Enhancing Attention Training through Gamification: A Comparative Study of Meditation-Inspired Training Method

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Abstract. Due to the repetitiveness and monotony of attention training, participants often feel bored, resulting in lower completion and response rates, which in turn limits the training effect. To boost participation and motivation, gamification can be a helpful approach, though its effect on enhancing cognitive tasks is proven to be mixed. Meditation, as an effective way of attention training, is characterized by comparatively short time consumption and quick results. This study proposed a new meditation-inspired, gamified attention training method to explore the impact of gamification on training effectiveness. In a controlled pilot experiment with 14 participants, the study evaluated participants' reaction time and accuracy on an Attention Network Test (ANT), with mean improvements of 5.64% and 6.79%. Combined with the results of semi-structured interviews, the superiority of the approach over the non-gamified approach and its potential to address motivation issues were demonstrated.

Keywords: attention training · gamification · meditation

1 Introduction

Attention is the ability to allocate processing resources to relevant stimuli appropriately. Maintaining a moderate level of attention over the long term is essential for many daily activities, such as reading, attending lectures, or doing homework [15]. By exploring attention and attention training, we can find practical strategies to effectively enhance attention and self-regulation capabilities [56].

Attention training is a type of cognitive task that helps people focus on tasks more easily while reducing distractions around them [45][56]. Although such training does help enhance various cognitive functions, its repetitive and time-consuming nature limits the effectiveness of the intervention [27][29], leading to participant disengagement, low completion and response rates [2][26]. This lack of motivation not only reduces the quality of task performance but also affects

the reliability of data collected from different studies to analyze specific tasks [25][58] and negatively affects data quality [10].

Meditation, especially mindfulness-based stress reduction (MBSR), has been widely used to help people focus and concentrate. As an effective way of attention training, its benefits lie in the short duration required to complete each section and the immediate impact it has afterward [1][31]. However, the process of practicing can be tedious [19]. Also, traditional mindfulness teaching methods are often difficult to reach, and finding a mentor and attending weekly classes often requires a lot of time and energy investment [1].

One way to address this is through gamification. By applying game elements to a non-game context [11], gamification can increase motivation and encourage long-term participation [32]. As a practical design method, gamification is interactive and can cultivate experiential knowledge, essential for attention training [19]. Furthermore, gamification is easy to implement in digital applications, which are easy to distribute widely, making it an ideal choice for designing such tasks [53]. However, some studies have suggested that gamification has a mixed effect on task performance [9][24]. For example, gamification may lead to task invalidation because the characteristics that are supposed to be cognitively assessed do not differ from the control group under the influence of the game elements, thus invalidating the measurement tool [9].

Considering the pros and cons of meditation in attention training, and the mixed results of gamification for improving performance in cognitive tasks, this study chose meditation as a special case of attention training and wanted to explore the effects of adding game elements to the design inspired by meditation in attention training.

In this paper, we proposed a gamified meditation-inspired attention training method and tested its effects on attention performance by comparing a gamified training group with a control group in which the participants followed one mindfulness meditation video by Jon Kabat-Zinn, which is one of the most well-researched and widely used meditation programs and conducted the meditation. To do so, it aims to answer the following research question:

What is the effect of a gamified meditation-inspired attention training method on attention performance and participants' motivation compared to non-gamified meditation-based attention training?

Based on this question, this paper also puts forward two hypotheses:

1. The gamified training method will have a positive effect on attention performance and participants' motivation.
2. The gamified training method will be more effective than non-gamified meditation training on attention performance and participants' motivation.

The experiment quantitatively analyzed the changes in attention performance by evaluating the reaction time and accuracy of participants in an attention test. It was followed by semi-structured interviews conducted to qualitatively analyze the participants' overall experience and expect to gain insight into motivation through their feelings about engagement and enjoyment. The results show the

superiority of this new method in terms of the reaction time decrease and accuracy improvement. Even in busy daily life, anyone can quickly return to a better state of attention through fifteen minutes of gamified training. The analysis of the interviews shows that by adding game elements, the participants' enthusiasm, and attention performance increased which shows the potential for gamification design of attention training methods.

2 Related Work

2.1 What is attention

Attention plays a crucial role in our daily tasks. William James defines attention as the brain's ability to focus on one clear target among multiple objects or thoughts occurring at the same time [22].

Generally, following a well-established and recognized framework by Posner [43], attention is understood as consisting of three main components: alertness, orienting, and executive attention.

Alertness refers to the readiness for impending stimuli [42]. Orienting involves selectively focusing on specific information from multiple sensory stimuli and may also include shifting attention from one stimulus to another [43]. Executive attention, the third component in Posner et al.'s framework, includes the control of goal-directed behavior, target detection, error detection, conflict resolution, and the inhibition of automatic responses [42].

2.2 Attention training

Attention training is a method of improving focus and concentration through a variety of techniques [56][54]. A meta-analysis conducted by Peng and colleagues indicated that, compared to control groups, attention training significantly improved performance on attention tests, with a moderate effect [41].

Attention training is primarily conducted through two methods: network training, which involves repeating specific tasks that engage attention networks, and state training, which involves exercises that alter brain states [45]. The former aims to modify specific networks related to cognitive tasks, while the latter achieves a state that promotes more effective self-regulation [56].

Network training typically includes practicing cognitive tasks, which are believed to strengthen specific attention-related brain networks. Given that attention involves multiple distinct neural networks [42], various methods exist to enhance the efficiency of one or more of these networks. Common network training primarily focuses on the three components of attention that were outlined before [41]. For example, alertness training focuses on improving sustained attention or vigilance. One exercise [48] requires participants to press the space bar each time a specific symbol appears on the screen.

State training, such as meditation, aims to develop brain states through exercises that affect attention and other networks [44][52][57]. For example, both aerobic exercise and mindfulness training can create a state that appears to improve cognition, attention, and mood [56].

2.3 What is meditation

Meditation refers to "a set of self-regulation practices that focus on training attention and awareness to bring mental processes under greater voluntary control and thereby foster general mental well-being and development and/or specific capacities such as calm, clarity, and concentration" [12]. Mindfulness meditation currently dominates the research landscape [40].

Mindfulness meditation requires attention to remain in the present state, but not to focus on specific content[45]. Mindfulness meditation consists of at least three closely related components that form the process of enhancing self-regulation: attention regulation, body awareness, and emotion regulation [21][54].

