



Review Article

The impact of meditation on sustained attention in nonclinical population: An extensive review

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ABSTRACT

Background: Meditation, encompassing focussed attention (FA) and open monitoring (OM) approaches, is recognised for its potential to enhance cognitive functions. Sustained attention, a critical component of attentional processes, influences cognitive capacity and is linked to meditation benefits. However, a robust and extensive review analysis needs to address the specific relationship between meditation and sustained attention in nonclinical populations.

Methods: Following PRISMA guidelines, the authors reviewed English articles published from 2013 to 2023 in Q1 SCOPUS-indexed journals. Inclusion criteria comprised original research studies exploring the impact of meditation on sustained attention in healthy individuals. The modified Jadad Scale assessed methodological quality.

Results: 12 studies (four RCTs, eight non-RCTs) with 1447 participants were included. Concentrative or FA meditation demonstrated consistent positive effects on sustained attention, including reduced perceived stress and increased focussed attention. OM meditation significantly improved sustained attention, as evidenced by reduced mind wandering and enhanced N2 responses. Meditators consistently outperformed non-meditators in sustained attention tasks, demonstrating faster reactions and lower error rates.

Discussion: This review explored the impact of meditation on sustained attention across diverse non-clinical populations through 12 investigations involving 1447 subjects with meditation interventions spanning from 21 days to 3 months. The study revealed that both FA and OM meditation approaches positively impact sustained attention, highlighting their potential role in enhancing cognitive function. Meditators consistently exhibited superior sustained attention abilities, suggesting the cognitive benefits of regular meditation practice. The findings of this study are consistent with prior research, contributing to the growing body of knowledge on the advantageous impacts of meditation on sustained attention. However, caution is needed in generalizing findings due to study limitations. Future research should use standardized methodologies and conduct longer-term follow-ups to better elucidate the effects of meditation interventions on sustained attention across diverse populations.

1. Introduction

Meditation is defined as a practise of intentionally cultivating mindfulness or directing one's focus toward a specific object, thought, or activity [1]. Regardless of their variety, all meditations have the same primary goal of developing awareness and attentiveness [2]. Among attentional processes, sustained attention is a fundamental component that influences the effectiveness of more advanced attentional functions such as selective attention, divided attention, and overall cognitive

capacity [3]. In real-world settings, meditation stands out as one of the most widely used methods for improving 'concentration,' 'focus,' or sustained attention [4]. Meditators practising concentrative or mindfulness meditation exhibited superior sustained attention performance compared to the control group, indicating their enhanced ability to ignore distracting thoughts [5]. Extended durations of meditation practice further improved attentional processes, with more significant benefits observed in individuals with longer practice durations [5]. Hence, meditation positively impacts sustained attention, irrespective of

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the specific approach employed (see Tables 1–3, Fig. 1).

Meditation refers to a family of self-regulation practices that focus on training attention and awareness to bring mental processes under greater voluntary control, fostering general mental well-being and development and/or specific capacities such as calm, clarity, and concentration [1]. Based on traditional meditation texts and contemporary neuroscientific perspectives, two categories of meditation practices have been proposed: "focussed attention" (FA) and "open monitoring" (OM) [6]. In the FA approach, individuals deliberately focus on a chosen object, akin to concentrative meditations. Conversely, the OM technique centers around observing the continuous Content of experience without reacting, taking it moment by moment, i.e. being mindful of the experiences. Thus, the OM technique involves awareness of the present moment, where one is non-judgmental to the unfolding of experience moment by moment [7].

Sustained attention, also known as vigilance or focussed attention, is defined as the ability to maintain consistent focus and concentration on a specific task, stimulus, or activity over an extended period, resisting distractions and fatigue [8]. It is a crucial ability that allows individuals to maintain focus, control impulses, and disregard distractions, showing significant improvement throughout development [9]. Other cognitive functions, such as learning, memory, and executive functions, rely on sustained attention [10,11].

Network and state training are two primary approaches for enhancing sustained attention [12]. Network training involves repetitive engagement in a cognitive task, which activates neural networks associated with attention. In contrast, state training aims to induce a specific brain state believed to impact attention and other networks

without focusing on particular cognitive tasks [13–17]. Physical activity and meditation are state training approaches suggested to enhance attention [12,18].

