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身心互動途徑初探：以「身心中軸覺察訓練」對身體感覺、工作記憶與注意力控制功能的提升效果為例

An Initial Inquiry about Body-Mind Interaction: Examining the Training Effect of Body-Mind Axial Awareness Practice for Children on Bodily Senses and Executive Functions

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摘要

在正念相關訓練的研究中，身體覺察的重要性總是不斷地被強調，但是身體到底在這個部分扮演怎樣的角色仍是未知。在本論文中，此議題將會從三個面向來檢驗：第一，是否孩童的身體覺察能力會和執行控制功能有關；第二，是否訓練可以同時提升孩童的身（身體感覺）與心（認知功能）；第三，是否孩童原本的身體感覺條件會影響訓練的成效。我利用我們實驗室所發展的兒童版的身心中軸覺察課程（Body-Mind Axial Awareness for Children, BMAA-C），來檢驗這些問題。58 位小孩（平均年齡 9.52 歲，男性 51.7%）參與了身心相關性研究（前測），而 48 位小孩進一步參與了訓練效果研究，他們被分配至訓練組—BMAA 組（27 位，平均年齡：9.59 歲，男性 51.9%，女性 48.1%）以及參加一般與正念無關營隊的對照組（21 位，平均年齡: 9.38 歲，男性 47.6%，女性 52.4%）。參與學童在訓練期前後兩週的時間內個別接受了本體覺的被動動作測驗、內感覺的心跳偵測作業、持續性注意力反應作業以及工作記憶的操作廣度作業。在前測的資料中發現學童的本體覺覺察度表現越好，他們的持續性注意力的表現也就越好（較低的 RTCV 以及較高的 NOGO accuracy），而工作記憶跟身體覺察度無關。此外，BMAA-C 課程較對照組更能提升孩童的工作記憶還有持續性注意力（較低的 RTCV）。此外，在前測中，本體覺精準度高於中位數與

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本體覺覺察度低於中位數的孩童相較於各自另一半的學童在持續性注意力的另一個指標（NOGO accuracy）更能受惠於訓練，後續分析更發現在前測本體覺覺察度低於中位數的孩童，其本體覺覺察度的提升跟 NOGO accuracy 的提升有關聯性。這些結果首度提供 BMAA 訓練有助於孩童提升認知功能的證據，同時也發現了身體覺察的重要性，也對於身心互動的關係提供一個初步的資料。

關鍵字：本體覺、工作記憶、持續性注意力、身心中軸訓練

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Abstract

Recently, there is growing evidence that mindfulness trainings benefit children's cognition, during which the body awareness is emphasized. However, how body awareness influences the mind via mindfulness trainings is still unknown. In this thesis, I aimed to examine this issue from three aspects. First, whether children's body awareness correlates to their executive functions; Second, whether the training benefits children's executive functions and body awareness at the same time; Third, whether children's initial states of their bodily senses would modulate the training effects of Body-Mind Axial Awareness practices for children (BMAA-C), a kind of movement-based contemplative practices (MBCPs) that emphasizes the body-mind integration much, on executive functions. Fifty-eight children (mean age = 9.52; boy: 51.7%, girl: 48.3%) were recruited for the correlational study and forty-eight of them were then participated the training effect study. They were assigned to either the BMAA group (*N* = 27; mean age = 9.59 years old) or the control group (*N* = 21; mean age = 9.38 years old). All the children completed tasks for proprioception, interoception, sustained attention and working memory capacity before (T1) and after (T2) the camp. With the T1 scores, I found that children's performance on

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proprioceptive awareness significantly correlated to their sustained attention, which was further moderated by interoceptive awareness. However, working memory did not correlate with bodily awareness. After training, the BMAA group improved more than the control group on the scores of working memory capacities and RTCV, an index of sustained attention. Furthermore, within the BMAA group, the training benefits children with better proprioceptive accuracy at T1 more on sustained attention, indicated by higher NOGO ACC, after training than those had poorer proprioceptive accuracy. Children with poorer proprioceptive awareness at T1 also improved more on NOGO ACC than those who had better proprioceptive awareness and further analysis showed that there is a contingency between the improvement on proprioceptive awareness and that on NOGO ACC in the children with poorer proprioceptive awareness at T1. These findings provide an evidence of the effectiveness of the BMAA-C practice for children on cognitive functions and partially support the importance of bodily awareness to executive or attentional control for children.

Keywords: Proprioception, Working memory, Sustained attention, mindfulness, MBCP

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Introduction

Recently, there is growing evidence showing that mindfulness practices have positive effects on mental functions, such as reducing mind wandering (e.g., Mrazek, Franklin, Phillips, Baird, & Schooler, 2013; Mrazek, Smallwood, & Schooler, 2012), enhancing attention control (for a review, see Chiesa, Calati, & Serretti, 2011), improving divergent creativity and cognitive flexibility (e.g., Colzato, Ozturk, & Hommel, 2012; Ding, Tang, Deng, Tang, & Posner, 2014), as well as promoting emotional regulation and the sense of well-being (e.g., Goleman, 2003; Ricard, 2006). However, how mindfulness practices have these wide-ranging effects is still controversial and unclear. Since mindfulness-based trainings or other types of contemplative practices often emphasized the practice of being aware of one's body or inner feelings, some researchers argued that body awareness plays an important role in mediating the effects found. For example, Hölzel et al. (2011) has stated that, "The enhancement of body awareness might have relevance for affect regulation and empathic processes and thus may be particularly relevant in the mindfulness-based treatment of patients with such deficits."

Researchers pointed out the possible role that body awareness may play. For

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example, somatic focus enhances top-down attentional control on mind-wandering (Kerr, Sacchet, Lazar, Moore, & Jones, 2013). Specifically, the ability of top-down control may be enhanced by repeatedly monitoring and redirecting attention to one's breath or inner feelings. As Flook et al. (2010) stated, "While in the mindfulness practices, one has to focus on the breath, then watching the breath and noticing if the attention runs out, and when the mind wanders redirect attention back to the breath." Other studies suggested strengthening one's meta-awareness is crucial for executive control or attention (e.g. Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Other researchers also, suggested that the effect of mindfulness-based treatment may be facilitated by improved meta-awareness (Hargus, Crane, Barnhofer, & Williams, 2010). While emphasizing on body awareness through mindfulness practices might, in the end, strengthen one's meta-awareness.

Based on the claims above, it is reasonable to infer that body awareness could be raised by mindfulness-related trainings, and influences the effects on attentional control in some way. However, to my knowledge, previous studies about the effects of mindfulness practices have never been focused on both body awareness and executive or attentional control at the same time. The role that body awareness, or more

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generally, the bodily senses, plays in the mechanism underlying the training effects of mindfulness practice remains unknown.

In this thesis, I aim to examine the enhancing effects of a movement-based contemplative practice (MBCP, will be explained later) on two aspects of bodily senses, including the ability per se and the awareness of it, as well as executive or attentional control for children. I am interested in exploring the following questions: 1) Whether children's body awareness correlates to their executive functions; 2) Whether the training benefits children's executive functions and body awareness at the same time; 3) Whether children's initial states of their bodily senses would modulate the training effects of MBCP, a practice that emphasizes the body-mind integration much, on executive functions.

In this introduction, I will first explain the reasons I chose to use children as the participants in my study. Next, I will review previous research about the training effects mainly on cognitive functions, of mindfulness trainings and MBCPs for children. This will be followed by an introduction of the MBCP I adopted in this thesis, the Body-Mind Axial Awareness practice (BMAA for short). Two kinds of bodily senses, interoception and proprioception, will be illustrated with objective

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measures through the two aspects mentioned above. I will conclude the introduction with an intervention study with pretest-posttest design and introduce my predictions.

Reasons for Using Children as Target Participants

I used children aged 8 to 11 as participants rather than adults in this thesis for several reasons. First, compared to adults, there are still relatively few studies about mindfulness training or MBCP for children (will be reviewed later). It is probably because children cannot stay in a static mindful or contemplative state for long. Nevertheless, it is important to conduct such research on children to learn whether children's bodily senses are related to their executive functions in some way that would in turn influence their behaviors. Impaired executive or attention control is related to poor goal-directed behaviors, low school performance (e.g., Blair and Razza, 2007) and would ultimately result in having a low socioeconomic status (Moffitt et al., 2011). Therefore, developing a feasible mindfulness course that can improve children's executive functions or attentional control is important and desperately needed in Taiwan. As reported, number of children diagnosed as attention deficit has increased. According to a report by Tzang, Wu and Liou. (2002), the prevalence rate of attention deficit and hyperactivity disorder (ADHD) for children in

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Taiwan was 8.4% compared to 5.29%, the worldwide-pooled prevalence (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007).

Second, previous studies have shown potential correlations between children's bodily senses and their performance on attentional control. For instance, children with developmental coordination deficiency (DCD) have long been known to be proprioceptive deficit (Smyth & Mason, 1998; Mon-Williams, Wann, & Pascal, 1999). Shum and Pang (2009) also found children who suffer from ADHD have difficulty using signals from bodily senses to keep balance compared to normal children. Furthermore, it has been reported that the occurrence of DCD is associated with attention deficit. For example, Fliers et al. (2008) showed that one third of children with ADHD also suffer from DCD, and vice versa, a large number of inattentive children also showed coordination deficiency (Fliers et al., 2008; Piek, Pitcher, & Hay, 1999). Based on these findings for these special groups of children, I would like to know whether the same relation between bodily senses and attentional control exist for normal children.