Some of the most compelling findings involve how mindfulness meditation training promotes attention and reduces mind-wandering [23][38][55]. Using the Attention Network Test (ANT) and other testing methods, researchers have explored the effects of mindfulness meditation on attention performance [54]. Recently, several studies have shown that short-term mindfulness meditation training can reduce mind-wandering and enhance attention [38][39]. For example, research by MacLean et al. demonstrated that mindfulness meditation training can improve attention in short duration [33]. This study compared one week of integrative body-mind training, which is one kind of mindfulness meditation, with an active control group receiving relaxation training, with participants randomly assigned to each group. They did the intervention for one week and 30 minutes for each session. The Attention Network Test has been used in this study to evaluate attention performance. Compared to the relaxation control group, one week of IBMT showed better executive attention [55].

2.4 Gamification and elements

Gamification uses game elements and combines multiple game elements [13] intending to encourage users to perform tasks that are not related to games[59]. These tasks may involve improving certain skills or promoting certain habits, such as exercise[51].

Game elements consist of game components, mechanics, and dynamics, all of which refer to the tools, techniques, and widgets used to build gamified websites or applications[4], which can be used individually or in combination to motivate users. Game components are the basic building blocks of games. Game mechanics refer to the player's behavior triggering a specific response from the system, and game dynamics refer to how game mechanics and interactions affect and drive the player experience, thus forming the overall gameplay [4][11][49][50].

This study illustrates the hierarchy of these three elements based on a pyramid structure proposed by Werbach and Hunter [59] (see Figure 1). The gamification design process starts with the basic dynamics of the requirements. It continues to determine the mechanisms selected based on the dynamics and the components related to them.

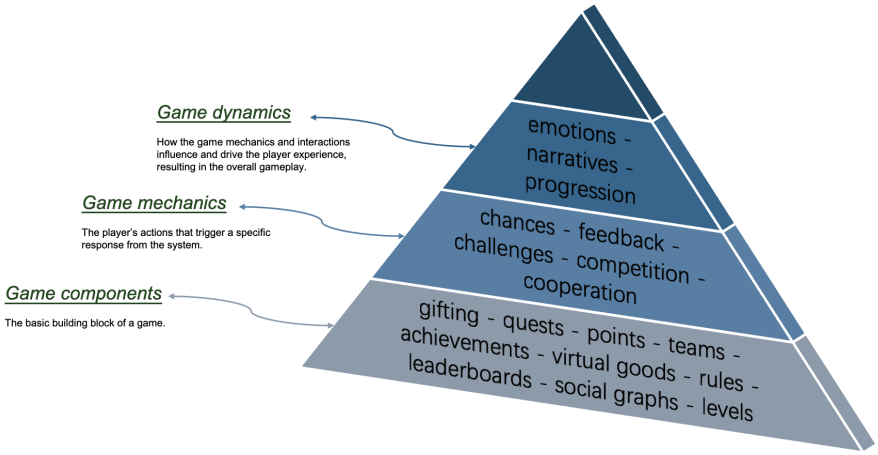

Fig. 1. Graphical illustration of game elements

2.5 Does gamification work?

These two systematic reviews [32][58] also identified 21 out of 33 studies that directly compared gamified cognitive tasks with non-gamified tasks, revealing specific impacts of gamification on testing and training tasks.

All studies measuring intrinsic motivation indicated that gamified tasks enhance motivation and engagement compared to non-gamified tasks [32][58]. Prins et al.'s study (Supermecha) [46]found that children showed higher engagement and enjoyment during working memory training tasks when using gamified approaches. Similarly, evidence from Ninaus et al. suggests that gamification can enhance the overall performance of participants in working memory training tasks, making gamified tasks suitable for measuring and training attention-demanding tasks [14]. Researchers have also explored the application of gamification concepts to meditation-inspired design. Asati et al. developed a Virtual Reality mindfulness meditation training using an archery game mechanism, encouraging users to maintain attention by focusing on the target. They chose to gamify meditation because meditation itself, as an attention training method, is limited by the boring process and the difficulty to reach. Its effectiveness has been demonstrated through the score improvement in a non-video game.[1].

Most gamification assessments successfully validated the relevance of gamified tasks and output measurements/scores. One study demonstrated that gamification, using a badge platform's reward mechanism to group students, made the process of acquiring new knowledge more enjoyable without affecting the original function of the platform [49]. Overall, these well-designed and empirical studies provide encouraging evidence that gamified cognitive training can serve as an effective research tool.

Although gamification has the potential to address the tediousness and repetitiveness of cognitive tasks (including attention training) [25][6], the effects on some cognitive outcomes are mixed [32][58].

Game elements can distract participants or invalidate tasks during cognitive training, which may outweigh their potential motivational benefits [8][32]. For example, Delisle et al. compared the experimental group with the Continuous Performance Task II [9] and found that a feedback-rich multitasking environment may normalize the inattention of ADHD patients and prevent the correct diagnosis of ADHD.

The impact of gamification on participant engagement and data quality is inconsistent. Some studies [32][37] indicate that adding game elements does not significantly affect user performance and may even reduce data quality. The gamification applied by Birk et al. [3] not only failed to have a positive impact on data quality and engagement but worsened them [32].

Meditation has been proven to be effective and popular as a form of attention training, so we chose meditation as a case to explore the effect of gamification on attention training. This paper then proposed a new method drawing inspiration from meditation to enhance the purpose of attention training through gamification.

3 Method

In order to examine our research question, this study designed a meditation-inspired game for attention training that was used in an experiment. First, the game design will be introduced, followed by a detailed experiment setup.

3.1 Game Design

The meditation-inspired gamified attention training this paper proposed consists of three tasks: a jigsaw puzzle, a visual breathing guide, and a mini-game to guide a boat. In the first task, participants will complete a puzzle-solving game with three difficulty levels. The second part involves a breathing exercise, where participants follow a dynamic visual balloon to regulate their breathing. In the third section, they will navigate a boat using arrow keys to connect with an avatar symbolizing their partner and reach the final destination. The entire experience lasts 15-20 minutes. Drawing inspiration from key elements of meditation (attention regulation, body awareness, and emotion regulation) and integrating them into a game-like format, this game aims to provide attention training throughout the whole experience.

Design principles and expressions

- The design of the game is based on the mindfulness meditation process proposed by Tang et al. [54], which includes three components: attention regulation, body awareness, and emotion regulation. These three components correspond to the three tasks of the game. By combining gamification training with these meditation principles, we expect that it also has the positive effects of meditation on attention training.

1. Attention regulation refers to practitioners redirecting their attention to the chosen object whenever they notice their mind wandering. Successful attention regulation is foundational to benefiting from mindfulness practice [54]. Tasks that require high concentration can effectively train participants to self-regulate and recognize patterns to complete tasks [20]. It can not only help stimulate a variety of visual-spatial cognitive abilities [17] but also improve attention [28]. Therefore, this study chose to design a set of jigsaw games with different levels of difficulty and complexity and provide clues (clicking a button can reveal the entire picture) to keep players interested.

