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IMMEDIATE EFFECT OF 10-MINUTE WEB-BASED GUIDED MEDITATIVE VISUALIZATION SESSION ON PERCEIVED STRESS, STROOP TASK PERFORMANCE, AND HEART RATE VARIABILITY IN YOUNG ADULTS: AN SINGLE-ARM PRE-POST STUDY

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ABSTRACT

Background: Brief web-based meditation interventions have emerged as accessible strategies for stress management; however, their immediate effects on perceived stress, cognitive performance, and cardiac autonomic function remain incompletely understood. This exploratory study evaluated the acute effects of a 10-minute guided web-based meditative visualization session on perceived stress, Stroop task performance, and heart rate variability (HRV) in healthy young adults.

Methods: In this single-arm pre-post interventional study, 38 healthy adults aged 18–30 years completed a 10-minute guided web-based meditative visualization session using headphones. Perceived stress was assessed using the 10-item Perceived Stress Scale (PSS-10). Cognitive performance was evaluated using a computerized Colour-Word Stroop task, including congruent, neutral, and incongruent reaction times, accuracy, and error measures. Resting HRV was recorded before and immediately after the intervention using a validated ECG-based system, and time-domain (SDNN, RMSSD, NN50) and frequency-domain (VLF, LF, HF, total power, LF/HF ratio) indices were analyzed. Pre- and post-intervention comparisons were performed using paired t-tests.

Results: PSS-10 scores decreased significantly following the intervention (19.55 ± 5.62 vs. 17.92 ± 6.32; $p = 0.001$). Stroop task performance demonstrated a significant reduction in incongruent reaction time (1021.73 vs. 949.70 ms; $p = 0.0175$), indicating improved executive function and inhibitory control. Congruent and neutral reaction times showed modest reductions, whereas accuracy and error measures did not differ significantly. No statistically significant changes were observed in HRV indices, although HF power, RMSSD, and NN50 showed non-significant increases suggestive of a trend toward enhanced parasympathetic activity.

Conclusions: A single 10-minute web-based meditative visualization session was associated with significant reductions in perceived stress and improvements in executive function in healthy young adults. However, immediate changes in cardiac autonomic modulation, as assessed by HRV, were not observed. These findings suggest that brief web-based meditation may rapidly enhance psychological and cognitive outcomes, while measurable autonomic adaptations may require longer or repeated practice. Further randomized controlled studies are warranted to confirm these findings.

KEYWORDS: Web-based meditation; Meditative visualization; Perceived stress; Stroop task; Executive function; Heart rate variability; Young adults.

INTRODUCTION

Stress is a major public health concern that adversely affects physical health, psychological well-being, and cognitive performance. Young adults are increasingly exposed to academic, occupational, and social stressors that may impair attention, executive function, and emotional regulation. [1,2] Persistent stress has also been associated with autonomic nervous system dysregulation, cardiovascular morbidity, and reduced quality of life. [3,4] Consequently, effective, accessible, and low-cost interventions for stress management have become an important area of research. Meditation and mindfulness-based interventions have gained considerable scientific interest because of their potential to improve psychological well-being and physiological functioning through modulation of attention, emotional regulation, and autonomic balance. [5,6] Numerous systematic reviews and meta-analyses have demonstrated beneficial effects of meditation on perceived stress, anxiety, depression, and overall mental health. [7,8]

Meditative visualization is a focused mental practice in which individuals intentionally direct their attention towards calming mental imagery while maintaining a relaxed and non-judgmental awareness. Advances in digital technology have facilitated the delivery of meditation through web-based platforms, allowing individuals to access guided meditation sessions conveniently using smartphones, computers, and other digital devices. [9] Such web-based interventions have become increasingly popular because of their scalability, accessibility, and cost-effectiveness. [10] Despite their widespread use, evidence regarding the immediate physiological and cognitive effects of brief web-based meditative visualization remains limited, particularly in healthy young adults. [11]