The Effects of Mindfulness and MBCP Training for Children

As mentioned, research about mindfulness trainings on children are limited

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compared those conducted on adults, and evidence is mixed. For example, Napoli, Krech and Holley (2005) conducted a 24-week mindfulness study (Attention Academy Program) on 97 students where they attended two 45-minute sessions a week. They found that after the program, the children's selective attention, but not sustained attention, improved compared to a control group without any treatment. Similarly, Corbett (2011) also reported a null effect of 5-week mindfulness training on children's sustained attention compared to the non-training group. However, Biegel and Brown (2010) studies showed a 5-week (three times a week, 15 minutes each time) mindfulness program at school improved children's executive control which tested by the attention network test, compared to themselves in the pretest. Felver, Tipsord, Morris, Racer and Dishion (2014) found a similar result for children who participated 8-week MBSR-C program compared to a wait-list control. Other positive effects of mindfulness training for children include: improved psychological well-being (Biegel, Brown, Shapiro, & Schubert, 2009; Burke, 2010; Flook et al., 2010; Semple, Lee, Rosa, & Miller, 2010), reduced anxiety symptoms (Lee, Semple, Rosa, & Miller, 2008; Semple, Reid, & Miller, 2005) and ADHD symptoms and attentional problems (Crescentini, Capurso, Furlan, & Fabbro, 2016; Singh et al., 2010), as well

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as enhanced children’s behavioral regulation, socio-emotional development, and academic skills (Beauchemin, Hutchins, & Patterson, 2008; Flook et al., 2010).

Movement-based contemplative practices (MBCPs) typically involve specific movement sequences, specialized use of breathing techniques, and modulation of attention (Wayne and Kaptchuk, 2008) to achieve a state of body-mind integration. Among them, yoga, Tai-chi, and other traditional mind-body exercises in Asia societies are commonly mentioned. Similar to mindfulness-based trainings, body awareness is also emphasized in MBCPs.

There is some evidence that although not much, proves MBCPs could benefit both adult and child trainees’ cognitive performance. For example, positive effects for adults include improving their working memory capacities (e.g. Gothe, Pontifex, Hillman, & McAuley, 2013; Taylor-Piliae et al., 2010; Teng & Lien, 2016), strengthening their cognitive inhibition (Bilderbeck, Farias, Brazil, Jakobowitz, & Wikholm, 2013; Gothe et al., 2013), and increasing their scores on mindfulness trait (e.g., Caldwell, Harrison, Adams, Quin, & Greeson, 2010; Teng & Lien, 2016). Studies for children are even fewer. For example, practicing Yoga 75 minutes a day for a week could increase 10 to 13-year-old female children’s planning abilities,

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measured with tower of London test, more than a control group with physical training at the same time (Manjunath & Telles, 2001). Rangan, Nagendra and Bhatt (2009) also found that an academic-year of yoga training improved 11 to 13-year-old children's sustained attention compared to an active control group which contains physical exercises, mathematical puzzles, music and normal sports. In another study, Slovacek, Tucker and Pantoja (2003) found that kindergarten to 8th grade students' academic performance, positive attitudes about themselves, physical fitness levels, and behaviors were improved after participating in a Yoga Ed program compared to the control group without treatment. Moreover, receiving a yoga training for 10 weeks, two sessions a week and 45 minutes for each, helped teenagers reduce their general tensions and stress symptoms such as headaches, compared to a control group who read magazines during the training period (Kalayil, 1988). Children who received a 10-day intensive yoga training also outperformed a control group who carried out their usual routine at the same time on static motor performance (Telles, Hanumanthaiah, Nagarathna, & Nagendra, 1993).

Studies on Tai-chi had also shown some positive effect. For example, ADHD adolescents' anxiety, tendency to daydreaming, inappropriate expression of their

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emotions, and hyperactivity could be reduced after a 5-week Tai-chi training (twice a week and 30 minutes per class across 5 weeks) (Hernandez-Reif, Field, & Thimas, 2001). Asthmatic children who participated in a 12-week Tai- chi program also found that their pulmonary function improved more than those who did not participate (Chang, Yang, Chen, & Chiang, 2008). Moreover, it has been found that MBCPs can enhance proprioception for particular groups of people. For example, practicing Tai-chi improves proprioception for the elderly (Tsang & Hui-Chan, 2003; Xu, Hong, Li, Chan, 2004) and yoga for the congenitally blind students (Mohanty, Pradhan, & Nagathna, 2014).

As can be seen, no matter in the studies of mindfulness-based practices or movement-based practices, most of the cases mentioned above examined the effects on body and mind separately. To my knowledge, no study has discussed the effect of mindfulness practices or MBCPs through the view of interaction between body and mind. Moreover, most of sustained attention related studies mentioned above used paper-sheet task. For example, studies of Corbett (2011); Napoli et al. (2005) and Rangan et al. (2009) all targeted sustained attention as the possible benefit from training. However, the former two found no benefit in sustained attention from

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mindfulness-related training and the latter found benefits from yoga training. To solve these problems, I used a MBCP to see its effect on both body and mind, and applied a computerized sustained attention task as measurement. These would be introduced later.

Body-Mind Axial Awareness program for Children (BMAA-C)

I chose one of the MBCPs rather than mindfulness-based practices for two reasons. First, movements are concrete and may be easier to follow for children than a kind of attitude usually emphasized in mindfulness-based training. In addition, with movements, children may not get bored easily. Second, it has been reported that children in Taiwan do not have enough exercise. According to Child Welfare League Foundation (2012), among 1015 children in fourth and fifth grades sampled in Taiwan, more than 70% of them exercised less than 2 hours a week. Instead, they spent more than 14 hours on watching TV and 10 hours on the internet a week. In the report of Li and Wu (2007), 25.6% of sampled children (11-12 years old) were diagnosed having developmental coordination disorder. While the reported prevalence rate for children (5–11) having developmental coordination disorder (DCD), has been estimated to be around 6% (American Psychological Association, DSM-IV, 1994;

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World Health Organization, ICD-10, 1992). Taiwanese children had shown a higher prevalence rate of DCD compared with children around the world. Therefore, conducting a program for children to move their bodies probably meets the needs of Taiwanese children.

The program I chose to examine is a type of MBCPs based on the Li-Yue (禮樂) tradition rooted in East Asian societies (Chen, 1994; Chen, 2011a, b; Teng & Lien, 2016). It was designed mainly on the principle of Body-Mind Axial Awareness (身心中軸覺察) deconstructed by Chen (2011a) from the movements of Ya-Yue (雅樂), which is ensemble of music (Yue) and movements (Li) used for heaven worshiping three thousand years ago in ancient China, and later spread over to neighboring countries including Korea and Japan (Chen, 1994; 2011b, Teng & Lien, 2016). The BMAA principles are decoded as:

1. Keeping body in a way that a hypothetical axis, connecting the top center of head to perineum is vertical to the ground.

2. Keeping one's eyes looking inward and downward, while projecting the attention to the hypothetical axis.

3. Moving one's body through the force from the standing points of the body

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(e.g., one's feet while standing up, the ischium (or sit bones) while sitting, or head, scapula, ilium and legs while lying down).

The first principle helps practitioners find their central body axis. The second principle is a traditional way for practitioners to pacify their minds, dismiss deliberative thinking, and volitional control over their bodies. The third principle would help one move efficiently by keeping most of the major surface muscles not involved relaxed. Through practices that follow these principles, a practitioner can finally experience a sense of body-mind union.

In my personal experience, doing BMAA practices benefits both my physical and mental state. Being constantly asked to pay attention to the central axis of my body while doing BMAA movements enables me to notice some obstructions I have due to physical or mental injuries buried deep in my body. The obstacles of maintaining the body-mind axial state, were further resolved via practice. In addition, looking inward and downward helped me reduce mind wandering and, moreover, void the mind. After practicing, I felt calm and happiness and gradually, mindful and relaxingly.

Although BMAA and Tai-chi practices are from the same cultural tradition and both emphasize body movements, BMAA is different from Tai-chi in various facets

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(Teng & Lien, 2016). For example, while Tai-chi requires practitioners to carry out a series of compound movement patterns (forms), BMAA instead practices deconstructive movements according to the revealed principles. Moreover, Tai-chi practices usually begin with standing position while BMAA starts practice in lying position or semi-supine, which is easier for beginners to stay relaxed. So the latter kind of practice may be more suitable for children.

The Bodily Senses

One's ability to focus on their own body is associated with the so-called bodily senses. In previous studies, the term "body awareness" was defined in a general way which caused ambiguity. In this study, I selected two bodily senses that corresponds to the ability to focus on one's body. They are the visceral senses (interoception) and the musculo-skeletal senses (proprioception).

Interoception refers to visceral senses, which monitor the physiological state of the body to maintain internal homeostasis, including respiratory, gastrointestinal, and cardiovascular organs (for review, see Ritchie & Carruthers, 2015). In addition to subjective self-report questionnaires (e.g., MAIA), the heartbeat detection task that was first established by Schandry (1981), is widely used as an objective measure for

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interoception. It requires participants to focus on their heartbeats and count them without trying to control it. Koch and Pollatos (2014) modified this task for children by decreasing the time of each trial to avoid the age-related problems mentioned by Eley, Gregory, Clark and Ehlers (2007), who found children may be prone to make errors by temporary distraction or miscount while doing this task.

Some studies showed meditation practices increase the activities in the brain areas associated to interoception. For example, Kirk, Downar and Montague (2011) indicated that the activities of interoception-related brain areas for long-term meditators were significantly higher than non-meditators while doing Ultimatum Game, and the former also demonstrated more rational decision-making behaviors than the latter. In Farb, Segal and Anderson (2012), participants who had received mindfulness training had different brain area activities to those who did not while keeping their attention inward (interoceptive attention). For example, the meditators showed greater brain activities in the anterior dysgranular insula regions and fewer activities in the dorsomedial prefrontal cortex (DMPFC). The evidence above seems to be in line with the claim that interoception is a likely mediator for the enhancement of cognitive functions resulted from mindfulness trainings.