2. Body awareness refers to the ability to attend to subtle bodily sensations [35]. In mindfulness practice, the focus of attention often includes internal experiences, especially the sensation of breathing [47]. In the regulation design, it is very important to give participants intuitive feedback on their breathing status to effectively guide and prompt the required breathing behavior [36]. Therefore, this study adopted a simpler form of representation and made a visualization of the balloon. Participants are prompted to take a deep breath according to the status of the balloon. There is no restriction on the frequency and timing of breathing, allowing participants to self-regulate their breathing. The contraction or expansion of the balloon is used to intuitively represent the state of inhalation and exhalation. Participants can choose to make the state of lung breathing consistent with the balloon according to their own understanding, or use the balloon as a target and exhale when the balloon expands.

3. Emotion regulation teaches practitioners to reinterpret stressful events as meaningful or benign adaptive processes [18]. Attention control here is adaptive regulation when attention is diverted from disturbing emotional materials, and to actively face unpleasant emotions (such as sadness, anger, and disgust) instead of turning away [21]. The task requires participants to control the boat to pass through each friend model and reach the endpoint. It uses the interactive form of controlling the movement of the boat as a carrier, and gifts given to participants as proof of successfully reaching each target point. The gift consisted of emotional stories (sadness, happiness, joy) collected through Google and blogs, and the color of the text is different according to the emotions when shown to participants.

– Secondly, by implementing specific game elements such as challenges and narratives, we hoped that the training would motivate users beyond the typical points, badges, and leaderboards and reduce potential shortcomings of meditation practice.

1. Narratives
   According to "Epic Meaning & Calling" in the Octalysis Framework created by Chou [7], the narrative such as the storyline is a core driving force. Players believe that they are doing something greater, or "chosen" to do something.

When participants experience a story, it can engage them with interest, attention, and fun [30].
At the beginning of the game, it is introduced that the participants will hold a party with five friends and some preparations need to be made before that (Fig 2). The friends have encountered different difficulties, and the participants are requested to embark on the journey to address these challenges with them.

Fig. 2. Start page of the game & friends' images

For the first task, Mr. Bee hopes participants can help collect all the pieces of three puzzles. The second task consists of a little elephant who invites the participants to blow up the balloons prepared for the party. Finally, the remaining three friends need to be picked up by a boat so everyone can go to the party together. During this task, friends give gifts to the participants in the form of short stories about accepting one's emotions.

2. Challenges
Games should push participants out of their current comfort zone in an achievable way. The game adjusts the difficulty of the challenge so that participants feel the game is challenging but feasible [49].
The puzzles are composed of $2 \times 2 = 4$, $3 \times 3 = 9$ to $4 \times 4 = 16$ pieces, and the assembled images are captured from part of the complete image. Three difficulty levels and the selection of only part of the raw pictures add challenges to the first task. The second task does not show a progress bar for the total number of balloons that need to be blown up but gives the number that has been completed. There is a fixed judgment logic when the boat moves. Sometimes participants will find that if they press a certain direction

button alone during the last task, the boat cannot move even does not touch the edge of the river. Instead, by pressing two direction buttons at the same time, it can move faster and correctly.

3. Achievements
   Good video games provide participants with achievements across various platforms. By rewarding participants with achievements, they gain a sense of competence and feel valued for their involvement [49].
   The first task shows motivational words (such as congratulations on successfully finding a piece!) when succeeding. For the second task, when you complete a deep breath, a small balloon will appear on the interface to show your small achievement. In the last task, a gift will be given to represent each successful connection with a friend.

Game play

1. First Task
   The first task of the jigsaw puzzle game (Fig 3) represents a puzzle that can only be solved through focused observation and patience. The main page briefly explains the rules of the game. There are a total of three puzzles of different difficulty levels that need to be solved, which are operated by dragging the pieces with the mouse. The puzzle that needs to be completed is composed of a pre-uploaded picture. A part of this picture is pre-cut into different numbers of pieces in the background and scattered on the right side of the screen. On the other side of the screen is a base divided into square grids. Each piece has a corresponding correct position (the pieces and the base are marked with serial numbers respectively, and the judgment standard is whether they match). The pieces can be moved by dragging the mouse and can be placed in any position on the base. However, a second piece cannot be placed in the position where a piece has already been placed. A new piece can only be placed in the same position after the current piece is moved. When participants release the mouse while dragging, the pieces will randomly return to a position on the right side. Participants can check the complete picture by pressing the "cue" button. When all the pieces are in the correct position, the task will be judged as successful, and display the raw picture.

2. Second Task
   The visual breathing guide contains almost no interactive elements. The homepage briefly explains the rules of this visualization (how many seconds to breathe each time, what the task objectives are). After reading it, participants have three seconds to prepare, and the page automatically jumps to the breathing guide interface with a character image. The character is moving slightly up and down, trying to blow up a balloon. In the center of the screen, there is a yellow balloon that keeps expanding and contracting (Fig 4).

