The Journal of Behavioral Science
2021, Vol. 16, Issue 2, 58-72

ISSN: 1906-4675 (Print), 2651-2246 (Online)

The Journal of Behavioral Science (TJBS)

Original Article

School-Based Mindfulness Intervention Improves Executive Functions and Self-Regulation in Preschoolers at Risk

Kanda Lertladaluck[1], Warabud Suppalarkbunlue[1], Yusuke Moriguchi[2], and Nuanchan Chutabhakdikul[3*]

Author Affiliation

[1] Ph.D. Candidate, Research Center for Neuroscience, Institute of Molecular Biosciences, Mahidol University, Thailand
[2] Associate Professor, Graduate School of Education, Kyoto University, Japan
[3] Associate Professor, Research Center for Neuroscience, Institute of Molecular Biosciences, Mahidol University, Thailand

*Corresponding author email: nuanchan.chu@mahidol.edu

Article Information

Received: *17.3.21*
Revised: *5.4.21*
Accepted: *7.4.21*

Keywords

mindfulness,
executive functions,
self-regulation,
preschool children,
early intervention

Abstract

In recent years, the mindfulness concept is increasingly applied to the education sector to promote executive functions (EFs) in young children. However, the evidence for benefits of mindfulness training on EFs in preschool children with initially poor EFs is still limited. In this study, a school-based mindfulness (SM) program was designed based on a universal concept of mindfulness, in which the activities were adapted to fit with the context in Thailand. The impact of the SM program on EFs and self-regulation was investigated in preschoolers at risk. Children were assessed their EF development using teacher reporting measures and they were then randomly assigned to either the SM group (n=15) or the control group (n=15). The SM program was delivered over the course of 8 weeks. Various methods were used to assess EFs for both behavioral and cognitive performance levels prior to and after the program. The results indicate that SM training improved children's behavior related to EF skill ($F(1,25) = 4.38$, $p = .05$) when compared to the control group. For performance levels, the SM group also showed greater development in working memory ($t(28) = 2.36$, $p = .03$) and inhibition (bear-lion, $t(28) = 2.35$, $p = .03$; peg tapping, $t(28) = 2.19$, $p = .04$), but not cognitive flexibility ($t(28) = 1.04$, $p = .31$). The findings suggest that the SM program could enhance EFs, self-regulation development, and improve classroom behavior in preschoolers with initially poor EFs. Policy implications must consider the use of an embedded SM program in early childhood education. Besides, the SM program can be further adjusted by teachers or caregivers to meet the needs of individual child.

The critical role that executive functions (EFs) play in young children's social-emotional competencies, school readiness, and learning is increasingly recognized by educators, parents, and policymakers. In recent years, the amount of empirical attention regarding the promotion of EF skills in early childhood education has increased. EFs broadly refer to higher cognitive abilities that underlie goal-directed behavior to control thoughts, actions, and emotions (Diamond, 2013; Zelazo & Müller, 2002). These skills are necessary for novel and non-routine situations in which following habitual patterns is insufficient or impossible. EFs progressively develop during the preschool period and its development is interrelated with the activity of the prefrontal cortex (Diamond, 2002; Moriguchi & Hiraki, 2013). EFs fundamentally consist of several components. In young children, three core components of EFs are typically focused: Working memory; inhibition; and shifting or cognitive flexibility (Diamond, 2013; Garon et al., 2008; Miyake et al., 2000).

Working memory refers to the ability to mentally retain and manipulate information (Diamond, 2013). Working memory develops very early and progresses quickly. Several cognitive tasks can be used to assess working memory in young children, including the backward digit span, the backward Corsi span, and the Missing scan task (Garon et al., 2008; Roman et al., 2014).

Next, inhibition involves the ability to control one's attention, behavior, thought, and emotions to overcome the prepotent response (Diamond, 2013; Garon et al., 2008). This ability helps us to regulate ourselves appropriately when reacting to the surrounding environment. Diamond (2013) indicated two types of inhibitory control including response inhibition and interference control. Response inhibition is behavioral inhibition and sometimes refers to self-control, including the ability to resist temptations and not perform impulsively. Interference control is a further aspect of inhibition, which can be further subdivided into cognitive inhibition and selective attention. Inhibitory control of attention involves one's ability to selectively attend and focus on certain stimuli and suppress attention to others. It is generally suggested that working memory and inhibitory control of attention are mutually supportive. Although several cognitive tasks can be utilized to assess inhibitory control ability, most inhibition tasks are not pure measures of inhibition and they occasionally employ more than one cognitive control process (Simpson & Riggs, 2005). Examples of cognitive measures of inhibition in preschoolers include the Bird and Dragon task, the peg tapping task, Stroop task, and Hand game (Diamond & Taylor, 1996; Garon et al., 2008; Kochanska et al., 1996).

Finally, shifting or cognitive flexibility is the ability to shift between mental states, perspectives, rule sets, or tasks. The individual must disengage from the previous task or mental state and then reconfigure a new response set to implement with the task at hand. It has been suggested that this EF component requires prior development of working memory and inhibitory control (Diamond, 2013; Garon et al., 2008). The Dimensional Change Card Sort (DCCS), a simplified version of the Wisconsin Card Sorting Test, is widely used to assess cognitive flexibility in preschoolers (Zelazo, 2006).

These three foundational EF skills have been proposed to promote successful self-regulation (Hofmann et al., 2012; Tiego et al., 2020). The term 'self-regulation' refers to intrinsic mechanisms to adjust mental and physiological states dependent upon context (Eisenberg et al., 2010; Nigg, 2017). Additionally, self-regulation involves various components to control one's behavior, thoughts, and emotions and allow the individual to perform appropriately to their environment. It has been suggested that self-regulation develops as a function of changes in a dynamic interaction between top-down (deliberate) and bottom-up (automatic) processes. Since the top-down aspect is predicated on the ability to inhibit a dominant response to perform a subdominant response, it may overlap with EFs in terms of attentional and inhibitory control (Nigg, 2017). During the preschool period, both EFs and self-regulation are necessary for school readiness and prosocial behavior (Blair & Raver, 2015; Eisenberg et al., 2010; Howard & Vasseleu, 2020; Kuhn et al., 2021; Woltering et al., 2016). In contrast, children with EF issues such as inattention, poor working memory, worse inhibitory control, and poor self-regulation are more likely to struggle at school and at older ages (Blair & Raver, 2015; Eisenberg et al., 2010; Kuhn et al., 2021; Woltering et al., 2016).

As EFs are trainable skills, various activities and programs have been applied to improve EFs in young children. One such program is mindfulness training (Diamond & Lee, 2011). In recent years, several mindfulness programs such as the Inner Kids Program, Learning to BREATHE, and MindUP program have been implemented to promote cognition, academic achievement, behavior, and socioemotional functioning among school-aged children (Maynard et al., 2017; Meiklejohn et al., 2012). In general, these programs have been designed to enhance relaxation and joyfulness, reduce stress, rather than emphasize on long periods of silence.