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However, behavior studies show inconsistent results which indicate an elaborated distinction between different facets of interoception might be necessary. For example, Cebolla et al. (2016) found that experienced meditators could lessen their rubber hand illusion which was associated with the heightened body awareness measured by self-reported questionnaire (multidimensional assessment of interoceptive awareness; MAIA). By contrast, Nielsen and Kaszniak (2006) and Khalsa et al. (2008) found experienced meditators' heartbeat perception did not differ from that of non-meditators. Khalsa et al. (2008) further pointed out that experienced meditators had better confidence in their heartbeat counting than the non-meditators for the latter tended to underestimate their interoceptive ability. Garfinkel and Critchley (2013) further suggested to distinguish a meta-cognitive aspect of interoception from one regarding accuracy. In their later work, Garfinkel, Seth, Barrett, Suzuki and Critchley (2015) defined interoceptive accuracy as a sense ability referring to how close is one's subjective feeling to one's own inner sense (e.g., the subjective count of one's heartbeats); whereas the interoceptive awareness refers to the congruency between one's accuracy and confidence judgments. That is, how well one can know how accurate his answer is. The researchers pointed out that it should

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be careful about the different facets of interoception, and supposed these different facets of interoception may solve the problem of inconsistent past findings.

Differing from interoception, proprioception, a musculo-skeletal sense, provides afferent feedback during movement for guiding action in addition to visual information (for review, see Ritchie & Carruthers, 2015). For example, one can move his body through proprioceptive sense in darkness (Liutsko, 2013). In clinical circumstances and laboratory studies, proprioception can be evaluated by the minimal detection threshold for passive movements (e.g., Deshpande, Connelly, Culham, & Costigan, 2003; Xu et al., 2004) or how well one can repeat the speed of joint movements (e.g., Deshpande et al., 2003). On the other hand, some researchers chose the passive movement task as the measure for proprioceptive ability (e.g. Deshpande et al., 2003; Pincivero, Bachmeier, & Coelho, 2001; Schaap, Gonzales, Janssen, & Brown, 2015; Smyth & Mason, 1998). In this task, participants had to actively move their limbs to a certain angle which had been passively placed by the supervisors without visual cues regardless of speed. Here I had also selected this task as our measure for proprioceptive accuracy in the thesis.

Recently, Alloway and Alloway (2015) found participants increased their

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working memory capacities after a two-hour proprioception-demanding training course, compared to the control groups that received two-hour classroom-style lecture or 1-hour yoga training. It is surprising that yoga training was not effective for enhancing working memory since yoga also heavily relied on proprioception. The possible reason for the ineffectiveness may be the relatively shorter dosage of yoga training: the experiment group spent double the time on proprioception training than the yoga control group. Most importantly, they did not directly measure participants' abilities of proprioception; therefore, whether the improvement on working memory capacity can be attributed to it is still unknown.

To specify proprioception, I adapted the methodology Garfinkel et al. (2015) used, where interoceptive accuracy and awareness are separately gauged. I proposed a new index for proprioceptive awareness to measure proprioception on the meta-cognitive level in addition to proprioceptive accuracy. Objective accuracy is about the location of one's limb in the passive movement task. Proprioceptive awareness is the meta-cognition to the proprioceptive accuracy: whether one knows their performance in passive movement task is good or not. The definitions, task examples, and mode of assessment for accuracy and awareness in proprioception and interoception are

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illustrated in Table 1.

In this study, I aim to examine whether our training can enhance both bodily awareness (proprioceptive or interoceptive) and executive control for children and the role of bodily awareness played in this process.

Table 1

The Definition, Examples and Modes of Assessment of Two Facets of Interoception and Proprioception

	Interoceptive Accuracy	Interoceptive Awareness	Proprioceptive Accuracy	Proprioceptive Awareness
Definition	Accuracy of detecting self visceral signals.	Metacognition to the interoceptive accuracy.	Accuracy of detecting self body location.	Metacognition to the proprioceptive accuracy.
Example	Can you accurately count the number of your heartbeat?	Do you know your heartbeat-counting is correct or incorrect?	Can you accurately replace your leg to where the other one have put your leg to without seeing it?	Do you know your replacement of your leg is identical to the right place or not?
Mode of Assessment	Assessed through objective task of interoceptive accuracy Ex. Heartbeat Detection task.	Assessed through the congruency between interoceptive accuracy and confidence judgment.	Assessed through objective task of proprioceptive accuracy Ex. Passive Movement task.	Assessed through the congruency between proprioceptive accuracy and confidence judgment.

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The Executive and Attentional Control

In this thesis, two types of mental ability involving executive and attention control were targeted. They are including working memory and sustained attention.

Working memory capacity, an aspect of executive control, is a constructed cognitive system which reflects one's capacity of manipulating and temporarily store information simultaneously and consciously. In this study, it is measured by the operational span task (OSPAN), one of the most widely used measurements for working memory capacity (Turner & Engle, 1989). The task I adopted was revised from Turner and Engle (1989). In this task, the participants were asked to remember several two-character Chinese words (the primary task) while doing mental arithmetic operations. The index for working memory capacity was the total number of words recalled by the participant.

Sustained attention refers to the ability of keeping focus on a target, which involves detecting one's mind wandering and redirect their attention to the task at hand. Sustained Attention Response Tasks (SART), derived from Robertson, Manly, Andrade, Baddeley and Yiend (1997), has been widely used for measuring children's sustained attention (e.g., Johnson et al., 2007; Adamo et al., 2012; Chang, Hung,

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Huang, Hatfield, & Hung, 2014; Vries, Prins, Schmand, & Geurts, 2015) and for indexing adults' mind-wandering (Smallwood et al., 2004; Smallwood, Fishman, & Schooler, 2007; Smallwood, McSpadden, & Schooler, 2008; McVay & Kane, 2009; Cheyne, Solman, Carriere, & Smilek, 2009; Mrazek, Smallwood, & Schooler, 2012; Morrison, Goolsarran, Rogers, & Jha, 2014). I thus also used it in my thesis as the measure of sustained attention. The adopted task is a GO/NOGO response task, which requires participants to respond to dominant stimuli (GO trials) continuously while withdrawing their responses to specific few stimuli (NOGO trials). There are two indices used to represent the quality of performance. The first one is Reaction Time Coefficient of Variability of GO trials (RTCV for short), which is gauged by dividing the standard deviation around one's reaction times of the correct GO trials by the mean reaction time of these trials. Greater RTCV represents a less consistent speed of responding, which are likely resulted from attentional lapses. The second index is the accuracy rate for NOGO trials (NOGO ACC for short). High NOGO accuracy indicates less distracting from the current task and better control of impulse.

Hypotheses

Based on previous review, I infer that 1) The BMAA training can enhance

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children's bodily awareness (including proprioception and interoception), sustained attention, and working memory. Furthermore, if the suggestion from previous studies about body awareness is true, then I also predict that 2) Better performances on bodily awareness, either proprioception or interoception, are associated with better sustained attention (lower RTCV and higher NOGO accuracy) or better working memory in our pretest correlational study. 3) The improvement in sustained attention and working memory may accompany the improvement of bodily awareness. Moreover, if proprioception is important for the movement-based training, then 4) Children with higher proprioceptive accuracy or awareness should benefit more from the training. Figure 1 shows the schematic diagram about the relationships among BMAA training, bodily awareness, and executive control mentioned in my hypotheses.

To test my hypothesis, a randomized control trial with pretest-posttest designed was used. All children would complete SART, OSPAN, heartbeat detection task and passive movement task before and after an intervention, BMAA program or a camp-like course as an active control. Two kinds of active control group were organized. Some of the participants in the control group received an active-control program designed by my research team during the same period as the group that did the

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BMAA practice. In this program, only BMAA practices were replaced with physical and mental games (for details, see Method session). The other participants in the control group were allowed to participate in summer camps or activities from other sources available to them during the same time as the study was held. Themes of these camps could be various kinds of sport games, science or language, handicraft, cooking, outdoor activities or travelling. Some participants attended several. These are typical activities that Taiwanese school children would do and enjoy during a summer vacation. Therefore, it is appropriate to use it a baseline control. Note that programs related to mindfulness-based training, martial arts or yoga was excluded.

My predictions are as follows: 1) Compared to the control group, the BMAA group would improve more on proprioceptive awareness and interoceptive awareness, working memory capacity, and sustained attention (i.e., higher NOGO ACC and lower RTCV) after training. In other words, a group effect which compared with the improvement ratio would be found; 2) Better proprioceptive awareness or interoceptive capacity are associated with better sustained attention or better working memory in the pretest; 3) Improvement on NOGO ACC, RTCV and working memory capacity would be accompanied with the improvement of bodily awareness in the

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BMAA group; 4) Children with better proprioceptive accuracy or awareness should benefit more from the BMAA training on sustained attention or working memory capacity more than those with poorer ones in the BMAA group.

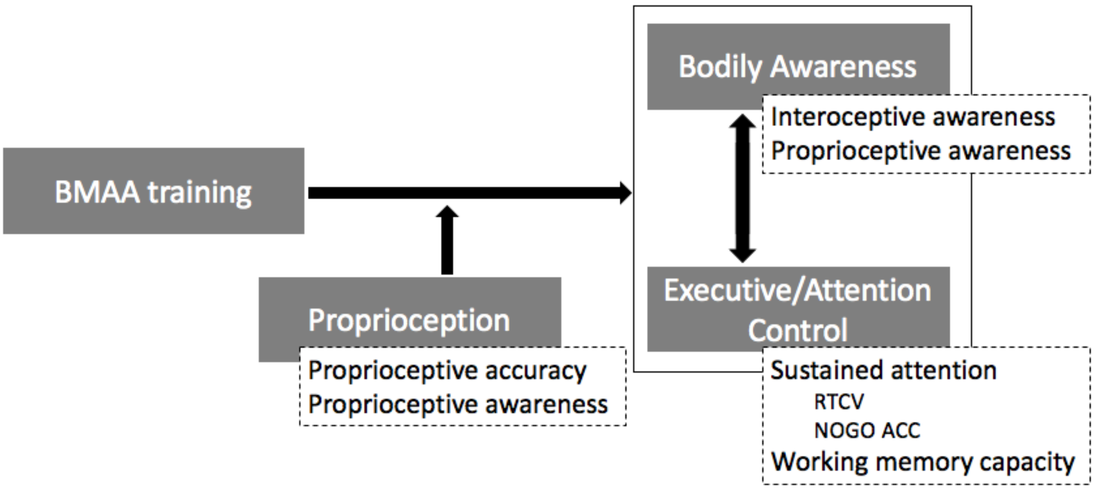

Figure 1. A conceptual diagram illustrating the possible relationship among bodily awareness and executive functions, and the possible training effect of BMAA-C.

