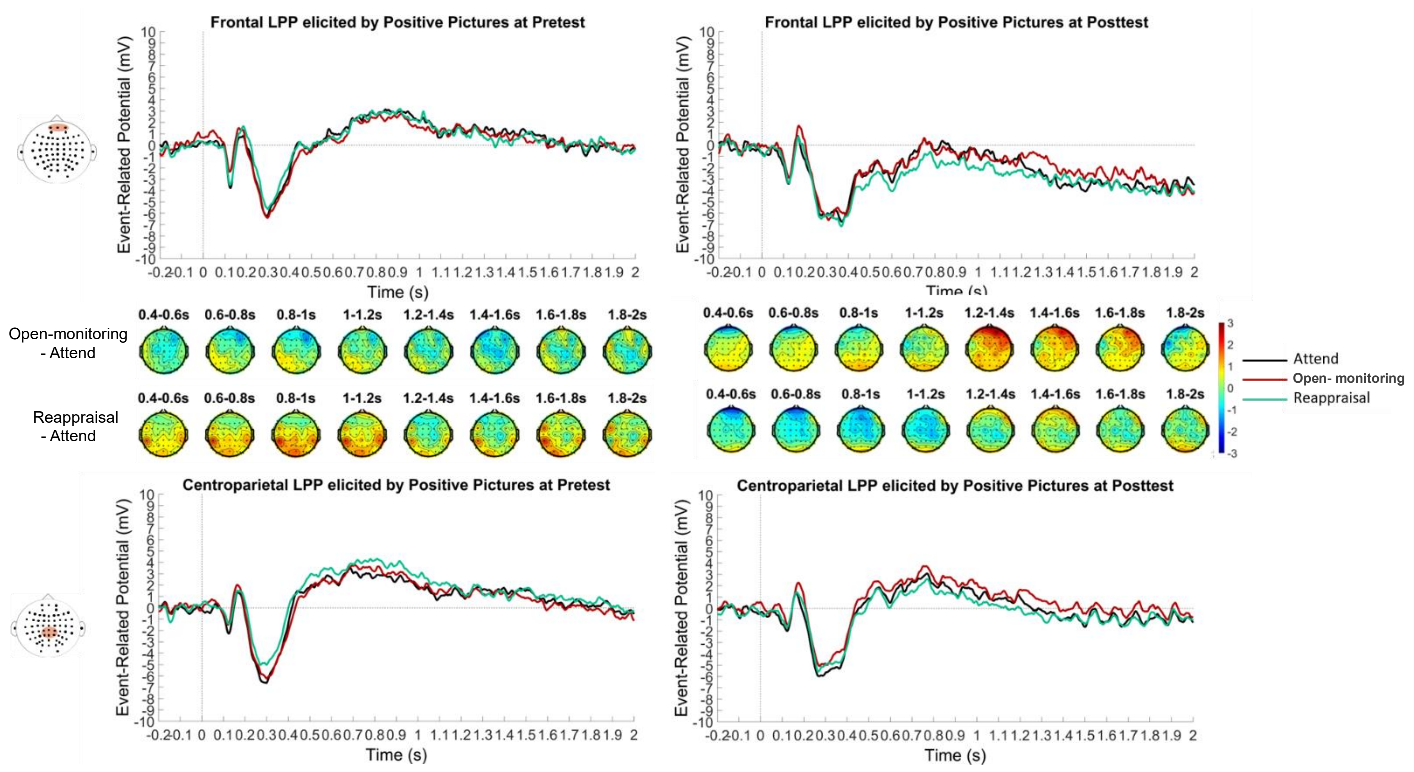
(a) **(b)**



(c) **(d)**



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(e) **(f)**

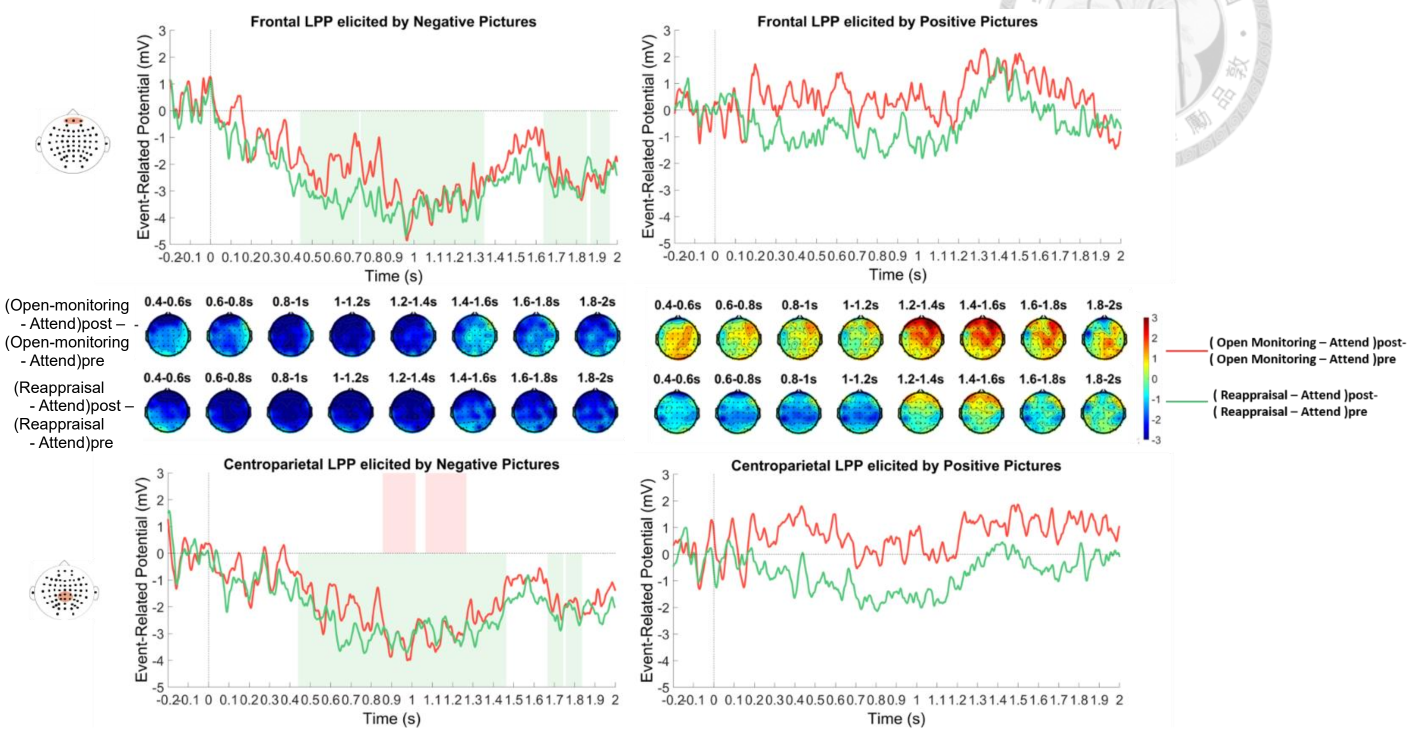

Figure 3

Picture-locked LPPs were averaged at centroparietal and frontal sites and topoplots from 0.4s to 2s after the picture onset during three strategies towards negative pictures **(a)** at the pretest and **(b)** at the posttest as well as positive pictures **(c)** at the pretest and **(d)** at the posttest. Significant time windows of Reappraisal - Attend comparisons were marked in green and Open-monitoring - Attend comparisons were marked in red. Pre-post difference waves and topoplots of open-monitoring and reappraisal minus attend condition were depicted towards **(e)** negative pictures and **(f)** positive pictures. Significant time windows of pre-post (Reappraisal minus Attend) comparisons were marked in green and pre-post (Open-monitoring minus Attend) comparisons were marked in red.

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3.4 Correlation between centroparietal/frontal LPPs & Questionnaires

For centroparietal LPP, 2 significant time windows of the amplification elicited by negative pictures of pre-post (Open-monitoring - Attend) difference wave showed significant moderate correlation ($r = -0.395$, $p < 0.05$; $r = -0.399$ $p < 0.05$) with NonJudge subscale scores of FFMQ but not other subscales of FFMQ or MAAS. 3 significant time windows of the amplification in pre-post (Reappraisal – Attend) difference wave