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Trait Mindfulness and Inhibitory Control in Young Adults: Moderation by Sex and Mediation by Resting EEG

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Research Article

Keywords: five facet mindfulness questionnaire, conflict monitoring, executive function, flanker task performance, neural oscillation, linear-mixed-effects models

Posted Date: March 5th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8868295/v1

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Additional Declarations: No competing interests reported.

Abstract

a. Objective

b. To determine the relationship between facet-level trait mindfulness (TM) and inhibitory control (IC), and whether the relationship is moderated by sex and mediated by resting cortical activity.

c. Methods

d. 283 young adults (149 women; 18–30 years old) completed the Five Facet Mindfulness Questionnaire and a flanker task involving congruent and incongruent trials to induce varying IC demands. A sub-sample (n = 174) completed resting-state electroencephalogram (rsEEG) to quantify power in theta, alpha, and beta bands using individualized alpha-peak frequency. Linear mixed-effects models tested the associations of TM facets with IC, and the moderation by sex. The sub-sample tested the mediation effect of rsEEG on associations between TM facets and IC.

e. Results

f. Acting with Awareness (AA) was positively associated with accuracy, selectively for incongruent trials. Among women, observing was positively related to response time, whereas higher nonjudging was related to shorter response time variability. Mediation analysis showed an indirect effect of AA on incongruent accuracy via eyes-open upper alpha: while the negative association of AA with upper alpha was not significant (a-path), higher upper alpha predicted better incongruent accuracy (b-path) and partially suppressed AA's otherwise beneficial association with incongruent accuracy.

g. Conclusions

h. The relationship between TM and IC varied across facets and differed between men and women. Upper alpha was positively related to IC but suppressed the beneficial association of AA with IC. These findings highlight the importance of facet-level analysis on TM when characterizing its associations with IC in a sex-specific manner and underlying neural mechanisms.

Introduction

Executive functions are a set of essential cognitive processes that allow individuals to regulate thoughts, emotions, and actions to achieve goal-directed behavior (Diamond, 2013). These processes include inhibitory control (IC), working memory and cognitive flexibility, which collectively support complex cognitive tasks such as planning, problem-solving, and self-regulation. Executive function is critically important across all life stages, influencing academic achievement in children, occupational success in adults, and cognitive resilience in older adults (Best & Miller, 2010; Harada et al., 2013; Turjeman-Levi et

al., 2024). IC, the process of suppressing automatic or dominant responses in favor of goal-directed behaviors, is particularly vital in young adulthood, and has been shown to support academic achievement by enhancing sustained attention, reducing distractibility, and managing impulsivity during challenging tasks (Best & Miller, 2010). Beyond academics, IC contributes to mental health by aiding stress management, emotional regulation, and decreasing vulnerability to anxiety and depression (Nigg, 2017). Moreover, it facilitates adaptive emotional responses and psychological resilience in various social and environmental contexts (Hofmann et al., 2012). Given IC's multifaceted importance, exploring its underlying mechanisms in young adulthood is essential for enhancing cognitive, emotional, and functional well-being.

Mindfulness is commonly understood as the psychological process of bringing attention to present-moment experiences with a nonjudgmental attitude (Bishop et al., 2004), and includes a trait mindfulness (TM) component. TM reflects an individual's stable, dispositional tendency to be mindful in daily life, characterized by natural openness and nonjudgmental attention to present-moment experiences. TM may benefit IC by strengthening attention monitoring and enhancing an accepting stance toward internal experiences, which together can reduce affective reactivity and support IC as part of the executive function (Lindsay & Creswell, 2017; Teper et al., 2013). Prior studies have shown positive associations between TM and mental health outcomes such as emotional regulation, reduced stress, attention, and executive function (Brown & Ryan, 2003; Carmody & Baer, 2008), including IC specifically (Cruz, 2021). However, most previous studies have not explored associations with the distinct facets of TM (Keith et al., 2017; MacAulay et al., 2022), limiting the ability to identify which TM facets are strongly linked to IC. This is important because specifying the TM facets tied to IC can inform mindfulness-based interventions by targeting intervention designs and activities that are most likely to support improvements in IC.

The Five Facet Mindfulness Questionnaire (FFMQ) is a widely used tool for assessing TM across five facets. The FFMQ assesses five dimensions of mindfulness: Observing (Ob; noticing internal and external experiences), Describing (De; labeling experiences with words), Acting with awareness (AA; attending to the present activity), Nonjudging of inner experience (NJ; refraining from evaluation thoughts and feelings), and Nonreactivity to inner experience (NR; allowing thoughts and feelings to come and go), providing a comprehensive evaluation of TM (Baer et al., 2006, 2008). Using the FFMQ,Lin et al. (2019) provided evidence linking not only higher TM but also specific TM facets to better IC performance. In their study, results from 60 woman undergraduates showed negative correlations of the AA facet with response time (RT) and error rate during a flanker task. In addition to behavioral measures, they examined the P3, which is a stimulus-locked event-related brain potential (ERP) component characterized by a centro-parietal positive deflection occurring approximately 300–600 ms after stimulus onset and is commonly interpreted as reflecting attentional processing and context updating during cognitive performance (Polich, 2007). In IC task, P3 amplitude is commonly taken to index the amount of attentional resources engaged during stimulus evaluation while P3 latency reflects the speed of stimulus evaluation. By examining the P3 amplitude interference score (incongruent - congruent P3 amplitude) to index the extent to which perceptual conflict was experienced, they showed that higher

scores on the AA facet were associated with smaller P3 amplitude interferences, suggesting more effective neural processing in suppressing conflicts involved in IC performance. Together, these results indicate that individual aspects of TM may influence IC performance, both behaviorally and neuroelectrically.

The relationship between AA and IC performance may stem from the theoretical overlap between mindfulness and executive attention (Tang et al., 2015). Specifically, Tang et al.'s review highlighted that mindfulness meditation engages the executive attention network, which is involved in conflict monitoring, goal maintenance, and self-regulation. The AA facet reflects a reduced tendency to operate on "autopilot" and a greater capacity to maintain conscious awareness of their actions, thereby reducing attentional lapses and susceptibility to distraction. This feature aligns closely with the executive attention system and may facilitate the recruitment of associated neural networks to optimize attentional control underlying IC processes. Supporting this perspective, a functional magnetic resonance imaging (fMRI) study by Dickenson et al. (2013) reported that increased activation in temporoparietal regions was related to attention and awareness among individuals with higher global TM. Despite the potentially specific association of AA and IC, the empirical evidence remains limited, as only two studies have reported that global TM scores were related to IC performance (Keith et al., 2017; Logemann-Molnár et al., 2024). However, because these studies used unidimensional mindfulness measures, which cannot clarify whether AA may be a unique facet to drive IC, and Keith et al. (2017) examined a sample with attention-deficit hyperactivity disorder (ADHD), which may limit generalizability to healthy adults. Moreover, the unique association of AA with IC reported in Lin et al. (2019) study was limited by a modest sample size ($N = 60$) which only included women. Given established sex differences in FFMQ scores (Gan et al., 2023), neuroelectric processing during IC tasks (Clayson et al., 2011), and activation of executive control networks (Liu et al., 2012; Omura & Kusumoto, 2015), it remains to be determined whether the association between AA and IC is specific to women or generalizable across sexes.

One way to further examine the association between TM and IC is to test whether TM is reflected in resting-state cortical activity that has been linked to IC. Behavioral IC measures alone cannot reveal whether TM is associated with baseline neural readiness for IC at rest. Resting-state electroencephalography (rsEEG) provides insights into the brain's baseline functional state by recording spontaneous electrical activity under eyes-open and eyes-closed conditions to index distinct spectral profiles with and without visual input (Barry et al., 2007). At rest, frontal midline theta is linked with the default mode network (DMN), which is a set of midline and lateral cortical regions that are active at rest and inactive during externally oriented tasks (Buckner et al., 2008). Simultaneous EEG-functional magnetic resonance imaging (fMRI) studies reported that increases in frontal theta power are negatively related to DMN blood-oxygen-level-dependent (BOLD) activity, linking resting theta to spontaneous, self-referential mentation during rest (Knyazev et al., 2011; Scheeringa et al., 2008). For parieto-occipital alpha, higher resting alpha power indexes cortical inhibition/idling. When alpha power increases, occipital BOLD signal and regional blood flow decrease, whereas decreases in alpha are accompanied with greater cortical activation/metabolism (Goldman et al., 2002; Laufs et al., 2003; Scheeringa et al.,

2012). Furthermore, individual differences in theta and alpha at rest are associated with performance in response inhibition (Pscherer et al., 2021; Warren et al., 2024), suggesting resting cortical activity may be associated with inhibitory processes.

Mindfulness intervention studies have demonstrated that habitual mindfulness practice can reshape resting cortical activity. Experienced mindfulness meditators exhibited elevated frontal midline theta at rest (Cahn & Polich, 2006), and both novice and experienced mindfulness practitioners showed increased resting-state theta and alpha power following mindfulness training (Lomas et al., 2015). Given TM can be developed through habitual practice, these findings suggest TM may be related to resting cortical activity. However, there is a paucity of research investigating the relationship between TM and rsEEG. Identifying specific rsEEG correlates of TM and its multiple facets would help understand potential mechanisms underlying the relationship between TM and IC, better explaining how and why TM relates to IC. This line of research may also highlight modifiable neural targets in future experimental and intervention studies to optimize mindfulness-based approaches for improving IC.

