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THE EFFECT OF MEDITATION ON METACOGNITIVE ABILITY, WORKING MEMORY ABILITY, ACADEMIC ACHIEVEMENT, AND STRESS LEVELS

Suwit Uopasai[1], Tassanee Bunterm[2], Keow Ngang Tang[3] and Chuleeporn Saksangawong[1]*

[1] Faculty of Veterinary Medicine, Khon Kaen University, Thailand
[2] Faculty of Graduate Studies, Udon Thani Rajabhat University, Thailand
[3] Institute for Research and Development in Teaching Profession for ASEAN, Khon Kaen University, Thailand

Corresponding author:
Suwit Uopasai
suwuop@kku.ac.th

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ABSTRACT

This research assesses the impact of meditation training on the learning abilities of undergraduate students. The existing literature reveals that meditation can improve sleep, reduce stress, help people cope with anxiety, increase happiness, boost self-esteem, overcome depression and anger, and improve concentration. It therefore has the potential to solve undergraduate students' learning problems. A quasi-experimental pretest and posttest research design was utilized to examine changes in the metacognitive ability, academic achievement, working memory ability, and stress levels of undergraduate students in a public university in Thailand following a meditation intervention. The sample comprised 60 healthy undergraduate students without neurological or psychiatric problems who were right-handed and had corrected-to-normal vision. The participants were randomly selected and equally distributed into control and experimental groups, the latter of whom participated in the meditation training program. Three research instruments: Metacognitive Awareness Inventory, Thai Working Memory Computerized Battery Test, and SPST-20 were employed to measure metacognitive ability, working memory ability, and stress levels, respectively. A univariate analysis was performed to determine whether the response variables were altered by the meditation. Initial results revealed no significant differences between the two groups in their metacognitive ability, working memory ability, academic achievement, and stress levels before the intervention. Following the intervention, significant differences were observed in all four dependent variables, including an improvement in metacognitive and working memory abilities and a reduction in stress levels. Furthermore, the experimental group exhibited better average academic achievement than the control group. In conclusion, meditation training can successfully promote metacognitive ability, working memory ability, and academic achievement while simultaneously reducing stress levels.

Keywords: Meditation training program; metacognitive ability; working memory ability; academic achievement; stress levels

1. INTRODUCTION

Meditation involves maintaining concentration on a direct skill while being free from disruptions. Examples include self-referential ideas and thinking roaming (Garrison et al., 2015). Davis et al. (2009) defined meditation as a stage set of concentration exercises leading to a change in status of the attribute of mindfulness, as described by extended consciousness, better existence, and an additional cohesive self-sense. The effects of meditation have been identified as reduced stress coupled with a reduction in numerous illnesses, increased comfort, and a renovated mind (Reynolds, 2016). Kabat-Zinn (2003) claimed that the benefits of meditation are a reduction in stress and propose its use as a potential method to cope with psychosis symptoms (Shonin et al., 2014). A meditation training program entails participating in regular mindfulness exercises, attending a multi-week lesson, or joining a rigorous retreat to develop one's emotional state (Van Vugt and Jha, 2011).

Metacognition refers to a student's capability to apply his or her previous experience to design a strategy for improving an assignment, take essential measures to resolve the challenge, consider estimate outcomes, and alter her or his method as necessary (Chauhan and Singh, 2014). In other words, the development of a student's metacognitive skills, so-called meta-learning, can stimulate their metacognitive ideas as a crucial element in the relocation of knowledge (Uopasai et al., 2018). Previous research (Sripongwiwat et al., 2016; Uopasai et al., 2017) has discovered how methods of studying and mental advancement are related to learning achievement if appropriate training can be provided.