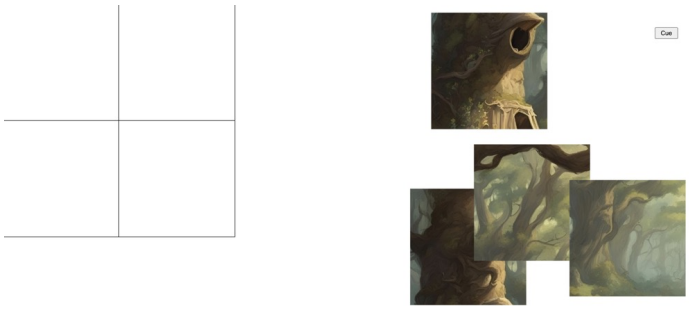

Fig. 3. One level of the jigsaw puzzle

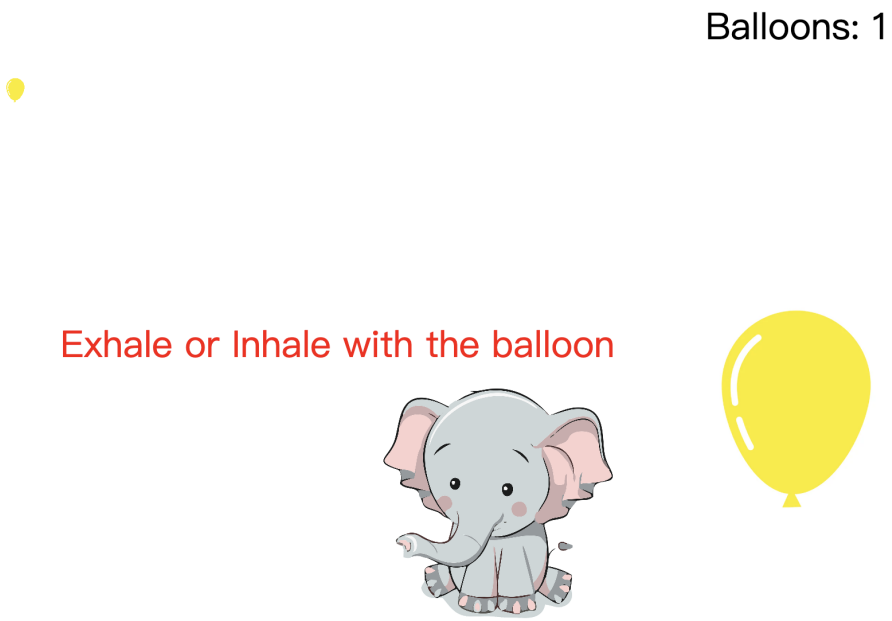

Fig. 4. Visualization of breath guide

Above the character, there is text in red reading "Exhale or inhale with the balloon", and participants can choose the rhythm of deep breathing according to their preferences. It takes about 7 seconds to take a deep breath (blow up a balloon in the task), that is, inhale for 3 seconds, hold your breath for 1 second, and then exhale slowly for 3 seconds. The blown-up balloon will be displayed on the screen as a small icon, and the number of balloons directly above will also increase by one. After blowing up 30 balloons, the page will pause for 2 seconds and jump to the next page.

3. Third Task
The goal of the last game is to guide a boat containing friends who need to be picked up to the destination. The operation is very simple. The participant only needs to use the arrow keys to move the boat along the river. The main page shows "Now you just need to pick up friends to start the party! The friend's icon will be displayed on the path, try to reach the destination!", and there is a button to click to enter the next page. The next page prompts that the friend is preparing a gift for you for which you need to use the keyboard to enter two sentences: the first sentence is what you are worried about recently, and the second sentence is what you are happy about recently. After this, participants can click start to enter the main part of this task. The river is curved and tortuous, and the boat can only move in the blue area (Fig 5).

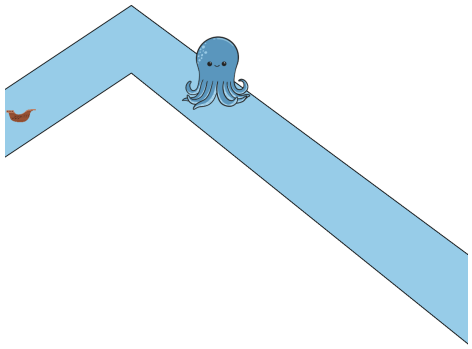

Fig. 5. Part of the boat game

There are 3 friend models placed in different places on the path. When the boat reaches the model, the boat remains in place. At this moment, a scroll appears on the screen as a gift (Fig 6) from a friend, which contains text and an illustration. After reading the scroll, participants can click a button to close it. The boat will return to its previous position when reaching the model, and the model will disappear. Then the participant can continue to move the boat. After all the friend models disappear, the game ends, a new

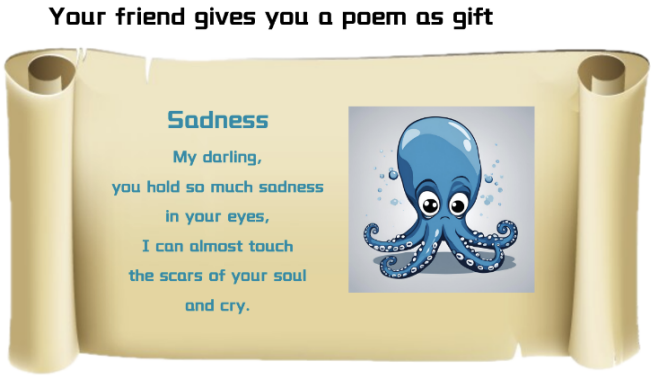

Fig. 6. An example of the gift

page appears and it shows the following text: "Anxiety is you, embarrassment is you, sadness is you, envy is you, and happiness is also you. Facing your own emotions, you no longer turn away. Facing other people's stories, you watch quietly. This journey is coming to an end here, you are already the master of your emotions and a peaceful self."

Settings and implementation The entire game was coded in JavaScript, including all the interaction logic, completion and failure determination, etc. The order of the game cannot be freely selected, the links redirecting between each other are automatic. Canvas's Magic Material Generator was used to generate the image of every character in the game, the original puzzle pictures, and the information pictures of each part, so there is no copyright issue. The code is published on the GitHub Page[1].

3.2 Experiment set-up

This study conducted a randomized controlled experiment as a pilot trial. Participants were pre-assigned to a gamified group (asked to experience the gamified training) and a control group (do meditation following an online MBSR course). We expected to test task (attention) performance and gain insights regarding motivational issues. We tested participants' attention performance before and after the intervention to evaluate the effectiveness of the new training method. Interviews were conducted to analyze subjective feelings about engagement and enjoyment which are related to motivation.

Specifically, this paper hypothesizes that:

1. Since the allocation in the groups is random, there should be no difference between the gamified group and the control group before the intervention.

[1] You can play the game via this link: `https://xiaotian0722.github.io/Puzzle-1/`.

2. The intervention can improve the attention performance of the gamified group.
3. The intervention effect of the gamified group is stronger than that of the control group.

The experiment lasted about 40 minutes. First, the purpose and plan of the study were introduced in the information sheet, and the participants were asked to sign the Informed Consent Form before the study. Next, participants were asked to complete a 5-minute pre-intervention ANT. After completion, participants were asked to participate in one of the two different attention training exercises, which both lasted for approximately 15 minutes. After the interventions, they were required to do the same ANT test again to measure their performance. The study ended with a semi-structured interview which lasted about 5-10 minutes. After this, they were asked to sign the Debriefing Form.

We met all the participants either at their places or invited them to our apartment. To create a relatively comfortable and independent environment for the participants, the participants stayed alone in the room. To encourage the participants to stay focused during the intervention, we only briefly introduced the process at the beginning of the study, conducted the interview at the end of the study, and left the room for the rest of the time.

Test design ANT has been used by many researchers including Tang et al.[55] which involves how mindfulness meditation training promotes attention and has been proven to be an effective tool for measuring attention performance[16][34][55]. The test used in this study was based on the attention test designed by Fan et al. [16] and written in JavaScript.