Accordingly, the purpose of this study was to investigate the relationship between TM and IC among young adults. Drawing upon the idea that the relationship between TM and IC may be reflected in baseline neural readiness for IC at rest, indexed by resting-state cortical activity, we aimed to 1) determine whether TM facets were differentially related to IC while considering the potential moderating role of sex in the relationship, and 2) examine the mediating role of resting cortical activity. The central hypothesis was that TM, particularly AA, would be positively associated with IC. We then hypothesized that the associations of TM facets with IC would be moderated by sex. Finally, we hypothesized that associations between TM facets and IC would be mediated by rsEEG, particularly in alpha frequency bands. Findings from this study could inform tailored sex-specific and targeted mindfulness interventions to enhance cognitive function.

Methods

Participants

Adults aged 18–30 years were recruited from Purdue University and the surrounding community. Exclusion criteria included current use of medications affecting cognitive function, a diagnosed cognitive disability, uncorrected visual acuity worse than 20/20 (not normal or corrected-to-normal vision 20/20), or lack of fluency in English. Eligible participants provided informed consent in accordance with procedures approved by the Purdue University Institutional Review Board (IRB-2022-1416; IRB-2020-1093). Data was pooled from two separate studies in which TM and IC were assessed using the same instruments and procedures. Study 1 (N = 236) required one laboratory visit while Study 2 (N = 47) required two laboratory visits (see Table 1). Participants from both studies completed the TM assessment and provided demographics through an online survey prior to their first lab visit and completed IC and EEG assessment during one of their lab visits (Day 2 for study 2 participants). Both studies recruited an identical population (e.g., healthy young adults from the same community), followed

the same protocol (screening test, instructions, and testing equipment and environment), and implemented the same IC task with identical stimuli, practices, and trials.

Trait Mindfulness

TM was assessed using FFMQ, which is a self-reported measure designed to assess individual differences in mindfulness as a multifaceted construct (Baer et al., 2006, 2008). The FFMQ consists of 39 items, each rated on a five-point Likert-type scale ranging from 1 (never or very rarely true) to 5 (very often or always true). The five facets measured by the FFMQ are observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to inner experience. Each facet was scored individually by computing the sum across related items. The total TM score was calculated by summing the scores of the five facets. The FFMQ has demonstrated strong psychometric properties (Baer et al., 2006, 2008), including internal consistency (Cronbach's alpha coefficients range from 0.75 to 0.91 across facet) (Baer et al., 2008).

Electroencephalogram recording

Electroencephalogram (EEG) was recorded using 64 Ag/AgCl scalp electrodes positioned according to the international 10–10 system with a Neuroscan Quick-Cap (Compumedics, Charlotte, NC). All electrodes were filled with conductive gel, referenced to the electrode positioned between Cz and CPz, grounded at AFz, and maintained at an impedance below 10 kΩ. Horizontal electrooculographic (EOG) activity was recorded from electrodes placed at the outer canthi of each eye, while vertical EOG was recorded from electrodes placed above and below the left eye. EEG signals were digitized at 1000 Hz, amplified 500×, and filtered using a DC to 70 Hz band-pass filter with a 60 Hz notch filter. Due to a lab-wise technical error from May 2023 to February 2024, EEG recordings for 107 participants from Study 1 were conducted using an incorrect sampling rate (100 Hz). Additionally, two participants from Study 2 did not complete EEG recording. Therefore, these participants were excluded from the statistical analysis involving EEG-related measures during both the resting and cognitive tasks.

Resting cortical activity: Power spectral density

Resting EEG was recorded for two sets of 90 seconds during eyes-open (EO) and eyes-closed (EC) conditions, in counterbalanced order. Offline processing was performed in MATLAB R2022a (MathWorks Inc.) using EEGLAB toolbox (v2023.0) (Delorme & Makeig, 2004). Continuous EEG data were re-referenced to the averaged mastoids and then separated into EO and EC segments, and each condition was processed independently. Channel cleaning was conducted by the 'catchbadchannels' function to automatically detect and remove bad channels (excluding EOG channels). Independent component analysis (ICA) was performed using RUNICA, followed by the automatic identification and removal of ocular blink components using 'icablinkmetrics and EyeCatch'. Removed channels were subsequently restored using spherical interpolation. EEG data were segmented into 4-second with 50% overlap, and

each epoch was baseline-corrected using the entire epoch. A 1–30 Hz band-pass filter (second-order Butterworth, DC removal on) was applied. After removing epochs containing artifacts exceeding ± 100 μV amplitude threshold, Fast Fourier Transform was applied to compute power spectral density (PSD) for each electrode across the 1–30 Hz frequency range. Power values were computed and log-transformed to achieve normality. Individual alpha peak frequency (IAPF) was identified separately for EO and EC conditions across PO3, POz, and PO4 electrodes. For each eye condition, the maximal peak was identified within the 7.5–12.5 Hz at 0.1 Hz resolution to define individualized bands: theta (IAPF − 6 to IAPF − 4 Hz), alpha-1 (IAPF − 4 to IAPF-2 Hz), alpha-2 (IAPF-2 to IAPF + 0 Hz), upper alpha (IAPF + 0 to IAPF + 2 Hz), and beta (IAPF + 2.5 to IAPF + 22.5 Hz) (Klimesch, 1999). Based on previous research (Cortes-Ospina et al., 2025) and the visual inspection of the grand-average topography (Fig. 1), frequency-specific regions of interest (ROIs) were used to quantify theta (F1/Z/2, FC1/Z/2), alpha-1 (F1/Z/2, FC1/Z/2, C1/Z/2, CP1/Z/2, P1/Z/2, PO3/Z/4), alpha-2 and upper alpha (P1/Z/2, PO3/Z/4, O1/Z/2), and beta (F1/Z/2, FC1/Z/2).

Inhibitory control

A modified version of the Flanker task was administered using E-Prime software (Psychology Software Tools, Pittsburgh, PA) on a 24-inch monitor with a black background. Each stimulus consisted of five white arrow-shaped figures (6 mm thick), arranged with a 40-degree spread angle and 8 mm spacing between arrows. Participants were instructed to respond as quickly and accurately as possible to the direction of the central arrow: pressing a button with their left thumb if the central arrow pointed left, and a different button with their right thumb if it pointed right. The task included two trial types, congruent trials in which all arrows pointed in the same direction, and incongruent trials in which the central arrow pointed in the opposite direction of the flanking arrows (Fig. 2). The inter-stimulus interval was randomly jittered at 1000 ms, 1200 ms, or 1400 ms. Participants completed two blocks of 96 trials each, with an equal number of congruent and incongruent trials, and an equal probability of left- and right-pointing central arrows. Prior to the main task, participants completed 20 practice trials and advanced to the main task only if they achieved an accuracy rate above 70% during practice. The outcome measures were reaction time (RT), coefficient of variation of RT (CVRT), calculated as the standard deviation of RT divided by the mean RT, and accuracy (ACC). RT-related measures were calculated using only correct responses.

Task-related EEG: Event-related potential(s)

EEG data recorded during the flanker task were processed offline in MATLAB R2022a (MathWorks Inc.) using EEGLAB (v2023.0)(Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014). Similar to resting EEG, task-related EEG data were re-referenced, followed by the removal of bad channels, ICA, removal of ocular blink components, and restoration of removed channels using spherical interpolation. Subsequently, corrected data were segmented into stimulus-locked epochs from − 100 to 1000 ms and baseline-corrected using the − 100 to 0 ms interval. Data were filtered with a 30-Hz low-pass filter and a

0.01-Hz high-pass filter. Epochs containing artifacts exceeding ± 100 μV were rejected and ERPs were averaged across remaining trials separately for congruent and incongruent correct responses. The P3 component was quantified within a 300–600 ms post-stimulus window; amplitude was computed as the mean voltage in a 50-ms window centered on the largest positive peak (± 25 ms), and latency was defined as the time point of this peak. P3 measures were extracted from a predefined ROI comprising CP1/CPz/CP2 and P1/Pz/P2, and values were averaged across these electrodes.

Procedure

Following the passing of screening and consent, eligible participants completed a demographic questionnaire (e.g., sex assigned at birth, age) and FFMQ online prior to their laboratory visit. On the day of the visit, participants' height and weight were measured using a digital scale (Tanita WB-3000). Each measurement was taken twice, and the average of the two values was used to compute body mass index (BMI) and for analysis. Next, participants were fitted with an EEG cap and sat comfortably on a chair in a sound-dampening room during rsEEG recording. Participants were instructed to focus on a small fixation cross on the screen and remain still and relaxed while avoiding excessive movement. Then, behavioral and ERP were recorded during IC tasks.

Statistical analysis

All statistical analyses were conducted in R (version 4.4.2; R Core Team, 2024) using RStudio (version 2024.12.0 + 467; Posit Software, PBC) and Quarto (version 1.5.57; Posit Software, PBC) on Windows 10 (64-bit), with the lme4, *lmerTest*, *emmeans*, *broom.mixed*, and *tidyverse* packages. The alpha level (α) was set at .05 (two-tailed) for all statistical tests.

For Aim 1, three dependent variables (ACC, RT, and CVRT) of behavioral IC performance outcomes were analyzed in separate mixed-effects models. Each model included one TM facet (Ob, De, AA, NJ, NR or Total), Congruency (congruent vs. incongruent), and Sex (women vs. men) as fixed effects, along with all two- and three-way interactions among these predictors. Age and BMI were included as covariates, and participant ID was modeled as a random intercept to account for repeated measures across Congruency. Continuous predictors (TM facet score, Age, BMI) were mean centered. We used Satterthwaite degrees of freedom for fixed-effect tests.