To date, only a limited number of studies have investigated the benefits of mindfulness training on EFs and self-regulation in preschool children (Flook et al., 2015; Janz et al., 2019; Lim & Qu, 2017; Poehlmann-Tynan et al., 2016; Thierry et al., 2016; Wood et al., 2018; Zelazo et al., 2018). Moreover, those studies have largely been undertaken with groups of children, regardless of their EF development background. Currently, only a single study by Flook et al. (2015) examined whether individual differences in baseline inhibitory control could predict treatment response. They reported that children with lower inhibitory control in the mindfulness training group could increase their social competence compared to the control group. Nonetheless, further work is required to clarify the effect of mindfulness training on EFs and self-regulation in children with lower baseline functioning.

It has been suggested that children with lower baseline performance experience greater benefit after EF training because they have the opportunity for greater improvement (Diamond & Ling, 2016). Concerning the normative criteria for EF development in Thai children aged between 2-6 years (N = 2,965) from all regions across the country, approximately 30% of Thai preschoolers demonstrate a high risk of delayed EF development that requires training, especially working memory and inhibitory control (Chutabhakdikul et al., 2017). In this study, it is hypothesized that a school-based mindfulness program could enhance EFs on a range of behavioral and cognitive outcomes in preschool children at risk of delayed EF development. Group differences between treatment and control groups were examined using performance-based tests and a behavioral rating scale. The experimental results offer further evidence to improve educational outcomes in preschool children at risk of delayed EF development.

Literature Review

In recent years, there has been great interests in promoting EF skills in young children. Various activities and programs have been applied including computerized trainings, non-computerized games, physical activities, certain school curricula, and mindfulness trainings (Diamond & Lee, 2011). Currently, there is a growing evidence base for mindfulness interventions in educational settings. Several studies showed that this approach could enhance EFs and self-regulation in preschool children. This section aims to review the activities and programs for EFs improvement in preschoolers, the definition of mindfulness and its mechanisms, and the mindfulness-based intervention and preschooler EF outcomes.

Activities and Programs to Improve EFs in Preschoolers

EFs are trainable skills that rapidly develop during preschool years. A variety of activities have been shown to improve EF skills in young children (Diamond & Lee, 2011; Diamond & Ling, 2016). For instance, preschool children who participated in a 5-week computerized working memory training, CogMed, presented greater working memory improvement than children in a control group (Thorell et al., 2009). By using a set of inhibition training games and exercises, 47 preschoolers improved their inhibition, attention, and working memory, resulting in a decline in external behavioral problems (Volckaert & Noel, 2015). There are currently many school-based interventions and classroom curricula in use which have been designed to enhance EF capacity, with examples including mindfulness training, Tools of the Mind, and Montessori (Diamond & Lee, 2011).

Diamond and Ling (2016) reviewed many studies exploring the diverse range of activities used for EF improvement in participants, ranging from young children to older adults, and concluded that there were many issues related to how individuals develop EFs from those approaches. For example, longer periods spent practicing (e.g., duration, session length, and frequency) can produce better EF outcomes. It could be seen in several studies in young children using the Tools of the Mind curriculum in which the all-day curriculum was marked benefits seen rather than an add-on (Blair & Raver, 2014; Bodrova & Leong, 2007). Moreover, EF practice should be continuous because EF benefits diminish after practice ends. In other words, although some researches revealed the benefits of EFs at follow-up, these benefits grew smaller over time (Klingberg et al., 2005). Interestingly, it has been suggested that children with the poorest EFs demonstrate the greatest gains from any EF-improving program. For instance, regarding mindfulness training in children, it has been reported that children with EF difficulties gain in the training group demonstrated larger gains in EFs and social competence compared to the control group (Flook et al., 2010; Flook et al., 2015). From the existing literature, three main aspects should be considered for designing or adopting a program that encourages EFs: (1) intervention effectiveness; (2) the conditions and mechanisms underlying the intervention; and (3) suitability for target groups (Meiklejohn et al., 2012). These factors can enhance the development of EFs for individuals.

Definition of Mindfulness and Its Mechanisms

Mindfulness refers to one's ability to maintain awareness of body sensations, thoughts, and feelings without judgment (Nārada, 2013). The term mindfulness is equivalent for sati in Pali, which derives from Buddhism. As the national religion, approximately 94% of the population in Thailand classify themselves to be Buddhist, mostly of the Theravāda tradition (National Statistical Office, 2018). Thai Buddhism is very influential in lifestyle, mannerisms, traditions, characters, health, and mind (Kuppako, 2016). Many Thai children are taught to pray and meditate by family or school. Moreover, some schools have implemented mindfulness-based education as an alternative education into kindergartens and elementary program. These behaviors grow substantially for adult living in Thailand as their belief and principals. In general, Thai adults make merits, respect to Buddhism places, pray, and practice mindfulness mediation when they are available. Regarding the manual of Buddha's teaching, so-called the Abhidhamma, the proximate cause for the arising of mindfulness is strong perception and the four foundations of mindfulness, namely the body, feelings, states of consciousness, and mental objects (Nārada, 2013). In mindfulness practice, an individual, moment-by-moment, observes the three characteristics of those objects in terms of their impermanence, suffering, and not-self.

In western countries, the Mindfulness-Based Stress Reduction (MBSR) program is popularly recognized as a therapeutic intervention to mitigate stress and enhance physical and mental well-being (Kabat-Zinn, 2003). Cognitive scientists have attempted to decipher a mindfulness mechanism to describe how mindfulness-based programs can affect both physical and psychological aspects. For instance, Shapiro et al. (2006) suggested three important components of mindfulness: Intention; attention; and attitude. Shapiro et al. (2006) also introduced the process of "reperceiving", which involves a fundamental shift in perspective. This process corresponds to a "decentering" mechanism which was described by Fresco et al. (2007). Moreover, Grabovac et al. (2011) explained that mindfulness leads to clinical benefits by interrupting mental proliferation and reducing habitual attachment or aversive reactions to feelings.

From neuroscience literature focusing on adults, four key components behind mindfulness practice include attention regulation, body awareness, emotional awareness, and change in self-perspective. The interaction between these four mechanisms further promotes self-regulation in practitioners (Hölzel et al., 2011; Tang et al., 2015). It has been proposed that these components are associated with functional alterations of various brain areas, including the anterior and posterior cingulate cortex, the striatum, multiple PFC region, the limbic system, the insula, and the temporoparietal junction.