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Method

Participants

Fifty-five normal children aged between 8 and 11 years old were recruited via internet with the agreement of their parents. To increase the validity or correlational study, nine children were further recruited here. None of them has taken any medicine regularly or had the history of psychological diagnosis based on parents' reports. Six of them were excluded because of task incompletion or they showed too much tiredness to focus on task in the pre-test. The analysis for correlational study were thus based on fifty-eight children, 30 boys (*M* = 9.43 years old; *SD* = 0.86) and 28 girls (*M* = 9.61 years old; *SD* = 0.83), with average age 9.52 years (*SD* = 0.84).

As for the next study of the training effect, forty-nine participants (excluding the later-recruited nine children) were randomly assigned to either BMAA-C program or other program according to their available time. One children in the BMAA group was further excluded for having an accuracy rate of zero in SART. Finally, the BMAA group thus included 27 children (14 boys and 13 girls) with the mean age of 9.59 (*SD* = 0.75) years old, and the control group consisted of 21 children (10 boys and 11 girls) with the mean age of 9.38 (*SD* = 0.74) years old. The participants of the BMAA

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group and the control group were matched for age and gender. The study was approved by Research Ethics Committee of National Taiwan University and the informed consents were collected.

Design and procedures

A pretest-posttest control group design was used. Both BMAA training group and the control group were tested with a set of tasks twice, within 2 weeks before (time 1, T1) and after the intervention program (time 2, T2). All the participants were tested individually in two separate days within two weeks at each test phase. In the first day, they were tested with the passive movement task, a proprioception test, for about 30 minutes and the sustained attention response task for about 20 minutes. The order between these two tasks were counter-balanced, with a 10-minute break between. In the second day, the participants completed a 15-minute heartbeat detection task for interoception among other tasks not relevant to the current study.

Interventions

<u>Body-Mind Axial Awareness practice for children (BMAA-C)</u>

As mentioned previously, BMAA emphasizes practices that take practitioners' attention back to the so-called body-mind axis to enhance self-awareness and be able

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to move and attend efficiently but relaxingly (Chen, 2011a; Teng & Lien, 2016). BMAA-C is lengthened and revised from the 12-hour adult version used in Teng & Lien (2016) to be appropriate for children by the research team that I belong to.

BMAA-C course consists of 11 3-hour sessions, 3 in each week, across 3 and half weeks. The course time was 33 hours in total. As can be seen in Table 2, each class session consists of 1) a 30-minute welcoming and warm-up at the beginning, during which children participants reported their arrivals, handed in home assignments, and participated group activity as a warming-up and help to develop a positive rapport with the trainers; 2) two separated parts of BMAA practice, an hour for each; 3) a 15-minute snack time; and 4) a 15-minute end routine, during which home assignment was delivered and the classroom was cleaned up by children. In addition, BMAA practice II was replaced with a one-hour outing around NTU campus once a week, 3 in total.

The main theme for BMAA practices in each class session is shown in Table 3, including knowing and feeling the body, pacifying the mind and feeling the central bodily axis, training the strength of one body part while keeping others relaxed, being in the state of body-mind axial awareness ……etc. In particular, the program starts

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with practicing the muscles involved in the five sense organs. Next, the practices of using upper and the lower limbs, the scapula, and the spinal column was then taught. All these practices were followed the principle of body-mind axial awareness. Children were also taught how to apply the principle to the movements in daily life such as walking, sitting, or even how to get up from a bed.

Table 2

The Components in Each Class Session of BMAA Program.

Minutes	Components
30	Warm-up:
	Welcoming.
	Students report arrival and hand in home assignments.
	Group activity.
60	BMAA practices I
15	Snack time
60	BMAA practices II
15	End Routine:
	Instructors deliver the take-home assignment. Students clean up the classroom.

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Table 3

The Main BMAA Practices in Each Class Session for the BMAA Group

Session	Main practices for each session
1	Knowing and feeling the body: a. Introducing body parts, joints, and bones. b. Introducing the concept of body-mind axis: A magic way to be the master of your body and mind. c. Self-massaging five sense faculties and feeling their flexibility and softness. d. Testing the nimbleness and strength of extremity endpoint.
2	Pacifying the mind and feeling the central bodily axis I: a. Practices on increasing the flexibility of the five sense faculties. b. Practices on keeping one's eyes looking inwards and downwards relaxingly with the eyes closed or semi-closed in a sitting or lying position. c. Stretching the five endpoints of one's body (i.e. head, two hands and two feet) while keeping the eyes closed and looking inwards to experience the central bodily axis. d. Feeling one's own breath and practice channeling the breath through abdominal movement.
3	Pacifying the mind and feeling the central bodily axis II: a. Practices on increasing the flexibility of shoulder blades and thoracic b. Practicing uninostril breath while projecting one's attention inwards to the bodily central axis.
4	Training the strength of one body part while keeping others relaxed in a lying position I: a. Practices on increasing the nimbleness and strength of fingers while keeping the shoulders, neck and head relaxed. b. Practices on increasing the nimbleness and strength of toes while keeping the upper part of body relaxed.
5	Practices on keeping one's back straight in accord with BMAA principles: a. Practices on stabilizing the trunk by keeping coccyx forwards and contracting the levator ani.

(continued)

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Table 3

The Main BMAA Practices in Each Class Session for the BMAA Group

Session	Main practices for each session
5	b. Feel the central bodily axis, a channel that connecting perineum and the top of head, when doing (a). Channeling one's attention towards the central bodily axis with the eyes closed while doing a movement
6	Practices on increasing the flexibility of spine with the principles: a. Feel and move each bone of the spine. Rolling one's back.
7	Being in the state of body-mind axial awareness I: the lower limbs. Meditative practices: a. Eating rice mindfully. b. Smelling and listening mindfully. b. Practicing sitting meditation in accord with the BMAA principles.
8	Being in the state of body-mind axial awareness II: c. Connecting each individual BMAA movement into a set of specific sequential movements and practicing it continuously for half an hour
9.	Walking by the BMAA principles: a. Practices on keeping the trunk moves as an integrated whole. Practicing to mark time and walk in accord with the principle.
10	Being in the state of body-mind axial awareness III: b. Practicing BMAA movements continuously and feeling the integration of mind and body.
11	Final review

<u>Intervention for the control group</u>

As previously mentioned, there were two types of control group. Nine out of 21 children participated summer camps or activities commonly offered during the summer in Taiwan. The camps chose were determined by those children or their

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parents and were not related to mindfulness-based training, martial arts or yoga. The remain participants (12 out of 21) in the control group were received an intervention, which was also designed by the research team, during the same period as the BMAA group. The procedure of this active-control program was almost the same as BMAA-C in Table 2. Only the time for BMAA practice were replaced with physical and mental games, such as group activities, drawing, ball playing, dancing, board games and puzzle games.

Both BMAA course and the active-control program designed by us are taught by the members of the research team mentioned above, most of them have had practiced BMAA for more than 2 years. There are 4 to 7 members in each session. The children participants never met with the trainers before the study.

Tasks and Materials

Sustained Attention Response Task (SART)

The task was programmed with PsychoPy (version 1.82; Peirce, 2009) and played on a PC laptop. Each participant was seated in front of the laptop on a table, with a distance that the participant felt comfortable, in a quiet room. SART consisted of 250 trials, in each a digit between 0 to 9 was randomly presented on the screen.

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Participants were asked to press the space key of a keyboard as fast as possible when the number appeared except for number 3, the NOGO trial, during which the participants should withhold key pressing.

In each trial, a number is shown for 250 ms and followed a 900 ms mask, during which a circled X is displayed. A following trial came immediately after participants' pressing the key or the fixation time was over. Twenty-five trials (10%) were the NOGO trials and the remaining 225 trials were GO trials (when the numbers other than "3" presented).

The reaction time coefficient of variability of correct GO trials (RTCV) and the accuracy of NOGO trials (NOGO ACC) were computed for each individual as previously mentioned, with higher NOGO accuracy and lower RTCV representing fewer attentional lapse, thus better sustained attention.

<u>The operational span task (OSPAN)</u>

In each trial of this task, the participants were asked to a) read out loud an equation involving single-digit addition and subtraction appeared on the screen of computer, b) verify the correctness of the equation by saying yes or no and c) stated and memorized a Chinese two-character word presented on the screen after the

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verification. In each trial, the above procedure was repeated 2-6 times making the number of words to be remembered ranged from 2 to 6. The Chinese two-character words were selected from Report of Word Frequency for Elementary School Children by Ministry of Education of Taiwan. Half of the equations was correct and the other half was wrong. At the end of each trial, a recall instruction will appear, the participants were then asked to recall the words appeared in the trial, in any order, as many as possible. According to the number of words to be recalled, there were five levels of trial difficulty, three trials at each level, making fifteen trials in total. The working memory capacity for each participant was measured by the total number of recalled words. The procedures of OSPAN is illustrated in Figure 2.