To evaluate overall model significance, we fitted models via maximum likelihood (ML) and conducted a likelihood-ratio test (LRT) comparing Full model with Null model (random intercept-only). Models for fixed-effect inference were estimated using restricted maximum likelihood (REML), and Type III ANOVA provided omnibus tests. Significant interactions were followed up by testing simple slopes using *emtrends* (estimating the slope of the TM facet at each level of the moderators) and pairwise contrasts of slopes. Estimated marginal means for Congruency and Sex were obtained with *emmeans* and compared using Bonferroni correction. In addition, ERP outcomes of IC performance (P3 amplitude and

latency) were used as dependent variables in similar mixed-effects models using the sub-sample with EEG data (n = 174; 129 from Study 1, 45 from Study 2).

For Aim 2, the same EEG sub-sample (n = 174) was also used to conduct a sensitivity analysis on the behavioral outcomes of IC performance to ensure the consistency with results based on the whole sample (n = 283). Only significant associations identified between TM facets with IC outcomes in the sub-sample were further submitted to mediation analysis using the rsEEG power in theta, alpha-1, alpha-2, upper alpha, and beta during EO and EC conditions as potential mediators. All continuous variables were mean centered prior to analysis. For each model, separate ordinary least squares regressions were fitted for the *a*-path (predictor → mediator) and *b*-path (mediator → outcome), adjusting for age and BMI. Indirect effects ($a \times b$) were estimated via nonparametric bootstrap (5,000 resamples) with bias-corrected 95% confidence intervals (CIs). When the predictor or outcome was measured repeatedly across Congruency conditions, linear mixed-effects models with random intercept for participant were used for both the *a*- and *b*-paths to account for within-subject dependencies. In these cases, indirect effects were estimated using a clustered bootstrap (5,000 resamples of participant IDs) to preserve the nested data structure. A mediation effect was considered statistically significant if the 95% CI for the indirect effect did not include zero.

Results

Aim 1: TM-IC relationships and moderation by sex

Table 1 provides the participant characteristics. Table 2 summarizes the overall model significance and statistics for predictors within each of the significant models.

ACC

The overall full AA-ACC model was significantly different than the null model. In the full model, AA, Congruency, Age, and AA × Congruency interaction were significant predictors of ACC. Follow-up simple slope analysis of the AA × Congruency interaction revealed that AA was positively associated with ACC for incongruent trials ($\beta = 0.186$, $SE = 0.054$, $t = 3.461$, $p = .001$, 95% CI [0.081, 0.292]) while there was no association for congruent trials ($\beta = 0.049$, $SE = 0.054$, $t = 0.911$, $p = .363$, 95% CI [-0.057, 0.155]). The incongruent slope was significantly larger than the congruent slope ($\beta = 0.137$, $SE = 0.062$, $t = 2.202$, $p = .029$). No significant effect on ACC was observed for other TM facets.

RT

The overall full Ob-RT model was significantly different than the null model. In the full model, Congruency, Sex, BMI, and Ob × Sex interaction were significant predictors of RT. Follow-up simple slope analysis of the Ob × Sex interaction revealed that Ob was positively associated with RT for women ($\beta = 1.958$, $SE = 0.823$, $t = 2.378$, $p = .018$, 95% CI [0.337, 3.579]) while there was no significant association for men ($\beta = -0.683$, $SE = 0.855$, $t = -0.799$, $p = .425$, 95% CI [-2.366, 0.999]). The slope for women was

significantly larger than the slope for men (β = 2.642, *SE* = 1.187, *t* = 2.225, *p* = .027). No significant effect on RT was observed for other TM facets.

CVRT

The overall full NJ-CVRT model was significantly different than the null model. In the full model, Congruency, Sex, and NJ × Sex interaction were significant predictors of CVRT. Follow-up simple slopes for the NJ × Sex interaction showed that NJ was negatively associated with CVRT for women (β = -0.001, *SE* = 0.000, *t* = -2.801, *p* = .005, 95% CI [-0.002, -0.000]), whereas the slope for men was not significant (β = 0.000, *SE* = 0.000, *t* = 0.624, *p* = .533, 95% CI [-0.001, 0.001]). The slope for women was significantly smaller than the slope for men (β = -0.001, *SE* = 0.001, *t* = -2.308, *p* = .022). No significant effect on CVRT was observed for other TM facets.

P3 components

The overall full NJ-P3 amplitude model was significantly different than the null model. In the full model, Congruency, Age, and NJ × Con × Sex interaction were significant predictors of P3 amplitude. Follow-up simple slopes for the NJ × Con × Sex interaction were not significant for congruent trials among men (β = 0.109, *SE* = 0.098, *t* = 1.113, *p* = .267, 95% CI [-0.084, 0.301]), for congruent trials among women (β = 0.080, *SE* = 0.098, *t* = 0.8200, *p* = .413, 95% CI [-0.113, 0.273]), for incongruent trials among men (β = 0.037, *SE* = 0.085, *t* = 0.433, *p* = .665, 95% CI [-0.130, 0.203]), and for incongruent trials among women (β = 0.158, *SE* = 0.085, *t* = 1.869, *p* = .063, 95% CI [-0.009, 0.325]). Between-slope comparisons showed no significant difference between slopes for women and men in congruent trials (β = 0.072, *SE* = 0.129, *t* = 0.558, *p* = .577) and in incongruent trials (β = -0.078, *SE* = 0.129, *t* = -0.603, *p* = .547). The difference between congruent and incongruent slopes was not significant in men (β = 0.029, *SE* = 0.043, *t* = 0.667, *p* = .506), whereas women showed a smaller slope for congruent than incongruent trials (β = -0.121, *SE* = 0.037, *t* = -3.260, *p* = .001). No significant effect on P3 amplitude was observed for other TM facets. Analysis on P3 latency showed no significant association with TM facets.

Aim 2: Mediation by resting EEG

Sensitivity analysis using the sub-sample with EEG data was first conducted to verify the TM-IC associations identified using the whole sample. The sensitivity analysis showed a similar association of AA with ACC only for incongruent trials (Table 2). Specifically, AA was positively associated with ACC for incongruent trials (β = 0.162, *SE* = 0.059, *t* = 2.757, *p* = .006, 95% CI [0.046, 0.277]) while there was no association for congruent trials (β = 0.006, *SE* = 0.059, *t* = 0.108, *p* = .914, 95% CI [-0.109, 0.122]). The incongruent slope was statistically larger than the congruent slope (β = 0.156, *SE* = 0.074, *t* = -2.111, *p* = .036). The sensitivity analysis also showed that NJ was negatively related to CVRT only in women. Specifically, NJ was negatively associated with CVRT for women (β = -0.001, *SE* = 0.001, *t* = -2.554, *p* = .012, 95% CI [-0.003, -0.000]), whereas the slope for men was not significant (β = 0.000, *SE* = 0.001, *t* = 0.704, *p* = .482, 95% CI [-0.001, 0.002]). The slope for women was significantly smaller than the slope for men (β = -0.002, *SE* = 0.001, *t* = -2.203, *p* = .029). However, the selective association of Ob with RT in

women were no longer significant. Accordingly, a mediation analysis was conducted to determine whether the two identified associations were mediated by resting EEG power in theta, alpha-1, alpha-2, upper alpha, and beta frequency bands.

Mediation analysis showed a significant negative indirect effect of AA on incongruent ACC through upper alpha power in EO condition (indirect effect; β = -0.028, 95% CI [-0.065, -0.000]) (Fig. 4). The a-path was not significant (*a*; β = -0.134, *SE* = 0.077, *t* = -1.736, *p* = .084, 95% CI [-0.286, 0.018]), whereas the b-path was significantly positive (*b;* β = 0.206, *SE* = 0.072, t = 2.846, *p* = .005, 95% CI [0.063, 0.348]). There was no other significant indirect effect between AA and incongruent ACC when using rsEEG in other frequency bands under eye conditions as a mediator. Similarly, there was no significant indirect effect between NJ and CVRT in women when using any rsEEG measure as a mediator.

Discussion

This study examined how TM was related to IC performance in young adults, and whether the relationship between TM and IC was moderated by sex or mediated by rsEEG power. The main findings were the positive association of AA with ACC only during the incongruent task condition and the associations of higher Ob and NJ scores with longer RT and smaller CVRT in women, respectively. Analysis on the sub-sample with rsEEG data replicated the beneficial associations of AA with incongruent ACC and of NJ with CVRT in women. In addition, resting upper alpha power during EO showed a suppressor mediation effect on the relationship between AA and ACC in incongruent trials. Taken together, the current findings suggest that individual difference in TM, especially AA and NJ, may contribute to IC performance during young adulthood, and that tonic brain activity may play a potential mechanistic role in the relationship between AA and IC.

Trait mindfulness facets and inhibitory control

Consistent with our hypotheses, TM, particularly the AA facet, showed a significant association with IC. Instead of the global TM, higher AA predicted better ACC, selectively for the incongruent task condition which placed greater demands on conflict monitoring and controlled responding (Yeung et al., 2004). The association specifically to the AA facet and increased IC demand suggests that individuals who habitually attend deliberately to their actions(Baer et al., 2008) may be better able to maintain task goals and suppress automatic responses when interference is high. These not only replicate prior work showing that higher AA was associated with better performance on IC tasks (Lin et al., 2019) but also extend this association to be generalizable across both women and men.

