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Meditation Based Brain Painting Promoting Foreign Language Memory through Establishing a Brain-Computer Interface

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***Abstract*—**In the current study, we designed an interactive meditation and brain painting application to cultivate users' creativity, promote meditation, reduce stress, and improve cognition while attempting to learn a foreign language. User tests and data analyses were conducted on 42 male and 42 female participants to better understand sex-associated psychological and aesthetic differences. Our method utilized brain-computer interfaces to import meditation and attention data to create artwork in meditation-based applications. Female participants showed statistically significantly different language learning outcomes following three meditation paradigms. The art style of brain painting helped females with language memory. Our results suggest that the most ideal methods for promoting memory attention were meditation methods and brain painting exercises contributing to language learning, memory concentration promotion, and foreign word memorization. We conclude that a short period of meditation practice can help in learning a foreign language. These findings provide insights into meditation, creative language education, brain-computer interface, and human-computer interactions.

***Keywords*—**Brain-computer interface, creative thinking, meditation, mental health.

I. INTRODUCTION

MEMORY is the most critical factor in learning a foreign language. Meditation is an intentional practice that calms the mind [1]. The practice of meditation was found to decrease stress and promote attention in prior studies [1], [2]. Cognitive and language tasks are associated with improved attention, whereas meditation has been shown to benefit learning effectiveness and knowledge retention [2]. Research has shown that meditation decreases anxiety and helps in foreign vocabulary language learning [3].

Pure language memorization, which is usually emphasized during language learning [4], can restrict or block one's creative thinking. The dorsal and ventral streams are believed to play an important role during visual information processing and influence the perception of objects and spaces during episodic memory, defined as the explicit memory of specific items or events tied to a particular spatiotemporal context [5]. Combining visual information processes and creative thinking cultivation, previous studies have used painting as a method to improve creative thought processes [6], [7]. Moreover, drawing has been shown to promote cognition and memory [8], [9], and technological innovation using visual art promotes creativity [10].

Human-computer interaction (HCI) is defined as "a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and the study of the major phenomena surrounding them" [11]. Brain painting is an HCI platform used to cultivate creative thinking while practicing meditation. A brain-computer interface (BCI) allows individuals to interact with external devices through mental activity [12]. Brain painting is a BCI application through which users can paint on a digital canvas without physical movement [13]. Hoesle [14] described the brain painting work, "Pingo Ergo Sum," as representing a new method allowing for the imagination of color and figures where "art is the journey rather than the destination." Meditation brain painting can improve creative thinking cultivation and brain activity. Past research found that painting can cultivate students' creative thinking [7], [15], [16]. Visual memories and stimuli within brain painting are associated with pleasant emotions [17], which can help in the memorization of foreign words with pictorial clues.

Music therapy can help people practicing meditation with healing and stress reduction and can promote wellbeing [18]-[20]. We utilized meditation music created by Dr. Wayne Dyer to accompany the participant's experience during meditation brain painting [21] and to determine how meditation music can support the brain painting process to support its effectiveness in promoting language, memory, and cognition. Meditation brain painting can decrease stress and promote interest in creative foreign language learning process, thereby improving creativity during language learning. HCI was combined with BCI to improve the user experience, explore daily meditation capabilities, and promote cognitive learning [22], [23]. A recent review summarized research on how artistic BCI can stimulate visual nerves in order to promote the quality of the original user experience [24]. This study develops a potential interactive strategy that could be used as a global language learning method.

This study aimed to determine whether the combination of meditation and creative thinking cultivation could improve memorization and influence the progress of language learning. We combined working memory tasks, music therapy, and visual biofeedback to explore whether creative thinking cultivation from brain painting via an artist BCI can promote

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the effects of meditation on cognition and memory. The findings of this study provide insights into meditation and creative language learning as tools for promoting overall wellbeing and quality of life.

II. Materials and Methods

This study combined meditation and brain painting technology using a NeuroSky Mindwave headset to import meditation and attention to create artwork during foreign language learning. We designed an experimental method to promote the effects of meditation in order to cultivate creative thinking during the foreign language learning process.