Mindfulness-Based Intervention and Preschooler EF Outcomes

The number of mindfulness-based programs implemented in preschools has expanded significantly. Research indicates that school-based mindfulness programs could enhance EFs and self-regulation in preschool children. More specifically, those programs play an important role in the development of working memory, attention, inhibition, and prosocial behavior in young children. For instance, Flook et al. (2015) reported that children who participated in a 12-week mindfulness-based Kindness Curriculum demonstrated greater improvements to their social competence and higher report card grades in the domains of learning, social-emotional development, and health. Moreover, Flook et al. (2015) also reported that children with lower inhibitory control in the mindfulness training group could increase their social competence compared to the control group. Meanwhile, Poehlmann-Tynan et al. (2016) indicated that a mindfulness intervention significantly increased attentional focus and self-regulation among young children from economically disadvantaged families. Moreover, a longitudinal study using the one-year MindUP training program showed a positive impact on preschoolers' working memory and planning and organizing abilities, as reported by their teachers (Thierry et al., 2016). Similarly, mindfulness combined with reflection training can improve EF skills in preschoolers at schools serving low-income families (Zelazo et al., 2018). Furthermore, a single-session of mindfulness training was found to improve children's attention scope, although it did not affect executive attention (Lim & Qu, 2017). A recent study among young children (i.e., kindergarten, Grades 1 and 2) revealed that a mindfulness-based program delivered through the classroom curriculum, CalmSpace, can improve children's EFs and attention (Janz et al., 2019). In contrast, a 12-session Mini-Mind program showed no significant differences on any measure of EFs in preschoolers (Wood et al., 2018).

From the literature, most previous studies were conducted with groups of children, regardless of their EF development history. The study of the effect of mindfulness training on EFs and self-regulation in children with lower baseline functioning is remains scarce, so further studies are required to fill this research gap.

Method

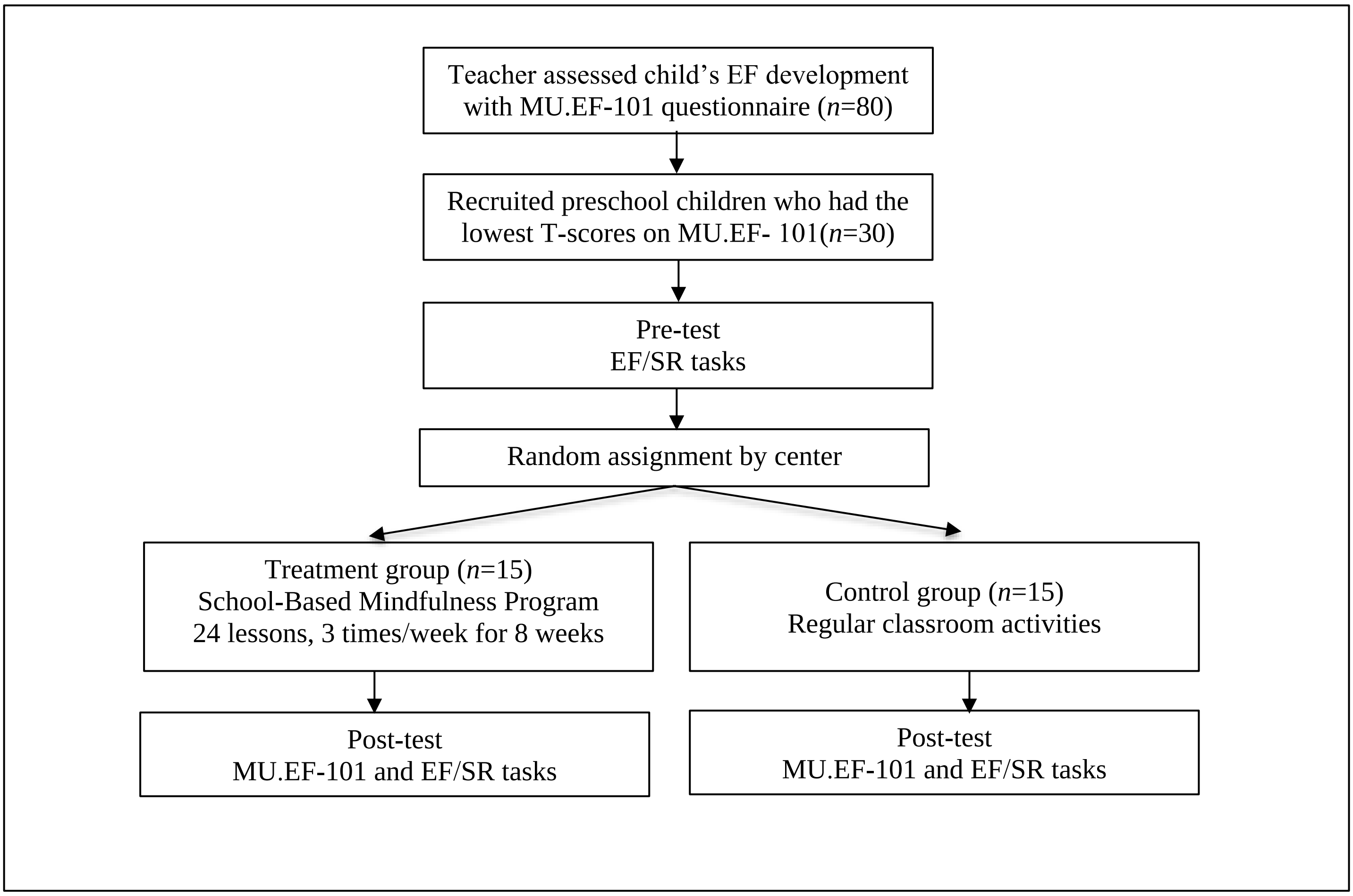
Participants

Two child development centers in Nonthaburi, Thailand were invited to participate in the study because of their focus on the promotion of children's EF skills. Both centers are equivalent in school and classroom sizes, with each center serving approximately 120 children. Also, both centers utilize the common early childhood curriculum. A total of 30 preschool children aged 48 to 60 months (*M* age = 52.73 months; *SD* = 2.57; 15 boys) from five classrooms across two centers that have no special EF training were recruited. Of the 80 children aged between 48-60 months, 30 were selected based on their lowest total EF score from the EF development behavioral checklist (MU.EF-101).

This number of participants was chosen because the normative data on EF development of Thai preschoolers suggests that almost 30% of Thai children demonstrate delayed development of behaviors related to EF skills (Chutabhakdikul et al., 2017). Moreover, a previous study of mindfulness practices with economically disadvantaged preschoolers has shown that data from 15 children per group were enough to reveal the improvement in EF and self-regulation skills (Poehlmann-Tynan et al., 2016). All children were healthy with no history of neurodevelopmental disorder or neuropsychiatric disease. One school was randomly assigned as the experimental group while the other school served as the control group. Data were collected from December 2016 to March 2017. All parents provided written legal guardian informed consent prior to the experiment. The experimental design is demonstrated in Figure 1.