In the domain of cognitive functions, sustained attention stands out as a crucial element. While the effectiveness of meditation in improving sustained attention is widely recognised [19], a discernible gap exists in the literature. While numerous studies and meta-analyses have explored meditation in various contexts, an extensive review focusing specifically on sustained attention in nonclinical populations remains scant. This review uniquely addresses this gap by systematically analysing high-quality, Q1 journal articles published over the past decade. It provides a focused inquiry into the effects of both focused attention (FA) and open monitoring (OM) meditation practices, thereby offering a refined understanding that supports precise, evidence-based applications in nonclinical settings.

2. Methods:

2.1. Source of data

The authors followed PRISMA guidelines [20]. The study considered English articles published between 2013 and 2023 in only Q1 journals indexed in the SCOPUS database.

2.2. Search strategy

The authors conducted a thorough search using the Scopus database alone. Two authors built the literature search using the keywords

Table 1

Details of the included studies (author(s), publication year, sample and type of article).

Article title	Author(s)	Publication year	Sample	Population type	Type of article
Mindful Text Comprehension: Meditation Training Improves Reading Comprehension of Meditation Novices [23].	Lusnig, L. et al.	2023	52	Undergraduate students, males and females, mean age: 20.92 years	Quasi-experimental longitudinal intervention study.
Mindfulness Training Improves Attention: Evidence from Behavioral and Event-related Potential Analyses [24].	Liu, Y. et al.	2023	45	University Students, males and females, mean age: 21.02 years,	Randomised controlled trial
The Effect of a Brief Mindfulness Practice on Perceived Stress and Sustained Attention: Does Priming Matter? [25]	Ueberholz, R. Y., & Fiocco, A. J.	2022	220	Undergraduate students, males and females, mean age: 20.04 years	Randomised controlled trial
Mindfulness and music interventions in the workplace: assessment of sustained attention and working memory using a crowdsourcing approach [26].	Axelsen, J.L. et al.	2022	623	Healthy volunteers, males and females, mean age: 38.80 years	Randomised controlled trial
Comparing Mindfulness and Positivity Trainings in High-Demand Cohorts [27].	Jha, A.P. et al.	2020	80	Healthy active-duty U.S. Army service members, only males, mean age: 24.55 years	Longitudinal experimental study
Heart Rate Variability, Cortisol and Attention Focus During Shamatha Quiescence Meditation [28].	Blasé, K.L., & Waning, A.V.	2019	20	Participants were mainly psychiatrists and psychotherapists, males and females, mean age: 52.60 years	Longitudinal experimental study
Mindfulness meditators show altered distributions of early and late neural activity markers of attention in a response inhibition task [29].	Bailey, N.W. et al.	2019	70	Meditators and non-meditators, males and females, mean age: 36.12 years	Comparative EEG study
Cognitive Aging and Long-Term Maintenance of Attentional Improvements Following Meditation Training [30].	Zanesco, A.P. et al.	2018	60	Experienced meditation practitioners, males and females, mean age: 48.96 years	Longitudinal experimental study
Multimodal Sustained Attention Superiority in Concentrative Meditators Compared to Nonmeditators [31].	Badart, P. et al.	2017	Experiment 1 40, Experiment 2 36	FA Meditators and meditation novices, males and females, mean age: 37.95 years	Mixed experimental design
Minds "At Attention": Mindfulness Training Curbs Attentional Lapses in Military Cohorts [32].	Jha, A.P. et al.	2014	104	Healthy active-duty U.S. Army male volunteers, only males, mean age: 26.50 years	Quasi-experimental
Sustained Attention and Motivation in Zen Meditators and Non-meditators [33].	Cardeña, E. et al.	2014	34	Meditators and non-meditators, males and females, mean age: 40.41 years	Quasi-experimental
No Sustained Attention Differences in a Longitudinal Randomized Trial Comparing Mindfulness Based Stress Reduction versus Active Control [34].	MacCoon, D. G. et al.	2014	63	Community participants who are in good health, males and females, mean age: 46 years	Randomised longitudinal trial

Table 2

Details of intervention, outcome measures and findings of the included studies.