showed no significant correlations with any trait mindfulness questionnaires. As to frontal LPPs, all 4 significant time windows of the amplification in pre-post (Reappraisal – Attend) difference wave didn't show any significant correlations with the trait mindfulness questionnaires.

3.5 Correlation between centroparietal LPPs during open-monitoring and reappraisal

Moderate correlations between shared significant time windows of pre-post (Open-monitoring minus Attend) and (Reappraisal minus Attend) difference waves were significant ($r = 0.4019$; $p < 0.05$ in mean amplitudes during - ms; $r = 0.4027$; $p < 0.05$ in mean amplitudes during – ms)

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Chapter 4 Discussion

4.1 Behavior Implications of the MBSR training effect

The present study mainly explored the MBSR training effect on emotion regulatory psychological and neurological characteristics. Pre-post change showed increased trait mindfulness and improved well-being variables of depression and life satisfaction. Participants also developed more adaptative emotion regulation strategies like reappraisal, distraction and decreased the use of rumination, which is a maladaptive emotion regulation strategy. Also, MAAS scores had a high correlation with well-being variables of life satisfaction and depression. This was in line with some previous studies (Campbell et al., 2012; Nyklíček et al., 2008; Würtzen et al., 2013), showing MBSR has a positive influence on promoting psychological well-being and coping skills.