Figure 1

Flowchart of Recruitment and Study Condition Allocation



Notes. MU.EF-101 = behavioral checklist of EF development; EF = executive functions; SR = self-regulation

School-Based Mindfulness Program

All teachings and learning processes of the school-based mindfulness (SM) program were designed based on the core components of mindfulness-based education, namely experiential, interactive, participatory, student-centered, and teacher-child relationships (Crane et al., 2017). Since attention is the foundation of mindfulness, the SM program greatly emphasized training attention and awareness of young children. In this program, teachers supported the young children to enhance their attention span, emotional and behavioral control, calmness, and compassion.

The SM program is comprised of two parts, Daily activities and Classroom activities. During the daily activities, children learned to pay attention to their own breathing for 1-3 minutes, three times per day, and they also considered food before having lunch at school. Next, 24 classroom activities were categorized into four units. Unit 1: Mindful Attention. This unit focuses on one's attention which is the most important and the first step of mindfulness practice. This involved the children practicing to focus on a single object (i.e., breathing, present job) and return their attention back to the object whenever they realized their mind was wandering. Unit 2: Mindful Sensation. In early childhood, sensorimotor development is essential for higher cognitive function. In this unit, children mindfully used their senses including sight, hearing, taste, smell, and touch to explore the external world. Unit 3: Mindful Movement. During preschool years, physical development changes dramatically, especially height and weight. Children move more fluently and perform some activities that require much energy. Their movement is an important basis for higher cognitive functions. Thus, this unit focused on the body awareness that young children could explicitly observe. This unit aims to increase exteroceptive and interoceptive awareness through activities such as a body scan and motor control through various games and artwork. The first three units are intended to improve exteroceptive and interoceptive awareness in young children. Unit 4: Mindful feeling. During preschool years, children express a wide range of emotions. Children need to explore both positive and negative emotions. This unit aims to enhance self-awareness, in which children learn to understand their own feelings and the feelings of others. The SM program was approved and accepted by early childhood experts and a monk that each lesson was designed based on child development and mindfulness principle. The Indexes of Item-Objective Congruence (IOC) score was 0.97 for content validity.

Measures

Measures were presented in Thai language and consisted of a behavioral checklist (MU.EF-101) and four cognitive assessments**.** All measures that were used in this research are described as follows**.**

Behavioral Checklist of EF development

The MU.EF-101 is a behavioral checklist for the assessment of EF development in preschool children. The questionnaire is constructed in the Thai language (Chutabhakdikul et al., 2017) and consists of 32 items about the child's behavior that represent an index of EF development in five domains, as follows: inhibit (10 items, $\alpha = 0.93$); shift (5 items, $\alpha = 0.85$); emotional control (5 items, $\alpha = 0.83$); working memory (6 items, $\alpha = 0.91$); and plan/organize (6 items, $\alpha = 0.89$). The overall α is 0.91. From the preliminary tests, the questionnaire had an index of Item-Objective Congruence (IOC) scores between 0.67-1.0 for content validity. The test-retest reliability was between 0.77-0.81. Teachers rated each item on a five-point frequency scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = always). All raw scores were converted to T-score for data analysis.

Dimensional Change Card Sort

The Dimensional Change Card Sort (DCCS) is a card sorting task to assess cognitive flexibility (Zelazo, 2006). In this study, children were asked to sort the test cards into trays according to a single trait of the target cards (e.g., by shape) for six trials in the pre-switch phase. Children who correctly sorted five or six cards were asked to continue the post-switch phase. They were then asked to sort the test cards in a different way (e.g., by color) for six trials. The percentage of correct responses was calculated by dividing all correct trials by a total of 12 trials across the two phases.

Missing Scan Task

The original version of Missing Scan Task (MST) was developed into a computerized version (Roman et al., 2014). This task sought to measure working memory in young children in which familiar animal pictures are used as test stimuli. Children were asked to name each animal out loud once the animal pictures were displayed on a 14-inch laptop.

The pictures were shown for approximately 5 seconds to allow children to memorize a set of animals before they disappeared. The pictures were shuffled and displayed on the screen again, but with one animal missing. Children then had to correctly identify the missing animal before continuing a new memory set size which had one additional item. The test began with a memory set of three animal pictures. If they could not identify the item correctly, they would be tested with new pictures in the second trial. Two points were given for the first trial and one point for the second trial. The test was complete when children failed to identify the missing animal on both trials or correctly completed a memory set size of ten pictures. The percentage of correct answers was analyzed.

Bear and Lion Task

This task used a bear and a lion puppet to assess inhibition in preschoolers (Kochanska et al., 1996). Children were asked to do what the bear told them to do (i.e., touch your nose) but not to do what the lion told them to do. There were 12 trials in total (6 bear trials and 6 lion trials). Children's movements were scored for the bear trials from 1 to 4 points (1 = no movement, 2 = wrong movement, 3 = partial movement, and 4 = correct movement), while the reverse score was applied for the lion trial. A composite score was computed by multiplying with the mean scores from the bear and the lion trials and converted to a percent correct for statistical analysis.

Peg Tapping Task

The peg tapping task was used to assess inhibition in the preschoolers (Diamond & Taylor, 1996) and consists of two sessions, a 2-rule and a 3-rule session. In the 2-rule session, when the experimenter tapped once, children should tap twice. In contrast, when the experimenter tapped twice, children should tap once. The 2-rule session was administered in a series of 12 trials in a counterbalanced sequence with a pseudorandom order. In the 3-rule session, an additional rule was added, in which children were asked to tap according to the 2-rule session, but to make no response when the experimenter did a triple tap. The test was administered in a series of 18 trials with a pseudorandom order. Children's responses were scored from 0-3 based on the proportion of correct responses (0 = fail to tap, 1 = incorrect and not self-correct, 2 = incorrect but self-correct, and 3 = correct on the first attempt). The percentage of correct responses was calculated by dividing the actual score by the highest possible score of 90.

Procedure

The entire study was conducted in four phases. The screening phase was conducted first. In the beginning, teachers rated the children's behavior in the classroom with the MU.EF-101 questionnaire that provided an index of EF development. Children with the lowest total EF score were recruited for the intervention session (n = 30). The pre-test was conducted second, in which each child performed four EF tasks for 15 minutes. Three experimenters who were blind to the conditions of the study administered the tasks continuously in the same sequence: DCCS (experimenter 1); the MST (experimenter 2); Bear and Lion (experimenter 3); and peg tapping (experimenter 3). All experimenters were trained to use the cognitive measures by the researchers before the experiment and they were instructed to assess children's EF by following the protocol during the experiment. The intervention phase was then conducted third, in which children in the SM group (n = 15) received mindfulness training with the SM program for 24 lessons, with each lesson lasting 40 minutes, 3 times per week over an 8-week period. The SM program was conducted by the first author. The control group (n = 15) received regular classroom activity. The post-test was conducted last, in which all measures (i.e., MU.EF-101 and EF tasks) were repeated in the same sequence.