Interestingly, sex-specific relationships between TM and IC performance were observed for the Ob and NJ facets. In the full sample, higher Ob scores were associated with slower RT among women but not men, suggesting that a heightened tendency to notice internal and external experiences (Baer et al., 2008) may be detrimental to the speed of IC performance. For some individuals, particularly women, greater observational awareness might coincide with increased processing of internal information,

leading to more cautious or slower responding (Golubickis et al., 2023; Lin et al., 2024) that are not necessarily accompanied by reliable gains in ACC (Heitz, 2014; Myers et al., 2022; Ratcliff & McKoon, 2008). However, this effect did not survive in the sensitivity analysis using the sub-sample with rsEEG data, possibly due to reduced statistical power (Button et al., 2013). Therefore, this women-specific Ob-IC relationship manifested by RT may be less robust and warrants further investigations into identifying other factors (i.e., mindfulness experience, anxiety-related reactivity) (Baer et al., 2008) contributing to this sex-related difference.

In contrast, NJ was associated with response stability across both the whole sample and sub-sample analyses in women. Specifically, higher NJ was related to lower CVRT among women but not men, indicating more stable and consistent responding even after adjusting for individual difference in mean RT. Such a sex-specific association was aligned with previous evidence that women exhibited greater variability in the speed-accuracy trade-off during IC tasks due to their wider RT distributions compared with men (Thakkar et al., 2014). Given that RT variability (e.g., CVRT) is often interpreted as an index of attentional stability and lapses (Antonini et al., 2013), this finding suggests that a nonjudgmental stance toward inner experiences may help women maintain more consistent engagement with task demands, potentially by reducing rumination or self-critical thoughts which can disrupt performance (Desrosiers et al., 2014; Eysenck et al., 2007; Lindsay & Creswell, 2017; Lyubomirsky et al., 2003). Together, the associations between AA and ACC, Ob and RT, and NJ and CVRT support the notion that different TM facets relate to different cognitive processes and strategies involved in IC performance.

Beyond behavioral task performance, the current study examined the neuroelectric correlations of IC and their associations with TM facets. Although the task-related modulation in P3 amplitude and latency (i.e., larger amplitude and longer latency for incongruent than congruent trials, Table 1) and the posterior topographical centralization (Fig. 3) were confirmed, the current study showed that AA was not associated with P3 measures, failing to replicate the previously reported relationship between AA and IC-related attentional allocation processes. (Lin et al., 2019). However, in Lin's study the flanker task was administered using a total of 512 trials through 8 separate blocks in which participants received feedback of their performance to reinforce accuracy and speed. Despite this design, the task performance at the sample level in their study were not only less accurate (~ 88%) and slower (421ms) compared to the current female sample (~ 96%, 400ms), particularly during the incongruent trials with higher cognitive demand (83% and 451ms in Lin's study compared to 92% and 424ms in the current study). It is possible that the IC demand experienced by the current sample was insufficient to elicit P3 amplitude that is needed to capture the attentional process in relation to AA.

Interestingly, the association of NJ with P3 amplitude was moderated by sex and IC demand. Specifically, the associations between NJ and P3 amplitude for the congruent and incongruent task conditions did not differ in men while in women NJ was more positively related to P3 amplitude during the incongruent than the congruent task conditions. Because larger P3 amplitude has been linked with superior attentional processing and subsequent behavioral task performance (Polich, 2007), these findings suggest the extent to which NJ may benefit attentional resource allocated to stimulus

evaluation can be different between men and women when the task demand for IC was high. This might also help explain the beneficial association of NJ with response stability (e.g., reduced CVRT) specifically observed in the current women participants. However, it should be noted that the simple slope analysis showed that NJ was not associated with P3 amplitude within each task condition and sex group, despite this association was positively trending toward significance for the incongruent task condition in women. Therefore, future research is needed to investigate whether NJ plays a meaningful role in women's attentional process in support of IC performance.

Resting EEG as a mediator: evidence for a suppressing pathway

The second aim was to test whether rsEEG mediates the relationship between TM and IC. Using a data-driven approach, we conducted targeted mediation analyses focusing on the AA-incongruent ACC association as well as women-only NJ-CVRT association. Of these two associations replicated in both the whole sample and the EEG sub-sample, no rsEEG measure was found to mediate the relationship between NJ and CVRT. This was likely because NJ is a facet to primarily indexes a reduced tendency to engage with judgmental thoughts and emotional reactivity that are more state-dependent or task-related in real time. It is possible that the relationship between NJ and response stability may operate more through these situation-specific processes in real time, rather than through baseline rsEEG (Eysenck et al., 2007; Weissman et al., 2006).

In the model exploring the mediating effect of rsEEG outcomes, upper alpha power during the EO condition significantly mediated the association between AA and incongruent ACC. Interestingly, this mediation represented a suppression effect that attenuated the direct positive association of AA with incongruent ACC. Traditionally, alpha power is interpreted as an index of cortical inhibition or "idling", with upper alpha activity being specifically linked task-specific functional inhibition and controlled selection processes (Jensen & Mazaheri, 2010; Klimesch, 2012; Klimesch et al., 2007). For instance, higher resting alpha corresponds to lower regional blood flow and less metabolically engaged baseline state (Goldman et al., 2002; Laufs et al., 2003; Scheeringa et al., 2012), such as the increased resting-state alpha over posterior regions during the EC condition as compared with the attenuated posterior alpha due to continuous visual input during the EO condition (Barry et al., 2007; Hartoyo et al., 2020).

Accordingly, EO upper alpha power may be interpreted as reflecting baseline inhibitory engagement under sensory input (Jensen & Mazaheri, 2010; Klimesch, 2012). Although there was a negative a-path (AA → EO upper alpha) selectively in the upper alpha bands under EO condition, suggesting a potential relationship between increased self-awareness to cortical activity specific to the processing of visual inputs, this association failed to reach significance in our sample, (p = .084). It is possible that TM facets do not robustly translate into specific resting-state EEG patterns in healthy young adults, even though mindfulness training can alter theta and alpha power at rest (Cahn & Polich, 2006; Lomas et al., 2015). Compared with intensive mindfulness training and long-term meditation experience that produce changes in alpha and theta activity at rest (Cahn & Polich, 2006; Lomas et al., 2015), the degree of TM

cultivated through everyday life experiences may not be sufficient to reshape baseline oscillatory dynamics in a consistent way (Dziego et al., 2024; Treves et al., 2024).

In contrast, the positive b-path (EO upper alpha → incongruent ACC) was significant, suggesting that individuals with more efficient cortical activity in response to the presence of visual stimuli showed higher ACC during task conditions with a greater IC demand. This replicates previous evidence that alpha activity at rest is related to cognitive performance and cognitive-control engagement. For example, Mahjoory et al. (2019) and Clements et al. (2021) suggest that greater resting alpha power reflects baseline network organization that supports attention and task ACC across cognitive contexts, and consistent with this interpretation, Cortes-Ospina et al. (2025) argued that higher power in faster alpha band may reflect cortical readiness or an optimized neural state to support cognitive engagement. The present positive b-path may indicate that individuals who maintained stronger upper alpha organization under sensory input may enter the IC task with greater readiness and therefore more likely to achieve higher ACC during incongruent trials.

Within this framework, the mediation findings suggest that although both AA and upper alpha power under EO condition contributed to better IC (c' path and b path), possibly via cognitive-attentional mechanisms (e.g., goal maintenance, reduced “autopilot”) (Baer et al., 2006; Teper et al., 2013) and enhanced neural efficiency and tonic cortical readiness, the AA-related shift in rsEEG may be characterized by somewhat more activated (less “idling”) cortical state that is less optimal for IC performance. As a result, the EEG pathway exerted by modulation of upper alpha under EO condition partially offsets the otherwise beneficial direct effect of AA on IC, producing a suppressing mediation pattern. This pattern suggests that AA-focused training may still produce IC gains when it is delivered in ways that promote more efficient baseline cortical activity reflected in preserved or strengthened EO upper alpha organization.

Strengths, limitations, and future directions

Methodological strengths of the current study included a large sample of both young women and men, the use of IAPF to define alpha bands and the other frequency bands of interest, and the examination of the moderation and mediation effects of sex and rsEEG. Nonetheless, several limitations should be acknowledged. First, the cross-sectional design precludes causal inferences. Although TM facets were conceptualized as predictors of IC and rsEEG, it is equally plausible that individual differences in IC or rsEEG influence the development of TM facets. Longitudinal or intervention studies are needed to determine causal directions. Second, the EEG sub-sample was smaller than the behavioral sample and may not be fully representative, raising the possibility of selection bias and reduced power to detect weaker effects (e.g., Ob–RT in women). Third, IC was indexed using a single modified flanker task that primarily captures the perceptual inhibition of the broader IC construct. It remains unknown whether similar TM–IC and EEG–IC relationships would emerge for the response inhibition domain of IC (e.g., go/no-go) or for other executive function domains (e.g., working memory, cognitive flexibility). Lastly, TM was assessed solely via self-reported questionnaire (FFMQ), which may be influenced by social desirability, introspective ability, or cultural response styles (Karl et al., 2020; Van Dam et al., 2018). Multi-

method assessments combining questionnaires with behavioral or momentary measures of everyday TM could help separate self-perceived mindfulness from in daily behavior and provide a more nuanced picture of TM and its cognitive correlations.