Cowan (2012) defined working memory as the extent of knowledge retained in our memory at any point. This is required for several forms of knowledge, such as understanding, goal-directed ideas, and problem-solving. This is further supported by Dahlin (2013) who emphasized that working memory extends the student's capabilities to concentrate on the undertaking in hand, impede unrelated knowledge, and adapt knowledge from numerous resources, thus leading to an enduring memory. Sanchez-Torres et al. (2015) stated that working memory is a functioning procedure for collecting and handling knowledge, thus it is vital for the precise operation of more complicated mental tasks. Srikoon et al. (2017) emphasized that the working memory of students grows with maturity and recommends creating effective working memory practices for optimum knowledge through educational advancement. Previous research (Alloway and Alloway, 2010; Engel de Abreu et al., 2010, Uopasai et al., 2017) has found that working memory is significantly related to academic achievement.

The Thailand Quality Framework is used to provide proper points of evaluation in relation to academic standards for higher education institutions through their arrangement and interior excellence assurance procedures. This enables them to effectively measure their undergraduate students' skills and abilities (Thailand Office of Higher Education Commission, 2006). Consequently, undergraduate students' academic achievement has to fulfill the five learning realms, namely cognitive skills, knowledge, interpersonal skills and responsibility, ethical and moral development, and analytical and communicative skills (Sripongwiwat et al., 2016). In short, the quality of training in Thai higher education institutions is intended to facilitate the execution of the learning standards set out in the National Education Act, which comply with the Thailand Quality Framework for higher education systems (Luanganggoon, 2017).

Potentially stressful life experiences are extremely familiar in learning surroundings, particularly for undergraduate students (Sripongwiwat, et al., 2018). Such students have to accomplish numerous tests and evaluations, and meet the targets of their assignment in their daily campus lives which can create massive stress (Monteiro et al., 2014). This may have a substantial and crucial effect on their learning as well as the memory process (Schwabe et al., 2012). However, Vogel and Schwabe (2016) revealed that stress can produce both enhancing and damaging impacts on undergraduate students' memory, depending on the particular remembrance procedure or phase that is affected by stress as well as the actions of the main physiological stress rejoinder schemes. This is because undergraduate students encounter stress at capricious methods and levels when they are exposed to prospective risks or stressors. According to Schwabe et al. (2012), their mind activates a system that distributes various spreaders, peptides, and hormones throughout their body to manage the hectic condition and return their body to a state of equilibrium, also known as homeostasis.

We conclude from these findings that meditation for learning is vital in enabling undergraduate students to enhance their academic achievement (Luanganggoon, 2017; Sripongwiwat et al., 2016); for example, maintaining focused attention during a lecture, having an overall anxiety-free undergraduate student experience, and increased concentration to amplify their study skills (Srikoon et al., 2017; Uopasai et al., 2017). We therefore hypothesized that meditation training can put undergraduate students in the best mental state for 'super learning' as well as ensuring their left and right brain hemispheres work together. Hence, meditation training can stimulate learning-associated brain regions and ultimately solve undergraduate students' learning problems.

2. OBJECTIVES OF THE STUDY

This research was designed to explore the impact of utilizing meditation training to promote undergraduate students' learning abilities. Specifically, it aimed to achieve the following objectives:

a) To examine the mean discrepancies in metacognitive ability between the experimental and control groups.
b) To examine the mean discrepancies in working memory accuracy and reaction time between the experimental and control groups.
c) To examine the mean discrepancies in academic achievement between the experimental and control groups.
d) To examine the mean discrepancies in stress levels between the experimental and control groups.

3. LITERATURE REVIEW

The Buddhist Anapanasati Meditation program is perhaps the most popular mindfulness-based stress reduction program. It has been adopted in psychotherapeutic techniques and is an essential concept in Buddhist meditation practice (Kobat-Zinn, 2011). This meditation program can stimulate a distorted state of mindfulness, in a weak sense, through adjustments in the focus of attention, for instance toward physical states (Manuello et al., 2016). The Buddhist Anapanasati Meditation program is derived from the central teaching of the Buddha on mindfulness, the Satipatthana Sutta, which consists of a series of discourses that present a number of meditation practices to develop mindfulness within four domains (Analayo, 2003). According to Dienes et al. (2016), only the first of these domains relates to awareness of the body, the remainder all involve awareness of mental states. Consequently, the metacognitive monitoring and control of cognitive processes is centrally engaged in mindfulness practice (Brefczynski-Lewis et al., 2007).

