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Cognitive Psychology

Does a 15-Minute Brief Mindfulness Breathing Exercise Temporarily Enhance Inhibitory Control and Cognitive Flexibility? A Within-Subject Experimental Approach

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Intensive mindfulness practices have been shown to improve cognitive abilities such as executive functions. However, most of these mindfulness-based practices require the participants to be involved either an extended immersive experience or repeated daily practice that may span over multiple weeks or months. Extending from the promising effect of intensive mindfulness training, recent studies have also suggested that a single session of brief mindfulness training is sufficient to temporarily enhance cognitive functions. However, the positive effect of brief mindfulness was not always consistent. In view of the inconsistent findings, the current study aims to critically examine the effectiveness of a single-session 15-minute brief mindfulness exercise on both inhibitory control and task-switching using a within-subject experimental design (N = 117). Contrary to our hypothesis, we did not find any evidence that engaging in a brief mindfulness exercise enhanced performance in the flanker task or color-shape task-switching paradigm. These results suggest that a mindfulness intervention of short duration may not be sufficient to immediately enhance higher-order cognitive processes such as inhibitory control and task-switching.

Interest in the psychological effects of cultivating mindfulness—the awareness that emerges through intentionally attending to one's moment-to-moment experience in a non-judgmental and accepting way (Kabat-Zinn, 2003; Shapiro et al., 2008)—has increased rapidly in recent years (Brown & Ryan, 2003; Jha et al., 2015; van Vugt & Jha, 2011). There are numerous studies that have demonstrated the benefits of mindfulness on well-being outcomes, including improvements in life satisfaction, positive affectivity, physical health, sleep quality, and reduction in stress, anxiety, and depressive symptoms (Brown & Ryan, 2003; de Vibe et al., 2018; Henriksson et al., 2016; Huang et al., 2015; Shapiro et al., 2008; Song & Lindquist, 2015). There is also an accumulating body of evidence that mindfulness-based practices provide health benefits such as improvement in sleep quality, inflammation, and cortisol levels (Creswell et al., 2012; Doorley et al., 2021; Gardi et al., 2022).

Beyond its benefits on both physical and mental health, mindfulness practices have also been shown to lead to improvement in cognitive abilities (Chambers et al., 2008; Jha et al., 2010; Moore & Malinowski, 2009). One aspect of cognitive abilities that have been closely linked to mindfulness is executive functions—a multifaceted construct of higher-order cognitive processes such as inhibitory control, task-switching, and working memory which are responsible for controlling and regulating thoughts and actions to achieve a goal (Hartanto & Yang, 2020; Miyake et al., 2000). The close link between mindfulness and executive functions is well-expected, given that the focused attention and cognitive monitoring in mindful awareness appear to share theoretical overlap with executive functions (Gallant, 2016; Holas & Jankowski, 2013; Raffone & Srinivasan, 2017). Moreover, mindfulness practice is postulated to promote a state of calmness and the capacity to be aware of attentional focus in a given moment, leading to the ability to allocate cognitive resources in a goal-directed manner (Larson et al., 2013; Vago & Zeidan, 2016).

Indeed, a growing body of research on intensive mindfulness-based practice shows promise in improving multi-

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ple domains of executive functions (Ainsworth et al., 2013; Chambers et al., 2008; Moore & Malinowski, 2009). For instance, Allen and colleagues found that 19 participants who were assigned to practice mindfulness meditation for 6 weeks performed significantly better in inhibitory control, compared to the participants who were assigned to a control condition (Allen et al., 2012). Similarly, Mrazek (2013) found that undergraduates who engaged in a 2-week mindfulness training program experienced enhanced working memory capacity as compared to those who did not. Overall, studies have shown that individuals who engage in intensive mindfulness training experience improvements in executive functions compared to individuals who are assigned to a control group (Quach et al., 2016; Ron-Grajales et al., 2021; Wong et al., 2017).

Besides evidence from intensive mindfulness training, recent studies have suggested that a single session of brief mindfulness training is sufficient to temporarily enhance cognitive functions. Supporting this notion was a recent study where Jankowski and Holas (2020) found that a 10-minute mindfulness exercise relative to control enhanced general efficiency of cognitive processes in task-switching tasks. Similarly, Mrazek et al. (2012) demonstrated that an 8-minute mindfulness breathing exercise contributed to less variable reaction time and fewer errors of commission during a sustained attention task. However, the cognitive benefit of brief mindfulness exercise is not always consistent. For example, Quek et al. (2021) conducted two high-powered experiments and failed to find any working memory capacity enhancement in a 15-minute mindfulness breathing exercise.

