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Simay Selek
Yeditepe University
Russell Chan
University of Twente
Funda Yildirim
f.yildirim@utwente.nl

University of Twente

Short Report

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Posted Date: April 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9014164/v1

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Additional Declarations: No competing interests reported.

Meditation Training Supports Attention and Performance During High Cognitive Load

Simay Selek[1], Russell Chan[2], Funda Yildirim[1,2]

[1] Cognitive Science Masters Program, Yeditepe University, Istanbul, Turkey,
[2] Section Cognition, Data and Education, Faculty of Behavioural Management and Social Sciences, University of Twente, Enschede, The Netherlands

Abstract

Meditation is increasingly recognized as a structured form of mental training that can induce plastic changes in neural systems supporting attention, cognitive control, and affect regulation. Although prior work links meditation to improved executive functioning, few studies have examined attentional performance under simultaneous cognitive conflict and emotional distraction. This study investigated whether experienced meditators outperform meditation-naive individuals on a modified Stroop task with affective auditory stimuli. Fifty participants (25 meditators, 25 controls) completed a number enumeration Stroop task in which congruent and incongruent trials were presented alongside emotionally salient sounds varying in valence and arousal. Accuracy and response time were analyzed using trial-level mixed-effects models. Results showed that meditators had higher overall accuracy and faster responses than controls. The absence of a Group × Congruency interaction indicates that the advantage was consistent across trial types, suggesting greater baseline attentional stability and more efficient allocation of cognitive resources. Both groups showed slightly higher accuracy on incongruent trials, potentially reflecting increased attentional engagement under conflict or a modest speed–accuracy adjustment. Meditators maintained superior performance despite emotional distraction, supporting the idea that meditation strengthens executive control under cognitive and affective load. These findings highlight the potential of meditation to enhance attentional efficiency and resilience in complex environments. Future longitudinal studies with targeted affective manipulations are needed to clarify the mechanisms underlying these benefits.

Keywords: meditation, attentional control, Stroop task, emotional distraction, executive functioning

Introduction

Meditation is increasingly recognized not merely as a relaxation technique, but as a structured form of mental training capable of inducing plastic changes in large-scale neural systems that support attention, cognitive control, and affect regulation. Converging behavioral and neuroimaging evidence indicates that meditation enhances psychological well-being and cognitive performance through strengthened top-down regulation and reduced bottom-up reactivity (Tang et al., 2015). A central mechanism proposed to underlie these effects is enhanced attentional stability, which allows sustained goal-directed processing in the presence of internal and external distractions (Hölzel, Lazar, et al., 2011; Lutz et al., 2019).

Focused attention meditation explicitly trains the iterative cycle of attentional engagement, distraction detection, and attentional reorientation (Lutz et al., 2008). With continued practice, this process is thought to recalibrate interactions between the dorsal attention network, salience network, and frontoparietal control systems. In particular, meditation has been associated with strengthened recruitment of anterior cingulate and lateral prefrontal regions implicated in conflict monitoring and executive control, alongside attenuated amygdala reactivity to emotionally salient stimuli (Hasenkamp & Barsalou, 2012; Tang et al., 2015). From a predictive processing perspective, such changes may reflect increased precision weighting of task-relevant signals and reduced capture by affectively salient but task-irrelevant inputs.

Behavioral studies using Stroop and other interference tasks provide mixed but informative evidence regarding meditation-related attentional improvements. Some work shows that meditators outperform non-meditators on Stroop tasks, indicating enhanced executive control, cognitive flexibility, attentional functions and skill development (Moore & Dwivedi, 2009; Chan & Woollacott, 2007; Teper & Inzlicht, 2013; Chan et al. 2018; Chan et al., 2020; Chan et al. 2025). Daily meditation time has been linked to reduced interference, suggesting a dose–response relationship (Chan & Woollacott, 2007). Meditation has also been shown to increase brain efficiency in attention tasks, reducing activation in regions related to impulse control while improving task performance (Kozasa et al., 2012). Nevertheless, other studies indicate that differences between meditators and non-meditators may be subtle, with high trait mindfulness rather than meditation per se predicting lower Stroop interference (Josefsson & Broberg, 2011). Mindfulness-based training has similarly been associated with fewer errors and enhanced executive functioning (Elkins-Brown et al., 2017), highlighting the nuanced relationship between meditation, mindfulness, and attentional control.