Research by Van Vugt and Jha (2011) explored the effects of meditation training on knowledge management in a working memory assignment with complicated graphical tasks. Respondents were examined prior to and after one-month of intensive meditation training. The accomplishment of the experimental group was compared to a control group of the same age and education level. A mathematical modeling approach was employed to extricate relevant components and help explain the methods by which meditation training delivers beneficial impacts on accomplishment. Their results indicated that reaction periods were more rapid and there was substantially less variation in the experimental group, even though precision did not vary within groups at the end of the period. Van Vugt and Jha concluded that meditation training can lead to increased knowledge excellence and decreased reaction conservativeness, with no alterations in non-decisional components.

Garrison et al. (2015) explored the effect of meditation on an additional vigorous mental assignment. Their preliminary results showed that meditation is connected and comparatively decreased defaulting means system action. They continued to investigate whether defaulting means action was decreased for the period of meditation, in addition to the usual decreases detected throughout effortful assignments. Their findings revealed that meditation is related to decreased initiations in the defaulting means system, compared to a vigorous assignment, for meditators linked to mechanisms. Areas of the defaulting means system indicate a Group x Assignment interface containing the subsequent cingulate/precuneus and frontal cingulate cerebral cortex. Their findings reproduce and expand previous findings that suggest the repression of managing defaulting means can involve a vital neutral procedure in enduring meditation. Therefore, they suggested that meditation directs to comparatively decreased defaulting means managing away from that remarked throughout an additional vigorous mental assignment.

Knytl and Opitz (2019) studied concentrating awareness meditation exercises as mental control movements whereby meditators strive to retain concentration and awareness when faced with the challenge of disrupting provocations. Their results indicated that focused attention meditation can predict knowledge from deleterious reactions on a probabilistic choice assignment. Furthermore, meditators demonstrated decreased reaction-associated disapproval compared with non-meditators, and this impacts measurements with meditation knowledge. Because strengthening knowledge and feedback-related negativity are regulated by dopamine levels, the results indicate that focused attention meditation training affects constant expansions in dopamine concentrations which are measured by the quantity of exercise, therefore varying reaction managing.

Uopasai et al. (2017) examined the impacts of constructionism, metacognition, and a neurocognitive-based (CMEN) model through working memory training and a traditional teaching model on behavioral, electrophysiological, and achievement changes among veterinary medicine undergraduate students. Both control and experimental groups contained 20 undergraduate students. The findings revealed that the impact of the CMEN teaching model used in working memory training had a greater effect than the traditional teaching model and thus was a suitably advanced teaching model to develop working memory. Uopasai et al. (2019) investigated the effects of the CMEN teaching model with working memory training on veterinary medicine undergraduate students' P300 event-related potential and brain topographical organization. A total of 40 veterinary medicine second-year undergraduate students were equally distributed into two groups as part of an experimental pretest and posttest design. The results indicated that the experimental group who received the CMEN teaching model with working memory training exhibited significantly higher voltage in the frontoparietal cortices and had shorter latency time and higher amplitude at all electrode sites compared to the control group who only received CMEN teaching model training.

Uopasai et al. (2018) examined the impacts of the CMEN teaching model on the learning outcomes of veterinary medicine undergraduate students, namely medical terminology and anatomical knowledge, metacognitive ability, and working memory ability. A total of 84 undergraduate students were evenly distributed into control and experimental groups on a volunteer basis. There were no differences between respondents at the beginning but, following the CMEN intervention, considerable discrepancies were found among the groups for all the learning outcomes. The researchers thus concluded that the CMEN teaching model can improve veterinary medicine undergraduate students' capabilities in recognizing medical terminology, increase their anatomical knowledge, improve their metacognitive capability, and stimulate their working memory capability.