Data Analyses

Data were analyzed using the statistical software SPSS, version 18. Analysis of covariance (ANCOVAs) was used to examine the effect of the intervention on post-test measures of the MU.EF-101 and the cognitive assessment of EF tasks, controlling for pre-test measures. In cases where the homogeneity-of-regression assumption test revealed a significant interaction effect between the independent variable and covariate, an independent samples t-test was used to examine the difference scores (post-test minus pre-test) instead.

Compliance with Ethical Standards

All parents were provided written legal guardian informed consent. The study protocol was approved by the Mahidol University's Central Institutional Review Board (COA No. MU-CIRB 2017/004. 1801) and was in accordance with the 1964 Helsinki declaration and its later amendments.

Results

In this study, the impact of the SM program on EFs and self-regulation in preschool children at risk was investigated. All data were analyzed statistically. This section aims to report the effects of the SM program on EF development and the performance of EF tasks**.** The descriptive participant data are shown in Table 1. There were no significant group differences based on age and gender)$p > .05$(.

Effects of the SM Program on EF Development

Since two questionnaires were not completed in the control group, data were analyzed using the data from 28 questionnaires. One-way ANCOVAs were conducted to determine a statistically significant difference between the groups on post-test scores controlling for pre- test scores of the MU.EF-101. The results reveal significant effect of group on inhibit ($F(1, 25) = 12.61$, $p < .01$, $\eta^2 = .34$), working memory ($F(1, 25) = 4.30$, $p = .05$, $\eta^2 = .15$), and total score ($F(1, 25) = 4.38$, $p = .05$, $\eta^2 = .15$). Additionally, the main effect of group on emotional control was marginally significant ($F(1, 25) = 3.87$, $p = .06$, $\eta^2 = .13$). However, the main effects of group were non-significant on shift ($F(1, 25) = .09$, $p = .76$, $\eta^2 = 0.00$) and plan/organize ($F(1, 25) = 1.25$, $p = .28$, $\eta^2 = .05$; see Table 2)

Effects of the SM Program on the Performance of EF Tasks

A preliminary analysis evaluating the homogeneity-of-regression assumption indicated that the relationship between the covariate and the dependent variable in the MST and the peg tapping tasks differed significantly as a function of the independent variable ($p < .05$). Thus, the independent samples t-tests were conducted for all cognitive assessments of EFs, with difference scores (post-test minus pre-test) as the dependent variable and group conditions as the independent variable. The pre-test score, post-test score, difference score and standard deviations (*SD*) for all EF measures are reported in Table 3.

An independent samples *t*-test indicated group difference on the MST task. The SM children ($M = 6.67$, $SD = 8.59$) showed greater change than the control children ($M = 0.00$, $SD = 6.73$; $t(28) = 2.36$, $p = .03$, $d = .86$; Figure 2a). The independent samples t-test analysis revealed a group difference on the Bear and Lion task. The SM children ($M = 34.97$, $SD = 32.53$) showed greater change than the control children ($M = 5.30$, $SD = 36.41$; $t(28) = 2.35$, $p = .03$, $d = .86$; Figure 2b). Similarly, the independent samples t-test analysis revealed a group difference on the peg tapping task. The SM children ($M = 8.97$, $SD = 11.49$) also had greater change than the control children ($M = 0.32$, $SD = 10.08$; $t(28) = 2.19$, $p = .04$, $d = .80$; Figure 2c). However, there was not a significant difference in the difference scores of DCCS accuracy for the SM ($M = 26.67$, $SD = 25.82$) and the control conditions ($M = 17.22$, $SD = 24.08$; $t(28) = 1.04$, $p = .31$, d = .38; Figure 2d).

Table 1

Descriptive Data of the Participants

Participants	*n*	Age in months	Gender
		Mean (SD)	% Male: Female
Screening session	80	53.56 (3.15)	50:50
Intervening session	30	52.73 (2.57)	50:50
SM group	15	52.40 (1.68)	53:47
Control group	15	53.07 (3.26)	47:53

Notes. SM = School-based mindfulness program

Table 2

Summary of Analyses of MU.EF-101 by Condition

	SM (n = 15)			Control (n = 13)			ANCOVA		
	Pre-test *M (SD)*	Post-test *M (SD)*	Adjusted post-test M^a *(SE)*	Pre-test *M (SD)*	Post-test *M (SD)*	Adjusted post-test M^a *(SE)*	*F*	*p*	η^2
INH	54.47 (9.42)	64.33 (7.08)	66.01 (1.89)	61.31 (6.98)	57.99 (9.30)	55.76 (2.04)	12.61	< .01**	.34
SHF	52.80 (11.28)	58.33 (9.54)	58.69 (2.12)	55.38 (10.82)	58.15 (7.55)	57.74 (2.28)	.09	.76	.00
EMC	53.47 (9.46)	61.07 (8.64)	62.38 (2.07)	60.31 (9.80)	58.08 (9.32)	55.53 (2.33)	3.87	.06	.13
WM	51.93 (8.81)	60.00 (9.24)	61.69 (1.96)	58.85 (9.05)	57.46 (7.72)	55.51 (2.11)	4.30	.05*	.15
PO	51.87 (8.77)	59.93 (10.35)	61.33 (2.28)	58.38 (8.48)	59.08 (7.82)	57.46 (2.46)	1.25	.28	.05
Total	53.33 (9.87)	62.27 (9.33)	63.87 (2.14)	60.54 (9.80)	58.92 (9.00)	57.07 (2.31)	4.38	.05*	.15

Note. MU.EF-101 = behavioral checklist of EF development; SM = school-based mindfulness group; INH = Inhibit; SHF = Shift; EMC = Emotional control; WM = Working memory; PO = Plan/Organize
** $p < 0.01$, * $p < 0.05$.
[a] Estimated marginal mean.