One of the proposed mechanisms underlying the beneficial effects of meditation is the enhancement of attentional control and executive function. [12] The Colour-Word Stroop task is a well-established neuropsychological tool for assessing selective attention, cognitive flexibility, processing speed, and response inhibition. [13] During the incongruent condition of the Stroop task, participants are required to inhibit the automatic tendency to read the printed word while correctly identifying the ink colour, thereby engaging higher-order executive processes. [13] Previous studies have demonstrated that mindfulness and focused-attention meditation can improve attentional performance and reduce cognitive interference, resulting in faster reaction times and improved executive control. [14,15]

In addition to cognitive effects, meditation has been suggested to influence autonomic nervous system activity. Heart rate variability (HRV), a non-invasive measure of beat-to-beat variation in cardiac rhythm, is widely used to assess sympathovagal balance and cardiac autonomic regulation. [16] Higher HRV is generally considered indicative of greater parasympathetic modulation and better physiological adaptability. [17] Although several studies have reported improvements in HRV following mindfulness-based interventions, recent systematic reviews and meta-analyses have reported inconsistent findings, indicating that the magnitude of autonomic changes may depend on intervention duration, meditation technique, participant characteristics, and methodological factors. [18,19] These observations suggest that while psychological and cognitive benefits may occur rapidly, measurable autonomic adaptations may require longer or repeated meditation practice.

Although several studies have investigated conventional mindfulness interventions, relatively few have examined the acute effects of a brief web-based meditative visualization session on perceived stress, executive function, and cardiac autonomic modulation within the same experimental protocol. Simultaneous assessment of subjective stress, cognitive performance, and HRV may provide a more comprehensive understanding of the immediate psychophysiological effects of meditation. Therefore, the present exploratory single-arm pre-post interventional study was undertaken to evaluate the immediate effects of a 10-minute guided web-based meditative visualization session on perceived stress using the Perceived Stress Scale-10 (PSS-10), cognitive performance using the Colour-Word Stroop task, and cardiac autonomic function using resting heart rate variability in healthy young adults. We hypothesized that the intervention would reduce perceived stress and improve cognitive performance, while any immediate changes in HRV would be modest because of the brief duration of the intervention.

MATERIALS AND METHODS:

Study design and setting

An exploratory single-arm pre-post interventional study was conducted in the Department of Physiology, Mahatma Gandhi Medical College and Research Institute, Puducherry, India, from August 2024 to August 2025. Institutional Medical Ethics Committee approval was obtained before recruitment. Written informed consent was obtained from each participant before recruiting for this study.

Participants and recruitment

A sample size of 38 Healthy adults aged 18-25 years were recruited by purposive sampling from attendants accompanying patients to hospital services. Individuals with severe psychiatric illness or ongoing psychiatric treatment, cognitive impairment, neurological disorders, significant cardiovascular or respiratory disease, or regular meditation or visualization practice were excluded.

Participants were asked to report to the physiology research laboratory at approximately 9:00 AM. They were advised to avoid tea, coffee, and cigarettes on the morning of assessment and to refrain from alcohol intake on the preceding night. Before HRV recording, participants rested supine in a quiet room maintained at approximately 24 degrees Celsius.

Intervention

The intervention consisted of one 10-minute guided meditative visualization session delivered through a web-based platform and heard binaurally using headphones. The session used focused attention, relaxation, and visual imagery. The protocol included an engagement rating, but engagement ratings were not analyzed.

Perceived stress was assessed immediately before and after the session using the 10-item Perceived Stress Scale (PSS-10). Each item was scored from 0 (never) to 4 (very often); items 4, 5, 7, and 8 were reverse scored. The total score ranged from 0 to 40, with higher scores representing greater perceived stress. Because PSS-10 is conventionally anchored to experiences during the preceding month, immediate pre-post administration was treated as an exploratory repeated assessment rather than a conventional measure of acute state stress.

Resting HRV was recorded from a 5-minute Lead II ECG in the supine position using RMS Polyrite version 2.2D. The R-R tachogram was analysed offline using Kubios software. Frequency-domain measures included very-low-frequency (VLF), low-frequency (LF), high-frequency (HF), and total power, together with LF/HF ratio. Time-domain measures included standard deviation of normal-to-normal intervals (SDNN), root mean square of successive differences (RMSSD), and NN50.