Purpose of the Current Study

In view of the inconsistent findings, the current study aims to critically examine the effectiveness of a single-session 15-minute brief mindfulness exercise on executive functions. Building upon existing studies, two major improvements were made. First, expanding from Quek et al. (2021) that solely focused on working memory capacity, the current study tapped into the other two major aspects of executive functions, which are inhibitory control and task-switching (Diamond, 2013; Quek et al., 2021). To improve the construct validity and reliability of our inhibitory control and task-switching task, a rank-ordered binning procedure was used to produce a single comprehensive score that combines speed and accuracy (Draheim et al., 2016; Hughes et al., 2014). In addition, the current study included a secondary measure of stress for an exploratory analysis, recognizing the established effect of mindfulness interventions in reducing stress (Chiesa & Serretti, 2009; Pascoe et al., 2017; Sharma & Rush, 2014). Second, we employed a within-person experimental approach to increase statistical power and minimise error rates due to individual differences (Charness et al., 2012; Hartanto et al., 2020, p. 2023). Counterbalancing was used to control for order effects by requiring participants to undergo both the intervention and control conditions, and a one-week washout period between the two conditions was used to minimise carryover effects. Taken together, based on the theoretical overlap between mindfulness and executive functions (Gallant, 2016; Raffone & Srinivasan, 2017) as well as the role of mindfulness in promoting the ability to allocate cognitive resources in a goal-directed manner (Larson et al., 2013), we hypothesized that participants would demonstrate higher inhibitory control and task-switching when they were instructed to perform a 15-minute mindfulness breathing exercise as compared to control.

Method

Transparency and Openness

This study was not pre-registered. We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the sections that follow (Simmons et al., 2012). The relevant materials, data, and code necessary for reproducing our analyses have been made publicly available on ResearchBox (#825; https://researchbox.org/825).

All analyses were conducted in JASP version 0.17.3 (JASP Team, 2023). Data visualization and scale reliability calculations were conducted in R version 4.3.1 (RStudio Team, 2023) using ggpubr version 0.64.0 (Kassambara, 2023), ggplot2 version 3.4.3 (Wickham, 2016), and gridExtra version 2.3 (Auguie, 2017) for data visualization and psych version 2.3.62.5 (Revelle, 2023) for scale reliabilities.

Participants

We recruited a total of 132 participants from a local university in Singapore, who participated for either course credits or cash compensation of S$13. We aimed to recruit as many participants as possible to maximize our statistical power, with a minimum aim of 100 participants to achieve at least 80% power to detect an effect size of $|d| = 0.30$ (two-tailed). Data analysis was only conducted after we ended our final data collection. Fifteen participants were excluded from our analyses as they failed the attention checks embedded in our study, resulting in a final sample of 117 participants (Table 1).[1] The final sample showed 80% power for $|d| = 0.26$, 90% power for $|d| = 0.30$, and 95% power for $|d| = 0.33$. All participants gave informed consent to participate in the study prior to the onset of the experiment and data collection was approved by the local Institutional Review Board [IRB-22-011-A015(222)].

1 All analyses were also repeated with the inclusion of the participants who failed the attention check (i.e., total N=132) and the results of these analyses are reported in the Results section.

Table 1. Demographics

Characteristic	*M* (*SD*) or %	Range
Sex (% Female)	78.0%	-
Ethnicity (% Chinese)	78.0%	-
Age (Years)	21.86 (1.90)	18-26
Household Income[1]	4.34 (2.50)	1-9
Personal Income[2]	1.90 (1.21)	1-7
Subjective Socioeconomic Status[3]	5.85 (1.39)	2-8

Note. Demographics data on 1 participant was missing
[1] Participants rated their household income on a 9-point scale (*1*=Less than $2,500, *2*=$2,500–$4,999, *3*=$5,000–$7,499, *4*=$7,500–$9,999, *5*=$10,000–$12,499, *6*=$12,500–$14,999, *7*=$15,000–$17,499, *8*=$17,500–$19,999, *9*=$20,000).
[2] Participants rated their personal income on a 9-point scale (*1*=$0, *2*=$1-$500, *3*=$501-$1,000, *4*=$1,001–$1,500, *5*=$1,501–$2,000, *6*=$2,001–$2,500, *7*=$2,501–$3,000, *8*=$3,001–$3,500, *9*=More than $3,500)
[3] Item was measured using a ladder which represented where people stood in society, and participants had to estimate where one stood on the ladder (Adler et al., 2000).

Procedure

The study consisted of a within-subjects experimental design (Mindful Breathing vs. Mind Wandering) where participants were randomly assigned using a random number generator to one of the two conditions in their first session and were thereafter assigned to the other condition in a second session one week later (Figure 1). The time gap of at least one week served to minimize practice effects on the cognitive tasks and served as a washout period to allow the effects of the experimental manipulation to dissipate. Moreover, counterbalancing was used to negate carry-over effects. Half of the participants completed the Mindful Breathing condition first followed by the Mind Wandering condition in their second session, while the other half completed the conditions in reverse order.

The study was conducted in the Psychology Lab of a local university where desktop computers were provided. Instructions to participants, such as “Put your mobile phones on silent mode and do not use your phone throughout the study”, were given verbally by the experimenter before an email containing the link to the Qualtrics survey was sent to the participants. Experimenters were also instructed to monitor the whole experiment in the Psychology Lab to ensure the quality of our data collection. None of the participants were using their phones while completing the mindfulness intervention and cognitive tasks.