Future research could address these limitations by (a) implementing TM-training interventions that selectively target specific facets (e.g., AA vs. NJ) and track changes in both resting and task-related EEG indices; If particular facets more reliably support stable performance in women, while others are beneficial across sexes, it may be possible to prioritize or tailor practice components according to individual profiles. However, such applications will require replication and, ideally, experimental manipulation of specific facets; (b) expanding samples to include adolescents, older adults, and clinical populations to test generalizability; and (c) integrating additional moderators such as stress, sleep quality, or affective symptoms and mediators such as mind-wandering and emotional regulation which may shape how TM is expressed neurally and behaviorally.

Conclusion

In summary, this study shows that TM was selectively linked to IC in young adults. AA was associated with better ACC under task condition requiring greater IC, and NJ was related to more stable performance in women. EO upper alpha at rest was positively associated with incongruent ACC but did not serve as a straightforward beneficial mediator of the AA-IC relationship. Instead, the observed suppressing mediation suggests that TM may enhance IC, while its influence on baseline neural activation is modest and not fully aligned with the most advantageous resting state for this task. These findings underscore the importance of considering TM facets, sex differences, and behavioral and neural levels when characterizing how TM relates to IC.

Declarations

Author Contribution

A and G conceived and designed the study. A led the project, curated the data, conducted the analyses, prepared the figures/tables, and wrote the original draft. G supervised the study, guided the analytic approach and interpretation, and critically revised the manuscript; G is the corresponding author. B made major contributions to study methodology, subject recruitment and running, interpretation of findings, and substantive manuscript revisions. C contributed to methodology, subject recruitment and running, interpretation of findings, and manuscript revisions. D and E contributed to interpretation of the results and critically reviewed and revised the manuscript. F contributed to interpretation and provided additional review of the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgement

We thank Dr. Igor Fernandes for his helpful feedback and guidance on this project.

References

1. Antonini, T. N., Narad, M. E., Langberg, J. M., & Epstein, J. N. (2013). Behavioral correlates of reaction time variability in children with and without ADHD. *Neuropsychology*, *27*(2), 201–209.
2. Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment*, *13*(1), 27–45. https://doi.org/10.1177/1073191105283504
3. Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., Walsh, E., Duggan, D., & Williams, J. M. G. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment*, *15*(3), 329–342.
4. Barry, R. J., Clarke, A. R., Johnstone, S. J., Magee, C. A., & Rushby, J. A. (2007). EEG differences between eyes-closed and eyes-open resting conditions. *Clinical Neurophysiology*, *118*(12), 2765–2773.
5. Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641–1660.
6. Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy/bph077
7. Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822.
8. Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, *1124*(1), 1–38.
9. Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, *14*(5), 365–376.
10. Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*(2), 180.
11. Carmody, J., & Baer, R. A. (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. *Journal of Behavioral Medicine*, *31*, 23–33.
12. Clayson, P. E., Clawson, A., & Larson, M. J. (2011). Sex differences in electrophysiological indices of conflict monitoring. *Biological Psychology*, *87*(2), 282–289.
13. Clements, G. M., Bowie, D. C., Gyurkovics, M., Low, K. A., Fabiani, M., & Gratton, G. (2021). Spontaneous alpha and theta oscillations are related to complementary aspects of cognitive control in younger and older adults. *Frontiers in Human Neuroscience*, *15*, 621620.
14. Cortes-Ospina, M., Baumgartner, N. W., Nagy, C., Noh, K., Wang, C. H., & Kao, S. C. (2025). The relationship between cardiorespiratory fitness and resting-state cortical activation: An EEG study on power spectrum density. *International Journal of Psychophysiology*, 112600.

15. Cruz, D. (2021). Stress, Positive Psychological Resources, and Executive Functioning. *Psychiatry Depression & Anxiety*, *7*(1), 1–9. https://doi.org/10.24966/PDA-0150/100042
16. Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9–21.
17. Desrosiers, A., Vine, V., Curtiss, J., & Klemanski, D. H. (2014). Observing nonreactively: A conditional process model linking mindfulness facets, cognitive emotion regulation strategies, and depression and anxiety symptoms. *Journal of Affective Disorders*, *165*, 31–37.
18. Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168.
19. Dickenson, J., Berkman, E. T., Arch, J., & Lieberman, M. D. (2013). Neural correlates of focused attention during a brief mindfulness induction. *Social Cognitive and Affective Neuroscience*, *8*(1), 40–47.
20. Dziego, C. A., Bornkessel-Schlesewsky, I., Schlesewsky, M., Sinha, R., Immink, M. A., & Cross, Z. R. (2024). Augmenting complex and dynamic performance through mindfulness-based cognitive training: an evaluation of training adherence, trait mindfulness, personality and resting-state EEG. *Plos One*, *19*(5), e0292501.
21. Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336.
22. Gan, R., Wei, Y., Sun, L., Zhang, L., Wang, J., Zhu, T., Chen, S., & Xue, J. (2023). Age and sex-specific differences of mindfulness traits with measurement invariance controlled in Chinese adult population: A pilot study. *Heliyon*, *9*(9).
23. Goldman, R. I., Stern, J. M., Engel Jr, J., & Cohen, M. S. (2002). Simultaneous EEG and fMRI of the alpha rhythm. *Neuroreport*, *13*(18), 2487–2492.
24. Golubickis, M., Tan, L. B. G., Saini, S., Catterall, K., Morozovaite, A., Khasa, S., & Macrae, C. N. (2023). Knock yourself out: Brief mindfulness-based meditation eliminates self-prioritization. *Psychonomic Bulletin & Review*, *30*(1), 341–349.
25. Harada, C. N., Love, M. C. N., & Triebel, K. (2013). Normal cognitive aging. *Clinics in Geriatric Medicine*, *29*(4), 737.
26. Heitz, R. P. (2014). The speed-accuracy tradeoff: history, physiology, methodology, and behavior. *Frontiers in Neuroscience*, *8*, 150.
27. Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, *16*(3), 174–180.
28. Jensen, O., & Mazaheri, A. (2010). Shaping functional architecture by oscillatory alpha activity: gating by inhibition. *Frontiers in Human Neuroscience*, *4*, 186.
29. Karl, J. A., Prado, S. M. M., Gračanin, A., Verhaeghen, P., Ramos, A., Mandal, S. P., Michalak, J., Zhang, C. Q., Schmidt, C., & Tran, U. S. (2020). The cross-cultural validity of the Five-Facet Mindfulness Questionnaire across 16 countries. *Mindfulness*, *11*(5), 1226–1237.

30. Keith, J. R., Blackwood, M. E., Mathew, R. T., & Lecci, L. B. (2017). Self-reported mindful attention and awareness, go/no-go response-time variability, and attention-deficit hyperactivity disorder. *Mindfulness*, *8*(3), 765–774.
31. Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Research Reviews*, *29*(2–3), 169–195.
32. Klimesch, W. (2012). Alpha-band oscillations, attention, and controlled access to stored information. *Trends in Cognitive Sciences*, *16*(12), 606–617.
33. Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition–timing hypothesis. *Brain Research Reviews*, *53*(1), 63–88.
34. Knyazev, G. G., Slobodskoj-Plusnin, J. Y., Bocharov, A. V., & Pylkova, L. V. (2011). The default mode network and EEG alpha oscillations: an independent component analysis. *Brain Research*, *1402*, 67–79.
35. Laufs, H., Kleinschmidt, A., Beyerle, A., Eger, E., Salek-Haddadi, A., Preibisch, C., & Krakow, K. (2003). EEG-correlated fMRI of human alpha activity. *Neuroimage*, *19*(4), 1463–1476.
36. Lin, Y., Fisher, M. E., & Moser, J. S. (2019). Clarifying the relationship between mindfulness and executive attention: A combined behavioral and neurophysiological study. *Social Cognitive and Affective Neuroscience*, *14*(2), 205–215.
37. Lin, Y., White, M. L., Viravan, N., & Braver, T. S. (2024). Parsing state mindfulness effects on neurobehavioral markers of cognitive control: A within-subject comparison of focused attention and open monitoring. *Cognitive Affective & Behavioral Neuroscience*, *24*(3), 527–551.
38. Lindsay, E. K., & Creswell, J. D. (2017). Mechanisms of mindfulness training: Monitor and Acceptance Theory (MAT). *Clinical Psychology Review*, *51*, 48–59.
39. Liu, J., Zubieta, J. K., & Heitzeg, M. (2012). Sex differences in anterior cingulate cortex activation during impulse inhibition and behavioral correlates. *Psychiatry Research: Neuroimaging*, *201*(1), 54–62.
40. Logemann-Molnár, Z., Veres-Székely, A., Demetrovics, Z., & Logemann, H. N. A. (2024). Mindfulness and inhibitory control: Insights from the stop signal task with neutral and reward-associated stimuli. *Plos One*, 19(5), e0303384.
41. Lomas, T., Ivtzan, I., & Fu, C. H. Y. (2015). A systematic review of the neurophysiology of mindfulness on EEG oscillations. *Neuroscience & Biobehavioral Reviews*, *57*, 401–410.
42. Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, *8*, 213.
43. Lyubomirsky, S., Kasri, F., & Zehm, K. (2003). Dysphoric rumination impairs concentration on academic tasks. *Cognitive Therapy and Research*, *27*(3), 309–330.
44. MacAulay, R. K., Halpin, A., Andrews, H. E., & Boeve, A. (2022). Trait mindfulness associations with executive function and well-being in older adults. *Aging & Mental Health*, *26*(12), 2399–2406.