A. Ethics Approval and Study Participants

This study was approved by the Science and Technology Ethics Committee of Shanghai Jiao Tong University and followed the principles of the Declaration by Helsinki. All participants provided their written informed consent. The study included 84 participants (42 male and 42 female) recruited from the affiliated university as well as industries associated with foreign language learning. Participants were aged 18-30 years, with a mean age of 23.65 years (SD = 2.54).

B. Equipment

The BCI tests were performed in a quiet laboratory room using the NeuroSky Mindwave headset. NeuroSky was connected to Processing software, a program created by Ben Fry and Casey Reas in 2001 [45]. Previous researchers have used meditation and attention data to design visualization and artwork in meditation practice using the NeuroSky Mindwave headset combined with Processing software [25]. Research has demonstrated that the NeuroSky Mindwave headset is a reliable tool for recording attention and meditation levels in scientific research [26]-[28].

C. Procedure

The participants performed two rounds of memorization tasks, as well as a meditation task between the memorization tasks. The number of participants in each group was limited to 26 individuals (13 male and 13 female). The experimental procedure is summarized in Fig. 1. The participants were randomly assigned to different meditation practice categories as follows: category 1, MBP (meditation and brain painting); category 2, MBPM (meditation, brain painting, and meditation music); and category 3, MOM (meditation on mindfulness).

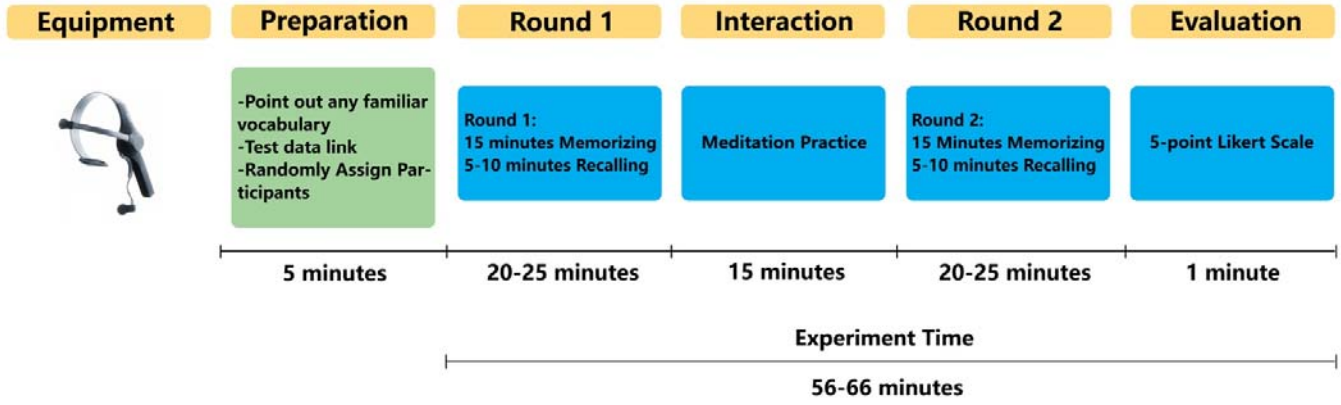

Fig. 1 Overall procedure

To calculate the optimal number of memorized foreign words in 15 min intervals, two participants (one male and one female) were asked to perform the memory tasks prior to the study. Based on these results, 30 words per 15 min was suggested as the optimal count. In Round 1, participants were instructed to memorize 30 English words that were matched with images (during a 15 min period). Participants were reminded to combine words and images during the memorization stage. At the beginning of the memory stage, participants were asked to point out any English words they had seen or been familiar with prior to the memory task in order to exclude these words from the final data analysis. Any words with spelling mistakes that the participants claimed were familiar or any words that were forgotten during the recall of results were regarded as unfamiliar in calculating the final statistics. After the participants memorized 30 English words, they were given a test paper containing random pictures corresponding to Chinese words. The participants had 5 min to recall the English words; they had the option to extend this timeframe to 10 min. Next, each participant wore the equipment and performed one of the three categories of meditation practice within 15 min. After finishing their meditation practice, they were asked to take the headsets off. Participants were asked to memorize another 30 English words within a 15 min period (round 2). The numbers of memorized words from both rounds were compared (excluding any words that participants were exposed to prior to the experiment). Finally, after the participants attempted to recall the English words, they rated their experience with the three kinds of meditation practice on a five-point Likert scale as follows: “good,” “not bad,” “neutral,” “not ideal,” and “bad.”