Weil et al. (2013) investigated the relationship between a particular metacognitive capability, the association between task performance, and confidence in adolescence, a phase of the life cycle linked to the development of self-concept and improved self-awareness. They utilized an assignment that separates goal accomplishment on a graphical assignment from metacognitive capability in a group of 56 respondents whose ages ranged from 11 to 41 years. Their results revealed that metacognitive capability increased substantially with age throughout adolescence. The older adolescents and plateaued moving into adulthood exhibited the greatest levels of improvement in metacognitive ability. The findings imply that recognition of one's own perceptual determinations reveals a persistent evolution during adolescence.

Srikoon et al. (2017) measured the attention, working memory, and mood of 76 Grade 9 students using a neurocognitive-based model and a conventional model as a treatment. They employed three types of psychological tests: the attention computerized battery test, the working memory computerized battery test, and the Bond-Ladder visual analog scale to collect data. MANOVA analysis was then performed to analyze the data. Their findings showed that there were significant changes in the experimental group. Specifically, the results indicated that the neurocognitive-based model had a substantial impact on Grade 9 students' attention, working memory, and mood compared to the conventional model. Additionally, Srikoon et al. (2018) found that creative thinking, research characteristics, and academic achievement all substantially increased following the application of either one of the instructional models. However, the impact of the neurocognitive-based model was stronger than the conventional model.

Sripongwiwat et al. (2018) explored the effects of six stressors related to studying: group social-related, intrapersonal-related, interpersonal-related, learning and teaching, academic-related, and teacher-related, among secondary school students in Thailand's northeast region. A total of 925 respondents comprising four student groups completed a series of cross-sectional surveys. The findings revealed substantial discrepancies in all six stressors between the higher secondary and lower secondary students. However, males and females were affected differently with respect to the academic-related stressor. The findings enhance understanding and facilitate the design of appropriate training while reducing study stressors among secondary school students.

The above review of the literature synthesizes the current state-of-the-art in how meditation training can affect undergraduate students' learning abilities. For example, meditation training can lead to increased knowledge excellence and decreased reaction conservativeness, with no alterations in non-decisional components (Van Vugt and Jha, 2011), decreased means managing away from that remarked throughout an additional vigorous mental assignment (Garrison et al., 2015), and affected constant expansions in dopamine concentrations which are measured by the quality of exercise, therefore varying the management of reactions (Knytl and Opitz, 2019). Furthermore, past researchers (Srikoon et al., 2017; Sripongwiwat et al., 2018; Uopasai et al., 2017; Uopasai et al., 2018; Weil et al., 2013) have emphasized the importance of appropriate training that can affect the learning abilities of undergraduate students, such as metacognitive ability, working memory ability, and academic achievement, while also reducing stress.

The literature review reveals a consensus on the importance of meditation training to enhance undergraduate students' cognitive development and learning outcomes.

4. MATERIALS AND METHODS

Study design and participants

The researchers employed a pretest-posttest experimental design to assess the impacts of 45 hours of meditation training on undergraduate students' metacognitive ability, working memory ability, academic achievement, and stress levels. This design was suitable because it enabled researchers to measure the effects of the meditation intervention on the experimental group directly. We took account of confounding influences, for example age, handedness, and health, in order to adequately implement the randomization procedure while managing the groups. A sample of 60 healthy, right-handed undergraduate students with no history of neurological or psychiatric conditions, corrected-to-normal vision, and aged between 19 to 22 years were recruited from a Thai public higher education institution located in Khon Kaen province and then dispersed into experimental and control groups, respectively.

To ensure homogeneity, there were 30 undergraduate students (15 males and 15 females) in each group. This ensured there were no differences in the groups in terms of gender. A 2 (meditation versus no meditation) x 2 (time of measure: pretest versus posttest) design was employed. The experiment group was assigned to attend the breathing meditation training for a period of 15 weeks. This involved being trained to practice breathing meditation 15 minutes/time based on Buddhist Anapanasati Meditation for 3 hours each week, for a total of 45 hours, in a calm and conducive environment. This type of meditation emphasizes mindfulness of breathing while the meditators are inhaling and exhaling. This is considered a true experiment because it is associated with the conditions that directly affect variation.

Both groups were evaluated using pretests and posttests at the start and end of the 15 weeks. This 2x2 experimental design aimed to identify discrepancies in knowledge with or without meditation training, which was postulated to replicate discrepancies or differences in undergraduate students' metacognitive ability, working memory ability, academic achievement, and stress levels.