Once participants clicked on the link, they were redirected to the informed consent page. Thereafter, participants in the Mindful Breathing condition heard a 15-minute audio track over earphones, consisting of instructions to exercise mindful breathing. Meanwhile, participants in the Mind Wandering condition heard a 15-minute audio track that directed them to let their mind wander, with no mindfulness advice given. The audio track was developed by Hafenbrack et al. (2014) and adapted from Arch and Craske (2006) and Clinton et al. (2018). Following the audio tracks, participants answered two manipulation check questions and then completed two cognitive tasks, which served as the dependent measures. The first outcome of interest, inhibitory control, was assessed via the flanker task (Hartanto & Yang, 2020; von Bastian et al., 2013). The second outcome of interest, the ability to task-switch, was assessed via the color-shape switching task (Rubin & Meiran, 2005; von Bastian et al., 2013). Both tasks were administered via Tatool (von Bastian et al., 2013).

To maximize data quality, we embedded one attention check and one honesty check to ensure that participants were attentive and truthful in their response, and one manipulation check to ensure that participants were fully immersed in either the mindfulness or mind wandering condition. After participants heard the 15-minute audio tracks, two questions regarding the contents of the audio clip were included, requiring participants to “describe what they were told in the audio clip” and “choose the option which best describes the contents of the audio”. This ensured that participants were paying attention during the manipulation. All participants passed the attention check regarding the audio content. At the end of each session, participants had to answer attention check and honesty check questions. Participants were given a distractor preamble about recycling but were instructed to ignore it and select the option “Other” to show that they were paying attention during the study. Furthermore, participants were asked, “After listening to the recording, how much do you feel absorbed in the present moment?” on a seven-point scale (1 = *Not at all absorbed*, 7 = *Extremely absorbed*), as a manipulation check to measure absorption. The manipulation check was adapted from Clinton et al. (2018) and Mrezek et al. (2013). In addition, participants were asked if they were honest in their responses throughout the course of the study, and demographic variables (sex, race, age, household income, personal income, and subjective socioeconomic status) were collected at the end of the second session. All participants also passed the honesty check.

As a secondary outcome of interest, we added two stress measures, pre-manipulation (before the audio track was played) and post-manipulation (after the audio track was played), via three items (*stress, worry, and calm*) on a five-point scale (1 = *Not at all,* 5 = *Extremely*).

Key Materials

Experimental Manipulation

During the mindful breathing condition, participants heard a 15-minute audio track consisting of “Now we are going to do a focus breathing exercise for 15 minutes [...] Bringing your awareness to your body, focus your attention on the sensations of touch and pressure, where your body makes contact with the chair [...] To help you pay attention to your breathing, place your hand on your lower abdomen and become aware of the change in sensations where your hand makes contact with your abdomen [...] Pay attention as best you can to the change in physical sensations in the lower abdomen, all the way through as the breath enters your body on the in-breath and all the way through as the breath leaves your body on the out-breath [...] There is no need to think about the breath, just experience the sensations of it, and there is no need to try to control the breathing in any way, simply let the breath be natural [...]