The test task requires participants to determine whether a central arrow points to the left or right. At the same time, distracting cues appear on the screen, which may provide information about where the target is or may hinder the participant's task. Targets have two types: the flank direction is the same as the arrow or the flank direction is incongruent. There is no key feedback during the whole testing process. The participants' average reaction time and accuracy before and after the intervention were the main indicators of the test. The greater the decrease in reaction time percentage and the higher the accuracy values, the better the attention performance.

At the beginning of the test (see Fig 7), a "+" fixation dot (also a distractor) was presented in the center of the screen to ask the participants to focus their attention. The duration of this phase was random, ranging from 400 to 1600 milliseconds. After the fixation dot disappeared, a cue, such as an "*", appeared for 200 milliseconds, which could appear in the center of the screen or offset above or below. This was followed by a 400-ms interval (the "+"), and then the target stimulus (5 arrows arranged horizontally) appeared above or below the "+". The arrows only pointed left or right, and could be congruent (all arrows pointed in the same direction) or incongruent. The task required participants to indicate the direction of the central arrow within 700 milliseconds (press the left key if it pointed left; press the right key if it pointed right). This was followed by a 1600-ms interval, after which the test was reset and a new test began. A

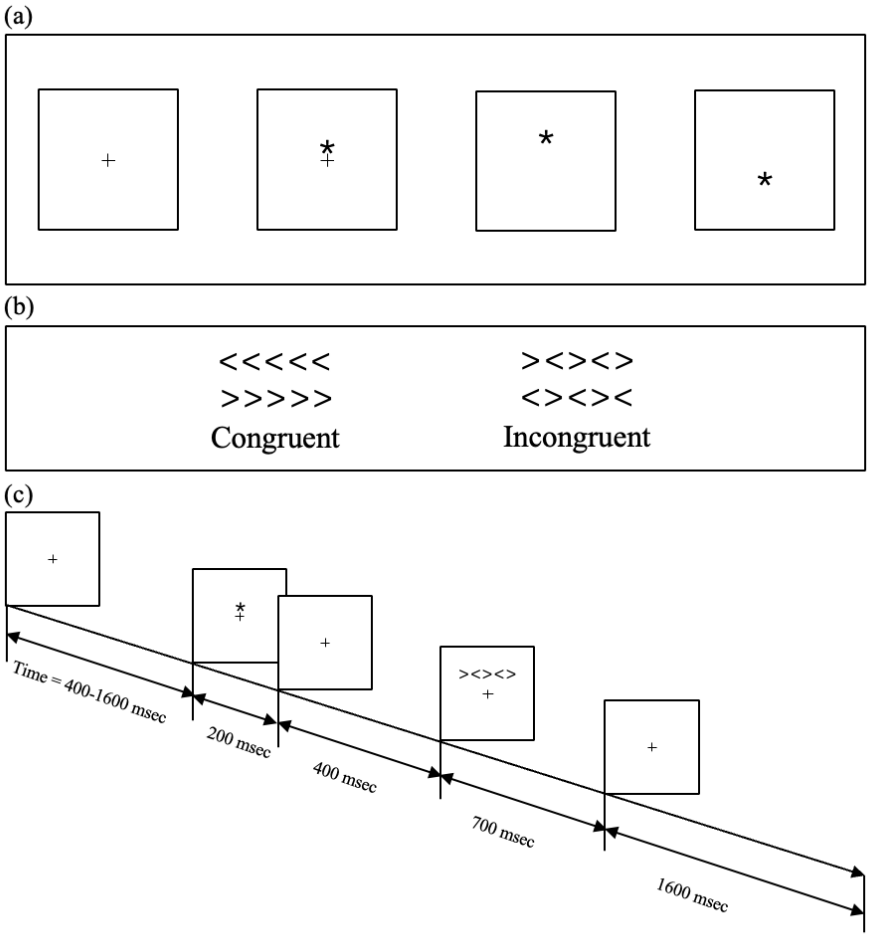

Fig. 7. Test procedure. (a) The different distraction cues; (b) The target stimuli; (c) An example of the procedure.

total of 80 trials were conducted, and the reaction time and accuracy of the participants from the appearance of the target stimulus to pressing the button were recorded each time. When all trials were completed, the program calculated the experimental results, including the accuracy of the reaction and the average reaction time. These data will be saved as a CSV file and triggered to download.

Interview design Participant interviews consisted of (1) quantitative questions that asked participants to score from 1 to 10, focusing on the overall experience related to engagement and enjoyment (e.g. "Do you think the training process is interesting?"), and (2) open questions for individual responses, such as suggestions for changes or additions. The interviews were transcribed and compiled into a document. Then the participant quotes were reviewed to understand their levels of engagement, enjoyment, and attention during the intervention and to collect design feedback. Interview insights supplemented the data analysis of the attention test and the design improvement space, helping to fully analyze the role of the intervention in the training process.

Participants All participants were recruited after posting the experiment and recruitment information on Instagram. A total of 14 participants [8 females, 6 males, mean age ($\pm$ SD) = 26.43 $\pm$ 3.01] were recruited, and all participants received the intervention and completed the interview successfully. The gamified training group will be referred to as Group A and the control group as Group B. The participants in each group were numbered from 1 to 7. Participants were numbered according to the order in which they participated in the experiment (serial number). When mentioning A1, it means the first participant in the gamification group.

Eight of them had no or limited meditation experience (we then category as beginners), while six regularly participated in meditation training in their daily lives (at least once a week). The study randomly assigned participants to either a gamified training group (n = 7) or a control group (n = 7), ensuring that the number of people with meditation experience was the same in each group (n = 3). This study received ethics approval from the Media Technology Board of Leiden University, and participants signed an informed consent form before starting. This study only collected the voice records during the interviews and the analysis was performed using transcription.

Intervention methods The experimental group participated in the gamified meditation training. The control group participated in a 15-minute individual practice mindfulness meditation video session. During it, participants chose to wear headphones or not and watched the recorded meditation course. Participants followed the video content to adjust body posture, do breathing exercises, and conduct mindfulness training. The meditation video [2]is part of the mindfulness-based stress reduction (MBSR) method developed by Jon Kabat-

[2] You can find the video here: `https://www.youtube.com/watch?v=9SwnJ6kqpa0&t=213s`.

Zinn (Fig 8), which is one of the most well-researched and widely used meditation programs [3].

Fig. 8. A frame from a meditation video

4 Results

This study compiled all the data for preliminary analysis, transcribed interviews, and formatted both indicators of attention performance tests. This section will describe how the data and the detailed analyses are collected and conducted step by step.