Study instruments

Three types of tests were employed to measure the effects of the meditation training program: Metacognitive Awareness Inventory (MAI), Thai Working Memory Computerize Battery Test (TWMBT), and Suan Prung Stress Test-20 (SPST-20). The MAI is a self-assessment test consisting of 52 items measured on a 5-level Likert scale. It is mainly utilized to assess the two elements of metacognitive ability, namely metacognitive knowledge and metacognitive regulation. The metacognitive knowledge element includes declarative, procedural, and conditional knowledge while the metacognitive regulation encompasses planning, monitoring, evaluating, information management, and debugging. The MAI employed in this research was a test modified from Schraw and Dennison (1994) and converted to Thai from English to ensure students would have a better understanding of the test items. Cross-adaptation and validation of the MAI was conducted in two stages. The first stage involved three bilingual professionals in English and Thai languages forming an expert committee to check the validity of the content translated from the original instrument to the modified instrument. This was followed by checking the Content Validity Index (CVI), which yielded a CVI value of 90 percent. In the second stage, the MAI was tested on 30 undergraduate students who were not participating in the study for internal consistency. The Cronbach's alpha coefficient value obtained from the second stage was 0.95.

The TWMBT was used to measure working memory ability, which consists of accuracy and reaction time. We adopted the TWMBT that was originally developed in the Thai language by Bunterm et al. (2015). This consisted of seven assignments: (i) Odd-even; (ii) Vowel-consonant; (iii) Switch-Thai letter-number; (iv) Thai Stroop; (v) Thai 0 back; (vi) Thai 1 back, and (vii) Thai 2 back. All the TWMBT tasks were evaluated for construct validity using the goodness of fit test developed by Bunterm et al. (2015). The test-retest reliability scores for these assignments varied from 0.822 to 0.979. Respondents were provided with 10 trials for each assignment, an overall total of 70 trials. Reaction times lower than 200 milliseconds were omitted, and data were examined in the assortment of $\bar{X} \pm 3$ S.D.

The SPST-20 was adapted by Uopasai (2015) to measure the stress levels of undergraduate students. It comprised the following five-level scale: (i) '1' means under no stress at all; (ii) '2' means slightly under stress; (iii) '3' means under moderate stress; (iv) '4' means under severe stress, and (v) '5' means under extremely severe stress. Uopasai (2015) further interpreted the score range as follows: 0 to 24, 25 to 42, 43 to 62, and more than 63, indicate mild, moderate, high, and severe levels of stress, respectively. The SP Stress Test-20 was piloted for validity and reliability. It was found to exhibit good internal consistency and equivalence of concepts compared to the original SPST-20. The academic achievement of students was measured according to the total scores students obtained in the posttests on the MAI, TWMBT, and SPST-20.

In this study, the researchers determined whether the mean score of the two groups was identical for each investigated construct. To achieve this, a univariate analysis of variance was performed to analyze the impact of time, meditation training, and the interface between time and meditation training on the four dependent variables: metacognitive ability, working memory ability, academic achievement, and stress levels. Univariate analysis is perhaps the easiest method of statistical evaluation as only one variable is engaged. It is mainly used to assess whether the vectors of means for the two groups are experimented from the identical sampling dissemination (Hair et al., 2013).

5. RESULTS AND DISCUSSION

The results are presented according to the objectives of the study outlined previously. The initial results highlight demographic data on the undergraduate students. This is followed by an evaluation of the effects of meditation training on their metacognitive ability, working memory ability, academic achievement, and stress levels. Finally, the different effects on the two groups are presented.

Demographic data of students

First, the demographic data of undergraduate students were measured. The initial results indicated no substantial discrepancy between the groups in terms of their age (t (57) = 0.267, p >.05), gender (χ^2= 1.248, df = 1, p >.05), and handedness (χ^2 = 0.553, df = 1, p >.05). Furthermore, there were no significant differences in the body mass index (BMI) of undergraduate students in both groups (T^2 = .03; $F_{(2, 57)}$ = .860; p = .429). Hence, the control and experimental groups were matched and it was appropriate to continue with the meditation training intervention. The experimental group attended 45 hours of meditation training while the control group did not attend any meditation training. Table 1 presents the mean scores and standard deviations of the demographic data of undergraduate students.