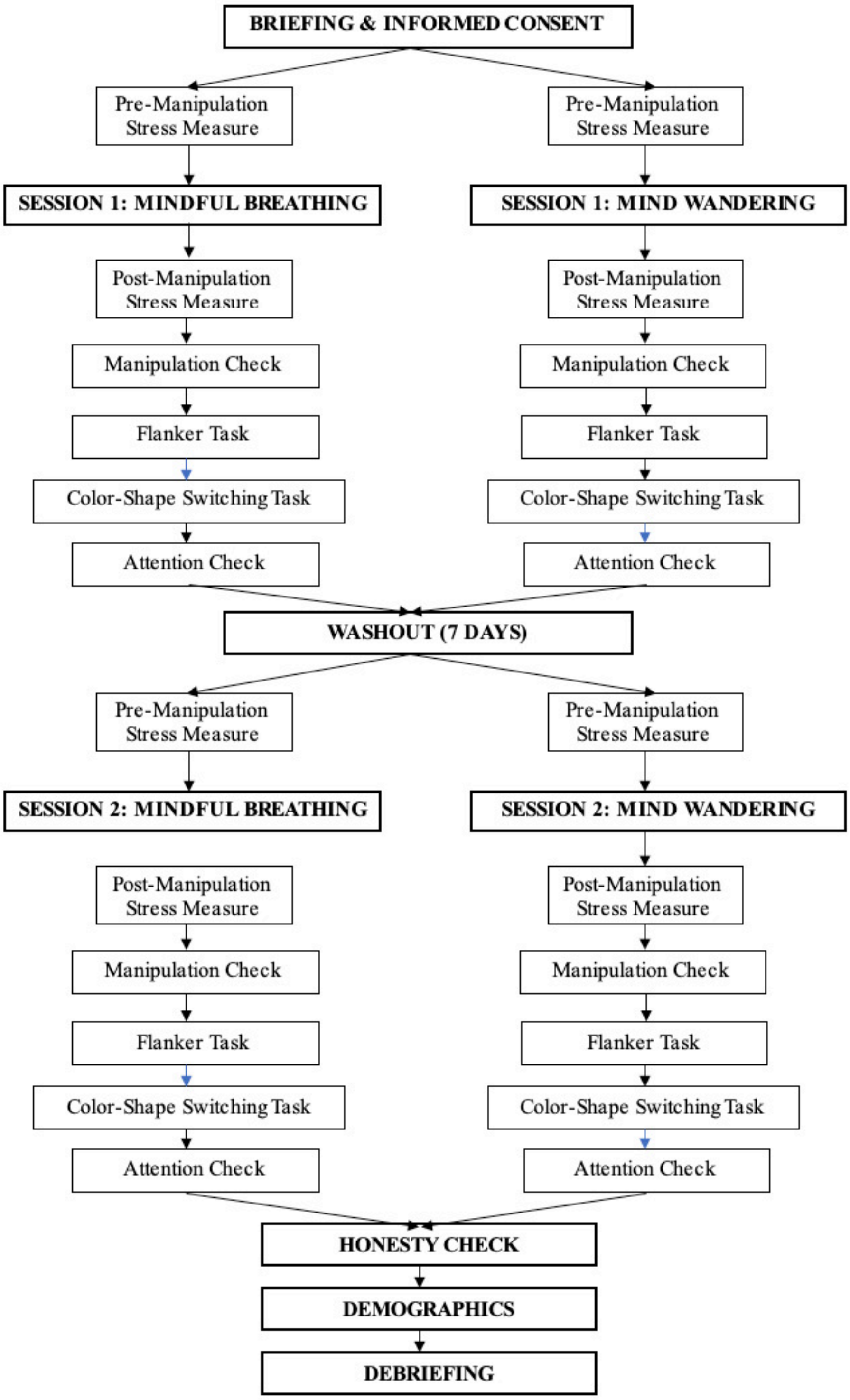

Figure 1. Overall Procedure

When you notice that your awareness is no longer on the breath, acknowledge briefly and gently where the mind has been, then gently bring your awareness back to the change in physical sensations in your lower abdomen, renewing your intention to pay attention to the breath going in and coming out [...] Focus your awareness on the sensations of slight stretching as the abdomen rise with each in-breath and the gentle deflation as it falls with each out-breath [...] Now when you are ready, slowly and gently open your eyes".

During the mind wandering condition, participants heard a 15-minute audio track consisting of such as "Now we're going to do an exercise for 15 minutes [...] Now simply think about whatever comes to mind, let your mind wander freely without thinking about anything in particular [...] Let your mind roam as it normally would [...] Allow your

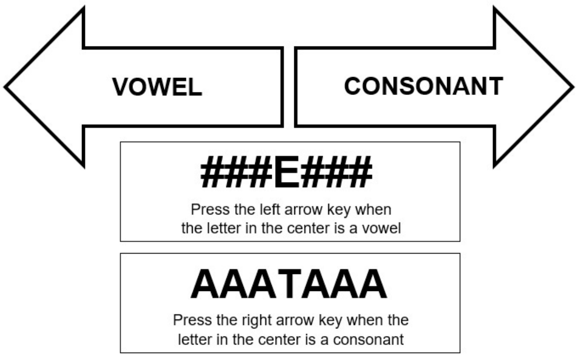

Figure 2. Flanker Task

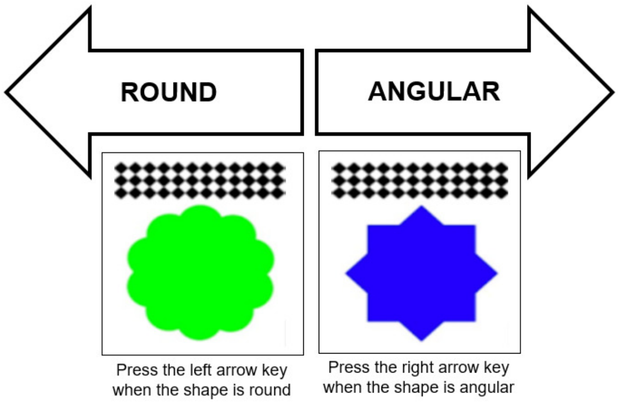

Figure 3. Color-Shape Switching Task

thoughts to wander wherever they may go [...] Go ahead and follow whatever thoughts that come to mind [...] Continue letting your mind wander, allowing your thoughts to wander wherever they may go"

Stress Measure

Perceived stress was measured as an exploratory outcome, after exposure to the intervention, via three items (*stress*, *worry*, and *calm*) on a five-point scale (1 = *Not at all*, 5 = *Extremely*), where the item "calm" was reverse-coded. The stress level of each participant (Mindful Breathing: pre-intervention α = .79, post-intervention α = .81; Mind Wandering: pre-intervention α = .76, post-intervention α = .83) in each of the condition was computed by taking the mean of the three items on the scale.

Cognitive Measures

The flanker task (Figure 2; Hartanto & Yang, 2020; von Bastian et al., 2013) first showed a line-up of seven characters (letters and symbols) in the middle of the screen, then required participants to make directional responses (left or right) according to the letter in the center. Depending on the central letter, participants would have to press the left arrow key when it was a vowel, and the right arrow key when it was a consonant. During congruent trials, the distractors and target are of the same category (e.g., "AAAEAAA"), while during the incongruent trials, the distractors and target are in different categories (e.g., "AAATAAA"). During neutral trials, the target is surrounded by symbols (e.g., "###E###") that did not correspond to any arrow key presses. In total, there were 12 practice trials and 144 main trials with an equal number of congruent, incongruent, and neutral trials. The trial sequence was pseudo-randomized.