Despite growing evidence for enhanced attentional control in meditators, fewer studies have examined performance under conditions in which cognitive conflict and emotional distraction co-occur. Real-world environments often require maintaining goal-directed behavior while affectively salient stimuli compete for limited attentional resources. The present study addresses this gap by combining a modified number-counting Stroop paradigm with concurrent affective auditory distractors varying orthogonally in valence and arousal. This design allows examination of executive control under simultaneous cognitive and emotional load.

Based on prior findings that meditation strengthens conflict monitoring, facilitates disengagement from emotionally salient stimuli, and reduces interference in Stroop-type tasks (Lutz et al., 2008; Tang et al., 2015; Teper & Inzlicht, 2013), we hypothesized that experienced meditators would demonstrate superior accuracy and faster response times relative to meditation-naïve controls. We further predicted that this advantage would reflect enhanced stability of task-set maintenance and reduced interference from affective distractors, indicative of more efficient allocation of attentional resources.

Methods

Participants

Fifty participants (*N* = 50; 42 female, 8 male) volunteered to participate in the study. Participants ranged in age from 22 to 62 years (*M* = 41.8, *SD* = 11.4). The meditation group (*n* = 25) consisted of experienced practitioners who had been meditating for at least two years and primarily engaged in concentrative meditation (focused attention) or mindfulness (open monitoring; *n* = 23), with a smaller subgroup practicing transcendental meditation (*n* = 2). The control group (*n* = 25) comprised meditation-naive individuals with no prior experience in any form of meditation.

All procedures were approved by the Yeditepe University Ethical Committee for Social Sciences (approval number: E.50532705-302.14.01-925) and conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study prior to their participation.

Psychometrics Testing Procedure

We used a modified version of the Stroop Task (Stroop, 1935; Pansky, 2001), shifting the traditional focus from color-word interference to quantifying accuracy in counting symbolic numbers. Participants performed a number enumeration task in which each trial displayed a 4 × 4 matrix containing a combination of digits (1–7) and asterisks (*). Congruent trials presented a match between digit identity and quantity (e.g., the digit “2” shown exactly two times), while incongruent trials featured a mismatch (e.g., the digit “2” shown five times). Figure 1 we present example visuals of congruent and incongruent trials.

To add the impact of distraction, affective auditory stimuli were integrated into the task design. A total of 28 affective sounds (6 s each), selected from the International Affective Digitized Sounds–2 (IADS-2) database (Bradley & Lang, 2007), were evenly distributed across four categories: high pleasure, low pleasure, high arousal, and low arousal. Each block of three trials was paired with a single sound type that played continuously throughout the block, and each unique sound was repeated four times. Sounds were selected from the IADS-2 database to create a 2 × 2 design crossing valence (pleasant vs unpleasant) and arousal (high vs low). Each category contained seven sounds matched for duration and presentation frequency.

The experiment was structured into 112 blocks, each containing three enumeration trials (total = 336). These were evenly split between congruent (*n* = 168) and incongruent (*n* = 168) conditions. Each trial began with a 2-s auditory presentation and a fixation cross, followed by three task stimuli (1 s each) with 0.5-s fixation intervals. A schematic of the task design and trial structure is shown in Figure 2. Instructions were displayed onscreen and explained verbally to ensure clarity. Participants completed a short practice block (three tasks without sound) prior to the main task. The entire experiment lasted approximately 11 minutes.