45. Mahjoory, K., Cesnaite, E., Hohlefeld, F. U., Villringer, A., & Nikulin, V. V. (2019). Power and temporal dynamics of alpha oscillations at rest differentiate cognitive performance involving sustained and phasic cognitive control. *Neuroimage*, *188*, 135–144.
46. Myers, C. E., Interian, A., & Moustafa, A. A. (2022). A practical introduction to using the drift diffusion model of decision-making in cognitive psychology, neuroscience, and health sciences. *Frontiers in Psychology*, *13*, 1039172.
47. Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *58*(4), 361–383.
48. Omura, K., & Kusumoto, K. (2015). Sex differences in neurophysiological responses are modulated by attentional aspects of impulse control. *Brain and Cognition*, *100*, 49–59.
49. Polich, J. (2007). Updating P300: an integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128–2148.
50. Pscherer, C., Bluschke, A., Mückschel, M., & Beste, C. (2021). The interplay of resting and inhibitory control-related theta-band activity depends on age. *Human Brain Mapping*, *42*(12), 3845–3857.
51. Ratcliff, R., & McKoon, G. (2008). The diffusion decision model: theory and data for two-choice decision tasks. *Neural Computation*, *20*(4), 873–922.
52. Scheeringa, R., Bastiaansen, M. C. M., Petersson, K. M., Oostenveld, R., Norris, D. G., & Hagoort, P. (2008). Frontal theta EEG activity correlates negatively with the default mode network in resting state. *International Journal of Psychophysiology*, *67*(3), 242–251.
53. Scheeringa, R., Petersson, K. M., Kleinschmidt, A., Jensen, O., & Bastiaansen, M. C. M. (2012). EEG alpha power modulation of fMRI resting-state connectivity. *Brain Connectivity*, *2*(5), 254–264.
54. Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. In *Nature Reviews Neuroscience* (Vol. 16, Number 4, pp. 213–225). Nature Publishing Group. https://doi.org/10.1038/nrn3916
55. Teper, R., Segal, Z. V., & Inzlicht, M. (2013). Inside the mindful mind: How mindfulness enhances emotion regulation through improvements in executive control. *Current Directions in Psychological Science*, *22*(6), 449–454.
56. Thakkar, K. N., Congdon, E., Poldrack, R. A., Sabb, F. W., London, E. D., Cannon, T. D., & Bilder, R. M. (2014). Women are more sensitive than men to prior trial events on the stop-signal task. *British Journal of Psychology*, *105*(2), 254–272.
57. Treves, I. N., Pichappan, K., Hammoud, J., Bauer, C. C. C., Ehmann, S., Sacchet, M. D., & Gabrieli, J. D. E. (2024). The mindful brain: A systematic review of the neural correlates of trait mindfulness. *Journal of Cognitive Neuroscience*, *36*(11), 2518–2555.
58. Turjeman-Levi, Y., Itzchakov, G., & Engel-Yeger, B. (2024). Executive function deficits mediate the relationship between employees' ADHD and job burnout. *AIMS Public Health*, *11*(1), 294.
59. Van Dam, N. T., Van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., Meissner, T., Lazar, S. W., Kerr, C. E., & Gorchov, J. (2018). Mind the hype: A critical evaluation and prescriptive

agenda for research on mindfulness and meditation. *Perspectives on Psychological Science*, *13*(1), 36–61.

60. Warren, T., Ashrafi, J., Shende, S., Lydon, E., & Mudar, R. (2024). Resting state electroencephalography and inhibitory control in cognitively unimpaired older adults. *Innovation in Aging*, *8*(Suppl 1), 707.
61. Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: conflict monitoring and the error-related negativity. *Psychological Review*, *111*(4), 931.

Tables

Table 1

Descriptive Statistics for Demographics, Trait Mindfulness, Inhibitory Control Performance, Resting EEG Power, and P3 components by sample size and Sex.

Category	Whole sample		Sub-sample	
	Men	Women	Men	Women
n	134	149	80	94
Study 1	111	125	58	71
Study 2	23	24	22	23
Age (years)	23.35 ± 3.27	22.93 ± 3.11	23.11 ± 3.09	22.45 ± 2.70
Height (cm)	173.91 ± 7.73	164.05 ± 6.52	174.04 ± 7.63	164.54 ± 6.21
Weight (kg)	74.83 ± 11.55	63.62 ± 12.33	75.61 ± 11.74	63.34 ± 11.33
BMI (kg/m²)	24.72 ± 3.37	23.59 ± 4.15	24.98 ± 3.74	23.37 ± 3.82
Ob	25.28 ± 5.12	26.07 ± 5.04	24.69 ± 5.58	26.54 ± 5.11
De	25.67 ± 4.24	25.87 ± 5.65	25.52 ± 4.22	25.79 ± 4.57
AA	26.48 ± 5.17	24.68 ± 5.84	26.55 ± 5.71	24.65 ± 5.96
NJ	25.52 ± 5.95	25.06 ± 6.52	25.15 ± 6.15	25.35 ± 6.55
NR	22.19 ± 3.57	20.35 ± 3.84	22.06 ± 3.56	20.27 ± 3.88
FFMQ(Total)	125.15 ± 13.16	122.03 ± 14.56	123.97 ± 14.21	122.60 ± 14.15
Cong RT (ms)	356.74 ± 45.89	376.64 ± 56.55	361.14 ± 47.50	372.92 ± 57.44
Cong CVRT	0.16 ± 0.04	0.17 ± 0.04	0.16 ± 0.05	0.16 ± 0.04
Cong ACC (%)	98.84 ± 1.81	98.03 ± 3.07	98.73 ± 2.00	98.24 ± 2.47
Inc RT (ms)	403.91 ± 44.10	426.35 ± 60.24	408.33 ± 44.80	423.53 ± 56.90
Inc CVRT	0.15 ± 0.03	0.16 ± 0.03	0.15 ± 0.03	0.16 ± 0.03
Inc ACC (%)	92.49 ± 5.77	92.78 ± 7.08	92.18 ± 5.95	92.44 ± 6.07
Cong P3 Amp (μV)	—	—	8.75 ± 5.01	8.68 ± 5.87
Cong P3 Lat (ms)	—	—	366.24 ± 47.05	381.58 ± 62.01
Inc P3 Amp (μV)	—	—	9.32 ± 4.99	9.51 ± 5.68

Note. Values are mean ± standard deviation. BMI = body mass index; FFMQ = Five Facet Mindfulness Questionnaire; Ob = observing; De = describing; AA = acting with awareness; NJ = nonjudging of inner experience; NR = nonreactivity to inner experience; Cong = congruent; Inc = incongruent; RT = reaction time; ACC = accuracy; CVRT = coefficient of variation of RT (unitless); EO = eye-open; EC = eye-close; Amp = amplitude; Lat = latency.

Category	Whole sample		Sub-sample	
	Men	Women	Men	Women
Inc P3 Lat (ms)	—	—	400.56 ± 50.16	421.61 ± 63.20
EO Theta (μV²)	—	—	0.44 ± 0.22	0.49 ± 0.23
EO Alpha-1 (μV²)	—	—	0.40 ± 0.31	0.44 ± 0.33
EO Alpha-2 (μV²)	—	—	0.67 ± 0.42	0.71 ± 0.43
EO Upper alpha (μV²)	—	—	0.06 ± 0.23	0.26 ± 0.31
EO Beta (μV²)	—	—	-0.61 ± 0.19	-0.47 ± 0.21
EC Theta (μV²)	—	—	0.57 ± 0.24	0.64 ± 0.25
EC Alpha-1 (μV²)	—	—	0.73 ± 0.32	0.83 ± 0.35
EC Alpha-2 (μV²)	—	—	1.09 ± 0.37	1.24 ± 0.42
EC Upper alpha (μV²)	—	—	0.34 ± 0.27	0.54 ± 0.31
EC Beta (μV²)	—	—	-0.52 ± 0.20	-0.39 ± 0.19

Note. Values are mean ± standard deviation. BMI = body mass index; FFMQ = Five Facet Mindfulness Questionnaire; Ob = observing; De = describing; AA = acting with awareness; NJ = nonjudging of inner experience; NR = nonreactivity to inner experience; Cong = congruent; Inc = incongruent; RT = reaction time; ACC = accuracy; CVRT = coefficient of variation of RT (unitless); EO = eye-open; EC = eye-close; Amp = amplitude; Lat = latency.

Table 2

Summary of Moderation Analyses with Significant Effect of Trait Mindfulness Using the Whole Sample and Sub-sample.

Fixed effects	**Whole Sample (n = 283)**				**Sub-sample (n = 174)**			
	Ob - RT							
	$\chi^2(9) = 5{,}379.480$, $p < .001$*, $R^2_{conditional} = .940$				$\chi^2(9) = 382.349$, $p < .001$*, $R^2_{conditional} = .951$			
	β	**SE**	**t**	**p**	**β**	**SE**	**t**	**p**
Ob	0.637	0.593	1.075	.283	1.330	0.722	1.841	.067
Con	-24.228	0.603	-40.206	< .001*	-24.528	0.713	-34.389	< .001*
Sex	-11.809	3.049	-3.873	< .001*	-7.507	4.012	-1.871	.063
Ob × Con	-0.071	0.119	-0.596	.552	-0.087	0.132	-0.657	.512
Ob × Sex	-1.321	0.594	-2.225	.027*	-1.096	0.726	-1.511	.133
Con × Sex	0.606	0.603	1.005	.316	0.768	0.713	1.076	.283
Ob × Con × Sex	-0.020	0.119	-0.169	.866	-0.076	0.132	-0.574	.567
	AA - ACC							
	$\chi^2(9) = 2868.930$, $p < .001$*, $R^2_{conditional} = .508$				$\chi^2(9) = 167.692$, $p < .001$*, $R^2_{conditional} = .485$			
	β	**SE**	**t**	**p**	**β**	**SE**	**t**	**p**
AA	0.118	0.044	2.681	.008*	0.084	0.046	1.839	.068
Con	2.908	0.172	16.903	< .001*	3.078	0.216	14.239	< .001*
Sex	-0.074	0.239	-0.309	.758	-0.170	0.270	-0.632	.528
AA × Con	-0.069	0.031	-2.202	.029*	-0.078	0.037	-2.111	.036*
AA × Sex	-0.045	0.043	-1.062	.259	-0.055	0.045	-1.225	.222
Con × Sex	0.336	0.172	1.951	.052	0.263	0.216	1.215	.226

Note. * $p < .05$; ⁺ values are rounded to three decimals; 0.000 indicates |x| < 0.0005. RT = reaction time; Ob = observing; Con = congruency; BMI = body mass index; AA = acting with awareness; CVRT = coefficient of variation of RT; NJ = nonjudging of inner experience.