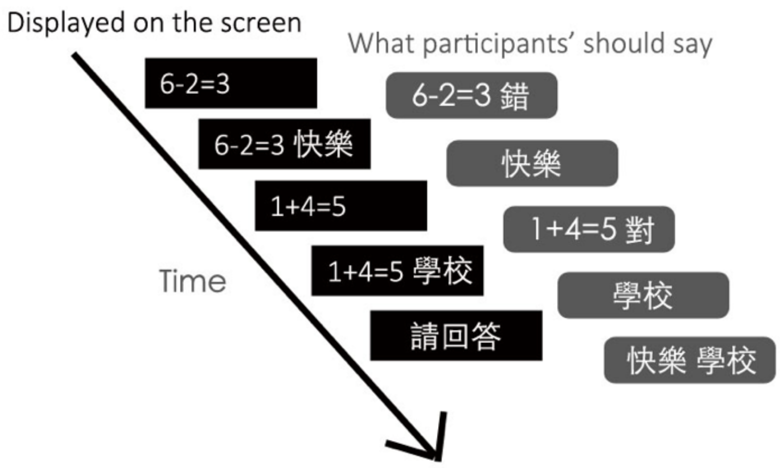

Figure 2. The procedures of operational span task.

<u>Heartbeat Detection Task</u>

Participants were seated restfully and instructed to concentrate on their

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heartbeat signals and counted their heartbeats silently without trying to control of it. Before the task, there was a 10-minute rest time for the participants to calm down and to wear a sensor of electrocardiogram (ECG) on their point-finger to measure their actual heartbeats. There were six trials with varied intervals, 13, 20, 25, 18, 23 and 15 seconds, respectively, and a 20-second break between each trial. The beginning and the end of each trial was orally given by an instructor, and no other feedback was given during or after the trial. Participants had to verbally report how much pulse they counted after they heard the “stop” instruction. In addition, they were asked to judge how confident they were in their counts with a 7-point Likert scale, 1 represents no confidence at all and 7 represents very confident.

Interoceptive accuracy (IAC) is indicated by the difference between the reported heartbeats and the actual ones counted by ECG for each trial suggested by Schandry (1981) as below:

$$\mathrm{IAC} = \frac{1}{\mathrm{N_{IAC}}} \times \Sigma\left(1 - \frac{|\text{recorded heartbeats} - \text{counted heartbeats}|}{\text{recorded heartbeats}}\right)$$

$\mathrm{N_{IAC}}$ = Number of IAC trials

The interoceptive awareness (IAW) is measured by a mean-square approach proposed by Meessen et al. (2016), which is an average degree of congruency

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between IAC and the confidence judgment for interoception (CJI) for each trial according to the following formula. Note that he CJI was converted from 7-point Likert scale to hundred-mark scale.

$$\mathrm{IAW} = \frac{\Sigma[(\mathrm{IAC} \times 100 - \frac{100}{7}\mathrm{CJI})^2]}{\mathrm{N_{IAC}}}$$

Passive Movement Task

In this task, how accurately a participant could sense the movement of his hip joints was chosen to represent the proprioceptive sense. The movements of hip joints was measured by twelve makers taped on relevant joints (including: trunk: xiphoid notch, xiphoid process, left acromion and right acromion; pelvic: right anterior superior iliac spine, left anterior superior iliac spine, right middle pelvic and left middle pelvic; and the knee of dominant leg: medial epicondyle, lateral epicondyle, thigh and greater trochanter), with which three-dimensional marker trajectories were captured with a six-camera motion analysis system (VICON MX, Oxford Metrics Inc, Oxford, UK). Although the angle of body limbs can be measured by protractor but the motion analysis system was more sensitive to the difference of angles and the error is also smaller than protractor.

After finishing marker taping, participants were told to lie down on a bed with

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their hands put on their abdomen and eyes closed. At each trial, a participant's dominant leg was passively moved to a particular angle, either above 45 degrees or under 45 degrees, and then moved back to the original position by an instructor. The participants were then asked to actively move their leg to the position that had been placed afterwards. Two types of movement of leg involving hip joints, abduction and flexion, were measured in this task. For each type of movement, there were two trials for each type of angle (i.e., above and under 45 degrees), constituting eight trials in total. The types of movement are illustrated in the Figure 3.

After each trial, participants were also asked to make a confidence judgment on how accurate their active placings were with a 7-point Likert scale, as 1 represents that they have no confidence at all and 7 very confident. The procedures of passive movement task is illustrated in the Figure 4.

I define proprioceptive accuracy (PAC) by the degrees that the active placing angels deviate from the passive placing ones, which is shown as follow:

$$\mathrm{PAC} = \frac{1}{\mathrm{N_{PAC}}} \times \Sigma(1 - \frac{|\text{angle of passive move} - \text{angle of active move}|}{\text{angle of passive move}})$$

$\mathrm{N_{PAC}}$ = Number of PAC trials

Analogous to how interoceptive awareness is gauged, I define proprioceptive

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awareness (PAW) by the mean-square approach based on the following formula:

$$\mathrm{PAW} = \frac{\Sigma[(\mathrm{PAC} \times 100 - \frac{100}{7}\mathrm{CJP})^2]}{\mathrm{N_{PAC}}}$$

CJP = Confidence Judgment for Proprioception task

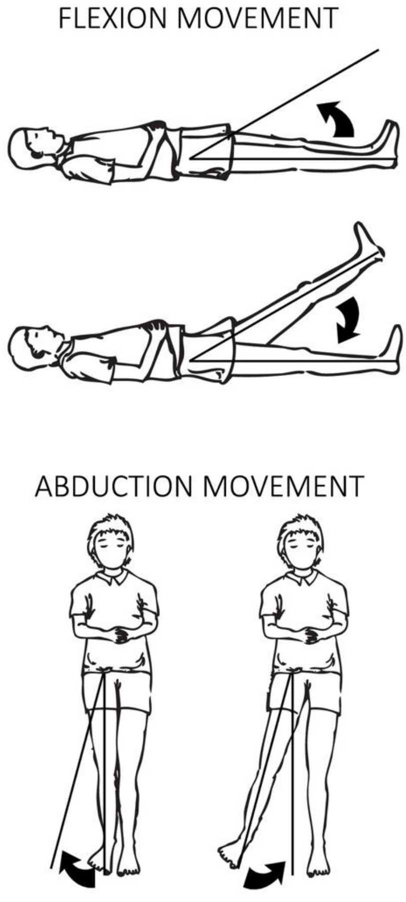

Figure 3. Two types of movement used in passive movement task.

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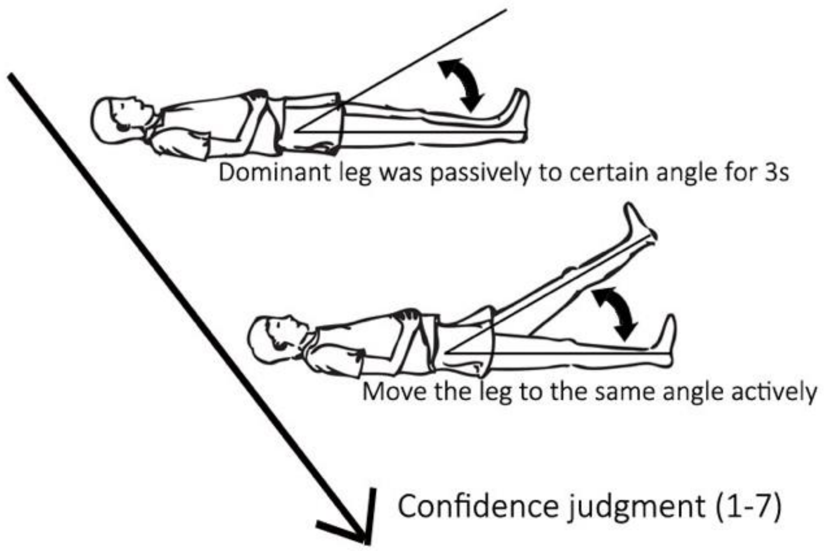

Figure 4. The procedures of passive movement task.

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Results of Pre-test Correlation

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Data Analysis

In order to examine if there is any relationship between body (bodily senses) and mind (sustained attention and working memory), the correlational analysis was done for the pre-test measures. The following statistics were calculated with SPSS version 21. Before examining the main concern about the correlations between each of the bodily senses (interoception and proprioception) and cognitive performance (working memory, RTCV and NOGO ACC) will be examined, the participants' performance on each of the three tasks with respect to gender and their ages will be reported first, and then the inter-domain correlations between the interoception and proprioception. All results were considered significant at $p < .05$, two-tailed.

Children's Performances of Interoception (Heartbeat Detection Task)

As shown in Table 4, the mean score of interoceptive accuracy for all the participants is 0.68 (SD = 0.16) and that of interoceptive awareness is 729.66 (SD = 578.40). There is an unexpected significant correlation between interoceptive accuracy and interoceptive awareness ($r = .43$, $p < .01$). Note that for the indices of awareness used in this study, smaller numbers represent better awareness (i.e., less

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incongruence between subjective confidence ratings and objective-measured accuracy) than the larger ones. The above finding thus indicates children better at counting heartbeat, nevertheless, do worse on judging how good their counts were. No gender difference is found for either interceptive accuracy or awareness (Accuracy: $F(1,56) = .01$, $p = .91$; Awareness: $F(1,56) = 1.97$, $p = .17$). In addition, neither one is significantly associate to age (Accuracy: $r = -.02$, $p = .89$; Awareness: $r = .11$, $p = .41$).