Cognitive performance was assessed using the colour-word Stroop task in PEBL. Participants responded using keyboard keys assigned to four colours. Practice, neutral, congruent, and incongruent stimuli were presented, and reaction times, errors, and accuracy values were recorded before and after the intervention.

RESULTS

Participant age distribution

The analytical sample comprised 38 participants. Ages ranged from 18 to 25 years. The largest group was 18 years old (17/38, 44.7%), followed by 19 years (10/38, 26.3%). Participants aged 24 and 25 years each represented 10.5% of the sample. The complete age distribution is shown in Table 1.

Table 1. Age distribution of participants (n=38).

Age (years)	N of participants	% of participants
18	17	44.7
19	10	26.3
22	2	5.3
23	1	2.6
24	4	10.5
25	4	10.5

Percentages are calculated using n=38.

Stroop task performance

Table 2 summarises pre- and post-intervention Stroop outcomes. The mean total error score declined from 6.11 (SD 9.74) to 4.08 (SD 4.40), but this difference was not statistically significant (p=0.712). Interference, repetition, and task-switching errors also did not change significantly. Congruent reaction time reduced from 916.90 (SD 108.76) to 907.72 (SD 111.10) ms (p=0.056). Incongruent reaction time declined from 1021.73 to 949.70 ms, a reduction of 72.03 ms (p=0.0175). Neutral reaction time decreased from 953.83 to 948.16 ms (p=0.0500), which meet the prespecified p<0.05 threshold. Accuracy measures did not differ significantly.

Table 2. Pre- and post-intervention Stroop task outcomes (n=38).

Stroop parameter	Pre-intervention Mean (SD*)	Post-intervention Mean (SD*)	p value
Total error	6.11 (±9.74)	4.08 (±4.40)	0.712
Interference error	1.05 (±1.47)	0.71 (±0.96)	0.221
Repetition error	3.11 (±6.16)	2.61 (±3.44)	0.647
Task-switching error	1.03 (±1.68)	1.03 (±2.61)	0.617
Congruent RT (ms)	916.90 (±108.76)	907.72 (±111.10)	0.056
Incongruent RT (ms)	1021.73	949.70	0.0175
Neutral RT (ms)	953.83	948.16	0.0500
Accuracy - congruent	0.96 (±0.14)	0.98 (±0.03)	0.903
Accuracy - incongruent	0.95 (±0.07)	0.96 (±0.03)	0.175
Accuracy - neutral	0.97 (±0.06)	0.97 (±0.04)	0.625

RT: reaction time; SD: standard deviation. The final summary output reported means without accompanying SDs for incongruent and neutral RT. p values were obtained using paired t-tests; p<0.05 was considered statistically significant.

Heart rate variability

Table 3 presents HRV measures before and after the session. None of the frequency-domain or time-domain HRV indices demonstrated a statistically significant pre-post change. VLF power decreased from 1309.00 (SD 1404.30) to 1049.20 (SD 956.80) ms² (p=0.185), while HF power increased from 598.82 (SD 493.40) to 645.16 (SD 642.20) ms² (p=0.822). SDNN, RMSSD, and NN50 also remained statistically unchanged. Figure 3 displays the spectral components VLF, LF, and HF.

Table 3. Pre- and post-intervention heart rate variability measures (n=38).

HRV measure	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	p value
VLF power (ms²)	1309.00 (±1404.30)	1049.20 (±956.80)	0.185
LF power (ms²)	855.60 (±710.60)	805.50 (±659.10)	0.483
HF power (ms²)	598.82 (±493.40)	645.16 (±642.20)	0.822
Total power (ms²)	2763.60 (±2231.08)	2500.80 (±1926.73)	0.204
LF/HF ratio	2.0711 (±2.1020)	2.48 (±3.13)	0.971
SDNN (ms)	53.70 (±22.70)	52.40 (±21.10)	0.557
RMSSD (ms)	37.889 (±18.62)	38.67 (±20.40)	0.335
NN50 (count)	20.23 (±18.39)	22.52 (±20.16)	0.103

VLF: very-low-frequency power; LF: low-frequency power; HF: high-frequency power; SDNN: standard deviation of normal-to-normal intervals; RMSSD: root mean square of successive differences. p values were obtained using paired t-tests.