The color-shape switching task (Figure 3; Rubin & Meiran, 2005; von Bastian et al., 2013) first showed participants a bivalent stimulus and a cue, and participants then had to classify the stimulus according to the cue type presented to them in each round. Depending on the cue displayed, which will either be a color cue (an image of a color gradient) or a shape cue (an image of a row of small black diamonds), participants then classified the stimulus by the color of the stimulus (either be blue or green) or its shape (either pointed or circular). The classification is done by pressing the corresponding left (for blue or circular) or right (for green or pointed) arrow key. The task consisted of four single-task blocks (i.e., only one cue) and one mixed-task block (i.e., a mix of color cue and shape cue), arranged in a sandwich-like design in the following order: two single-task blocks, one mixed-task block, and two single-task blocks. There were 64 trials in each single-task block and 129 trials for the mixed-task block. Half of the trials in the mixed-task block were repeat trials in which participants were repeatedly presented the same cue as in the previous trial. Another half of the trials were switch trials, where participants were presented with a different cue from the previous trial. The trials were presented in a pseudo-random order within blocks.

Both inhibitory control and task-switching ability were assessed by bin scores (Draheim et al., 2016; Hughes et al., 2014), where for both tasks, higher bin scores indicate worse performance. Bin scores were computed from the flanker task for inhibitory control, and from the color-shape switching task for task-switching ability.

First, the "baseline" reaction time of each participant was determined by the mean of their reaction times on accurate neutral (inhibitory control) or repeat (task-switching) trials. For the accurate responses, consistent with Hartanto et al. (2023), we trimmed responses that were below 200 milliseconds. We also trimmed accurate responses that were 2.5 *SD* above or below an individual's mean reaction time for color-shape switching task and were 3 *SD* above or below an individual's mean reaction time for flanker task. Second, the mean for each participant was subtracted from their accurate incongruent (inhibitory control) or switch (task-switching) trials, and the new score for each accurate incongruent or switch trial determines the reaction speed of each participant compared to their own baseline, reflecting the interference effect (inhibitory control) or switch cost (task-switching). Third, all interference effects or switch costs across all participants were ranked based on deciles and assigned a bin value from 1 (fastest 10%) to 10 (slowest 10%). Fourth, all inaccurate incongruent or switch trials were assigned a bin value of 20 regardless of their actual reaction time, to penalize for inaccuracy. Lastly, a mean bin score was computed for each participant.

Results

A paired-samples t-test, using both Frequentist and Bayesian approaches, was first conducted to test if the experimental manipulation was successful. Following that, to test whether participants' cognitive performance differed between the Mindful Breathing and Mind Wandering conditions, paired samples *t*-tests were conducted using both Frequentist and Bayesian approaches (Table 2). Results are presented for the main sample (i.e., excluding those who failed the attention checks) as well as for the full available sample (i.e., including those who failed the attention checks).

Manipulation Check

In terms of the manipulation check as measured by the absorption measure, the paired-samples t-test revealed that the difference between the two conditions was significant (main sample: d = 0.36, 95% CI = [0.17, 0.54], $t(116)$ = 3.85, p <.001; full sample: d = 0.35, 95% CI = [0.17, 0.52], $t(127)$ = 3.92, p <.001), such that participants were more absorbed in the Mindful Breathing condition (main sample: M = 3.61, SD = 1.09; full sample: M = 3.64, SD = 1.06) than they were in the Mind Wandering condition (main sample: M = 3.12, SD = 1.15; full sample: M = 3.17, SD = 1.16). There was also very strong evidence in favor of the alternative hypothesis (main sample: BF_{10} = 94.36, BF_{01} = 0.01; full sample: BF_{10} = 121.75, BF_{01} = 0.01). This implies that the manipulation was a success.