Children's Performances of Proprioception (Passive Movement Task)

For all participants, the mean score is 0.81 (*SD* = 0.06) for proprioceptive accuracy and 663.80 (*SD* = 431.49) for proprioceptive awareness. Unlike interoception, there is no correlation between proprioceptive accuracy and awareness ($r = -.06$, $p = .66$). For each of the index, neither gender difference (Accuracy: $F(1,56) = .68$, $p = .41$; Awareness: $F(1,56) = .06$, $p = .80$), nor the correlation to age (Accuracy: $r = .11$, $p = .43$; Awareness: $r = .11$, $p = .42$) was found.

Children's Performance of Sustained Attention (SART)

For SART, the measurement of sustained attention, the mean accuracy of NOGO trials (NOGO ACC) is 0.40 (*SD* = 0.20) and the mean Reaction Time Coefficient of

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Variability of GO trials (RTCV) for GO trials is 0.39 (*SD* = 0.12). There was a significant difference in RTCV between male (*M* = .43, *SD* = .12) and female (*M* = .35, *SD* = .11), $F(1,56) = 6.26$, $p < .05$. Children's RTCVs were also significantly correlated with age, $r = -.39$, $p < .01$. As for NOGO ACC, neither a gender difference, $F(1,56) = 2.55$, $p = .11$, nor a significant correlation with age, $r = .19$, $p = .15$, was found.

Children's Performance of Working Memory (OSPAN)

The working memory capacity was measured by the total number of OSPAN. The mean score was 38.34 (*SD* = 6.40). There was no significant gender difference $F(1,56) = .63$, $p = .43$ but it correlated with ages significantly, $r = .29$, $p = .03$.

Table 4

Descriptive Statistics for Children's Performance on Proprioception, Interoception, Sustained Attention and Working Memory Capacity at T1 (N=58)

Indexes	*Mean*	*SD*	*Min*	*Max*
Proprioceptive Accuracy	0.81	0.06	0.66	0.92
Proprioceptive Awareness	663.80	431.49	63.60	1771.14
Interoceptive Accuracy	0.68	0.16	0.27	0.96
Interoceptive Awareness	729.66	578.40	36.29	2508.74
GO trial RTCV	0.39	0.12	0.17	0.71
NOGO trial ACC	0.40	0.20	0.04	0.96
Working memory capacity	38.34	6.40	21.00	49.00

Note: RTCV is short for reaction time coefficient of variability.

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Correlation between Interoception and Proprioception

The inter-domain correlations between interoception and proprioception for accuracy and awareness were also examined, respectively. There was a significant positive correlation (r = .30, p < .05) between proprioceptive and interoceptive awareness but no any relation was found in accuracy across domains (r = -.13, p = .34)

Correlations between Bodily Senses and Sustained Attention

As predicted, children's proprioceptive awareness is positively correlated with their performance on sustain attention. Specifically speaking, children's scores of proprioceptive awareness was positively correlated with RTCV (r = .30, p < .05) and negatively correlated with NOGO accuracy (r = -.28, p < .05). In other words, children who have better proprioception awareness tend to have higher accuracy and respond in a more stable way in the sustain attention task, both of which indicating fewer mind wandering and better sustained attention, than those have worse awareness. In contrast, there is no significant correlation between interoceptive awareness and measures of SART (RTCV: r = -.14, p = .29; NOGO ACC: r =.07, p = .59).

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In addition, it shows that proprioceptive accuracy has a significant correlation with RTCV (r = -.37, p < .01) and a no-significant-trend in relating to NOGO ACC (r = .24, p = .07). That is to say that children with higher proprioceptive accuracy showed more consistent speed of responding, and thus have fewer mind wandering, than those with lower accuracy. However, no such correlation was found between interoceptive accuracy and sustained attention (Accuracy: r = .00, p = 1.00; Awareness: r = .05, p = .71).

On the other hand, different from the results above about sustained attention, no any indexes of bodily senses (interoception or proprioception) correlated with working memory, neither awareness nor accuracy (ps > .10). All the above results are shown in Table 5.

Did Interoceptive Awareness Play the Other Role than the Predictor for Sustained Attention?

In the previous analysis, the direct relation between awareness and sustained attention was found only in proprioception but not interoception. However, interoceptive awareness associate with proprioceptive awareness significantly. It is possible that interoceptive awareness may have effect on the relation between

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proprioceptive awareness and sustained attention, so two separate moderation analyses were carried out for RTCV and NOGO ACC. In all the regression analysis, the proprioceptive awareness and interoceptive awareness were all mean centered (to reduce the possibility of multicollinearity among the interaction terms and their component predictors) and the interaction term between them were computed (Aiken & West, 1991). The two predictors and the interaction term were simultaneously entered into regression model. At first, RTCV was analyzed and it showed that the overall regression reached significance (R^2 = .16; $R_{adjusted}$ = .11; F(3,54) = 3.34, p = .03) and proprioceptive awareness (β = .35, p = .01) was significantly predictive for RTCV which was in line with our relational results that mentioned above. In addition, the interaction term had a trend toward significance (β = -.23, p = .09) while interoceptive awareness was not significantly predictive for RTCV (β = -.08, p = .56). The slopes were illustrated in Figure 5.

In other words, we can see from Figure 5 that the relation between proprioceptive awareness and RTCV was more obvious in the children who have better interoceptive awareness. For the children who have lower interoceptive awareness, this kind of relation is not clear. That is, although interoceptive awareness didn't directly associate

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with RTCV, the role it played was the moderator for the effect of proprioceptive awareness on RTCV.

As for the NOGO ACC, overall regression did not reach significance (R^2 = .10; $R_{adjusted}$ = .05; F(3,54) = 2.01, p = .12). Identical with previous relational results, only proprioceptive awareness was significantly predictive for NOGO ACC (β = -.30, p = .03). Neither the predictiveness of interoceptive awareness nor the interaction term was significant or has the trend toward significance. (interoceptive awareness: β = -.02, p = 91; interaction: β = .15, p = .27)

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Table 5

Inter-correlation Matrix among the Scores on Proprioception, Interoception, Sustained Attention and Working Memory Capacity at T1 (N=58)

	Proprioceptive Accuracy	Proprioceptive Awareness	Interoceptive Accuracy	Interoceptive Awareness	GO trial RTCV	NOGO trial ACC	Working memory capacity
Proprioceptive Accuracy	1						
Proprioceptive Awareness	-.06	1					
Interoceptive Accuracy	-.13	-.03	1				
Interoceptive Awareness	-.07	.30*	.43**	1			
GO trial RTCV	-.37**	.30*	.00	-.14	1		
NOGO trial ACC	.24$^{\Delta}$	-.28*	.05	.07	-.66**	1	
Working memory capacity	-.03	-.04	-.003	.14	-.20	.17	1

Note: RTCV is short for reaction time coefficient of variability.

$^{\Delta}$ *p*<.10. * *p*<.05. ** *p*<.01.

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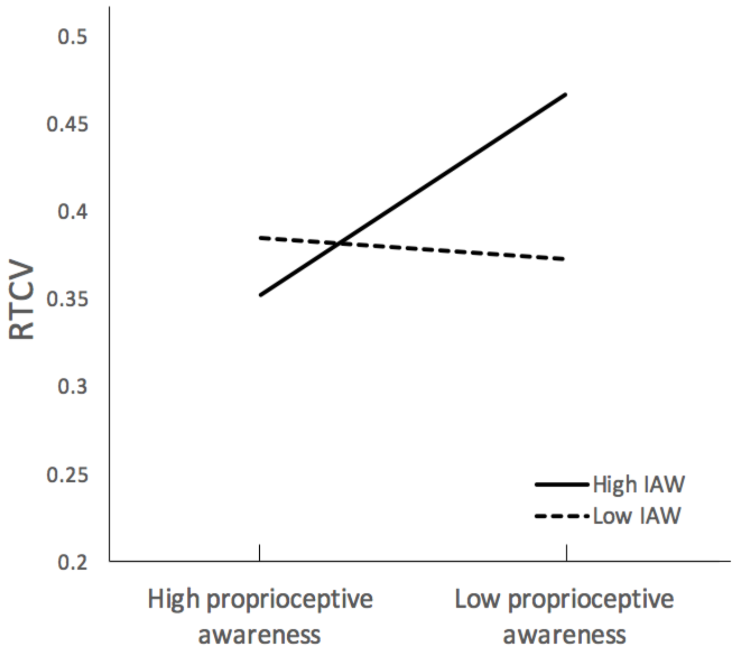

Figure 5. The scores of RTCV (reaction time coefficient of variability) for children with high/low interoceptive awareness (IAW) and high/low proprioceptive awareness.

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Discussion I

In summary, there are three main findings about the correlational analysis on the pretest scores. First, children's abilities regarding proprioception are related to their performance on sustained attention. Specifically speaking, children better at proprioceptive awareness respond to GO trials with a more constant speed (i.e., smaller RTCVs) and have higher accuracy rates for NOGO trials (NOGO ACC) in SART than those worse. In addition, children better at proprioceptive accuracy also tend to be better at RTCV. Remind that high stability of reaction time for Go trials and high accuracy rate for NOGO trials both represent better control of attention. Although practicing body awareness or somatic attention has been thought to be crucial for the positive training effect of mindfulness training on attention, my finding, for the first time, demonstrates that children's body awareness, i.e., proprioceptive awareness, is associated to their attention control.

Second, although no correlation between sustained attention and interoception is found, children's interoceptive awareness is nevertheless significantly correlated with proprioceptive awareness, and moderates the relation between proprioceptive awareness and RTCV. That is, the positive correlation between proprioceptive

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awareness and RTCV is statistically significant only for children with high interoceptive awareness but not for those with low interoceptive awareness.