Table 3

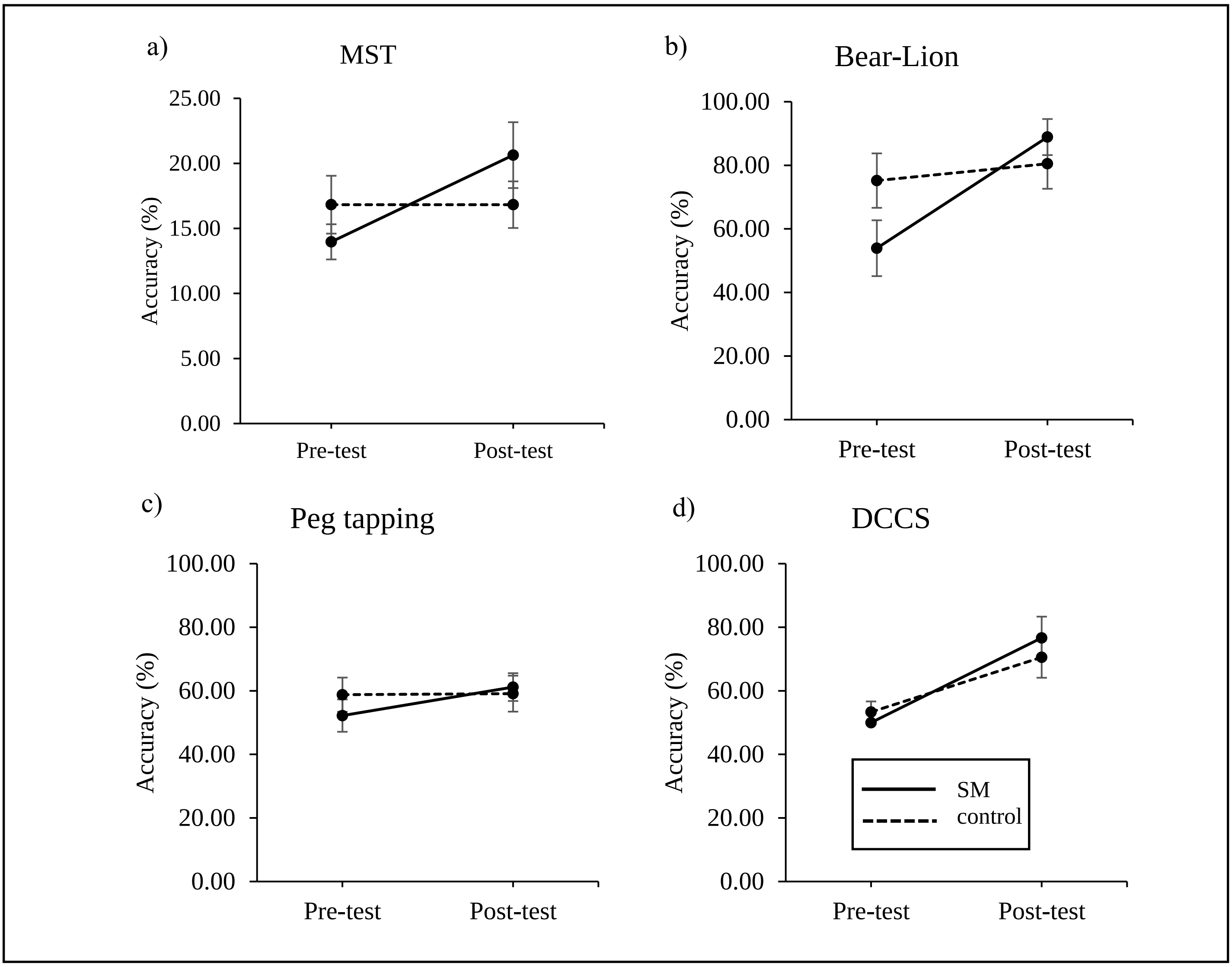
Data for Mean Differences in the Performance of EF Tasks at the Pre- and Post-Test, Compared Between Groups

Tasks Performance	SM (n = 15)			Control (n = 15)			Stat		
	Pre-test	Post-test	Mean Difference	Pre-test	Post-test	Mean Difference	*t(28)*	*p*	*d*
DCCS (%)	50.00 (0.00)	76.67 (25.82)	26.67 (25.82)	53.33 (12.91)	70.56 (24.97)	17.22 (24.08)	1.04	.31	.38
MST (%)	13.97 (5.24)	20.63 (9.80)	6.67 (8.59)	16.83 (8.61)	16.83 (6.94)	0.00 (6.73)	2.36	.03*	.86
Bear-Lion (%)	53.92 (34.05)	88.89 (21.97)	34.97 (32.53)	75.20 (33.15)	80.50 (30.50)	5.30 (36.41)	2.35	.03*	.86
Peg tapping (%)	52.20 (19.72)	61.17 (16.93)	8.97 (11.49)	58.79 (20.82)	59.11 (21.92)	0.32 (10.08)	2.19	.04*	.80

Notes. SM = School-based mindfulness program; DCCS = Dimensional Change Card Sort; MST = Missing Scan Task
* $p < 0.05$

Figure 2

Children's Performance on the EF Tasks at the Pre and Post-test, Compared between the SM (Straight Lines) and the Control Group (Dash Lines).



Notes. Error Bars Indicate the Standard Errors

Discussion

In the present study, the effectiveness of mindfulness training on EF skills in preschool children at risk of delayed EF development was investigated. The children's behavior and performance on various cognitive tasks were assessed. Following an eight-week school-based mindfulness program, children presented greater improvement of EFs—particularly working memory and inhibition—at both behavioral and performance levels compared to the control group. The results indicate that school-based mindfulness training is beneficial through its improvements to EFs which are necessary precursors of self-regulation in preschool children with initially poor EF skills.

After the teachers rated each child's behavior, the SM group showed greater improvement following the intervention in some EF domains, including inhibition, emotional control, and working memory. The results are consistent with studies documenting improvements to working memory and social-emotional development in young children (Flook et al., 2015; Thierry et al., 2016). These domains are the core domain of EFs, especially the response inhibition which is a precursor of self-regulation at later ages (Hofmann et al., 2012; Teigo et al., 2020). In contrast, the control group which did not receive an intervention presented a tendency to decrease T-score in all EF domains at the post-test. The results imply that the control group of children was more vulnerable to developmental regression if they had not received appropriate interventions. Since preschool age is the critical period for strengthening EFs and self-regulation, the present study highlights the importance of a school-based mindfulness program to promote EFs and self-regulation in preschool children at risk of delayed EF development.

With regards to performance data, the SM group displayed greater improvement in working memory performance when compared to the control group. The results correspond to previous studies in which attention training through mindfulness practice was found to enhance working memory capacity in adult participants (Jha et al., 2007; Mrazek et al., 2013). In this study, the SM program mainly focused on attention training, for example, children were daily trained to regularly direct their attention to their breathing and redirect their attention back to breathing again when they notice their mind wandering. Furthermore, children were trained to focus on their sensations, body movement, and feelings as frequently as possible. It has been proposed that working memory occurs when one engages in a mindful breathing exercise. Mindfulness training potentially optimizes the amount of relevant information to use working memory more effectively (Morrison & Jha, 2015). Moreover, several EF models suggest that attentional control ability is strengthened through the training and may help to promote working memory (Diamond, 2013). Moreover, in the present study, the SM group underwent a significant improvement in performance with the Bear and Lion task and the peg tapping task at the post-test. These tasks measured the children's ability to inhibit the dominant response to perform the subdominant response. Indeed, inhibition and attention are the precursors of self-regulation at a later age (Hofmann et al., 2012; Tiego et al., 2020). Previous research also suggests that mindfulness training could alter the state of the mind and body, leading to better self-regulation (Hölzel et al., 2011; Tang et al., 2015). Thus, the findings of the present study suggest that school-based mindfulness training could be a useful tool to enhance working memory capacity, inhibition, as well as self-regulation in young children with poor EF.