The magnitude of flanker-interference effect and task-switching effects in reaction time (RT) and accuracy were also calculated to ensure the robustness and validity of our cognitive tasks. Flanker-interference effects were calculated by subtracting the reaction time (main sample: M = 596.65, SD = 68.15; full sample: M = 593.91, SD = 67.08) or accuracy (main sample: M = 0.94, SD = 0.05; full sample: M = 0.93, SD = 0.05) of incongruent trials from the reaction time (main sample: M = 581.15, SD = 67.70; full sample: M = 578.01, SD = 66.06) or accuracy (main sample: M = 0.95, SD = 0.04; full sample: M =0.94, SD = 0.04) of neutral trials. Task-switching effects were calculated by subtracting the reaction time (main sample: M = 1035.76, SD = 187.51; full sample: M = 1029.32, SD = 185.84) or accuracy (main sample: M = 0.91, SD = 0.07; full sample: M = 0.90, SD = 0.07) of switch trials from the reaction (main sample: M = 883.96, SD = 171.72; full sample: M = 880.26, SD = 171.23) or accuracy (main sample: M = 0.96, SD = 0.05; full sample: M = 0.95, SD = 0.06) of repeat trials. Overall, we found robust and significant flanker-interference effects in reaction time (main sample: d = 0.78, 95% CI = [0.57, 0.98], $t(115)$ = 8.37, p < .001, BF_{10} > 1000, BF_{01} < 0.001; full sample: d = 0.81, 95% CI = [0.61, 1.00], $t(130)$ = 9.23, p < .001, BF_{10} > 1000, BF_{01} < 0.001) and in accuracy (main sample: d = -0.23, 95% CI = [-0.42, -0.05], $t(115)$ = -2.52, p =.013, BF_{10} = 2.09, BF_{01} = 0.48; full sample: d = -0.24, 95% CI = [-0.41, -0.07], $t(130)$ = -2.76, p = .007, BF_{10} = 3.64, BF_{01} = 0.27). We also found robust and significant task-switching effects in both reaction time (main sample: d = 1.77, 95% CI = [1.47, 2.05], $t(116)$ = 19.09, p < .001, BF_{10} > 1000, BF_{01} < 0.001; full sample: d = 1.70, 95% CI = [1.43, 1.96], $t(131)$ = 19.48, p < .001, BF_{10} > 1000, BF_{01} < 0.001) and accuracy (main sample: d = -0.87, 95% CI = [-1.08, -0.65], $t(116)$ = -9.39, p < .001, BF_{10} > 1000, BF_{01} < 0.001; full sample: d = -0.90, 95% CI = [-1.10, -0.70], $t(131)$ = -10.36, p < .001, BF_{10} > 1000, BF_{01} < 0.001).

Inhibitory Control

In terms of inhibitory control as measured by the flanker task (Figure 4, and Table 2), paired samples t-tests revealed that the scores on the flanker task when participants were in the Mindful Breathing condition (main sample: M = 6.38, SD = 0.98; full sample: M = 6.41, SD = 0.94) versus the Mind Wandering condition (main sample: M = 6.35, SD = 0.98; full sample: M = 6.52, SD = 1.18) were not statistically different and that there was extreme evidence for the null hypothesis (main sample: d = 0.04, 95% CI = [-0.14, 0.22], $t(115)$ = 0.41, p = .684, BF_{10} = 0.11, BF_{01} = 8.95; full sample: d = -0.10, S95% CI = [-0.27, 0.07], $t(130)$ = -1.15, p = .254, BF_{10} = 0.18, BF_{01} = 5.42).

Task-Switching

In terms of task-switching as measured by the color-shape task-switching task (Figure 4, and Table 2), paired samples t-tests revealed that the scores on the color-shape switching task when participants were in the Mindful Breathing condition (main sample: M = 6.79, SD = 1.27; full sample: M = 6.88, SD = 1.31) versus the Mind Wandering condition (main sample: M = 6.77, SD = 1.37; full sample: M = 6.97, SD = 1.51) was not statistically different (main sample: d = 0.02, 95% CI = [-0.16, 0.20], $t(116)$ = 0.21, p = .832; full sample: d = -0.08, 95% CI = [-0.25, 0.09], $t(131)$ = -0.90, p = .371) and that there were extreme evidence for the null hypothesis (main sample: BF_{10} = 0.10, BF_{01} = 9.53; full sample: BF_{10} = 0.14, BF_{01} = 6.97).

Order Effects

A repeated-measures mixed-factor ANOVA was performed with Order (Mindful Breathing Condition – Mind Wandering Condition Order vs. Mind Wandering Condition – Mindful Breathing Condition Order) and Mindfulness (Mindful Breathing Condition vs. Mind Wandering Condition) to test the order effects in the inhibitory control and task-switching. Results showed that there was a significant interaction effect between Order and Mindfulness on participants' inhibitory control ($F(1, 114)$ = 24.73, p < .001, η^2 = .178, BF_{10} = 6794.25, BF_{01} = 0.0001). Participants who were first assigned to the Mindful Breathing condition had significantly better scores in the flanker task during the Mind Wandering condition (M = 6.61) as compared to the Mindful Breathing condition (M = 6.20), p = .001, whereas participants who were first assigned to the Mind Wandering condition had significantly better scores in the flanker task during the Mindful Breathing condition (M = 6.54) as compared to the Mind Wandering condition (M = 6.11), p =