Third, unlike sustained attention, children's working memory capacities are independent to their body awareness. It may be not too surprising if we compare the natures of the tasks measuring sustained attention, SART, and working memory capacity, OSPAN. Unlike SART, a working memory capacity task is usually more challenging and demanding for it intends to measure a person's maximal cognitive resources available at a time. It is known that a person is usually more alerted and tend to have fewer mind wanderings when doing a high-demanding task compared to a low-demanding one like SART (e.g. Rummel & Boywitt, 2014). Therefore, good performance on SART requires more attention monitoring and could be more sensitive to one's meta-awareness than a challenging one like OSPAN. Interestingly, improving on working memory capacity is the most-frequently-reported effect of mindfulness training on cognitive functions (Teng & Lien, 2016). The above result might indicate that this improvement is not through the enhancing body awareness. In next study, I would further test this conjecture.

In addition to the aspect of awareness, children's proprioceptive abilities, i.e.,

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how accurate they know where they bodies are, also predict their performance on the sustained attention task (i.e., reducing RTCV in SART). A plausible account is that children with better proprioception require fewer attention resources to keep their motor or postural control (such as sitting or standing) during an attention task, so that less interfere children's performance on attention-related tasks. It is known that proprioception plays an important role at motor or postural control (e.g. Marsh & Geel, 2000; Riemann & Lephart, 2002; Teasdale & Simoneau, 2001). In addition, for the elderly, who has reduced attention resources, sensory integration required for postural control is also known to depend on their ability of attention (e.g. Redfern, Jennings, Martin, & Furman, 2001). Therefore, for children who also has very limited capacity of attention, being endowed with better proprioception may leave more attentional resource for the attentional task at hand. However, this account would also predict that children's performance on working memory capacity would be influenced by their proprioceptive accuracy for the same reason. As the results show, this is not true. Another possibility is proprioception and attention might involve some common cognitive process or brain areas, which requires further investigation.

Some other might argue that children with higher proprioception may trade

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speed for accuracy. Therefore, it is nothing to do with the so-called body-mind interaction. Previous studies have shown that there is speed-accuracy trade-off between GO trials reaction time and NOGO accuracy (e.g. Seli, 2016). My data also showed that these two indices are correlated to each other (r = .60, p < .001). However, children's proprioception does not correlate to the reaction time of GO trials (accuracy: r = -.03, p = .84; awareness: r = -.19, p = .18). So the trading-off account cannot explain the relationship between NOGO accuracy and proprioception.

Unexpectedly, instead of directly associating to sustained attention, interoceptive awareness is positively associated with proprioceptive awareness and moderates the relation between proprioceptive awareness and sustained attention. The moderating effect of interoception says that children's proprioceptive awareness can predict their sustained attention better when they are relatively good than poor at interoception, which indicate an indirect influence of interoception on sustain attention. It is likely that these two kinds of body awareness may come from a general kind of meta-awareness and jointly influence the attention monitoring. Further investigation is required to know more about the relationship among the three.

As previously mentioned, the aspects of accuracy and awareness of

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interoception were usually found to be independent to each other for adults (Garfinkel et al., 2015; Meessen et al., 2016). However, my data show that children who score higher on interoceptive accuracy are worse on awareness than those who score lower on accuracy. To make the picture clearer, I further split participants into high- and low-accuracy groups along the median score of interoceptive accuracy. I found that the correlation no longer exists for the low-accuracy group. That is, only in the high-accuracy group (the average rate is 0.81), children who scored higher in accuracy tend to have larger gap between their confidence judges and accuracy than those who with relative lower scores in accuracy (0.55). As the data show, the confidence of high accuracy group (the average confidence rating is 4.84) did not high enough to match their accuracy performance, compared to that of the low accuracy group (4.21). It may be easier for children at 8-11 years old to know that they have messed thing up than that they have done a good job in the heartbeat counting task.

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Results of Training Effects

Data Analysis

The following statistics were also calculated with SPSS version 21. First, I will examine if there is any difference in these indices between the BMAA group and the control group before training. Second, the training effect will be examined through one-way ANOVA with group (BMAA/control) as the between-subject factor and the improvement ratio for each measurement as the dependent variables. Finally, to examine the hypothesis about body-mind interaction, a series of multiple regression was preformed to see if those who had better proprioception would benefit more from BMAA training than those who did not. All results were considered significant at $p < .05$, two-tailed.

The Baseline Difference between the BMAA Group and the Control Group

There was no significant difference between the BMAA group and the control group in gender ($p = .77$) or in age (BMAA: $M = 9.59$ years old, $SD = 0.75$; CONTROL: $M = 9.38$ years old, $SD = 0.74$, p = .33) at T1.

As shown in Table 6, there was also no significant difference across groups in proprioceptive accuracy ($p = .48$), interoceptive accuracy ($p = .56$), interoceptive

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awareness (*p* = .32), RTCV (*p* = .49) and working memory (*p* = .28) at T1. However, there was a tendency that the BMAA group (*M* = .45, *SD* = .21) performed better than the control (*M* = .35, *SD* = .17) on accuracy rate for the NOGO trials (NOGO ACC) in SART, *F*(1, 46) = 3.12, *p* = .08. In contrast, the BMAA group scored worse on proprioceptive awareness (*M* = 768.48, *SD* = 499.12) than the control group (*M* = 531.41, *SD* = 324.19) at T1 (*F*(1, 46) = 3.56, *p* = 0.07).

The Training Effects of BMAA

Next, in order to examine whether the BMAA group has significantly improved more than the contrast group in bodily senses and cognitive abilities measured after intervention, a one-way ANOVA was used to compared improvement ratios for each of the measures across groups. The ratios were the difference scores (T2-T1) divided by scores at T1.

As shown in Table 6, the BMAA group was significantly improve more in working memory (ratio: *M* = .14, *SD* = .13) than the contrast group (*M* = .04, *SD* = .18), *F*(1,46) = 4.88, *p* = .03. The BMAA group also had a tendency to improve more for RTCV (ratio: *M* = -.06, *SD* = .27) than the contrast group (ratio: *M* = .11, *SD* = .40), *F*(1,46) = 3.11, *p* = .08. In other words, there was a significant training effect

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of BMAA in improving children participants' working memory capacities and had a tendency training effect on sustained attention, compared to the control group. No group effects for other measures including proprioception (accuracy and awareness), interoception (accuracy and awareness) and NOGO ACC was found (*ps* > .10).

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Table 6

T1 scores, T2 scores and Improvement Ratio on Proprioception, Interoception, Sustained Attention and Working Memory Capacity for the BMAA Group (N = 27) and the Control Group (N = 21), respectively

Indexes	Groups	Time 1 *M*(*SD*)	Time 2 *M*(*SD*)	Improvement ratio	Training effect (*p-value*)
SART - GO trial ACC	BMAA	0.96 (0.07)	0.97 (0.03)	0.02 (0.09)	.17
	CONTROL	0.98 (0.02)	0.97 (0.04)	-0.01 (0.04)	
SART - GO trial RT	BMAA	450.11 (93.73)	478.61 (125.16)	0.07 (0.23)	.32
	CONTROL	406.07 (73.43)	407.15 (55.98)	0.02 (0.12)	
SART - GO trial RTCV	BMAA	0.4 (0.13)	0.37 (0.15)	-0.06 (0.27)	.08
	CONTROL	0.37 (0.11)	0.4 (0.15)	0.11 (0.4)	
SART - NOGO trial ACC	BMAA	0.45 (0.21)	0.55 (0.26)	0.48 (0.92)	.74
	CONTROL	0.35 (0.17)	0.45 (0.21)	0.59 (1.44)	
Working memory capacity	BMAA	37.37 (6.42)	42.11 (7.27)	0.14 (0.13)	.03
	CONTROL	39.43 (6.46)	40.43 (7.21)	0.04 (0.18)	
Proprioceptive Accuracy	BMAA	0.81 (0.06)	0.8 (0.06)	0 (0.09)	.17
	CONTROL	0.79 (0.07)	0.82 (0.08)	0.04 (0.1)	
Proprioceptive Awareness	BMAA	768.48 (499.12)	625.46 (366.62)	0.13 (0.86)	.86
	CONTROL	531.41 (324.19)	527.49 (402.89)	0.09 (0.66)	
Interoceptive Accuracy	BMAA	0.69 (0.15)	0.7 (0.19)	0.06 (0.44)	.79
	CONTROL	0.67 (0.17)	0.68 (0.21)	0.04 (0.26)	
Interoceptive Awareness	BMAA	802.71 (625.01)	1080.32 (1203.06)	1 (2.41)	.47
	CONTROL	639.35 (459.42)	691.59 (590.57)	0.55 (1.76)	

Note: Improvement ratio: (T2 scores – T1 scores)/ T1 scores.

Training effect is the comparison between the BMAA group and the control group for improvement ratio of each indexes.

RTCV is short for reaction time coefficient of variability.

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Who Would Benefit More from BMAA Training?

Based on the hypothesis and the features of BMAA training, I examine, with a series of linear regression analysis, whether children with better proprioception would benefit more on sustained attention than the worse ones from the training.

The regression models included T1 cognitive measures as controlled variable, effect of proprioceptive accuracy at T1 (PAC_{T1}), effect of proprioceptive awareness at T1 (PAW_{T1}), and difference scores for a cognitive measures (working memory capacity, RTCV and NOGO ACC for SART, respectively) were used as the dependent variable.

In the terms regarding the effect of PAC_{T1} and PAW_{T1}, children were split into two groups according to the median for each, and the better half was coded as +.5 and the remains -.5, respectively, according to mean-center recommendations of Kraemer & Blaséy (2004), The significance of these terms indicate that individual's condition of PAC and PAW at the beginning could influence how much they would improve on cognitive functions through BMAA. A series of linear regression models was then tested for each of the cognitive measures mentioned. The models were illustrated as follows:

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$$dRTCV = RTCV_{T1} + PAC_{T1(H/L)} + PAW_{T1(H/L)}$$

$$dNOGO = NOGO_{T1} + PAC_{T1(H/L)} + PAW_{T1(H/L)}$$

$$dWMC = WMC_{T1} + PACT1_{(H/L)} + PAW_{T1(H/L)}$$

As shown in Table 7, the overall model, the effect of PAC and PAW for NOGO ACC were all significant (overall: $p = .01$; PAC: $p = .02$; PAW: $p = .05$). The models, however, were not significant for RTCV ($p = .17$) and working memory ($p = .38$) for the BMAA group. Besides, for reader's interest, not any effect of bodily sense was found for the control group ($ps > .10$).