Next, in the emotional regulation task, the training effects of MBSR showed in subjective emotional valence and arousal. Valence was significantly closer to neutral through MBSR across different strategies and picture valence. This may be explained by developing “Equanimity”, which was defined as an “even-minded mental state” (Desbordes et al., 2014). As to emotional arousal rating, before the MBSR, reappraisal condition displayed significant regulatory effect on emotion intensity compared to attend condition, which accords with a previous finding (Schönfelder, Kanske, Heissler & Wessa, 2014; Thiruchselvam et al., 2011). The open-monitoring condition also showed a more regulated arousal level compared to the attend condition. Through the MBSR training, not only emotion arousal level in open-monitoring condition turned to significantly attenuate, which supports the hypothesis, but the rating scores in attend condition also showed significant reduction, indicating the way of attending to pictures seemed to change through MBSR on behavior level. Reappraisal, on the other hand, had no

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significant change through the training. It may confront with floor effect for already showing a large reduction before the MBSR.

4.2 Neural Implications of the MBSR training effects

Emotional Intensity Change during Differential Emotion Processing

At the neural level, centroparietal and frontal LPPs were computed to examine the neural dynamics of emotion generation and cognitive efforts before and after the MBSR training. For centroparietal LPPs, at the pretest, LPP deflections did not exhibit lower amplitudes during reappraisal compared to attend condition, which was contrary to some studies (Ma et al.,2019; Qi et al., 2017), but some studies did not demonstrate the LPP reduction either (Langeslag, 2017). According to Langeslag (2013), this might be caused by the floor effect, which indicated the intensity of the emotional stimuli were not strong enough to leave room for regulatory effects. In the present study, the original arousal ratings of the pictures indeed were lower than those in the studies showed the typical regulatory effect on centroparietal LPP amplitudes, which might cause difficulty in decreasing the LPP deflections. As for the open-monitoring condition, it induced similar centroparietal LPP amplitudes as in the attend condition. This finding was reasonable considering the results in Uusberg et al.'s study (2016), in which the deflections were increased at former trials but turned out not to be different from the attend condition later.

At the posttest, as predicted, both reappraisal and open-monitoring attenuated centroparietal LPPs elicited by negative pictures compared to attend condition. This LPP reduction appeared early and long-lasting during reappraisal with few non-significant time windows while just appeared at the late stage and a short period during open-monitoring. In reappraisal blocks, participants might consist of holding a detached

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perspective toward emotional stimuli and thus influenced LPP amplitudes just upon its generation. Open-monitoring, on the other hand, referred to observing and doesn't try to alter one's emotion, which may serve as a gentle process that slowly modulates the emotional neural response. From the pretest to the posttest, the centroparietal LPP amplification of regulatory effect only appeared towards negative pictures, for reappraisal showed a significant reduction from an early stage and continued an extended period while open-monitoring just showed a significant reduction at the late stage. The current study hence provided evidence that MBSR could modulate the neural regulatory effect of reappraisal and open-monitoring towards negative pictures. Additionally, mindfulness stress-buffering account (Creswell & Lindsay, 2014) could serve as a possible explanation of why centroparietal LPP changed selectively for negative stimuli. The MBSR training seemed to help improve the regulatory effects of reappraisal and open-monitoring to buffer the influence of negative and more stressful state induced by the pictures and help one deal with the negative-affective state less reactively.

Cognitive Effort Consumption Change during Differential Emotion Processing

Frontal LPP, reported as an index of cognitive resources assumption, showed no amplitude difference in open-monitoring and reappraisal compared to attend condition at the pretest while at posttest, both open-monitoring and reappraisal significantly decreased LPP amplification compared to the attend condition towards negative pictures, with reappraisal showed early and long reduced frontal LPP amplification almost from LPP generation and lasted for a long while open-monitoring showed late and just short-lasting LPP decrease. For reappraisal, consistent with previous studies, self-focused type typically would not enhance frontal LPP compared to attend condition (Ma et al., 2019; Qi et al., 2017). However, at the posttest, self-focused reappraisal needed less attention

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resource recruitment compared to attend condition, serving as a more effortless way. For open-monitoring, contradicted with our hypothesis of showing higher frontal LPPs both at pretest and posttest, this emotion regulation process didn't recruit more attention resource compared to attend condition at both timepoints. As to the pretest, this may indicate that although compared to experienced practitioners, the novice may tend to use a more cognitive control way, this strategy wouldn't retrieve more cognitive resources than attend condition. At the posttest, open-monitoring recruited less cognitive resources than the attend condition in the late stage during short time windows, which also demonstrated a more effortless implementation compared to attend condition.