Author(s) and year	Type, details and duration of intervention	Outcome Measures	Findings
Lusnig, L. et al. (2023)	For six weeks, the experimental group had 2-h mindfulness sessions: 15 min setup, 30 min technique explanation, 25 min sitting meditation, 15 min walking meditation, 25 min sitting meditation, 15 min Q&A and clean-up.	d2-Revision test (Attention test) to assess sustained attention, Emotion Experience Test for individuals' emotional experiences, The Big Five personality test to assess personality traits, Reading Speed and Comprehension Test and Vocabulary Intelligence Test	The meditation group (MG) showed enhanced concentration, processing speed, and sustained attention, with more target objects processed post-intervention. Improved sustained attention also correlated with better reading comprehension.
Liu, Y. et al. (2023)	30-min mindfulness training each day for 21 days (average training days: 20.3). The training included mindful breathing, body scanning, mindful walking, and mindful eating.	Five-Facet Mindfulness Questionnaire (FFMQ) for daily mindfulness, State-Trait Anxiety Inventory (STAI) for anxiety, Sustained Attention Response Task (SART) for sustained attention, and EEG for Event-related potentials (ERPs).	Post-training, the mindfulness group had higher mindfulness scores, lower state anxiety, decreased mind wandering, improved response speed, and increased N2 amplitudes, indicating enhanced sustained attention. No significant P3 changes were observed.
Ueberholz, R. Y., & Fiocco, A. J. (2022).	Two groups, apart from the control group, received interventions: The PMC (Priming + Meditation Condition) group read a mindfulness infographic before a 10-min focused attention meditation session. The MC (Meditation-Only Condition) group engaged in a 10-min focused attention meditation session.	Sustained Attention to Response Task (SART) for sustained attention, Visual Analog Scale (VAS) for momentary perceived stress, Mindful Attention and Awareness Scale (MAAS) for trait mindfulness, Researcher-Designed Questionnaire for demographics and meditation habits.	Both meditation conditions (MC and PMC) led to reduced perceived stress and improved sustained attention, with fewer errors of omission compared to the control condition (CC). The PMC, which included priming, improved overall accuracy and fewer commission errors.
Axelsen, J.L. et al. (2022)	Two groups, other than the control, received interventions. The mindfulness group (HS) used the Headspace app for 30 days, completing ten 10-min sessions on breath awareness and body scanning. The music group (MM) listened to instrumental music for 10 min daily from playlists like 'focus' and 'Lo-Fi.'	App-based n-back task to assess working memory and app based go/no go task to assess sustained attention. These apps were mobile games, namely 'Animal Parade' and 'Go Sushi Go', designed to assess working memory and sustained attention.	The results show that a daily 10-min mindfulness meditation practice through the app for 30 days resulted in a 20% improvement in sustained attention, significant at the alpha level of 0.05.
Jha, A.P. et al. (2020)	Two groups received 16-h, 8-week interventions.	Working Memory Delayed-Recognition Task	The MT group had significantly higher Sustained Attention

Table 2 (continued)

Author(s) and year	Type, details and duration of intervention	Outcome Measures	Findings
	The mindfulness training (M.T.) group completed Mindfulness-Based Mind Fitness Training, blending mindfulness with sensorimotor psychotherapy and Somatic Experiencing. The Positivity Training (P.T.) group followed a positive psychology course to enhance emotional well-being and optimize emotional strategies in military contexts.	with Affective Distracters (WMDA) to assess working memory performance, Sustained Attention to Response Task (SART) to assess sustained attention and Positive and Negative Affect Schedule (PANAS) to assess trait levels of mood (emotional states).	to Response Task (SART) scores than the PT group, suggesting mindfulness training may enhance sustained attention in high-demand military contexts.
Blasé, K.L., & Waning, A.V. (2019)	Participants practiced Shamatha meditation, a focused attention meditation, for six weeks, 60 min daily. It included breath meditations, Settling the Mind, Awareness of Awareness, Loving-kindness, and Tonglen.	HRV patterns, cortisol levels, and Clock Drawing Test (CDT) to assess attention.	Six weeks of regular practice in Shamatha meditation contributes to a substantial increase in attention focus and a significant increase of 18.7% in sustained attention.
Bailey, N.W. et al. (2019)	The study focused on comparing meditators and non-meditators. Meditators were mindfulness practitioners with at least six months of experience, practicing at least 2 h weekly.	Go/No-Go tasks were conducted using EEG recordings to assess neural responses, focusing on N2 amplitude for response inhibition. Percentage accuracy, reaction time (R.T.), and global field potential were also assessed to measure the strength of neural responses to Go/No-Go trials.	Experienced mindfulness meditators outperformed controls in Go and No-go trials, showing better response and inhibition. Their P3 response was more frontally distributed, indicating increased frontal involvement in sustained attention. This suggests mindfulness practice enhances attentional function.
Zanesco, A. P. et al. (2018)	Participants received meditation training twice daily for three months, including 6 h of Solitary Shamatha meditation and 45 min of Four Immeasurables meditation (compassion, loving-kindness, empathetic joy, and equanimity).	Response Inhibition Task (RIT) for perceptual sensitivity (A) and Reaction Time Coefficient of Variability (RTCV) to assess sustained attention and response inhibition performance.	The findings suggest that intensive and continued meditation leads to enduring improvements in sustained attention, highlighting its substantial and lasting impact on practitioners' attentional capacities throughout their lifespan
Badart, P. et al. (2017).	The study focused on comparing differences between meditators and non-	Experiment 1: Unimodal (visual or auditory) and Bimodal (visual and	In experiment 1, meditators had lower error rates in visual and auditory