Table 1: Results of Undergraduate Students' Demographic Data

Demographic data	Experimental group		Control group	
	Mean score	*S.D.*	Mean score	*S.D.*
Age (year)	20.01	0.79	20.30	1.02
BMI (Kg/m2)	21.47	4.83	20.91	3.10

Metacognitive ability of undergraduate students before and after intervention

The pretest result indicated no mean discrepancy in metacognitive ability before the intervention (T^2 = 0.06; $F_{(8, 51)}$ = 0.365; p = 0.934, η^2 = 0.05). However, the experimental group seemed to possess higher metacognitive ability compared to the control group after the intervention (T^2 = 4.18; $F_{(8, 51)}$ = 26.68; p <0.01, η^2 = 0.81). Table 2 presents the pretest and posttest results for metacognitive ability in terms of metacognitive knowledge and metacognitive regulation components.

Table 2: Results of Undergraduate Students' Metacognitive Ability

Metacognitive ability (Knowledge + Regulation)	Pretest				Posttest				Uni-variate Analysis
	Meditation training		Without meditation training		Meditation training		Without meditation training		
	$\bar{X}$	*S.D.*	$\bar{X}$	*S.D.*	$\bar{X}$	*S.D.*	$\bar{X}$	*S.D.*	
Declarative knowledge	29.70	3.82	29.13	3.18	34.63	1.92	28.50	3.16	82.55**
Procedural knowledge	14.87	2.33	14.37	2.63	19.00	1.66	15.00	2.21	62.70**
Conditional knowledge	18.77	2.93	18.50	2.87	24.07	2.91	19.17	1.80	61.43*
Planning strategies	26.70	4.19	26.83	3.39	28.67	3.86	26.20	3.66	6.44*
Monitoring strategies	24.53	2.40	24.17	3.05	28.90	3.85	26.83	3.99	4.16*
Information management strategies	21.07	2.27	20.57	3.76	25.23	2.90	19.97	2.97	48.62**
Debugging strategies	37.40	5.09	36.03	5.19	42.07	5.63	37.23	4.64	13.17*
Evaluation strategies	19.67	2.78	19.33	2.51	23.03	1.69	20.70	2.14	22.00**

*p<.05; **p<.01

Accuracy of the working memory of undergraduate students before and after intervention

Working memory ability was evaluated in terms of accuracy and reaction time. The pretest results indicated no mean difference in working memory in terms of accuracy between the two groups for the seven TWMBT tasks (T^2 = 0.12; $F_{(7, 52)}$ = 0.90; p = .51, Partial Eta Squared =.11). However, the experimental group exhibited greater accuracy of working memory ability on the TWMBT compared to the control group (T^2 = 1.31; $F_{(7, 52)}$ = 9.76; p <.01, Partial Eta Squared = .57). The results of a univariate analysis to compare the mean scores and standard deviations of accuracy between the two groups for each working memory assignment is presented in Table 3.

Table 3: Results of Undergraduate Students' Accuracy of Working Memory Ability

Accuracy of working memory ability	Pretest				Posttest				Uni-variate Analysis
	Meditation training		Without meditation training		Meditation training		Without meditation training		
	X̄	*S.D.*	X̄	*S.D.*	X̄	*S.D.*	X̄	*S.D.*	
Odd-even	75.30	15.16	72.57	9.20	89.60	6.22	79.30	8.20	30.03**
Vowel-consonant	35.63	4.35	35.70	4.76	39.67	3.12	35.10	5.02	17.90**
Switch-Thai letter no.	37.67	2.88	36.87	7.06	43.07	2.00	38.10	8.34	10.05**
Thai Stroop	22.43	5.18	20.13	4.80	29.70	7.83	24.43	6.88	7.66*
Thai 0 back	7.10	1.54	7.13	2.01	8.43	1.10	7.30	1.53	10.78**
Thai 1 back	5.63	1.40	5.23	1.30	7.47	1.28	6.10	1.21	18.02**
Thai 2 back	4.10	1.16	4.00	1.70	5.83	1.32	3.60	1.33	42.81**