From the pretest to the posttest, the regulatory effect of reappraisal but not open-monitoring showed significant improvement for more decreased frontal LPP amplitudes. The finding suggested that through MBSR, one can adopt a detached way to view emotional stimuli in a more effortless way while observing one self's internal experience may still need similar cognitive resources consumption as without training. Thus, it could be implicated that self-reappraisal may serve as a more effortless way than open-monitoring in the current stage of 8-week training and practice of MBSR, but chances are that open-monitoring can produce the regulatory effect due to more time and keep on practice. Further studies can be conducted to track the follow-up results of the emotion regulation process of these two emotion regulation strategies

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4.3 Integrated Neuropsychological View on the MBSR training

Through exploring the relationship between the pre-post amplitude change of centroparietal/frontal LPPs and psychological questionnaires, the present study showed specific facet of how MBSR modulating the emotion regulation process. Improved regulatory effect during open-monitoring strategy toward negative pictures indexed by centroparietal LPPs was found have correlation with promoted non-judgement attitude fostered through MBSR course, showing the downregulation of neural emotional intensity during open-monitoring had relation with taking an attitude of acceptance toward emotions. On the contrary, improved reappraisal regulatory effects indexed both in centroparietal and frontal LPPs were not correlated with all kinds of trait mindfulness, which meant self-focused reappraisal capability may not be directly benefited from increased trait mindfulness and further studies need to be conducted in the future to explore why reappraisal improves through MBSR. A possible conjecture might be reappraisal capability improved through MBSR practice' side effect that would enhance attentional functions, but these attentional functions improvement were not the core value of MBSR that represented in trait mindfulness of observing, describing, act with awareness, non-judgement, non-reactivity or meta-awareness. However, when examining amplification during overlapped significant time windows showing pre-post regulatory effects on centroparietal LPP elicited by negative pictures, the level of reappraisal and open-monitoring did correlate with each other. It means if one has better regulatory effects on open-monitoring, he or she also performs better on the reappraisal task. MBSR's training effects have consistent directions towards these two strategies although they may induce different regulatory processes.

There are still several limitations to the present study. First, the stimuli used in the current study didn't seem to induce high arousal emotion reactivity and thus couldn't

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replicate typical reduced centroparietal LPP amplification during self-focused reappraisal before MBSR. Second, subjective arousal and valence scores of emotional pictures were rated by the same subject sample. Hence, participants were re-exposed to these emotional stimuli, which made this baseline not a clean baseline. Third, to control the valence and arousal rating of the emotional stimuli, we also used the same three picture sets at the pretest and the posttest. Although which picture set was used in the specific condition was randomized and the duration between the pretest and posttest longer than 8-week, it was possible that participants still remembered these pictures and thus contaminated the experimental manipulation for the pictures were re-exposed and might elicit a more reduced emotion reactivity in some regulatory conditions. Four, the current study didn't include a control group who didn't receive the MBSR training, which weakened the evidence of the MBSR's training. But the present findings can somehow provide some indications supported the training effect for the improved trait mindfulness showed correlation with the reduction level of centroparietal LPP towards negative pictures during open-monitoring. Those who less improve their trait mindfulness also don't change their neural emotion regulation process on open-monitoring.

To sum up, previous studies on how the MBSR program influences the emotion regulation process remains little. The present study used self-focused reappraisal and open-monitoring to unfold certain facets of behavioral and neural emotion regulation process through MBSR, with self-focused reappraisal displaying an obvious regulatory effect on centroparietal and frontal LPPs and open-monitoring reflecting a moderate regulatory effect on centroparietal LPPs. This study first provided evidence on improved self-focused reappraisal through MBSR while situation-focused reappraisal has shown significant improvement through mindfulness-based interventions (Rayan & Ahmad, 2016). This was also the first time that open-monitoring strategy was reported to perform

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regulatory effects through MBSR, suggesting the importance of the MBSR training and continuous in-class and at-home practice to make the effect of the open-monitoring approach come off. Further studies need to investigate on the follow-up performance and if practice amount of the MBSR training modulates the LPPs. FMRI can also be utilized to explore the MBSR training effects on the change of the functional brain areas during the process of these two strategies to discriminate if there is a spatial difference between self-reappraisal and open-monitoring.

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