(continued on next page)

Table 2 (continued)

Author(s) and year	Type, details and duration of intervention	Outcome Measures	Findings
	meditators. Meditators practiced focused attention meditation, averaging 4.3 years of experience, with 6.5 sessions per week and 32.8 min per session.	auditory together) Response Switching Task (RST) for error rate and reaction time. Experiment 2: Bimodal 1 RST had visual targets and auditory nontargets, while Bimodal 2 RST had auditory targets and visual nontargets.	tasks, indicating better sustained attention. In experiment 2, meditators made fewer errors in both bimodal RST versions, showing an advantage in bimodal sustained attention
Jha, A.P. et al. (2014)	Two groups, apart from the control, received 8-h, 8-week interventions. The Training-Focused Mindfulness-Based Mind Fitness Training (MMFT), emphasising practical applications of mindfulness in operational environments. The Didactic-Focused (M8D) group received Didactic-Focused MMFT, focusing on stress, resilience, neuroplasticity, and autonomic nervous system self-regulation.	Sustained Attention to Response Task (SART) to assess sustained attention and its facets, including A prime (A) sensitivity index, errors of commission reflecting automated task performance, average reaction time (R.T.), and Intraindividual Coefficient of Variation (ICV).	Mindfulness Training (M.T.), particularly the training-focused (M8T) variant, improved attention and awareness, outperforming the non-MT group (NTC). Objective measures showed M.T.'s effectiveness in preventing attention decline during high-demand intervals. Short-form M.T. may enhance cognitive resilience and sustain attention in military training.
Cardena, E. et al. (2014)	The study focused on comparing differences between Zen meditators and non-meditators. Zen meditation progresses from focused attention (FA), typically counting breaths, to open monitoring (OM), specifically Shikantaza, in later stages. Meditators had varying meditation experience (120–28,000 h, M = 7,900 h, SD = 8,500 h).	The Sustained Attention to Response Task (SART) is used to assess sustained attention, and the Dundee Stress State Questionnaire (DSSQ) is used to assess success motivation and intrinsic motivation.	Meditators reacted faster to non-target stimuli with no difference in commission errors. Error levels were similar after adjusting for reaction times. Meditators reported fewer task-related interferences, suggesting attentional advantages. Both groups had similar accuracy and task-irrelevant interferences in the SART.
MacCoon, D. G. et al. (2014).	For eight weeks, two groups received interventions. The Mindfulness-Based Stress Reduction (MBSR) group did body scans, sitting meditation, yoga, and walking meditation, with similar homework. The Health Enhancement Program (HEP)	Visual Continuous Performance Task (CPT) for assessing sustained attention.	The study suggests that Mindfulness-Based Stress Reduction (MBSR) may not directly improve sustained attention but could indirectly impact it through compassion and patience. The 8-week duration might be insufficient for

Table 2 (continued)

Author(s) and year	Type, details and duration of intervention	Outcome Measures	Findings
	group had body scans, relaxation with music, functional movement, and a 'Spa Day,' with homework on relaxation, meal planning, and journaling. Both groups included discussions and exercises.		measurable changes in sustained attention.

"sustained attention" and "meditation". The complete SCOPUS advanced search strategy was TITLE-ABS-KEY ("meditation" OR "mindfulness") AND TITLE-ABS-KEY ("sustained attention" OR "attention span" OR "focussed attention"). The last search was done on December 14, 2023.

2.3. Inclusion and exclusion criteria

The inclusion and exclusion criteria for this study were established to guide the selection of relevant research articles. Inclusion criteria encompassed original research studies, excluding reviews, case studies, and commentaries. The focus of the investigation was on studies exploring the impact of meditation, whether it be focussed attention or open monitoring, on sustained attention. Both randomised controlled trials (RCT) and non-randomised studies, including longitudinal, mixed experimental, and quasi-experimental designs, were considered. Moreover, the research encompassed studies that specifically involved healthy human participants.