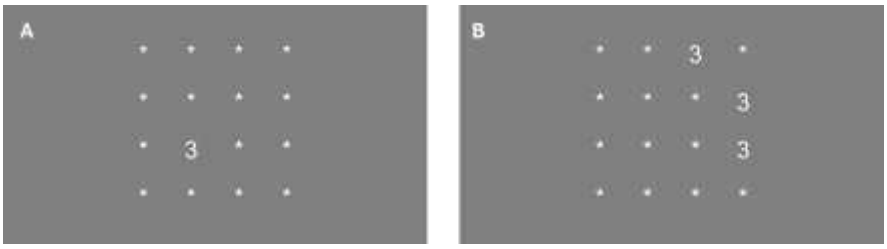


Figure 1. Example visuals of (A) Incongruent trial and (B) Congruent trial.

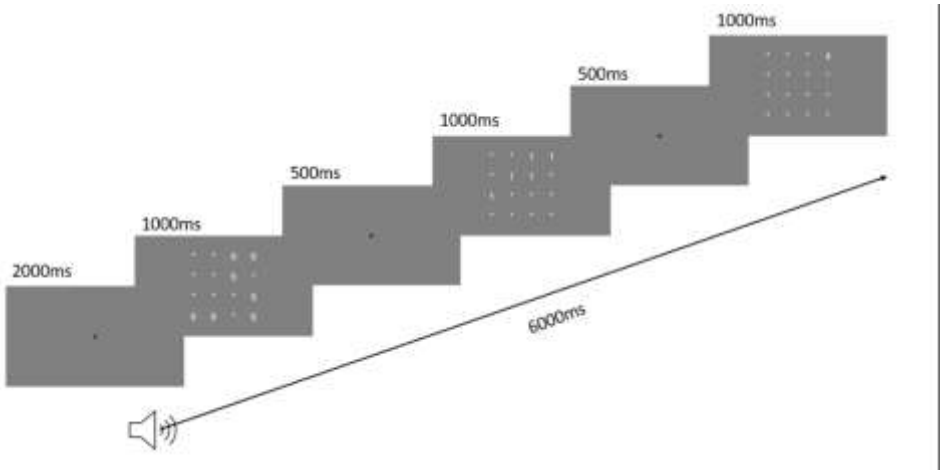


Figure 2. Schematic representation of one trial block in the modified Stroop task. Each block began with the onset of an affective auditory stimulus (6 s), followed by a series of three visual enumeration tasks (1 s each), separated by 0.5-s fixation intervals. A total of 112 blocks were presented, each associated with a different sound condition.

Behavioral Data Analysis

Behavioral analyses were conducted using IBM SPSS Statistics (Version 27). Reaction time (RT) and accuracy were analyzed separately using mixed-effects models at the trial level. Group (meditation vs. control) was included as a between-subjects factor, and Congruency (congruent vs. incongruent) as a within-subjects factor.

RT data, recorded in seconds, were analyzed using a linear mixed-effects model with Group, Congruency, and their interaction as fixed effects. A random intercept was specified for each participant to account for repeated measures.

Accuracy was analyzed using a generalized linear mixed-effects model with a binomial distribution and logit link function. Fixed effects included Group, Congruency, and their interaction, with a random intercept specified for participants.

All fixed effects were evaluated using Type III tests, with statistical significance defined as $p < .05$. Descriptive statistics were calculated to support interpretation of group and condition differences.

Results

Accuracy

A generalized linear mixed model with a binary logistic link was conducted to examine the effects of Group (meditation vs. control) and Congruency (congruent vs. incongruent) on accuracy. There was a significant main effect of Group, $F(1, 16{,}796) = 207.99$, $p < .001$, indicating that the meditation group responded more accurately overall ($M = 0.70$, $SD = 0.46$) than the control group ($M = 0.60$, $SD = 0.49$). A significant main effect of Congruency was also observed, $F(1, 16{,}796) = 305.56$, $p < .001$, with participants performing more accurately on incongruent trials ($M = 0.72$, $SD = 0.45$) than congruent trials ($M = 0.59$, $SD = 0.49$). The Group × Congruency interaction was not significant, $F(1, 16{,}796) = 0.20$, $p = .657$, indicating that the accuracy difference between groups was comparable across both trial types. In the incongruent condition, meditators had higher accuracy ($M = 0.77$, $SD = 0.42$) than controls ($M = 0.66$, $SD = 0.47$), and a similar pattern was observed in the congruent condition ($M = 0.64$, $SD = 0.48$ vs. $M = 0.54$, $SD = 0.50$). The group differences in accuracy across trial types are illustrated in Figure 5.