4.1 Attention performance test

Data pre-processing The data from all 14 samples are clean and ready for analysis. In this step, we calculated:

– Percentage of reaction time decrease (RT): The difference between the reaction time before intervention and the reaction time after intervention divided by the reaction time before intervention (Fig 9).

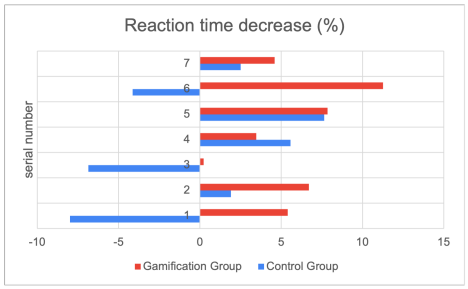

Fig. 9. Reaction time decrease (%)

[3] Homepage of the meditation course: `https://palousemindfulness.com/`.

– Accuracy improvement (AC): Post-intervention accuracy minus pre-intervention accuracy (Fig 10).

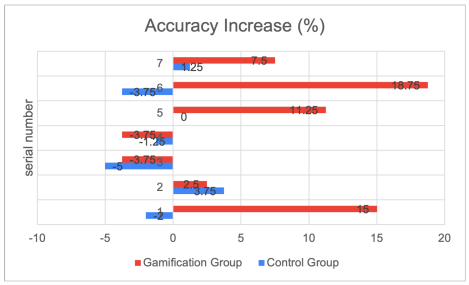

Fig. 10. Accuracy increase (%)

Descriptive statistics By calculating the descriptive statistics of each group, we can have an intuitive understanding of the basic characteristics of the data. Among them, mean(for reaction time of gamified training group) = 5.64, SD = 3.48; mean(for reaction time of control group) = -0.19, SD = 6.15. mean(for accuracy of gamified training group) = 6.79, SD = 8.86; mean(for accuracy of control group) = -1.00, SD = 2.98. (Check Fig11 and Fig12 for both indicators.)

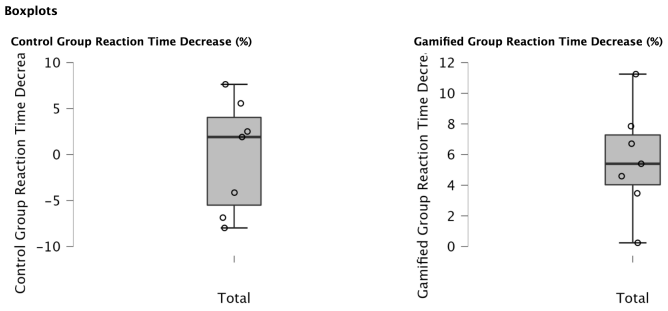

Fig. 11. Boxplots: Percentage of reaction time decrease

Normality test For each group's reaction time and accuracy improvement, a normality test (this study used the Shapiro-Wilk test) was performed to determine whether the data conformed to a normal distribution. This can help decide whether to use a parametric test later.

For both the gamified group and the control group, all four data were following a normal distribution ($p_A(RT)$=1.00, $p_B(RT)$=0.46, $p_A(AC)$=0.55, $p_B(AC)$=0.99,

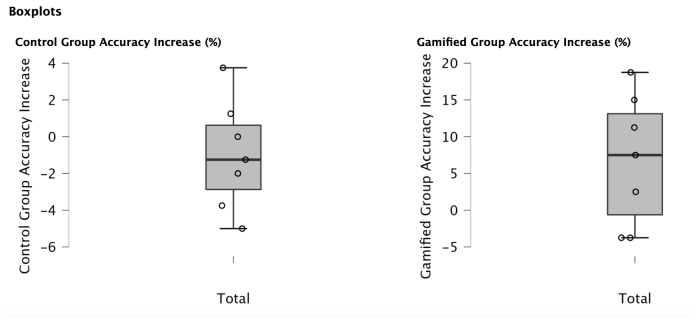

Fig. 12. Boxplots: Accuracy improvement

If the p-value is greater than 0.05, the data can be considered to be normally distributed).

Parametric test for hypothesis 1: Since the allocation is random, there should be no difference between the gamified and control groups before the intervention.

This study used an independent sample t-test to analyze the differences in attention performance between the two groups before the intervention. The results showed that there was no significant difference in the average reaction time or accuracy between the two groups before the intervention ($p(RT) = 0.25 > 0.05$, $p(AC) = 0.21 > 0.05$). This means that Hypothesis 1 is true. Due to the randomness of allocation, the attention performance of participants in the two groups before the intervention was relatively consistent.

Parametric test for hypothesis 2: The intervention can improve the attention performance of the gamified group.

Since there is a pre-hypothesis direction, a one-tailed t-test analysis is more appropriate. Directly select the reaction time (milliseconds) and accuracy rate (%) before and after the intervention for analysis. The paired sample t-test results show that the average performance after the intervention ($M_{RT} = 566.92, M_{AC} = 77.14$) is significantly better than before the intervention ($M_{RT} = 600.89, M_{AC} = 70.36; p_{RT} = 0.003 < 0.05, p_{AC} = 0.045 < 0.05$), which means that the intervention of the gamified group can have a positive impact on attention.

Parametric test for hypothesis 3: The intervention effect of the gamified group is stronger than that of the control group.

The independent sample t-test was utilized to analyze the difference in attention performance between the two groups after the intervention. The results showed that after the intervention, the attention performance of the gamified group ($M_{RT} = 5.64, M_{AC} = 6.79$) was significantly better than that of the control group ($M_{RT} = -0.19, M_{AC} = -1.00; p_{RT} = 0.028 < 0.05, p_{AC} = 0.031 < 0.05$), which means that the intervention effect of the gamified group is better under this small sample size.

Effects of meditation experience We also compared the data of beginners and experienced meditators separately and then conducted the independent samples t-test to analyze whether participants' meditation experience affected the results.

After analysis, no significant results were found for both beginners ($p_{RT} = 0.12 > 0.05, p_{AC} = 0.15 > 0.05$) and experienced meditators ($p_{RT} = 0.13 > 0.05, p_{AC} = 0.11 > 0.05$).

4.2 Interviews

This study took an inductive and semantic approach to analyzing the transcribed texts.

Overall experience The interviews asked participants to rate the game from 1 to 10 on multiple dimensions, including easy for beginners or not, fun, and level of distraction (See Fig 13 14 15).

Fig. 13. Question: Is this training method easy to get started?