On the contrary, qualitative studies were not included, and neither were studies that did not specifically investigate the impact of meditation on sustained attention. Furthermore, studies involving participants with clinical conditions were excluded, aligning with the focus on healthy human participants. The selection process also excluded studies not published in Scopus-indexed Q1 journals to ensure a standard level of quality and rigour. This comprehensive set of inclusion and exclusion criteria aimed to systematically identify and include relevant research in investigating the impact of meditation on sustained attention.

2.4. Quality assessments

The methodological quality of each study was evaluated using the modified Jadad Scale. The scale consists of eight methodological items: (1) Was the study described as randomised? (2) was the method of randomisation appropriate? (3) was the study described as blinding? (4) was the method of blinding appropriate? (5) was there a description of withdrawals and dropouts? (6) was there a clear description of the inclusion/exclusion criteria? (7) Was the method used to assess adverse effects described? and (8) Were the methods of statistical analysis described?

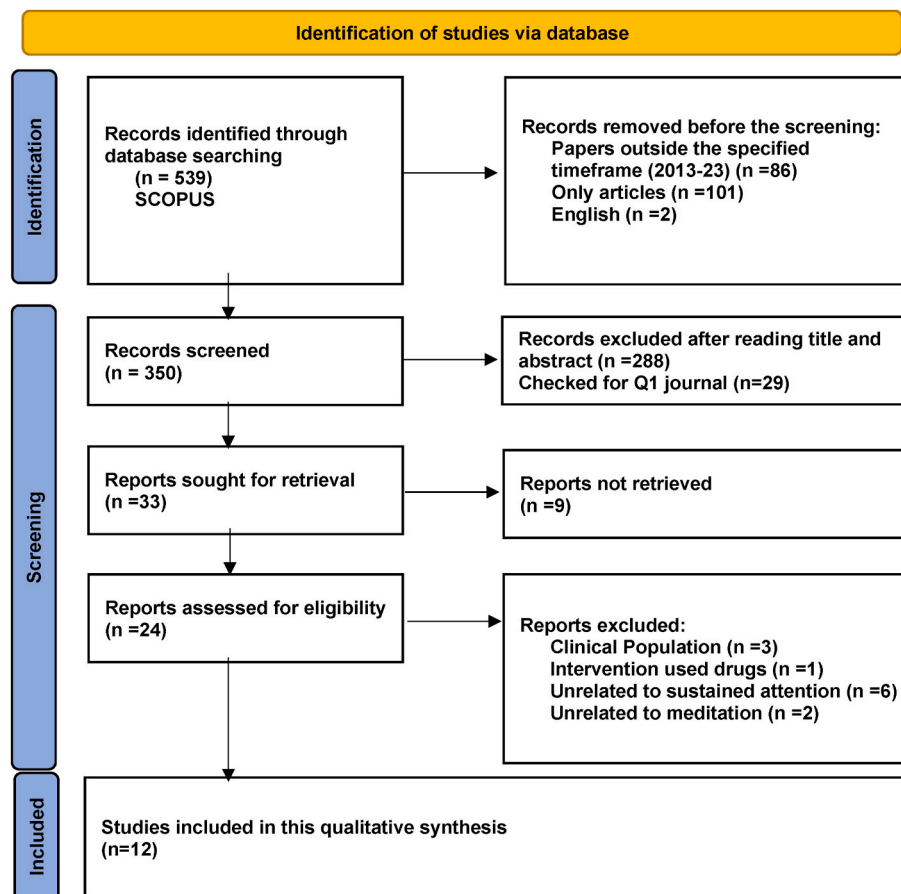
For item numbers 1, 3, 5, 6, 7, and 8, two options were available for answering (i.e., either "Yes," which gets 1 mark or "No," which gets 0 marks). However, for items 2 and 4, there were three available options to answer (i.e., "Yes," which got 1 mark; "No," which got 1 mark; or "Not described," which got 0 marks). The total score for each study was calculated by summing the scores for each item and ranged from 0 to 8. Studies with a score of 0–3 were considered low-quality, and studies with a score of 4–8 were considered high-quality [21,22].

Table 3

The modified Jadad Scale score of the included studies.