Perceived Stress Scale score

The mean PSS-10 score decreased from 19.55 (SD 5.62) before intervention to 17.92 (SD 6.32) after intervention, a difference of 1.63 points. This pre-post difference was statistically significant (p=0.001), as shown in Table 4 and Figure 4. Higher PSS-10 totals reflect greater perceived stress.

Table 4. PSS-10 score before and after the intervention (n=38).

Outcome	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	p value
PSS-10 score	19.55 (±5.62)	17.92 (±6.32)	0.001

PSS-10 score range: 0-40; higher values indicate greater perceived stress. Because PSS-10 has a preceding-month reference period, immediate pre-post score change should be interpreted as exploratory. p value was obtained using paired t-test.

DISCUSSION

The present exploratory single-arm pre-post study evaluated the immediate effects of a brief 10-minute web-based guided meditative visualization session on perceived stress, executive function, and cardiac autonomic modulation in healthy young adults. The principal findings were that the intervention was associated with a significant reduction in perceived stress and a significant improvement in inhibitory control, as demonstrated by faster incongruent Stroop reaction times. In contrast, no statistically significant changes were observed in resting HRV indices immediately following the intervention. These findings suggest that brief web-based meditation may rapidly influence psychological and cognitive processes, whereas measurable autonomic adaptations may require longer or repeated practice. [20-22].

The significant reduction in PSS-10 scores observed after the intervention indicates that even a single short session of guided meditative visualization may positively influence participants' perception of stress. Meditation practices are known to reduce emotional reactivity by enhancing present-moment awareness, decreasing rumination, and improving cognitive appraisal of stressful experiences. Neuroimaging studies have demonstrated that mindfulness-based practices reduce activity within the amygdala while strengthening functional connectivity between the prefrontal cortex and limbic structures, thereby improving emotional regulation. [23,24] Although the PSS-10 traditionally assesses stress experienced during the preceding month and is not specifically designed to measure acute changes, the observed reduction may nevertheless reflect an immediate shift in subjective stress perception following the intervention. Therefore, these findings should be interpreted as exploratory evidence of rapid psychological benefit rather than definitive evidence of acute changes in chronic perceived stress.

An important finding of the present study was the significant reduction in incongruent Stroop reaction time, indicating improved executive function and inhibitory control following meditation. The incongruent condition requires suppression of the automatic tendency to read the written word while correctly identifying the ink colour, making it highly dependent on selective attention, cognitive flexibility, and response inhibition. Focused-attention meditation trains individuals to continuously monitor attention and redirect it whenever distraction occurs. This repeated attentional training is believed to enhance prefrontal cortical function and anterior cingulate cortex activity, resulting in improved conflict monitoring and cognitive control. [25,26] The observed improvement therefore supports previous evidence suggesting that even brief mindfulness practices can acutely enhance executive performance. [25,26]

Although congruent and neutral reaction times also showed reductions, these changes did not reach statistical significance. Similarly, accuracy and error measures remained unchanged after the intervention. These findings may be explained by the relatively high baseline accuracy of healthy young adults, resulting in a ceiling effect that limits the detection of further improvement after a brief intervention. Meditation is thought to primarily enhance processing efficiency rather than response accuracy in cognitively healthy individuals. [25,26] Consequently, faster response times without compromising accuracy may represent improved neural efficiency and attentional processing rather than changes in overall task performance.