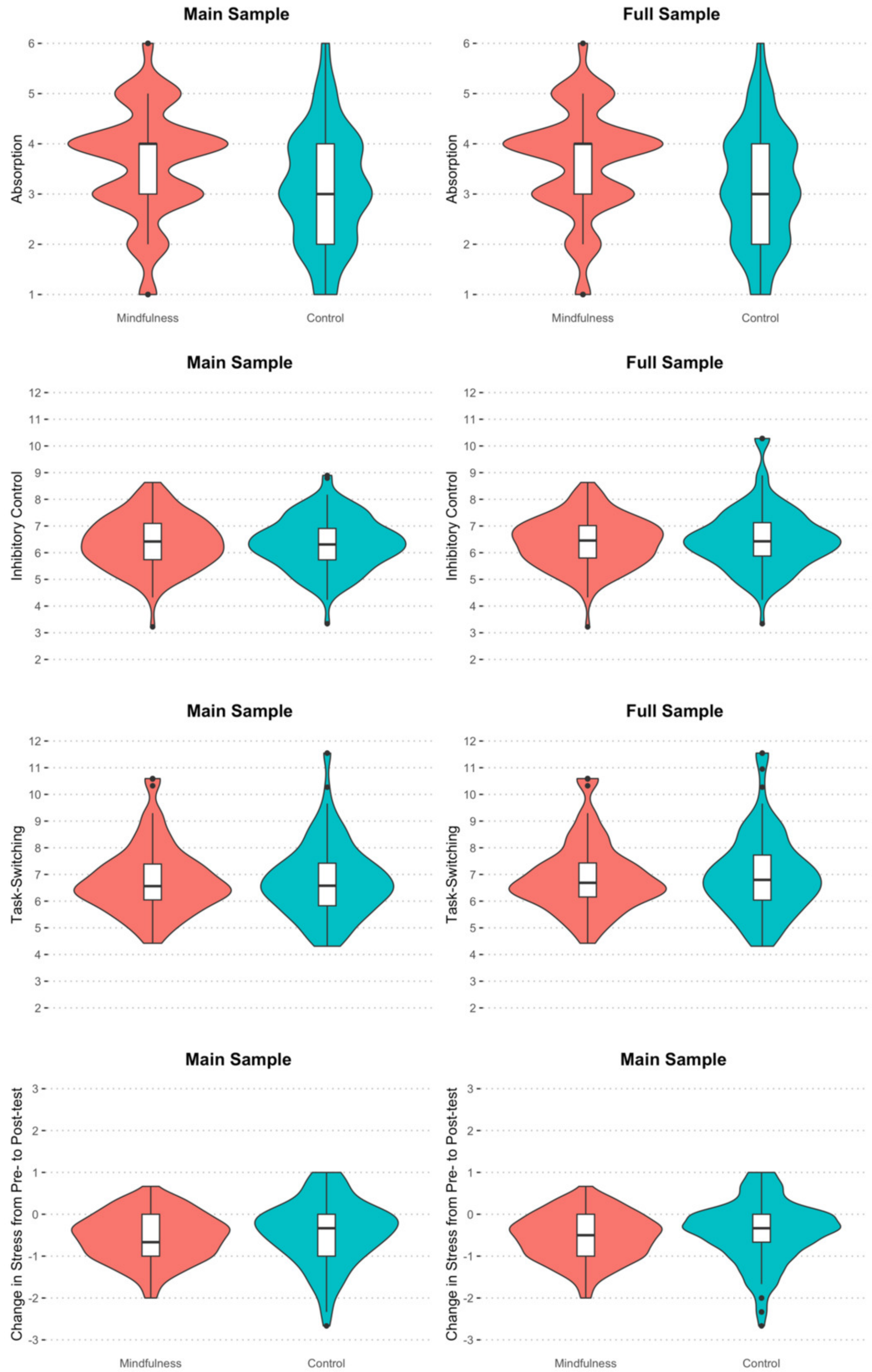

Figure 4. Box and Violin Plots

Note: Horizontal line in each box plot represents the median, the whiskers represent quartile, and the dots are the outliers.
[1]The higher the score, the poorer the inhibitory control.

Table 2. Summary of Results

Outcome	*N*	Mindful Breathing *M* (*SD*)	Mind Wandering *M* (*SD*)	*d*	*95% CI*	*t*	*df*	*p*	BF_{10}	BF_{01}
Inhibitory Control										
Main Sample	116	6.38 (0.98)	6.35 (0.98)	0.04	[-0.14, 0.22]	0.41	115	.684	0.11	8.95
Full Sample	131	6.41 (0.94)	6.52 (1.18)	-0.10	[-0.27, 0.07]	-1.15	130	.254	0.18	5.42
Task-switching										
Main Sample	117	6.79 (1.27)	6.77 (1.37)	0.02	[-0.16, 0.20]	0.21	116	.832	0.10	9.53
Full Sample	132	6.88 (1.31)	6.97 (1.51)	-0.08	[-0.25, 0.09]	-0.90	131	.371	0.14	6.97

Note. Main sample refers to the sample which excludes data from participants who failed the attention checks while full sample refers to the sample consisting of all available data.

.001. Both results showed that participants performed better during their second session as compared to the first, indicating that there was a practice effect for the flanker task. However, there was no main effect of Order on participants' inhibitory control ($F(1, 114) = 0.011$, $p = .917$, $\eta^2 = .000$, $BF_{10} = 0.25$, $BF_{01} = 4.08$), suggesting that overall inhibitory control performance in participants assigned in Mindful Breathing Condition – Mind Wandering Condition Order was not significantly different from participants assigned in Mind Wandering Condition – Mindful Breathing Condition Order. Similarly, there was no significant main effect of Order on participants' task switching ($F(1, 115) = 0.015$, $p = .904$, , $\eta^2 = .000$, $BF_{10} = 0.18$, $BF_{01} = 5.47$) and no significant interaction between Order and Mindfulness on participants' task-switching ($F(1, 115) = 2.41$, $p = .123$, , $\eta^2 = .021$, $BF_{10} = 0.18$, $BF_{01} = 5.60$),