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total Jadad score	Quality
Lusnig, L. et al. (2023)	Yes	Yes	Yes	Yes	No	Yes	No	Yes	6	High
Liu, Y. et al. (2023)	Yes	Not described	No	Not described	Yes	Yes	No	Yes	4	High
Ueberholz, R. Y., & Fiocco, A. J. (2022)	Yes	Yes	No	Not described	Yes	Yes	No	Yes	5	High
Axelsen, J.L. et al. (2022)	Yes	Not described	No	Not described	No	Yes	No	Yes	3	Low
Jha, A.P. et al. (2020)	No	Not described	No	Not described	No	Yes	No	Yes	2	Low
Blasé, K.L., & Waning, A.V. (2019)	No	Not described	No	Not described	No	Yes	No	Yes	2	Low
Bailey, N.W. et al. (2019)	No	Not described	No	Not described	No	Yes	No	Yes	2	Low
Zanescio, A.P. et al. (2018)	Yes	Yes	No	Not described	Yes	Yes	No	Yes	5	High
Badart, P. et al. (2017)	No	Not described	No	Not described	No	Yes	No	Yes	2	Low
Jha, A.P. et al. (2014)	Yes	Yes	No	Not described	Yes	Yes	No	Yes	5	High
Cardena, E. et al. (2014)	No	Not described	No	Not described	No	Yes	No	Yes	2	Low
MacCoon, D. G. et al. (2014)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	7	High

NB: Eight questions were available in the Jadad scale for the quality assessment of each trial. Questions were: Q1: Was the study described as randomised? Q2: Was the method of randomisation appropriate? Q3: Was the study described as blinding? Q4: Was the method of blinding appropriate? Q5: Was there a description of withdrawals and dropouts? Q6: Was there a clear description of the inclusion/exclusion criteria? Q7: Was the method used to assess the adverse effects described? Q8: Were the methods of statistical analysis described? The three options for each question were: yes, no and not specified. Articles that received a score of 0–3 were considered low-quality studies, and articles that received a score of 4–8 were considered high-quality studies. The options for each question were yes, no, and not described. The total score for each study was calculated by summing the scores for each item and ranged from 0 to 8. Studies with a score of 0–3 were considered low-quality, and studies with a score of 4–8 were considered high-quality.

**Fig. 1.** PRISMA flow diagram of study search and included studies.

3. Results:

3.1. Study characteristics

The present review included a total of 12 studies, comprising four RCTs and eight non-RCTs, which included five longitudinal experimental studies, one quasi-experimental research, one observational study, and one mixed experimental study. A total of 1447 subjects

participated in these studies. Each study employed either FA or OM meditation interventions, with the majority incorporating mindfulness meditation. The analysis revealed that publication years peaked in 2014 (three studies), 2019 (two studies), 2022 (two studies), and 2023 (two studies), with individual studies in 2020, 2018, and 2017.

3.2. Methodological quality

Two authors independently worked in evaluating the twelve papers included in the study, a distinction was made between high and low-quality studies, resulting in six papers being categorised as high-quality and the remaining six as low-quality. Specifically focusing on the subset of randomised controlled trials (RCTs), three were high-quality out of the four examined. Conversely, in the non-randomised controlled trials (non-RCTs) category, the assessment revealed three high-quality and five low-quality studies.

3.3. The impact of meditation on sustained attention

Out of twelve studies, five of the studies employed focussed attention [25,28,30,31,33], while the other seven used open monitoring meditation [23,24,26,27,31,32,34]. FA meditation, as demonstrated in various studies, profoundly impacts sustained attention. Participants engaged in a 10-min FA meditation session, reducing perceived stress and improving sustained attention [25]. Additionally, research on Shamatha meditation, a form of FA meditation, revealed a substantial increase in attention focus and a significant 18.7% improvement in sustained attention [28]. The advantages of FA meditation were further supported by another study, which found enduring improvements in sustained attention with intensive and continued meditation, explicitly focusing on FA meditation techniques [30].

In multiple studies, OM meditation consistently demonstrate positive effects on sustained attention. One study reported that a 30-min mindfulness training for 21 days enhanced sustained attention, reducing mind wandering and improving N2 responses [24]. Another found that a 2-h weekly mindfulness session over six weeks improved sustained attention, concentration, and processing speed [23]. Additionally, a 30-day mindfulness practice through an app showed a 20% improvement in sustained attention [26]. An 8-week mindfulness-based intervention demonstrated better attention and awareness, especially in the training-focussed variant, emphasising the protective effect of mindfulness against attention decline during high-demand intervals [32]. These findings collectively highlight the consistent and beneficial impact of OM meditation on sustaining attention and improving overall attentional function.