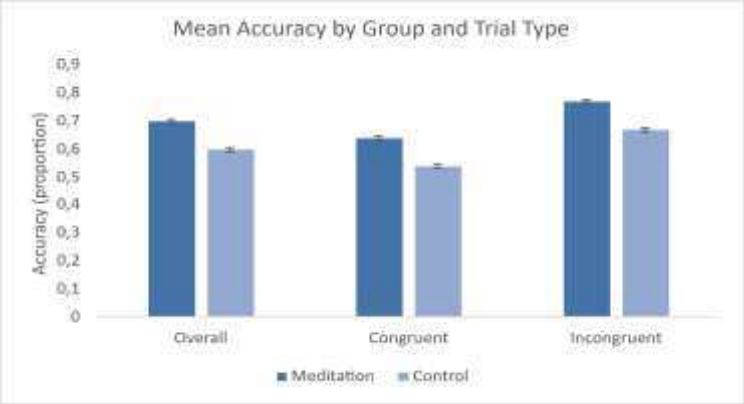


Figure 5. Mean accuracy (%) of the meditation and control groups across the overall experiment, congruent trials, and incongruent trials. Error bars represent the standard error of the mean (SEM).

Response Time

A linear mixed-effects model was conducted with Congruency (congruent vs. incongruent) and Group (meditation vs. control) as fixed effects and response time (in seconds) as the dependent variable. The analysis revealed a significant main effect of Group, $F(1, 13{,}156) = 74.54$, $p < .001$, indicating that participants in the meditation group responded faster overall ($M = 0.71$, $SD = 0.13$) than those in the control group ($M = 0.73$, $SD = 0.14$). A significant main effect of Congruency was also found, $F(1, 13{,}156) = 4.46$, $p = .035$, with slower responses on incongruent trials ($M = 0.73$, $SD = 0.14$) compared to congruent trials ($M = 0.72$, $SD = 0.14$). However, the Congruency × Group interaction was not significant, $F(1, 13{,}156) = 0.49$, $p = .483$, indicating that the group difference in response times did not differ by trial type. Specifically, in the incongruent condition, meditators responded faster ($M = 0.72$) than controls ($M = 0.74$), and a similar pattern was observed in the congruent condition ($M = 0.71$ vs. $M = 0.73$). These group differences in response time across trial types are depicted in Figure 6.

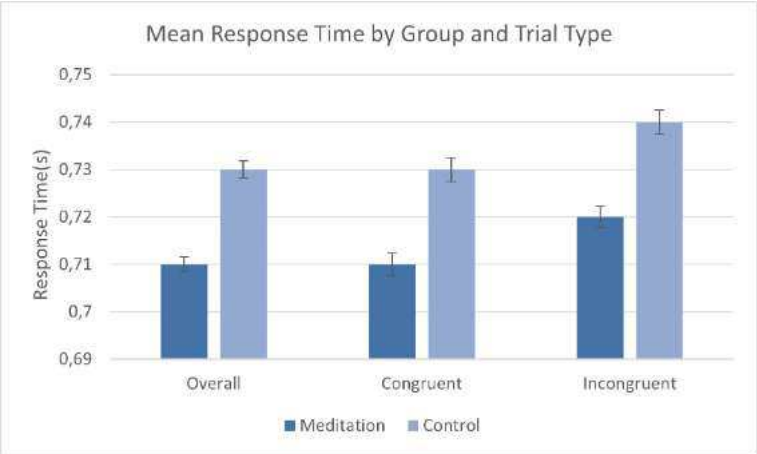


Figure 6. Mean response time (in seconds) for the meditation and control groups across the overall experiment, congruent trials, and incongruent trials. Error bars represent the standard error of the mean (SEM).