At the same time, an independent sample t-test was conducted to compare the values of the two groups. Participants in the gamified training group believed that the gamified training method was more acceptable to beginners ($p = 0.031 < 0.05$), more interesting than the control group ($p = 0.029 < 0.05$) and experienced less distractions ($p = 0.001 < 0.05$).

Individual response

The effect of gamification in training During interviews, participants were asked in detail about the accessibility of the intervention. Six of the seven participants in the gamified group thought that the training was straightforward after gamification. For example, A5 pointed out that meditation courses usually require time to feel the state you are asked to enter, while the game is very simple: "When I first got into contact with it (meditation), I went to a class, and the

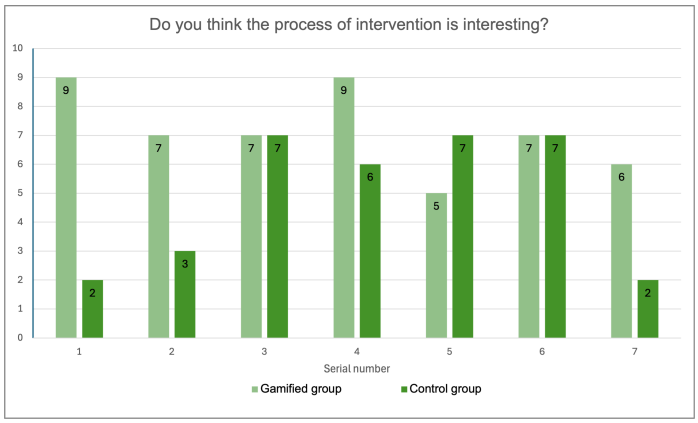

Fig. 14. Question: Do you think the training process is interesting?

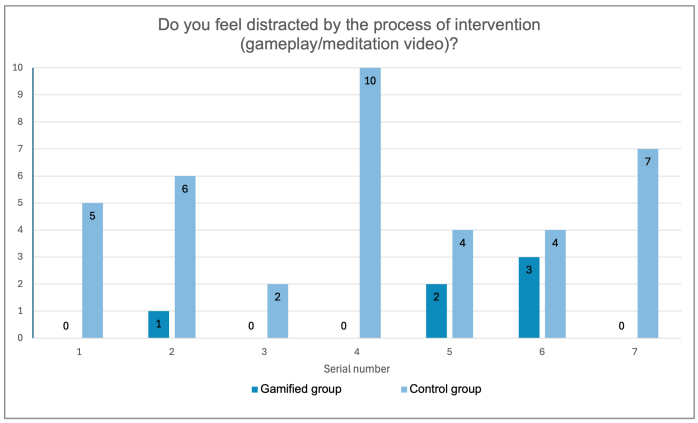

Fig. 15. Question: Do you feel distracted during the training?

teacher said, 'your body is in a good state now. It's very loose', I had a hard time feeling what it means to be very loose..., but this game seems very easy as long as you have hands (you can play it)." A3, A4, A6, and A7 felt that gamification was more friendly to participants because the operation of the three games was simple.

The responses of the control group confirmed that meditation, as attention training, is difficult. B1 could not understand his physical condition during meditation, and B2 and B7 thought that the video progressed too fast. B3 felt that although she could understand the metaphors in the video and apply her previous meditation experience, there were still problems: "I can understand that it is boring and difficult for beginners to imagine themselves as a mountain." Only two people in the control group reported liking the intervention when asked about their overall feelings. Both of them (B3 and B5) were experienced meditators. Three people (B1, B2, and B6) felt sleepy after meditation, and B4 even felt that the video material was very confusing: "This video made me very confused. The person giving the guidance was often silent and then suddenly spoke. I found the process boring.".

The jigsaw puzzle was well received by participants, all of whom self-reported that it was fun and playable. A1 and A3 both felt that they were very focused during the process, and A4 and A7 commented that the challenge of the three different levels of the puzzle helped them concentrate. A5 further commented, "The jigsaw puzzle..., I felt that I was focused on how to solve the puzzle without any external distractions.".

A3 noted that feedback, including the number of balloons, was helpful to her: "I like the feeling of having feedback, ... I felt very nervous when there was no feedback during the test task." A5 and A7 both affirmed the importance of feedback, with A7 explaining, "Without feedback, the game would be boring, ..., I can imagine that for meditation, the guidance alone would not provide effective information for me." A2 and A4 both mentioned the pressure of negative feedback, with A4 reporting, "Too much feedback is unnecessary for me, and sometimes it can be stressful.".

There were also some mixed responses. A2, as an experienced meditator, felt that traditional meditation was more suitable for her because of the music used in meditation: "I like meditation music, such as some white noise, which allows me to focus more on myself rather than completing tasks." B5 and B6 believed that the choice of meditation courses may have a great impact on the participants' acceptance. (B5): "Some meditation videos are too difficult for beginners to follow, and it depends a lot on the level of the teacher and the quality of the course.". (B6): "This video is also difficult for experienced people.".

The impact of adding more game elements When asked if they wanted to add new game elements, 5 participants from the gamified group thought that points, rankings, or social systems (which we provided as examples) added too much competition to the game. A2 explained: "Competitive elements make me feel very stressed, but if I just complete a small task, I will feel more accomplished and can concentrate more." A4 also mentioned that meditation focuses mainly

on herself: "I feel that meditation is a more private behavior and should not be shared with others. I will feel accomplished when I complete the task myself, and I don't want to exchange things or compare with others."

Participants in the control group found some game elements attractive, but score-related elements made them feel stressed. B1 mentioned the sense of judgment brought by scores. B4 thought that the addition of gamification elements would enrich the meditation experience: "I think it sounds interesting and more suitable for me if some gamification elements can be added. Because if I am just given instructions, I will be easily distracted, but interactive games can keep me focused and stay in the present." B3 and B5 wanted to choose the environment and duration of meditation independently: "It would be good if I could freely choose the theme or exercise more in a chosen section", "I want to freely choose the length of meditation, such as 5 minutes, 10 minutes or 15 minutes. It would be better if I could choose to meditate in different environments." B7 mentioned: "The game elements sound interesting, especially telling me the progress or how much time is left." B2 wanted more interaction: "It would be very interesting if the scenery could become dynamic and I could interact with it."

Perceiving changes in attention The gamified group generally reported positive effects, and A7 also mentioned the possible impact of the limitations of the test itself: "Although cognitive tests may have errors caused by repeated experiments, I did not feel that I had mastered the test and became more comfortable when taking it." Moreover, A4 pointed out that the purpose of training is also crucial: "I meditate mainly to help me sleep, this game cannot help me fall asleep well. However, it can help me stay focused to complete the task".