**p<.05; **p<.01*

Working memory reaction time of undergraduate students before and after intervention

The pretest results indicated no mean difference in working memory in terms of reaction time between the two groups for the seven TWMBT tasks (T^2 = 0.11; $F_{(7, 52)}$ = 0.85; *p* = .56, Partial Eta Squared = .10). However, the experimental group exhibited a shorter reaction time compared to the control group (T^2 = 4.77; $F_{(7, 52)}$ = 35.42; *p* <.01, Partial Eta Squared = .83). The results of a univariate analysis to compare the mean score and standard deviations of reaction time for both groups on each working memory task are presented in Table 4.

Table 4: Results of Undergraduate Students' Reaction Time of Working Memory Ability

Reaction time of working memory ability	Pretest				Posttest				Uni-variate Analysis
	Meditation training		Without meditation training		Meditation training		Without meditation training		
	X̄	*S.D.*	X̄	*S.D.*	X̄	*S.D.*	X̄	*S.D.*	
Odd-even	574.59	41.67	587.63	46.81	458.89	43.90	586.25	43.52	46.99**
Vowel-consonant	705.90	54.38	702.54	27.76	622.77	32.75	685.48	42.66	40.79**
Switch-Thai letter no.	703.78	45.68	725.16	57.43	627.38	48.77	684.84	49.76	20.40**
Thai Stroop	720.01	65.01	737.60	65.79	583.29	46.36	704.11	60.62	75.17**
Thai 0 back	525.13	76.48	533.50	70.20	422.71	66.70	525.37	47.77	46.97**
Thai 1 back	591.96	98.43	581.59	101.89	466.74	76.69	557.18	76.87	31.03**
Thai 2 back	704.30	76.28	689.444	61.19	534.76	64.81	665.77	102.48	35.02**

***p<.01*

Academic achievement and stress levels of undergraduate students before and after intervention

The academic achievement of undergraduate students was measured according to the total scores they obtained on the MAI, TWMBT, and SPST-20 posttests. Following the meditation training intervention, the average academic achievement of the experimental group improved significantly (3.27 ± 0.33) and was higher than the control group (2.86 ± 0.51).

Before the intervention, the stress score of the control group was 50.50 ± 9.25, which was higher than the experimental group (46.10 ± 14.43). The results of the independent t-test indicated a substantial discrepancy in stress levels between the control and experimental groups (t = 1.40, *p* = 0.17). The stress scores of both groups ranged from 43 to 62, which meant that both groups were at a high stress level. However, following the intervention, the stress levels of the experimental group were successfully reduced from a high to moderate level (37.13 ± 13.56) while the control group remained at a high-stress level (45.57 ±1 6.31) with only a mild change. Moreover, an independent t-test identified a substantial discrepancy between the two groups (t = 2.18, *p*<.05). This implies that meditation training can reduce undergraduate students' stress levels.

We investigated the effects of 45 hours of meditation training on undergraduate students' metacognitive ability, working memory ability, academic achievement, and stress level. The meditation training intervention successfully improved all factors compared to the group who did not receive meditation training, even though they had a similar demographic background. The significant changes in their performance corresponded to Van Vugt and Jha's (2011) results for the EZ-diffusion model. Their study revealed that the drift rate increased while the decision boundary reduced for those respondents who attended meditation training. Thus, their conclusions support our research hypothesis that meditation training can enhance undergraduate students' working memory via concentration, especially knowledge excellence and subsequent decisional procedures, which were reflected in their improved levels of academic achievement.