According to the mindfulness mechanisms, cognitive flexibility may occur when practitioners look for novel and adaptive ways of responding to stimuli and change their perspective of themselves (Hölzel et al., 2011). However, an effect of mindfulness training on shifting or cognitive flexibility was not found in this study, both at the behavioral and the performance levels. This finding is similar to Flook et al. (2015) study in young children but it is different from Janz et al. (2019) study in older children. This was likely due to an age-related improvement in the ability to refocus attention to relevant stimuli. Using the DCCS task, several studies demonstrate that 3-year-old children often persevered and continued to apply the first rule when they should have applied the second rule, whereas 5-year-old children did not (Moriguchi & Hiraki, 2013). Moreover, the shifting or cognitive flexibility required prior sufficient development of working memory and inhibition (Diamond, 2013; Garon et al., 2008). Hence, future studies regarding the effect of mindfulness training should consider the cognitive development of young children.

In this study, although data have been collected since December 2016, the results are consistent with several studies in young children which were published in recent years (Lim & Qu, 2017; Poehlmann-Tynan et al., 2016; Thierry et al., 2016; Zelazo et al., 2018). Furthermore, the studies of the benefits of mindfulness training on EFs, especially in preschool children with initially poor EFs, are still limited. Thus, this study provided further evidence to support that mindfulness training could promote EFs and self-regulation development in preschool children at risk.

Limitations

This study has some limitations that need to be considered. Regarding the data analyses, the sample size of this study was small and many null hypotheses were tested; thus, the probability that the Type I errors are committed increases. Next, data collection occurred at the end of academic year and some children had to move to new schools; thus, we could not follow-up on the effects of the mindfulness intervention in all participants from this study. Previous studies in young children from low-income families revealed that the effect of mindfulness practice was maintained following intervention for up to 3 months (Poehlmann-Tynan et al., 2016; Zelazo et al., 2018). Hence, longitudinal studies in preschoolers at risk are needed to investigate how long the effects of training could persist.

Conclusion

EFs and self-regulation are relevant to many aspects of life including mental and physical health, quality of life, academic and job success, and social relationships (Diamond, 2013). Young children who struggle with such skills may experience social-emotional immaturity and classroom behavioral difficulties. It has been suggested that early childhood investments are worthwhile for society and children alike, and those with poor EFs should not be left behind. Since EFs are subject to environmental influence and trainable, policy implications must consider the appropriate educational climate to foster children's EFs and self-regulation development according to age. The SM program developed in the present study integrated multidisciplinary knowledge including philosophy, developmental psychology, and early childhood education. The results of the present and previous studies indicate that school-based mindfulness programs should be considered for implementation in the kindergarten classroom to enhance EFs and self-regulation development in young children, especially those with initially poor EFs. Due to individual variations in baseline EFs and self-regulation, teachers or caregivers could further adapt mindfulness programs to suit the needs of individual children.

Moreover, the findings contribute to existing knowledge in developmental psychology and behavioral science by providing additional evidence on the impact of mindfulness training on EF and self-regulation development in young children at risk of delayed EF development. The SM program could improve children's behaviors and cognitive performance regarding EFs, and more specifically enhance their working memory and inhibition. These EF components could be necessary precursors for self-regulation development at a later age. Nevertheless, further research at a larger scale and with a longer timeframe is required in this area. Furthermore, a systematic investigation of mindfulness-based activities on brain development would be beneficial.

Acknowledgment

This research was supported by a doctoral scholarship from the Royal Golden Jubilee project of the Thailand Research Fund (PHD/0046/2557) to Kanda Lertladaluck and Nuanchan Chutabhakdikul, and a grant from Japan Society for the Promotion of Science (16H05956). We thank the children, parents, and teachers of the child development centers for their cooperation.

References

Blair, C., & Raver, C. C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS ONE, 9*(11), e112393. https://doi.org/10.1371/journal.pone.0112393

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology, 66*, 711-731. https://doi.org/10.1146/annurev-psych-010814-015221

Bodrova, E., & Leong, D. J. (2007). *Tools of the Mind: The Vygotskian Approach to Early Childhood Education* (2nd ed.). Pearson/Merrill Prentice Hall.

Chutabhakdikul, N., Thanasetkorn, P., Lertawasdatrakul, O., & Ruksee, N. (2017). *Tool Development and Evaluation Criteria for Assessment of Executive Function in Early Childhood*. Health System Research Institute and the Institute of Molecular Biosciences, Mahidol University.

Crane, R. S., Brewer, J., Feldman, C., Kabat-Zinn, J., Santorelli, S., Williams, J. M., & Kuyken, W. (2017). What defines mindfulness-based programs? The warp and the weft. *Psychological Medicine, 47*(6), 990-999. https://doi.org/10.1017/s0033291716003317

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (Eds.), *Principles of Frontal Lobe Function* (pp. 466–503). Oxford University Press.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959-964. https://doi.org/10.1126/science.1204529

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience, 18*, 34-48. https://doi.org/10.1016/j.dcn.2015.11.005

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "do as I say, not as I do". *Developmental Psychobiology, 29*(4), 315-334. https://doi.org/10.1002/(SICI)1098-2302(199605)29:4%3C315::AID-DEV2%3E3.0.CO;2-T

Eisenberg, N., Valiente, C., & Eggum, N. D. (2010). Self-regulation and school readiness. *Early Education and Development, 21*(5), 681-698. https://doi.org/10.1080/10409289.2010.497451

Flook, L., Goldberg, S. B., Pinger, L., & Davidson, R. J. (2015). Promoting prosocial behavior and self-regulatory skills in preschool children through a mindfulness-based Kindness Curriculum. *Developmental Psychology, 51*(1), 44-51. https://doi.org/10.1037/a0038256

Flook, L., Smalley, S. L., Kitil, J. M., Galla, B. M., Kaiser-Greenland, S., Locke, J., Kasari, C. (2010). Effects of mindful awareness practices on executive functions in elementary school children. *Journal of Applied School Psychology, 26*(1), 70-95. https://doi.org/10.1080/15377900903379125

Fresco, D. M., Moore, M. T., van Dulmen, M. H., Segal, Z. V., Ma, S. H., Teasdale, J. D., & Williams, J. M. (2007). Initial psychometric properties of the experiences questionnaire: validation of a self-report measure of decentering. *Behavior Therapy, 38*(3), 234-246. https://doi.org/10.1016/j.beth.2006.08.003. Epub 2007 Apr 24. PMID: 17697849

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*(1), 31-60. https://doi.org/10.1037/0033-2909.134.1.31

Grabovac, A. D., Lau, M. A., & Willett, B. R. (2011). Mechanisms of mindfulness: A buddhist psychological model. *Mindfulness, 2*(3), 154-166. https://doi.org/10.1007/s12671-011-0054-5

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174-180. https://doi.org/10.1016/j.tics.2012.01.006.