It is worth noting that B2, B4, and B5 from the control group all adopted some special strategies for the second test. (B2): "In the second test, I paid more attention to the overall direction of the arrows", (B4): "I found that some arrows were arranged like fish, and some arrow combinations were like ripples on water", (B5): "I felt that I had mastered the rules when I tried the experiment for the second time, and I started to count the third arrow from left to right instead of looking away from the middle of the picture." No one in the gamified group reported similar experiences.

The gamified group was not disturbed by the mechanism during the game process, only A5 and A6 were affected by the shaking of the character image in the breathing session: "The shaking little man in the breathing session disturbed me. Several times I forgot that I was taking a deep breath, ..., it was cute." Four people in the control group found that the sound or rhythm of the video guidance made them unable to concentrate. B1 and B6 felt that the instructor's speaking intervals were too short, and they were forced to move on to the next state before they could enter the state mentioned. B7 added: "..., the total time was too long, and the intervals between his speaking were too short, so I quickly became impatient. When I continued to try, I was constantly interrupted." B4 further explained: "He talked about a lot of things, so when he kept alternating between silence and speaking, my attention was completely distracted. When I

tried to concentrate again, he said, 'You become one with the mountain,' and I burst out laughing."

5 Discussion

5.1 Using gamification to design attention training

First, we want to answer the research question: What is the effect of a gamified meditation-inspired attention training method on attention performance and participants' motivation compared to non-gamified meditation-based attention training? By examining the results, we believe that this gamified training method can have a positive effect and outperform non-gamified meditation-based training methods in terms of attention performance and motivation.

First, according to the t-test for hypothesis 2, we can conclude that combining principles that are relevant to meditation and gamification into attention training still carries over the positive effect associated with meditation for attention training. The attention performance of the experiment group becomes better after the gamified training.

According to the experimental results for hypothesis 3, it is not difficult to see that after the intervention, the gamified group had significant improvements in both indicators compared with the control group. The analysis of the interviews shows that the addition of gamification seems to have made the training simple, and easy to get started compared to following a mindfulness meditation session. Since increased engagement and enjoyment are expected to be directly reflected in improved data quality in cognitive tasks [25], we can also assume that the narratives, game challenge, and other elements can maintain the motivation of participants, reduce external interference to a certain extent, and enable them to continue to focus.

5.2 Gamification techniques shape the experience

We assume that successfully conducting gamification relies on choosing proper game elements for different tasks, especially aiming for a better overall experience.

This study mainly uses narratives and challenges to motivate users instead of typical points, levels, or leaderboards which might give them a sense of competition. We arranged the game mechanisms reasonably, making the entire game look more like three tasks rather than a competition with others. No matter how good or bad the participants' performance is, the time for the first and third games is unlimited. This is to prevent participants from feeling anxious about the passage of time, and they are free to focus on the entire game at their own pace. In addition, the game does not prevent poor performance or identify "failed" attempts. For example, the puzzle game does not prompt the participant whether the current action is wrong or correct and has three levels with increasing difficulty. The visual breathing guide does not reduce the number of balloons completed because the participant chooses the frequency of breathing

by himself. The boat game does not give any penalties when the participant touches the river border.

While mentioning feedback or rewards, these elements may make the game more competitive and participants are not willing to add to the game. We could tell from the interview results that these competitive elements may distract the participants or invalidate the training.

5.3 Does experience with the test task have an impact?

Since the repeatability of cognitive tasks will affect the experimental results according to individual differences [5], it is interesting to explore whether the improvement in attention after the intervention is due to gamification or because people have mastered doing it for the second time.

First, according to the results of the interviews, although the participants in the control group adopted many strategies to take the second test (B4) or felt that they had mastered the essence of the test (B5), their data showed that the outcome was not as good as that of the gamified group. The effect of the gamified group was significantly superior in speeding up reaction time and improving accuracy. However, no one in the gamified group reported similar strategies.

Also, we repeatedly emphasized the rules of the test before the test, and the participants said that they all regarded the first time as more important. In the second test, because the link automatically redirected, we did not play a role in drawing attention. The participants said that they gradually relaxed during the game/meditation and forgot the core of the test. Therefore, we think that in this study, repetitiveness did not have much impact on the results, and gamification was still successful.

5.4 Interaction effect of meditation experience

We expected to find an interaction effect, with experienced meditators benefiting more from longer periods of meditation, whereas beginners can be helped through gamification methods.

According to the results of the interviews, experienced meditators, regardless of whether they underwent gamification intervention or meditation training, expressed that they enjoyed the traditional meditation experience very much. Beginners found meditation difficult for them, while participants in the gamified group said the game intervention was very easy to operate. However, no significant results were obtained after quantitative analysis, which suggests that the participants' previous meditation experience did not significantly affect the experiment results. This may be affected by subjective preferences, or it may be a limitation of the small sample.

5.5 Limitations and future work

For this type of experiment, the number of participants may be a limitation. One possible answer to this is to consider this study a trial run, which could provide good insights and possibilities for other researchers to explore training methods with gamification.

Limitations are also related to the control intervention itself. It can be observed that some participants' attention performance decreased after meditation. The effect of the intervention may be affected by the quality of the selected meditation videos, and as an online course, it may not achieve the full expected effect. At the same time, meditation itself can have a relaxing effect. A4 believes that similar tests require more active brain state concentration rather than free mind concentration. It is worth noting that this research experience lasted for a minimum of 15 minutes and a maximum of 20 minutes. So further research on long-term effects and comparison between these two groups would be interesting. We expect the control group would have a better intervention effect than this study and the difference in attention performance might not be significant. However, the gamified method would still be slightly superior in engagement and enjoyment.

As for the reflection on the aesthetics, although it looks cartoonish, it is still suitable for young or middle-aged people, depending on the average age of the participants. However, there is still space for improvement such as the background of the third task could be made more realistic, perhaps with some shore elements and dynamic effects of the waves.

Finally, future work may try to gamify other attention training methods, which can be adjusted according to individual user needs, and choose the duration and content of the training independently.

6 Conclusion

This study introduces a novel gamified attention training method inspired by meditation and experimentally confirms its effectiveness in enhancing attention training. Compared with traditional non-gamified meditation training, this approach significantly improves participants' attention performance. Integrating game elements such as challenges and narratives motivates users beyond the typical points, badges, and leaderboards and reduces potential issues that cognitive tasks may have. Interview results further highlight its potential to enrich motivation, offering a more engaging and sustainable option for attention training. These findings could be helpful for the future design of more effective gamified attention training tools.

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