In contrast to the psychological and cognitive outcomes, none of the HRV indices demonstrated statistically significant changes immediately after the meditation session. Frequency-domain measures, including HF power and LF power, as well as time-domain indices such as RMSSD and NN50, showed only small, non-significant trends toward increased parasympathetic modulation. These findings are consistent with the hypothesis that autonomic adaptations require a greater duration or repeated exposure to meditation practice before becoming physiologically detectable. [21,27] Heart rate variability reflects complex interactions between sympathetic and parasympathetic influences on the sinoatrial node and may be less responsive to a single brief intervention than subjective psychological measures. [27]

Several methodological and physiological factors may also explain the absence of significant HRV changes. The intervention lasted only ten minutes, whereas many previous studies demonstrating significant improvements in HRV have employed interventions lasting several weeks or months. [21,27] Furthermore, participants in the present study were healthy young adults with relatively normal baseline autonomic function, leaving limited scope for immediate physiological improvement. Individual variability in baseline vagal tone, breathing patterns during meditation, circadian influences, and environmental factors may also have contributed to the observed variability in HRV measures. Consequently, subtle autonomic changes may not have reached statistical significance within the available sample size.

The present findings are broadly consistent with previous systematic reviews reporting that mindfulness interventions reliably improve psychological well-being and attentional performance, whereas evidence regarding acute autonomic changes remains inconsistent. [20, 21] Meta-analyses have suggested that improvements in HRV are more consistently observed after structured meditation programs involving repeated practice over several weeks. [21] The current findings therefore support the concept that cognitive and emotional responses to meditation may emerge more rapidly than measurable autonomic adaptations.

From a practical perspective, the study highlights the potential utility of brief web-based guided meditation as an easily accessible intervention for stress management among young adults. Because the intervention can be delivered remotely using commonly available digital devices, it may represent a feasible strategy for students, healthcare professionals, and working individuals who often experience time constraints. [22] Even a ten-minute session may provide immediate psychological benefits and improve executive functioning, both of which are important for academic performance, decision-making, and emotional well-being.

The study possesses several strengths. It simultaneously evaluated subjective stress, cognitive performance, and cardiac autonomic function within the same experimental protocol using validated assessment tools. The intervention was brief, standardized, inexpensive, and easily reproducible, enhancing its potential for real-world application. Nevertheless, several limitations should be acknowledged. The single-arm pre-post design without a control group limits causal inference and does not exclude placebo effects or practice effects in the Stroop task. The modest sample size may have reduced statistical power to detect subtle physiological changes. Furthermore, the immediate post-intervention assessment precludes conclusions regarding sustained benefits. Finally, although the PSS-10 demonstrated significant changes, it was originally developed to assess stress over the previous month rather than acute state stress, and therefore its repeated administration within a single session should be interpreted cautiously. [28]

Future randomized controlled trials with larger sample sizes should compare guided meditative visualization with active control interventions and evaluate multiple sessions over extended follow-up periods. Incorporating acute state stress measures, salivary cortisol, continuous heart rate monitoring, electroencephalography, or functional neuroimaging may provide a more comprehensive understanding of the mechanisms underlying the immediate cognitive and physiological effects of meditation. [24,29] Examining different meditation durations and participant populations with elevated stress levels may also clarify the dose-response relationship between meditation practice and autonomic regulation.

Overall, the present findings suggest that a brief 10-minute web-based guided meditative visualization session can rapidly reduce perceived stress and improve executive function in healthy young adults, whereas immediate alterations in cardiac autonomic modulation are not readily detectable. These observations support the growing role of brief digital meditation interventions as practical tools for promoting psychological well-being and cognitive performance, while highlighting the need for longer-duration studies to establish their effects on autonomic function.

CONCLUSION

A single 10-minute web-based guided meditative visualization session was associated with a significant reduction in perceived stress and improved executive function, as evidenced by faster incongruent Stroop reaction times, in healthy young adults. However, no significant immediate changes were observed in resting heart rate variability, suggesting that acute psychological and cognitive benefits may precede measurable autonomic adaptations. These findings indicate that brief, digitally delivered meditative visualization is a feasible and accessible intervention for promoting mental well-being and cognitive performance. Nevertheless, the absence of a control group, the exploratory use of the PSS-10 for immediate assessment, and the lack of significant autonomic changes warrant cautious interpretation. Future randomized controlled trials with larger sample sizes, validated state-stress measures, and longer intervention durations are needed to confirm these findings and to determine the sustained effects of web-based meditation on psychological, cognitive, and autonomic outcomes.

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