A full mark indicated that the participant made no recall mistakes in both rounds. A few participants had full marks in both rounds. These participants were excluded from the final results since the increment or decrement in their performance could not be calculated. The participants who scored full marks in either round 1 or round 2 but had a lower count of correctly memorized words in the other round were included in calculating these results. The data showed either improvement

or regression due to the influence of the three meditation conditions. In order to calculate the data for exactly 26 participants per group, if one participant was excluded due to a perfect score, researchers would invite another participant to the corresponding group. Six participants received full marks for the entire memorization test. Their test data were not used in improvement or regression evaluations within the final statistical analyses. Following this, three male and three female participants were additionally invited to compensate for the lost data.

Fig. 2 Memory card

To characterize differences according to sex, each group included 13 male and 13 female participants. Previous findings have suggested that differences in sex can influence mental health effects and processes [29]. This study analyzed potential psychological and aesthetic sex-associated biofeedback within the three different meditation conditions while learning foreign language words.

D. Wordlists

The words that participants were asked to memorize in English were selected from the Baicizhan application, which was developed by Chengdu Chao You AI Technology. This application assists in the memorization of English words through image clues. All words were included in the Test for English Majors-Band 8 module [30]. This test was the most difficult Chinese English test among all major-band programs. During the experiments, the participants were permitted to memorize difficult ("hard-level") English words to improve their English language literacy. The memory and recitation cards for both rounds are shown in Fig. 2.

E. Artwork

The study developed a brain painting application that recorded brainwave data and transformed these data into abstract artwork. The artistic BCI allows for recording brainwave data to determine the user's affective state through artistic forms [31]. The concept of brain painting was inspired by generative design [32] and was coded using the Processing language module [33]. The canvas screen was 1,900 × 350 pixels. The artwork creators followed the "less is more" [34], [35] and "keep it simple, stupid" design principles [36] to design the interactive visual art interface.

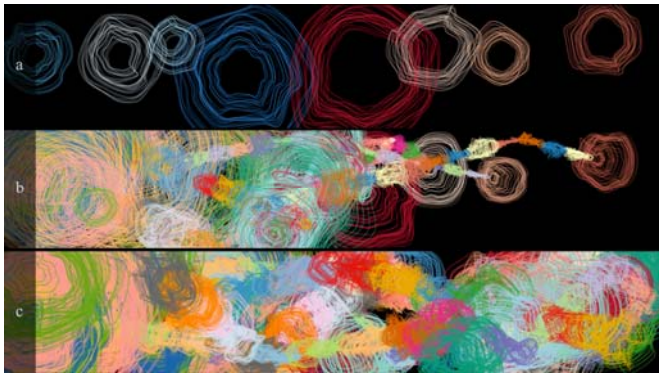

Fig. 3 Brain painting: (a) initial state, (b) one participant artwork, (c) longer recording

Meditation and attention data were used to create the artwork. The participants used data to control the bulb size on a digital screen via the BCI (Fig. 3). The initial artwork included four blue meditation bulbs and four red attention flower-like bulbs. Higher meditation and attention values resulted in bigger abstract meditation and attention bulbs. The participants interacted with bulb size variations to create artwork through brain interaction, which avoids complex interaction processes that influence meditation. Participants were instructed to focus on the meditation bulbs to experience "meditation on mindfulness." To consider the painting's visual effect, the abstract bulbs changed color (within four groups of colors) every minute and moved slowly and gradually across the screen for a stimulating visual experience. The artwork was created by the authors and has therefore not been used previously. The aim of the artwork was to help participants enter a state of meditation. The participants were encouraged to meditate and perform other meditation-associated practices while wearing EEG headsets to attain relaxed states. The artwork was created directly from the user's brainwave data and was output via complex data processing. The more the participants relaxed, the more effectively the brain painting developed. A recording of the brain-painting animation is provided at https://vimeo.com/425910439.