The combined findings demonstrate the positive impact of FA and OM meditation on enhancing sustained attention abilities. These results suggest a consistent and beneficial influence, demonstrating the effectiveness of these meditation practices in sustaining attention and improving overall attentional function.

3.4. Sustained attention in meditators

Meditators consistently exhibit advantages in sustained attention compared to non-meditators [29,31,33]. In various experiments, meditators demonstrated lower error rates, especially in bimodal sustained attention tasks, suggesting fewer lapses in attention [31]. They reacted faster to nontarget stimuli and displayed higher accuracy in tasks requiring response and inhibition [33]. Meditators also showed increased frontal involvement in sustained attention, as indicated by the distribution of P3 responses [29]. These findings collectively highlight the enhanced capacity for sustained attention in meditators, contributing to improved overall attentional function associated with meditation or mindfulness practices.

4. Discussion:

4.1. Study characteristics, outcomes and possible mechanism

The objective of the present study was to find evidence of meditation-induced alterations in sustained attention in healthy individuals. There were 12 investigations, each with a meditation

intervention and a nonclinical population. The studies involved 1447 subjects with independent meditation interventions of various durations, spanning from 21 days to 3 months.

The interventions covered a variety of focussed attention to open monitoring meditation methods: various mindfulness training and app-based mindfulness meditation, Shamatha Meditation, and Zen Meditation. Mindfulness-based meditations also involve diverse mindfulness activities. The study population showcased diversity in professions, encompassing predominantly undergraduate university students (mean age: 21 years), mental health professionals like psychiatrists and psychotherapists (mean age: 52.60 years), healthy active-duty U.S. Army service members (mean age: 24.55 years for males and 26.50 years overall), as well as meditation novices and experienced practitioners (mean age: 37.95 years and 48.96 years, respectively). Notably, except for the two studies involving soldiers, all other studies include participants of both genders, ensuring a comprehensive exploration of the effects of meditation across diverse professional backgrounds and genders.

The interventions employed a variety of tests to precisely measure sustained attention, including the Sustained Attention Response Task (SART) in different variations, Visual Continuous Performance Task (CPT), Unimodal and Bimodal Response Switching Task (RST), and Response Inhibition Task (RIT). Mobile game-based tasks, namely 'Animal Parade' and 'Go Sushi Go,' offered interactive assessments of sustained attention. Additionally, physiological measures such as heart rate variability (HRV) patterns, cortisol levels, and attention focus tests were integrated to evaluate sustained attention in response to meditation interventions comprehensively.

Overall, the findings from the twelve studies are in line with previous studies and emphasise a consistent and positive impact of meditation on sustained attention [35–37]. Mindfulness training and practices like Mindfulness-Based Stress Reduction (MBSR) have notably improved sustained attention across various contexts. These enhancements reflected reduced mind wandering, increased response speed, and improved accuracy. Meditators consistently exhibited lower error rates and fewer lapses in sustained attention than non-meditators, emphasising continued meditation practice's enduring benefits. The studies also highlighted the potential for mindfulness training to mitigate attentional lapses in high-demand situations, showcasing its relevance in military contexts. Overall, the results suggest that diverse forms of meditation contribute to sustained attention improvements, offering valuable insights for both general well-being and performance in specific environments.

Meditation profoundly influence sustained attention by engaging distinct neurobiological mechanisms inherent in different practices. Concentrative meditation, characterised by focussed attention, activates the frontal system, empowering practitioners to resist distractions and disregard irrelevant stimuli [38]. This resistance is evident in the absence of alpha wave suppression observed in advanced concentrative meditation practitioners during stimuli exposure [39]. In contrast, receptive meditation, which emphasises open attention to all stimuli, involves the posterior temporal system and disrupts the habituation response in the alpha suppression pattern [38]. These observed neurophysiological alterations in experienced meditators signify the cultivation of specific attentional states by each meditation type. In essence, the impact of meditation on sustained attention is intricately linked to the activation of cortical systems during practice, with concentrative meditation enhancing focussed attention and distraction resistance. In contrast, open monitoring meditation fosters constant open attention to stimuli.