The results of the univariate analysis revealed that the experimental group possessed higher metacognitive ability in terms of metacognitive knowledge and metacognitive regulation (T^2 = 4.18; $F_{(8, 51)}$ = 26.68; *p* <0.01, η^2 = 0.81). This result is supported by Peter and Zoltan (2019) who proposed the cold control theory of hypnosis. Hypnosis depends on the imprecise metacognitive ability of planned movements and experiences while meditation primarily involves the experience of awareness and intentions. Thus, it can be concluded that meditation coupled with the better metacognitive contact to intentions, will act as meditator that can remain on the reverse sides of a continuum concerning metacognitive open to intention-linked knowledge.

Moreover, meditation training seemed to significantly enhance undergraduate students' working memory ability in terms of accuracy and reaction time. This result is in agreement with Uopasai et al.'s findings Uopasai et al. (2017) discovered that working memory is a compelling predictor of ensuing intellectual achievement for veterinary medicine undergraduate students. This is because working memory symbolizes a dissociable mental competence with exceptional connections to students' intellectual achievement. This implies that information processing in the cortical networks of the experimental group improved the encoding, retention, and retrieval of the information held in working memory through meditation practices.

Stress has extensive effects on undergraduate students' ability to understand and recall information, as has been demonstrated by previous research (Maloney et al., 2012; Sripongwiwat et al., 2018). Compared to previous findings (Garrison et al., 2015; Knytl and Opitz, 2019), our results showed similar outcomes as meditation training significantly reduced stress levels. Because learning under stress is a common issue among undergraduate students and may have harmful impacts on consequent memorizing, meditation training may be the best solution. A probable explanation is that stress operated as a distractor during encoding, deflecting concentration from the information that needs to be studied (Sripongwiwat et al., 2018).

6. CONCLUSION

The results of this research imply that meditation is a useful technique to train undergraduate students by focusing their mind on a particular object, thought or activity, otherwise known as mindfulness. We found that meditation can train undergraduate students' attention and awareness to achieve a stable, mentally alert, emotionally calm state. Unlike mindfulness, meditation usually involves a specific body posture; for instance, most traditional meditation encourages an upright seated posture. Nevertheless, there is no doubt that meditation is a powerful tool in fostering metacognition among undergraduate students as it involves direct observation of mental operations through introspection. Based on this line of reasoning, meditation can be used to cultivate metacognitive awareness, reflection, and insight to enhance metacognitive power and skills, such as self-monitoring and self-regulation learning.

The above conclusion is endorsed by the results of previous research (Broderick and Metz, 2009; Chambers et al., 2008; Flook et al., 2010; Zeidan et al., 2010). For example, Broderick and Metz reported that meditation can decrease negative effects and strengthen serenity, moderation, and self-acceptance. Furthermore, there is a good evidence to suggest that meditation can enhance mental function and awareness (Chambers et al., 2008), improve executive function (Flook et al., 2010; Zeidan et al., 2010), and increase metacognitive insight (Zeidan et al., 2010). Therefore, we endorse the effects of meditation as a contemplative practice and mental training to support the development of positive potential and dispositions by inducing variations in mind function and construction, as well as increasing the pro-social performance and academic achievement of undergraduate students, as stated by Davidson et al. (2012) further is being proven in this study.

Finally, our results support the hypothesis that meditation training can improve undergraduate students' metacognitive ability, working memory ability, and academic achievement while significantly reducing their stress levels. The current study has successfully added to the flourishing area of knowledge on the development of metacognitive and working memory abilities. Our results are subject to certain limitations that highlight directions for future work. For instance, subsequent researchers should consider the impacts reflected in the meditation training group and investigate the expansion of current theories on metacognition, stress, and working memory. They should also explore other facets of meditation training, such as whether the emphasis on the breath or compassion practices triggers the outcomes.

In summary, there is a transformation impending in Thai higher education. The results concerning the effects of meditation training will therefore have important consequences for higher education, ultimately enhancing the ability of institutions to exercise and plan. The brain results for undergraduate students are useful for learning only insofar as they alter our perception of how studying and advancement occur, irrespective of their scientific value in educational research (Srikoon et al., 2017). Therefore, it is recommended that academics should collaborate to identify and practice innovative methods of advancement that have pragmatic consequences for higher education.

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