The above results indicate that children who came with better PAC improved more on NOGO ACC through BMAA training than children with poorer PAC. As for PAW, it showed an opposite pattern: Children with poorer PAW before training benefited more on NOGO ACC via the training than children with better PAW.

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Table 7

Multiple Regression Analyses Regarding the Effects of Proprioception at T1 on Sustained Attention and Working Memory, respectively

		$Score_{T1}$			PAC_{T1}			PAW_{T1}			Model statistics			
Groups	Dependent Variables	β	*t*	*p*	β	*t*	*p*	β	*t*	*p*	R^2	*df*	*F*	*p*
BMAA	GO trials RTCV	-.31	-1.59	.13	-.36	-1.83	.08	.12	.65	.52	.20	3, 23	1.86	.17
	NOGO trial ACC	-.16	-.92	.37	.43	2.58	.02	-.37	-2.06	.05	.39	3, 23	4.89	.01
	Working memory	-.12	-.62	.54	.03	.15	.88	.31	1.54	.14	.12	3, 23	1.07	.38
CONTROL	GO trials RTCV	-.40	-1.67	.11	-.33	-1.37	.19	.09	.40	.69	.19	3, 17	1.30	.31
	NOGO trial ACC	-.44	-2.01	.06	.37	1.70	.11	.05	.26	.80	.25	3, 17	1,93	.16
	Working memory	-.46	-1.94	.07	-.28	-1.20	.25	.22	.99	.34	.21	3, 17	1.53	.24

Note: RTCV is short for reaction time coefficient of variability.

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Discussion II

In sum, as predicted, BMAA-C is effective on improving children's working memory capacities and sustained attention indicated by the decreased variability of response speed (lower RTCV). However, contrary to my prediction, no training effect on bodily senses, particularly on bodily awareness, was found. However, for the BMAA group, children who scored better than the median on proprioceptive accuracy before training improved more for NOGO accuracy, another index for sustained attention, than the worse. Similarly, children with poorer proprioceptive awareness before training also improved more for NOGO accuracy than the counterpart.

The finding that the training effect of BMAA-C on working memory capacity (WMC) is in line with previous findings for adults showing that WMC is the most reliable effect of MBCPs in general (e.g. Gothe et al., 2013; Taylor-Piliae et al., 2010) and BMAA in specific (Teng & Lien, 2016). There are several plausible explanations why BMAA or, more general, MBCPs could facilitate practitioners' working memory capacities. First, some might argue that BMAA practice is kind of a multi-tasking practice which exerted on working memory. Note that practitioners have to monitor several places of their bodies (such as keeping the eyes downwards, doing some kinds

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of movement, and keeping some body parts relaxed at the same time) to meet the principle. Therefore, working memory capacities could be enhanced by repeatedly exercise. If so, the practitioners would be exhausted after the training, which is not the case as I observed.

Second, as BMAA movements are mostly practiced while eyes are closed, it is likely that proprioception is heavily involved in these practices, and as Alloway and Alloway (2015) suggests, proprioception-demanding trainings could benefit trainees' working memory capacities. However, my data does not support this explanation since my participants' proprioceptive accuracy was not improved as their working memory capacities were.

Third, the BMAA practice might help our participants to learn an effective way to quiet or void one's mind, which could further enhance their cognitive capacities in two ways. They can either restore their attention more efficiently or/and do a challenging task more concentratedly as the occurrence of emotion and mind wandering are both gradually reduced. Note that this explanation would predict attention restoration rather than exhaustion. More studies are required to test which one is the case.

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My results also showed, for the first time, that BMAA could improve children's performance on sustained attention by showing a more stable response speed than the control group. In addition, unlike the previous studies about other MBCPs such as yoga (e.g. Rangan et al., 2009), I use an objective behavior measure for sustained attention (i.e., SART) rather than pencil-and-paper tests. This finding also adds a piece of supporting evidence, with a different objective measure, to the positive effect of MBCPs on sustained attention.

As for NOGO ACC, another index of SART, no training effect for the BMAA group was found compared to the control group. However, further analysis shows an interesting result that children with better proprioceptive accuracy benefit more on NOGO ACC from the training than those who had poorer accuracy in pretest, which is partially support my fourth hypothesis concerning about whether bodily senses moderate the training effect of BMAA on executive functions. It is probably because that the BMAA practices were heavily exerted on proprioceptive ability so that children with poor proprioceptive accuracy need more time to get the benefit from the training.

In contrast, children with poorer proprioceptive awareness (PAW) improved

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NOGO ACC more than those who had better PAW in the pretest. Since PAW was significantly correlated with NOGO ACC in pretest, I wonder whether children with poorer PAW had more room to improve on PAW, and led to the improvement on sustained attention indicated by NOGO ACC. To test this hypothesis, I examined whether the differential score (T2-T1) of NOGO ACC and PAW correlated with each other. However, there is no significant correlation between them in the BMAA group (r = -.12, p = .55). To further know whether there is a contingency between the improvement on PAW and NOGO ACC, children in the BMAA group were further separated into four groups according to whether they improved on PAW and NOGO ACC: children were categorized as PAW-improved group if their PAW scores at T2 was lower than that at T1 (remember that for PAW, the lower the better), and PAW-not-improved group, otherwise. Similarly, they were labelled as NOGO ACC-improved group if their NOGO ACC scores at T2 higher than that of T1, and NOGO ACC-not-improved group, otherwise. I found that higher proportion of the low-PAW groups had improvement on PAW than the high-PAW group, *Fisher's Exact Test*, p = .04 (one-tailed). Furthermore, proportion of the PAW-improved group improved on NOGO ACC was higher, marginally significant, than that of the PAW-not-improved

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group, *Fisher's Exact Test*, p = .08 (one-tailed). As for the control group, no such trend was found.

Contrary to my prediction, no training effect was found for bodily awareness including interoception and proprioception although during BMAA-C program. However, although the control group outperformed the BMAA group on PAW at T1 with a marginal significance, the BMAA group caught up with the control group after training. Further studies should examine this issue more carefully with well-matched participants and perhaps with a longer training time for children.

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General Discussion

In sum, my hypotheses are partially supported. My first hypothesis is that BMAA-C practice can enhance children's sustained attention, working memory capacities and bodily awareness. This hypothesis is partially supported. As predicted, there is a positive training effect of BMAA-C on children's working memory capacities and sustained attention (RTCV). However, no training effect on any of the indices regarding bodily senses was found.

Second, the finding that children's abilities of bodily awareness of proprioception can predict their performance on sustained attention (less RTCV and higher NOGO ACC) supports my second hypothesis. However, unexpectedly, children's abilities regarding interoception are not associated to any of their executive functions I measured. Children's working memory capacities are also independent to their bodily awareness.

My third hypothesis is that the improvement on cognitive functions is accompanied by the improvement of bodily awareness. It was also partially supported. Since through further analysis, I found that there is a contingency between the improvement on proprioception awareness (PAW) and that on NOGO ACC in

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below-median-PAW group.

My last hypothesis predicts that children with better bodily senses can benefit more from the training. The data again partially supported my hypothesis showing that only children with better proprioceptive accuracy or poorer proprioceptive awareness before the training benefit more on sustained attention, indicating by the increased averaged rate of NOGO ACC, from the training than their counterparts, respectively. No individual differences in bodily senses influence the degree of training effect on working memory capacities and RTCV, another index for sustained attention.

As reported above, the findings about the two indices of sustained attention, NOGO ACC and RTCV, are somewhat inconsistent. In correlational study, interoceptive awareness was found to moderate the correlation between proprioceptive awareness and sustained attention only for RTCV but not NOGO ACC. In contrast, children's proprioception before training could influence how much they improved on NOGO ACC but not RTCV after the BMAA training in the next study. It is likely that performance indicated by NOGO ACC not only influenced by sustained attention but also by motor inhibition process. Thus, the benefit from BMAA training

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in NOGO ACC was influenced by proprioception at T1.

There are several contributions of my thesis. First, a new objective measure of proprioceptive awareness is introduced. In addition, it is found to be a good predictor for children's performance on sustained attention. Second, a feasible short-term movement-based mindfulness intervention program for children, BMAA-C, is introduced and tested. It is found to be effective on improving children's working memory capacities and sustained attention, both are crucial for learning and goal-derived behaviors.

Third, I have examined, for the first time, whether practitioner's abilities regarding different aspects of bodily sense would influence the training effect of my intervention program, during which bodily senses are emphasized, on executive functions. Although I found that the effect of bodily sense only occurred in a subgroup of trainees, it is nevertheless intriguing and may serve as the first step to understand how body and mind interact with each other in the context of contemplative training, including mindfulness-based and movement-based trainings.

There are also some limitations in this thesis and the findings should be interpreted cautiously. First, the number of participant may not be enough for a study

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examining moderating effect. Further studies with more participants are needed to replicate the moderating effects reported here. Second, my children participants' ages mostly were at 8-9 years old. It should be cautious to generalize the findings to children not at these ages or to adults. Third, our control group was performed better on proprioceptive awareness, which was found to be correlated to children's sustained attention. Future studies with well-matched control group are needed for replication. Fourth, although I found a short-term training effect of BMAA-C on executive functions right after the training period, how long the effects will last is still unknown. Finally, whether my findings about the BMAA training can be generalize to other MBCPs and mindfulness-based trainings is still unknown and should be examined in the future.

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