Fixed effects	Whole Sample (n = 283)				Sub-sample (n = 174)			
AA × Con × Sex	-0.002	0.031	-0.077	.939	0.016	0.037	0.443	.658
	NJ - CVRT							
	$\chi^2(9) = 34.964$, $p < .001$*, $R^2_{conditional} = .684$				$\chi^2(9) = 22.812$, $p = .007$*, $R^2_{conditional} = .709$			
	β	**SE**	**t**	**p**	**β**	**SE**	**t**	**p**
NJ	0.000⁺	0.000⁺	-1.365	0.173	0.000⁺	0.000⁺	-1.136	.258
Con	0.004	0.001	4.873	< .001*	0.004	0.001	3.697	< .001*
Sex	-0.005	0.002	-2.722	0.007	-0.003	0.003	-0.985	.326
NJ × Con	0.000⁺	0.000⁺	0.232	0.816	0.000⁺	0.000⁺	0.828	.409
NJ × Sex	0.001	0.000⁺	2.308	0.022*	0.001	0.000⁺	2.203	.029*
Con × Sex	0.000⁺	0.001	-0.192	0.848	0.001	0.001	0.965	.336
NJ × Con × Sex	0.000⁺	0.000⁺	-0.190	0.849	0.000⁺	0.000⁺	-0.289	.773
	NJ - P3 Amplitude							
	—				$\chi^2(9) = 37.447$, $p < .001$*, $R^2_{conditional} = .909$			
	β	**SE**	**t**	**p**	**β**	**SE**	**t**	**p**
NJ	—	—	—	—	0.096	0.063	1.520	.130
Con	—	—	—	—	-0.344	0.090	-3.837	< .001*
Sex	—	—	—	—	0.230	0.410	0.562	.575
NJ × Con	—	—	—	—	-0.023	0.014	-1.633	.104
NJ × Sex	—	—	—	—	-0.001	0.063	-0.023	.982
Con × Sex	—	—	—	—	0.062	0.090	0.686	.494
NJ × Con ×	—	—	—	—	0.037	0.014	2.640	.009*

Note. * $p < .05$; ⁺ values are rounded to three decimals; 0.000 indicates |x| < 0.0005. RT = reaction time; Ob = observing; Con = congruency; BMI = body mass index; AA = acting with awareness; CVRT = coefficient of variation of RT; NJ = nonjudging of inner experience.

Fixed effects	Whole Sample (n = 283)	Sub-sample (n = 174)
Sex		

Note. * $p < .05$; + values are rounded to three decimals; 0.000 indicates |x| < 0.0005. RT = reaction time; Ob = observing; Con = congruency; BMI = body mass index; AA = acting with awareness; CVRT = coefficient of variation of RT; NJ = nonjudging of inner experience.

Figures

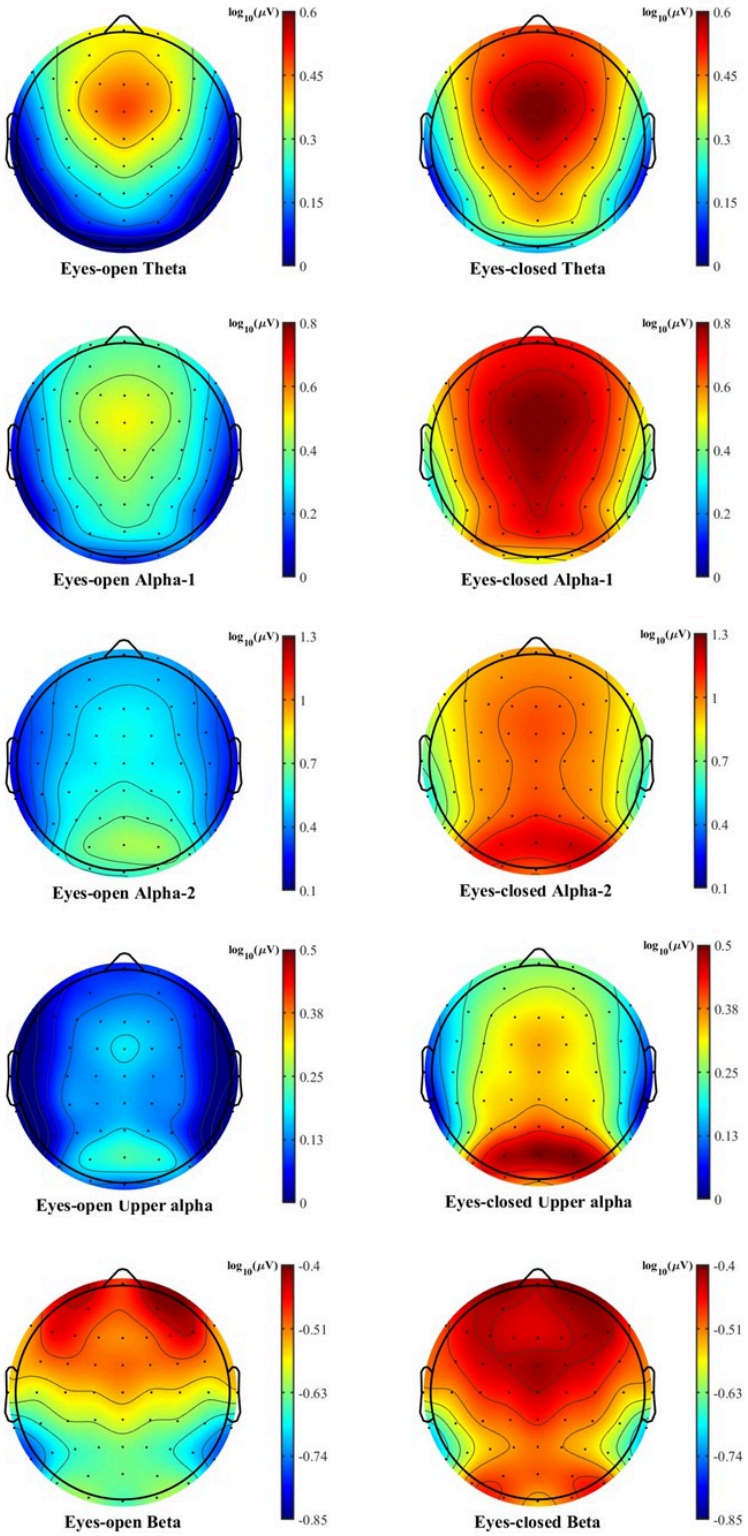


Figure 1

Resting-state EEG topographies for eyes-closed and eyes-open conditions in theta, alpha-1, alpha-2, upper alpha, and beta bands defined by individual alpha peak frequency.