F. Meditation Practice

The meditation on mindfulness concept was developed by Christina Cornioley and Dr. Caitilin de Bérigny, meditation instructors of authors. In meditation practice, participants sat comfortably and were instructed to perceive their bodies through a breathing rhythm. At this stage, the participants observed their surroundings, including environmental sounds. Table I show instructions and time information and list eye conditions as open or closed.

G. Data Analysis

The participants' brainwave data were collected and analyzed. All statistical analyses, including analysis of covariance (ANCOVA), analysis of variance (ANOVA), paired-sample t-tests, independent t-tests, exploratory analyses, and frequency analyses were performed using Statistical Package for the Social Sciences (SPSS) statistical software (ver. 23, IBM, Chicago, IL, USA). All evaluated data were developed using normal distribution curves.

To consider the correct sample size for conducting independent t-tests between the male and female groups, the effect size was set to 0.8 [37], [38], the alpha error probability was set to 0.05, and statistical power was set to greater than 0.8 [39]. ANCOVA considered the participants' individual baseline scores for word learning ability [40]. The participants' age was calculated for establishing the individual's baseline in order to demonstrate age-associated differences in memory performance. We did not regard the English recitation results in round 1 as the individual baseline in this study, since all participants' familiar words were excluded in rounds 1 and 2 and round 1 listed different vocabulary from round 2. Paired-sample t-test results were indicated via ANOVA or ANCOVA analyses. To calculate differences in word memorization between the two rounds, word learning performance was calculated by recording the words memorized in the second round and by subtracting the words memorized in the first round. All evaluated data were developed using normal distribution curves. Anonymized and de-identified study data are available in the data statement.

III. Results

The descriptive data analysis for foreign vocabulary learning performance presented in Table II demonstrated that female participants memorized more words during the MBP practice as compared with males. More specifically, the mean MBP score for word learning for the female participants was higher (M = 5.15, standard deviation [SD] = 4.30) than for the MBPM (M = 1.0, SD = 2.35) and MOM (M = 3.00, SD = 3.63) practices. Moreover, compared with the female participants,

MBP did not influence learning performance in males according to a mean value analysis (M = 0.77, SD = 4.75). We found that the MOM practice was more suitable for males in terms of learning vocabulary. When combining male and female data (Figs. 4 (a)-(c)), the MBP group showed the greatest word improvement (M = 2.96, SD = 4.96) as compared with the other two groups (M = 1.61, SD = 2.33; M = 2.35, SD = 4.38).

TABLE I
MEDITATION ON MINDFULNESS

Duration	Instruction	Eyes Condition (MBPM, MBP)	Eyes Condition (MOM)
0-2 min	• As you look at the screen, loosen your body before beginning - neck, shoulders, hands and legs. • Sit comfortably with your back well supported while looking at the screen.	Eyes open	Eyes closed/MOM Group does not contain any interactions with the screen
2-9 min	• Set the intention that you will now focus on your breath and on feelings in your body. • Tighten all the muscles in your body and face – hold and breath out slowly as you relax these muscles. • Bring awareness to your chair or cushion. Pass the connection with your "sitting boxes." • Bring awareness to how you are feeling right now - just let that feeling pass. • Bring awareness into your skin - how your clothing touches it, how different the uncovered parts (face, hands) feel. • Now, focus on your nostrils, and the inflow and outflow of your breath - do you smell anything around you? • Focus on your sense of taste. • Now, be aware of any sounds occurring to your LEFT. Just acknowledge these sounds, don't analyze them. Change awareness to sounds occurring to your RIGHT - again, just observe. • Be aware of the darkness behind your eye lids.	Eyes closed	Eyes closed
9-10 min	• Eyes open: Look at the screen for 1 minute. (Note: Remind users of the locations of the main meditation and attention patterns.)	Eyes open	Eyes closed/MOM Group does not contain any interactions with the screen
10-14 min	• Focus on breathing – the rise and fall of your chest and abdomen. Keep coming back to breath awareness if other thoughts arise. • Remain in this state of full awareness of everything happening in your body. • Stay in this mindfulness state for as long as you are comfortable. • Don't force anything. Just let the process happen naturally and be the observer. • If any noises occur outside, let them pass like clouds across your mind. Just acknowledge them (e.g., a motorbike, door slamming). Come back to breath awareness. • You will know when it is time to finish - as the "outside world" will draw you into an active state again, and you won't be able to draw your attention back to your breathing. That's ok. • Slowly begin to become present to your surroundings. Take a deep breath. Stand up. Shake it out! • Whenever you can during your day, try to focus your concentration fully on anything you are doing - e.g., drinking coffee, walking, showering.	Eyes closed	Eyes closed
14-15 min	• All of this can be considered meditation or mindfulness. Now with your eyes open, keeping looking at the screen for 1 minute. (Note: Remind users of the locations of the main meditation and attention patterns.) • Be here……Now!	Eyes open	Eyes closed/MOM Group does not contain any interactions with the screen