Moreover, in a comparative study of FA meditation and OM meditation, significant differences in brain connectivity relevant to sustained attention were identified. FA meditations enhanced connectivity between the striatum and regions like the visual cortex and retrosplenial cortex, which are crucial for focused attention and task-specific memory [40]. This suggests an improvement in the neural mechanisms underpinning sustained attention. Conversely, OM meditations reduced

connectivity in these areas, supporting its objective of promoting a broad, non-reactive awareness [40]. Both meditation styles showed reduced connectivity with the Default Mode Network, which correlates with decreased mind-wandering, a key aspect of sustaining attention [40]. Moreover, the enduring changes in connectivity observed post-meditation in both FA and OM meditation indicate long-term benefits for attentional control [40].

Additionally, research indicates prolonged Sahaja Yoga Meditation correlates with increased grey matter volume and regional enlargement in specific right hemispheric cortical and subcortical brain regions associated with sustained attention [41]. This suggests a structural adaptation in the brain due to meditation, further supporting its positive impact on sustained attention.

The mechanism through which meditation influences sustained attention involves modulation of both physiological and cortical arousal. Additionally, meditation operates through critical neural networks, such as the salience network, which calms emotions and prompts a reassessment of what warrants attention, and the frontoparietal network, which facilitates maintaining focus on certain stimuli while excluding others [4]. This multi-faceted approach underscores the comprehensive impact of meditation on sustaining attentional focus.

4.2. Influence of age and activity level on the impact of meditation

Our review suggests that age and physical activity levels may affect the efficacy of meditation on sustained attention. Younger individuals likely see more benefits from meditation due to their higher neuroplasticity, which supports cognitive adaptations [42]. Similarly, more active individuals could experience better outcomes, aligning with research linking physical fitness to enhanced cognitive function [43].

Additionally, the impact of physical activity may be mediated through improved cerebral blood flow, which is crucial for maintaining cognitive function during tasks requiring sustained attention [44]. This physiological mechanism provides a plausible explanation for the observed differences and underscores the importance of incorporating physical health metrics in studies on meditation and cognitive performance.

These insights indicate that meditation interventions might need to consider demographic and lifestyle factors to effectively enhance mindfulness practices across different groups. By understanding these influences, interventions can be more effectively designed to meet the specific needs of diverse populations.

4.3. Limitations

While the studies included in this review collectively contribute valuable insights into the impact of meditation on sustained attention, it is essential to acknowledge certain limitations across the body of literature. Variability in intervention durations, ranging from brief practices to several weeks, makes it challenging to draw consistent conclusions about the optimal duration for sustained attention improvements. Additionally, the diverse participant demographics, including university students, meditators of varying experience levels, and military cohorts, pose challenges in generalizing findings to broader populations. The use of different outcome measures and experimental designs further complicates direct comparisons. Furthermore, the inclusion of studies identified as lower quality based on the modified Jadad Scale invites careful consideration in interpreting the aggregated effects of meditation on sustained attention. While these studies add valuable perspectives, they highlight the importance of continuous quality assessment to enhance the robustness of future reviews. Future research could benefit from more standardized methodologies and longer-term follow-ups to better elucidate the sustained effects of meditation interventions on attention across diverse populations.

4.4. Recommendation for future research

Furthermore, future studies should clarify the mechanisms through which meditation impacts sustained attention in nonclinical populations. Investigating the underlying cognitive and neural processes involved will contribute valuable insights, potentially informing targeted interventions and optimising meditation practices for enhancing sustained attention in diverse contexts.

5. Conclusion

In conclusion, the review findings suggest that meditation interventions, including focussed attention (FA) and open monitoring (OM), significantly enhance sustained attention in nonclinical populations. The improvements are consistent across various study durations and methodologies, indicating meditation's potential as a cognitive enhancement tool. Despite this, the variation in study quality and duration points to the need for more standardized research to refine guidelines for meditation practice. Additionally, factors such as age and physical activity level affect the effectiveness of meditation, suggesting that future studies should adapt meditation practices to individual characteristics. Addressing these areas will help optimize meditation interventions and clarify their role in cognitive training programs aimed at improving sustained attention.

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Author contributions

Abinash Roy: Conceptualization, Abstract, Introduction, Data curation, Review, Results, Discussion, Conclusion, Writing - Original Draft, Writing - Review & Editing.

Dr. Pailoor Subramanya: Supervision, Conceptualization, Methodology, Quality assessment, References, Oversight, Writing - Review & Editing.

Data availability statement

The data analysed in this study are derived from publicly available sources and previously conducted studies, which have been cited accordingly in the manuscript. The extracted data supporting the findings of this review are available from the corresponding author, Dr. Pailoor Subramanya, upon reasonable request. No new data were created or analysed in this study.

Conflict of interest

o None

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