Discussion

The present study examined attentional performance in experienced meditation practitioners compared with meditation-naive individuals using a modified Stroop task presented with affective auditory background stimuli. Overall, meditators showed higher accuracy and faster response times, indicating more efficient performance on a task requiring sustained attention and conflict monitoring.

The Stroop findings provide important insights into the nature of this attentional advantage. The absence of a Group × Congruency interaction suggests that meditators did not benefit selectively under high-conflict (incongruent) trials. Instead, their performance advantage was consistent across both congruent and incongruent trials. This pattern may reflect greater baseline attentional stability or more efficient allocation of cognitive resources, consistent with prior evidence linking meditation practice to improved executive control, conflict monitoring, and cognitive flexibility (Moore & Malinowski, 2009; Tang et al., 2015; Teper & Inzlicht, 2013). The faster responses observed in meditators even on congruent trials suggest that meditation may enhance overall processing efficiency, beyond conflict resolution alone.

Interestingly, both groups showed slightly higher accuracy on incongruent trials. This counterintuitive pattern may reflect increased attentional engagement when conflict is present, aligning with theories of conflict-driven performance adjustment. It could also indicate a modest speed–accuracy tradeoff, where participants slow responses to maintain accuracy on more demanding trials. Future trial-level analyses could clarify whether meditation influences such dynamic adjustments or reflects a more stable enhancement in attentional control.

The inclusion of affective auditory stimuli was intended to increase ecological validity by introducing emotionally salient background input. While meditators outperformed controls in

this context, the study design did not include a silent baseline, and valence and arousal were not manipulated as primary factors. Therefore, the findings should be interpreted as evidence of attentional performance during tasks with emotional background stimuli rather than a direct test of emotional distraction. Future studies incorporating baseline conditions and systematic manipulation of affective dimensions would help clarify how meditation affects susceptibility to emotional interference.

Our findings have important implications that strengthen existing theoretical and applied contexts. They suggest that meditation practice may enhance the efficiency and stability of attentional control not only under standard cognitive demands but also in environments with competing emotional stimuli (i.e. distraction protective effect). This supports the idea that meditation could be a useful tool for improving focus and resilience in everyday tasks that require simultaneous management of cognitive and emotional load, such as work, study, or high-stress professions. The results provide empirical support for interventions aiming to strengthen executive functioning and emotion regulation through contemplative training, highlighting the potential of meditation-based programs in educational, occupational, and clinical settings.

Several limitations should be considered. The cross-sectional design prevents causal conclusions about meditation practice. The absence of a no-sound baseline limits interpretation of the role of emotional distraction. The sample also included a mix of meditation styles, which may engage distinct attentional mechanisms, and the sample size restricted the ability to examine interactions between meditation experience, task difficulty, and affective load.

Despite these limitations, the study adds to the literature by demonstrating that experienced meditators perform more efficiently on a Stroop task in the presence of affective auditory stimuli. These results are consistent with theoretical accounts proposing that meditation practice enhances attentional stability, top-down control, and flexible allocation of cognitive resources under both cognitive and emotional challenge (Hölzel, Lazar, et al., 2011; Lutz et al., 2019). Longitudinal studies with more refined affective manipulations, and larger, more homogenous samples will be important for clarifying the mechanisms underlying these Stroop-related advantages and their generalization to real-world attentional demands.

Consent to Participate Declaration

Informed consent was obtained from all individual participants included in the study prior to their participation. All procedures were explained in detail, and participants were informed of their right to withdraw at any time without penalty. The study was conducted in accordance with institutional ethical standards and the Declaration of Helsinki.

Funding Declaration

No external funding was acquired to conduct this study.

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