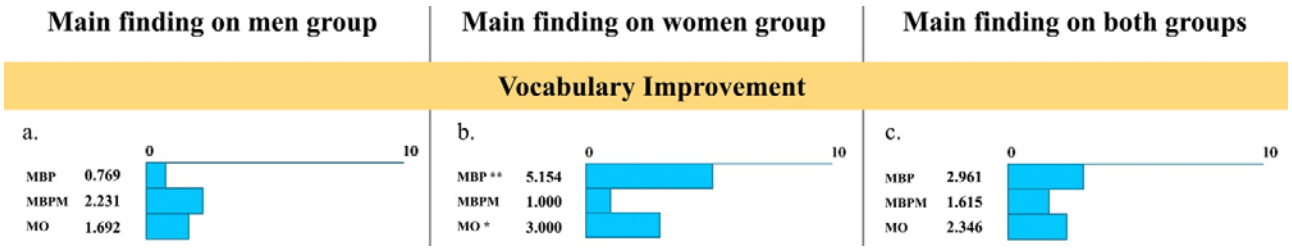

Fig. 4 Main findings

ANCOVA demonstrated that participant age was the main influencing covariate. The meditation category was found to significantly influence learning results for females (p = 0.005), and the age covariate likewise had a statistically significant influence (p = 0.006). In contrast, the male participants did not show statistically significant associations according to meditation practice categories (p = 0.814). The ANCOVA pairwise comparisons for female participants demonstrated that MBP differed at the level of statistically significance (p = 0.004) as compared with MBPM.

Since the female participants showed stronger memory performance in MBP practice as compared with that in the MBPM and MOM practices, a paired-sample test was applied based on the results of an ANOVA evaluation. As shown in Table III, MBP showed a statistically significant difference (p = 0.001) in meditation practice interference in terms of learning when the number of memorized words was compared prior to and following the three meditation practices. Moreover, a paired t-test demonstrated that the score in the second round of the MOM meditation practice was significantly higher than in

the first round (p = 0.011). The MBP practice had a statistically significant influence on improving vocabulary memory in females, whereas the MOM meditation practice was found to be statistically significant in the paired t-test but not in the ANCOVA.