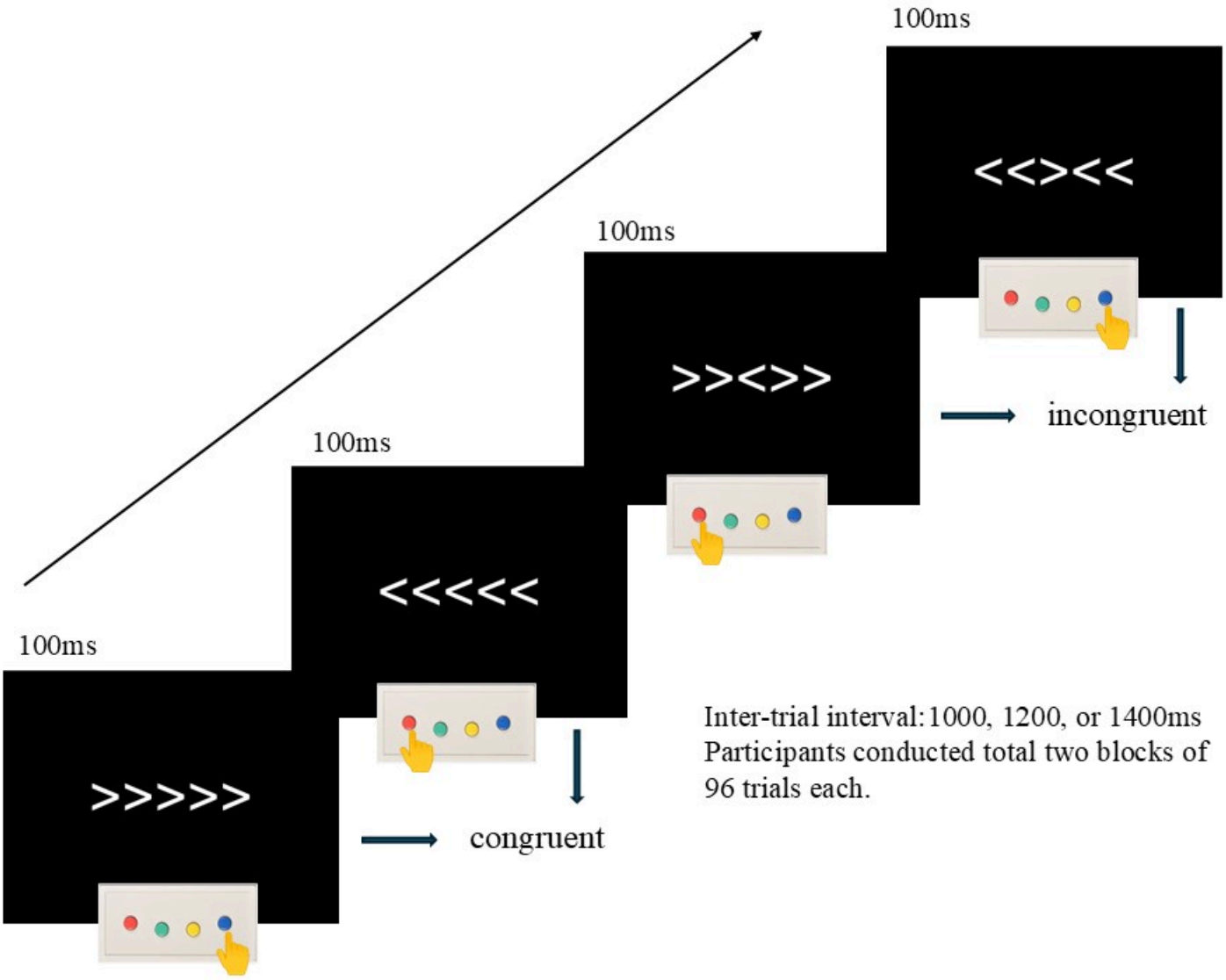


Figure 2

The figure illustrates the structure of the flanker task. Each stimulus was presented for 100 ms on the screen with randomized inter-trial intervals of 1000 ms, 1200 ms, and 1400 ms.

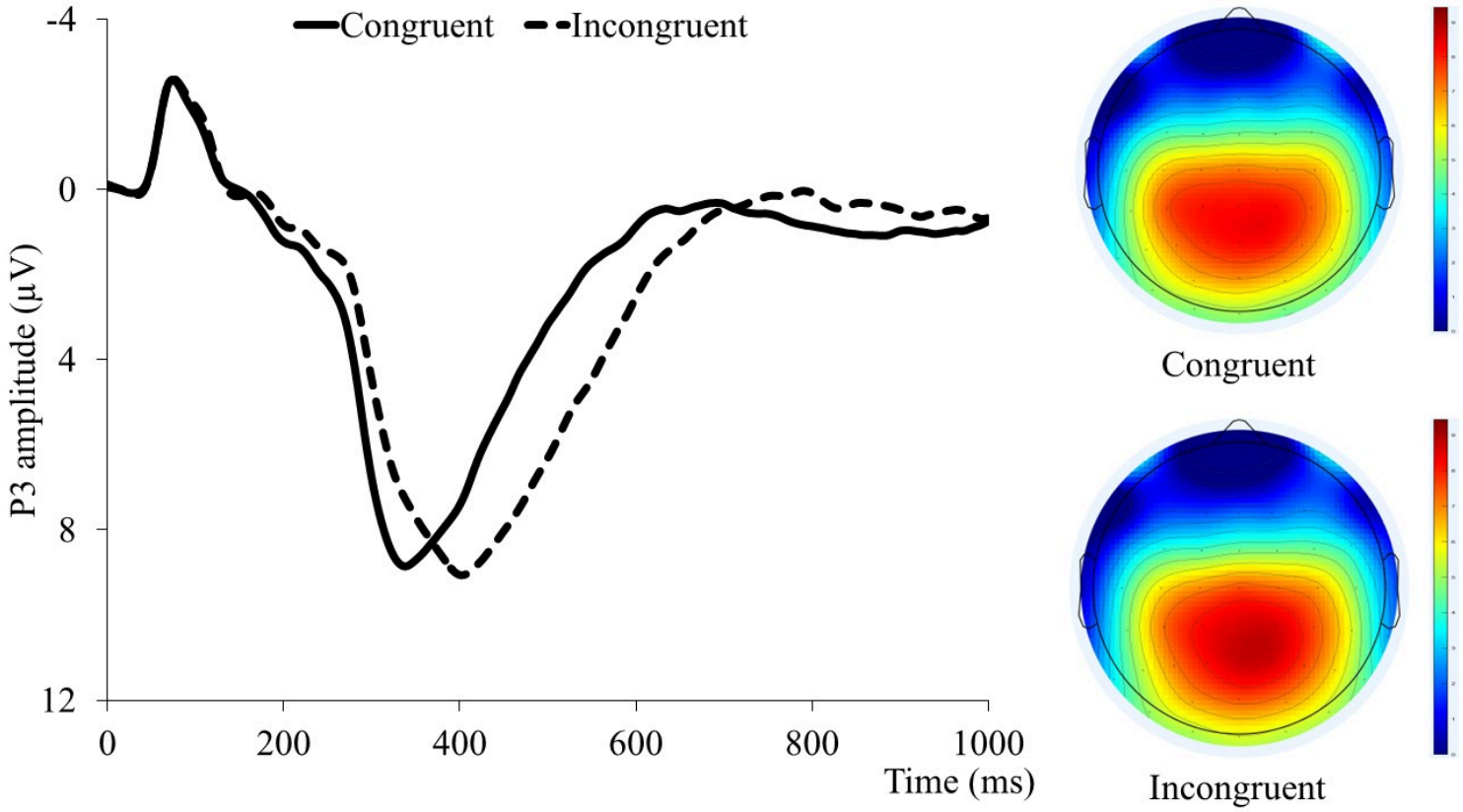


Figure 3

ERP waveforms and scalp topographies for congruent and incongruent trials (350–400 ms mean amplitude).

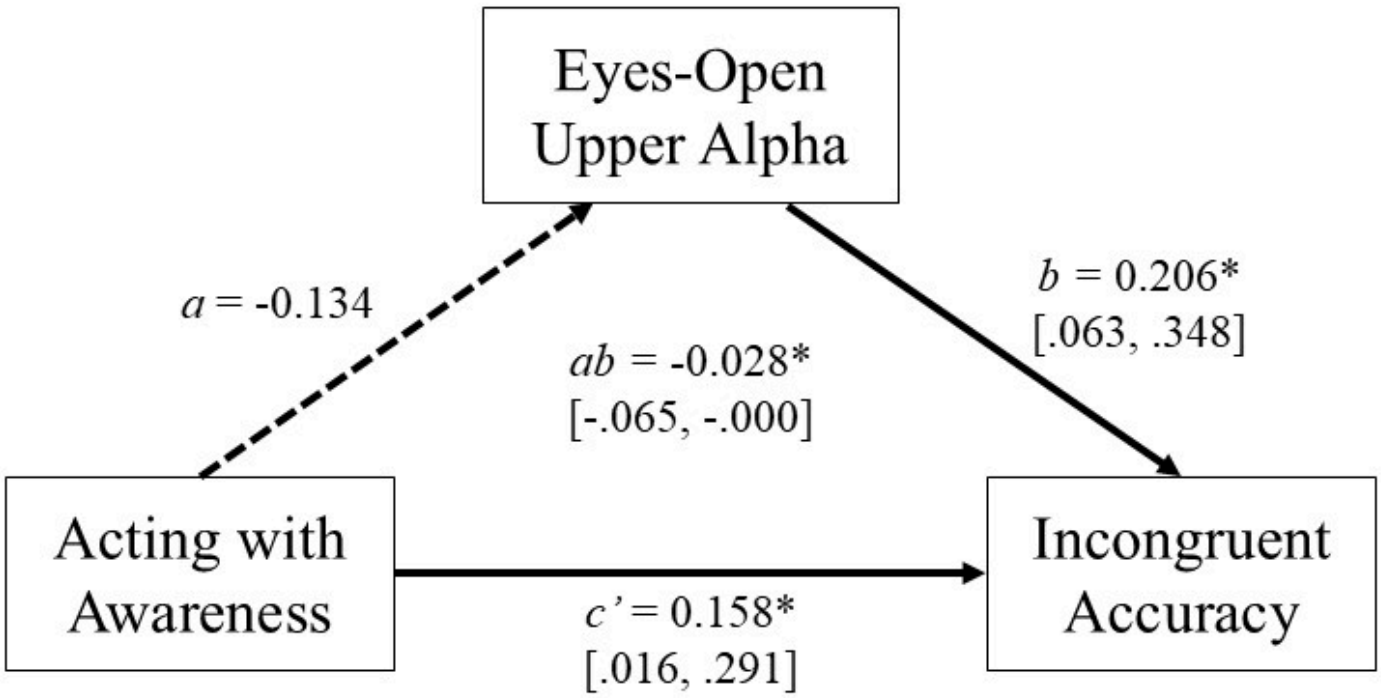


Figure 4

Mediation of Acting with Awareness (X) on incongruent-trial accuracy (Y) via eyes-open upper alpha power (M). Solid lines denote significant paths ($p < .05$) while dotted lines denote a non-significant path.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplement1.docx