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science, 6*(6), 537-559. https://doi.org/10.1177/1745691611419671

Howard, S. J., & Vasseleu, E. (2020). Self-regulation and executive function longitudinally predict advanced learning in preschool. *Frontiers in Psychology, 11*, Article 49. https://doi.org/10.3389/fpsyg.2020.00049

Janz, P., Dawe, S., & Wyllie, M. (2019). Mindfulness-based program embedded within the existing curriculum improves executive functioning and behavior in young children: A waitlist controlled trial. *Frontiers in Psychology, 10*, Article 2052. https://doi.org/10.3389/fpsyg.2019.02052

Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective & Behavioral Neuroscience, 7*(2), 109-119. https://doi.org/10.3758/CABN.7.2.109

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice, 10*(2), 144-156. https://doi.org/10.1093/clipsy.bpg016

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C. G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD--a randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(2), 177–186. https://doi.org/10.1097/00004583-200502000-00010

Kochanska, G., Murray, K., Jacques, T. Y., Koenig, A. L., & Vandegeest, K. A. (1996). Inhibitory control in young children and its role in emerging internalization. *Child Development, 67*(2), 490-507.

Kuhn, M., Boise, C., Marvin, C. A., & Knoche, L. L. (2021). Challenging Behaviors and Executive Function in Preschool-Aged Children: Relationships and Implications for Practice. *Infants & Young Children, 34*(1), 45-65. https://doi.org/10.1097/IYC.0000000000000183

Kuppako, D. (2016). Buddhism in Thai life: Thai model for ASEAN. *Mahachula Academic Journal, 3*(1), 138-158.

Lim, X., & Qu, L. (2017). The effect of single-session mindfulness training on preschool children's attentional control. *Mindfulness, 8*(2), 300-310. https://doi.org/10.1007/s12671-016-0600-2

Maynard, B. R., Solis, M., Miller, V., & Brendel, K. E. (2017). *Mindfulness-Based Interventions for Improving Cognition, Academic Achievement, Behavior and Socio-Emotional Functioning of Primary and Secondary Students.* The Campbell Collaboration. https://files.eric.ed.gov/fulltext/ED573474.pdf

Meiklejohn, J., Phillips, C., Freedman, M. L., Griffin, M. L., Biegel, G., Roach, A., Frank, J., Burke, J., Pinger, L., Soloway, G., Isberg, R., Sibinga, E., Grossman, L. & Saltzman, A. (2012). Integrating mindfulness training into K-12 education: Fostering the resilience of teachers and students. *Mindfulness, 3*(4), 291-307. https://doi.org/10.1007/s12671-012-0094-5

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

Moriguchi, Y., & Hiraki, K. (2013). Prefrontal cortex and executive function in young children: a review of NIRS studies. *Frontiers in Human Neuroscience, 7,* Article 867. https://doi.org/10.3389/fnhum.2013.00867

Morrison, A. B., & Jha, A. P. (2015). Mindfulness, attention, and working memory. In B. D. Ostafin, M. D. Robinson, & B. P. Meier (Eds.), *Handbook of Mindfulness and Self-Regulation* (pp. 33-45). Springer.

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological Science, 24*(5), 776-781. https://doi.org/10.1177/0956797612459659

Nārada, T. (2013). *A Manual of Abhidhamma: Being Abhidhammattha Saṅgaha of Bhadanta Anuruddhācariya* (Revised edition). Maha Bodhi Book Agency.

National Statistical Office. (2018). *4 Religion Arts and Cultural Branch.* http://statbbi.nso.go.th/staticreport/page/sector/en/04.aspx

Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psycho-pathology. *Journal of Child Psychology and Psychiatry, 58*(4), 361-383. https://doi.org/10.1111/jcpp.12675

Poehlmann-Tynan, J., Vigna, A. B., Weymouth, L. A., Gerstein, E. D., Burnson, C., Zabransky, M., Lee, P., & Zahn-Waxler, C. (2016). A pilot study of contemplative practices with economically disadvantaged preschoolers: Children's empathic and self-regulatory behaviors. *Mindfulness, 7*(1), 46-58. https://doi.org/10.1007/s12671-015-0426-3

Roman, A. S., Pisoni, D. B., & Kronenberger, W. G. (2014). Assessment of working memory capacity in preschool children using the Missing Scan Task. *Infant and Child Development, 23*(6), 575-587. https://doi.org/10.1002/icd.1849

Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of Clinical Psychology, 62*(3), 373-386. https://doi.org/10.1002/jclp.20237

Simpson, A., & Riggs, K. J. (2005). Inhibitory and working memory demands of the day-night task in children. *British Journal of Developmental Psychology, 23*(3), 471-486. https://doi.org/10.1348/026151005X28712

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews: Neuroscience, 16*(4), 213-225. https://doi.org/10.1038/nrn3916

Thierry, K. L., Bryant, H. L., Nobles, S. S., & Norris, K. S. (2016). Two-year impact of a mindfulness-based program on preschoolers' self-regulation and academic performance. *Early Education and Development, 27*(6), 805-821. https://doi.org/10.1080/10409289.2016.1141616

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*(1), 106-113. https://doi.org/10.1111/j.1467-7687.2008.00745.x

Tiego, J., Bellgrove, M. A., Whittle, S., Pantelis, C., & Testa, R. (2020). Common mechanisms of executive attention underlie executive function and effortful control in children. *Developmental Science, 23*(3), e12918. https://doi.org/10.1111/desc.12918

Volckaert, A. M. S., & Noel, M.-P. (2015). Training executive function in preschoolers reduce externalizing behaviors. *Trends in Neuroscience and Education, 4*(1), 37-47. https://doi.org/10.1016/j.tine.2015.02.001

Woltering, S., Lishak, V., Hodgson, N., Granic, I., & Zelazo, P. D. (2016). Executive function in children with externalizing and comorbid internalizing behavior problems. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 57*(1), 30-38. https://doi.org/10.1111/jcpp.12428

Wood, L., Roach, A. T., Kearney, M. A., & Zabek, F. (2018). Enhancing executive function skills in preschoolers through a mindfulness-based intervention: A randomized, controlled pilot study. *Psychology in the Schools, 55,* 644–660. https://doi.org/10.1002/pits.22136

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1*(1), 297-301. https://doi.org/10.1038/nprot.2006.46

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In *Blackwell Handbook of Childhood Cognitive Development* (pp. 445-469). Blackwell Publishers Ltd.

Zelazo, P. D., Forston, J. L., Masten, A. S., & Carlson, S. M. (2018). Mindfulness plus reflection Training: Effects on executive function in early childhood. *Frontiers in Psychology, 9*, 208. https://doi.org/10.3389/fpsyg.2018.00208