TABLE II
DESCRIPTIVE DATA ON THE NUMBER OF MEMORIZED FOREIGN WORDS

Meditation Category	n	Mean	SD	SE	95% Confidence Interval for the Mean Values		Min	Max
					Lower	Upper		
Males								
MBP	13	0.7692	4.74612	1.31634	-2.0988	3.6373	-7.00	8.00
MBPM	13	2.2308	2.24179	.62176	.8761	3.5855	-1.00	6.00
MOM	13	1.6923	5.08895	1.41142	-1.3829	4.7675	-7.00	8.00
Total	39	1.5641	4.15360	.66511	.2177	2.9105	-7.00	8.00
Females								
MBP	13	5.1538	4.29818	1.19210	2.5565	7.7512	-3.00	13.00
MBPM	13	1.0000	2.34521	0.65044	-0.4172	2.4172	-2.00	5.00
MOM	13	3.0000	3.62859	1.00639	.8073	5.1927	-4.00	10.00
Total	39	3.0513	3.83165	.61355	1.8092	4.2934	-4.00	13.00
Males and Females								
MBP	26	2.9615	4.96774	0.97425	0.9550	4.9681	-7.00	13.00
MBPM	26	1.6154	2.33370	0.45768	0.6728	2.5580	-2.00	6.00
MOM	26	2.3462	4.38125	.85923	.5765	4.1158	-7.00	10.00
Total	78	2.3077	4.03976	.45741	1.3969	3.2185	-7.00	13.00

MBP, meditation and brain painting; MBPM, meditation, brain painting, and meditation music; MOM, meditation on mindfulness

TABLE III
PAIRED-SAMPLE T-TESTS IN WOMEN

Word Learning Performance	Mean	SD	SE	95% Confidence Intervals of the Difference		t	df	Sig.
				Lower	Upper			
Before vs. after MBP	-5.15385	4.29818	1.19210	-7.75121	-2.55648	-4.323	12	0.001
Before vs. after MBPM	-1.00000	2.34521	0.65044	-2.41719	.41719	-1.537	12	0.150
Before vs. after MOM	-3.00000	3.62859	1.00639	-5.19274	-0.80726	-2.981	12	0.011

df, degrees of freedom; MBP, meditation and brain painting; MBPM, meditation, brain painting, and meditation music; MOM, meditation on mindfulness; SE, standard error

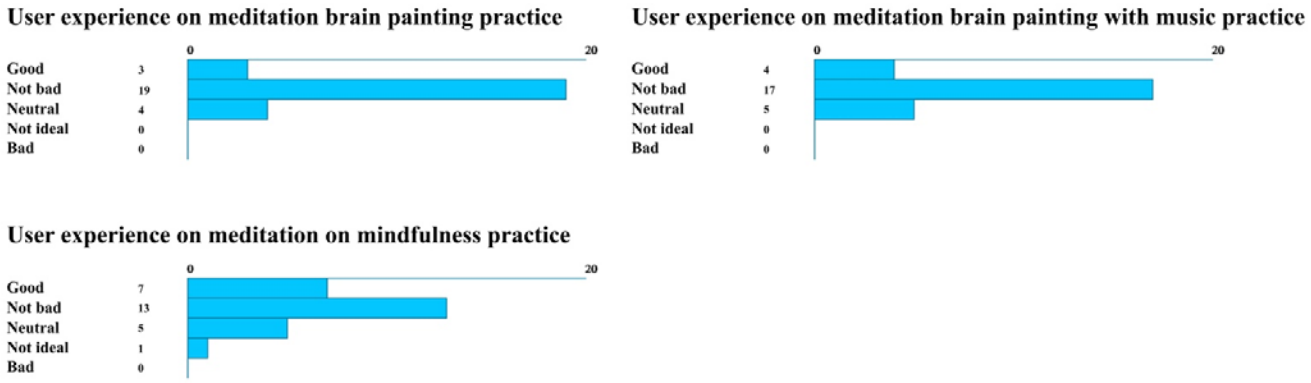

Fig. 5 User experience for the three mindfulness exercises

Regarding participants' feedback on the artwork and meditation practice, 14, 49, and 14 participants rated their experience as "good," "not bad," and "neutral," respectively. There were no differences among the three experimental categories (Fig. 5). Most participants were satisfied with their brain paintings and meditation experiences in terms of promoting the efficacy of their foreign language learning.

IV. DISCUSSION

The findings of this study suggest that visual stimulation and creative thinking cultivation due to brain painting enhance language memory. Previous meditation and language learning research has reported that meditation can improve engagement in learning a foreign language in terms of presentation, writing, and cooperation [6]. Meditation reportedly increases the volume of the hippocampal building human episodic memory [5]. Our study demonstrated that creative thinking cultivation intensifies meditation effects during foreign language memorization using image clues.

Our descriptive data analysis showed that males and females

had different outcomes on foreign language (English) vocabulary learning tasks when comparing three types of meditation practices. Statistically significant findings were noted for MBP; the MOM and MBPM practices also led to improvements in word memorization. These improvements may be attributed to the cognitive effects of entering relaxed states by practicing meditation. Male participants showed no statistically significant differences when evaluating any of the three meditation practices via ANOVA. However, men showed words mean improvements after three meditation practices.

Regarding the individual baseline data for each participant, both age and meditation practice categories were found to influence the foreign word learning results in female participants. Previous research has similarly reported that females' age can influence performance visual-spatial memory tasks [41]. In females, the currently evaluated brain painting art style activated visual reflections, whereas MBP visual stimulation compensated for episodic memory and enhanced visual impressions based on image clues. We found that females learned more words at a faster rate as compared with males after the painting experience. Previous research has found that men and women have different aesthetic preferences on artwork [42]. These sex-specific differential preferences might be reflective of cognitive processes arising from the hunter-gatherer strategies of ancient humans. For example, men tend to perform navigation tasks, while women prefer landmark searching and gathering tasks (i.e., fruit and vegetable gathering; [43]). Past painting research found that attention was drawn to the binary couple of women and flowers and men with commerce and culture on the landscape [46]. In the current study, the flower-like pattern design was found to facilitate women's motivation in the learning process. Thus, we suggest that currently available modules for brain painting artwork might be more suitable for creative thinking and supporting biofeedback during the visual memorization stage in females as compared with males. However, the meditation practice category showed no influence on ANCOVA findings in male group. Another artwork style needs to be explored for males based on the findings of this and other studies. The possible inspirations can be related to commercial and navigation designs [43], [46]. Another potential reason for the observed results could be that, although meditation instructions were provided by a qualified meditation instructor in the current study, this was the first time that most participants of the enrolled participants had practiced MOM. Moreover, participants' positive emotions may have affected their learning. This is important as positive emotions improve cognitive processing, visual sensory perception, attentional resources, memory ability, and effective decision making [44]. Consequently, positive experiences with meditation practice and brain painting might have improved the participants' feelings.

The key strength of the current study was our use of creative thinking concepts and abstract art as applied to improve language research to promote the beneficial effects of meditation. Our findings suggest that creative thinking as well as meditation effects can improve foreign language literacy learning results and likewise demonstrate that MBP statistically significantly improved the domains of vocabulary memory performance in females.

V. Limitations and Scope for Future Investigation

First, the participants' performance in the current study might be associated with their lack of experience in meditation. Future studies should consider enrolling individuals who are experienced in meditation to confirm our findings across a range of experience levels. Second, as English was the only language assessed in the current study, we acknowledge an overall limitation in terms of generalizability. Other languages should be assessed in future studies. Third, future research should also explore visual activation or artistic methods for activating visual memory in males using meditation practices and brain painting techniques. Our findings do not support the speculation that visual stimuli have no influence on male participants. However, in the current study, brain painting was found to be more appropriate for females in terms of promoting effective language learning.

VI. Conclusion

Our study evaluated the effects of meditation on the process of foreign language learning and established associations between the evaluated tasks and processes. The study provides a creative language learning platform that cultivates creative thinking. For example, we evaluated the use of meditation, abstract brain painting, music therapy, HCI, and BCI for stress reduction. Our findings suggest that creative thinking cultivation enhances meditation practice and improves language learning outcomes. Moreover, meditation music did not perform well with MBP in terms of promoting language learning, although participants who were administered the MBPM practice showed some improvements while recalling words in the second round of testing. In evaluating a range of 15 min meditation practices, females had the highest mean word increment (5.15) following MBP. Future studies should consider individuals with varying levels of preexisting meditation experience to better utilize the advanced EEG experimental apparatus described herein to study creative thoughts and visual memory influence. Our preliminary findings provide a platform for improving wellbeing and overall quality of life.

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CONFLICTS OF INTEREST

The authors claim that they have no conflict of interest.

DATA STATEMENT

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