Sensitivity Analyses

We conducted a series of sensitivity analyses to determine whether the effect of brief mindfulness breathing exercise on inhibitory control and task-switching was consistent across different binning procedures and scoring methods. In total, we used three different variants of the original binning procedure, a simple difference score in reaction times, an inverse efficiency scoring (Townsend & Ashby, 1983), and linear integrated speed-accuracy scoring (Vandierendonck, 2017). The second variant of the binning procedure (Binning Procedure 2) was similar to the original binning procedure except that inaccurate incongruent trials/inaccurate switch trials were assigned with a bin score of 11 instead of a bin score of 20. In the last two variants of our binning procedure, a bin score of 20 (Binning Procedure 3) or 11 (Binning Procedure 4) was assigned to the number of incongruent-minus-neutral errors/switch-minus-repeat-errors, which was added to the bin scores of the accurate incongruent/switch trials calculated with the original binning procedure, and the total was divided by the number of incongruent/switch trials. The results were summarized in Table 3. Overall, the null effects for both inhibitory control and task-switching were consistent across different binning procedures and scoring methods.

Exploratory Outcome

For our exploratory outcome, we sought to understand if there was significant difference in stress between the two conditions for the participants. Change in perceived stress scores were calculated by subtracting pre-exercise perceived stress scores from post-exercise perceived stress scores. Then, paired samples *t*-tests were conducted using both Frequentist and Bayesian approaches on the change in perceived stress scores. A two-tailed paired-samples t-test indicated no significant difference (main sample: $d = -0.13$, 95% CI = [-0.31, 0.05], $t(116) = -1.44$, $p = .154$; full sample: $d = -0.14$, 95% CI = [-0.31, 0.04], $t(127) = -1.57$, $p = .119$) in the Mindful Breathing condition (main sample: $M = -0.54$, $SD = 0.56$; full sample: $M = -0.54$, $SD = 0.55$) versus the Mind Wandering condition (main sample: $M = -0.42$, $SD = 0.75$; full sample: $M = -0.42$, $SD = 0.73$) and there was moderate evidence for the null hypothesis (main sample: $BF_{10} = 0.28$, $BF_{01} = 3.59$; full sample: $BF_{10} = 0.32$, $BF_{01} = 3.09$).

We also conducted an exploratory analysis on RTs in the neutral/control conditions in each task. First, a repeated-measures mixed-factor ANOVA was performed with Order (Mindful Breathing Condition – Mind Wandering Condition Order vs. Mind Wandering Condition – Mindful Breathing Condition Order) and Mindfulness (Mindful Breathing Condition vs. Mind Wandering Condition) on neutral condition RTs in inhibitory control task. We did not find significant main effect of Mindfulness ($F(1, 114) = 0.03$, $p = .851$, $\eta^2 = .000$) and Order ($F(1, 114) = 1.04$, $p = .310$, $\eta^2 = .009$). However, similar with the results testing the interaction between Mindfulness and Order in inhibitory control using binning score, there was a significant interaction effect between Order and Mindfulness on neutral condition RTs in inhibitory control task ($F(1, 114) = 61.95$, $p < .001$, $\eta^2 = .352$). Participants who were first assigned to the Mindful Breathing condition had significantly faster neutral condition RTs in the flanker task during the Mind Wandering condition ($M = 548.64$) as compared to the Mindful Breathing condition ($M = 599.14$), $p <.001$, whereas participants who were first assigned to the Mind Wandering condition had significantly faster neutral condition RTs in the flanker task during the Mindful Breathing condition ($M = 562.60$) as compared to the Mind Wandering condition ($M = 610.73$), $p < .001$. We also conducted a repeated-measures mixed-factor ANOVA was performed with Order (Mindful Breathing Condition – Mind Wandering Condition Order vs. Mind Wandering Condition – Mindful Breathing Condition Order) and Mindfulness (Mindful Breathing Condition vs. Mind Wandering Condition) on repeat condition RTs in color-shape switching task. We did not find significant main

Table 3. Summary of Sensitivity Analysis Results

Variation in Analyses	*d*	95% CI	*t*	*df*	*p*	BF_{10}	BF_{01}
Inhibitory Control							
Original Results							
Main Sample	0.04	[-0.14, 0.22]	0.41	115	.684	0.11	8.95
Full Sample	-0.10	[-0.27, 0.07]	-1.15	130	.254	0.18	5.42
Binning Procedure 2							
Main Sample	0.04	[-0.14, 0.23]	0.47	115	.642	0.11	8.73
Full Sample	-0.05	[-0.22, 0.12]	-0.54	130	.590	0.11	8.92
Binning Procedure 3							
Main Sample	0.08	[-0.10, 0.26]	0.84	115	.404	0.15	6.89
Full Sample	0.05	[-0.12, 0.22]	0.59	130	.555	0.12	8.68
Binning Procedure 4							
Main Sample	0.07	[-0.11, 0.25]	0.75	115	.457	0.14	7.40
Full Sample	0.07	[-0.11, 0.24]	0.76	130	.449	0.13	7.77
Reaction Time Difference Score							
Main Sample	0.05	[-0.13. 0.23]	0.55	115	.580	0.12	8.35
Full Sample	0.05	[-0.12, 0.22]	0.61	130	.545	0.12	8.59
Inverse Efficiency Score							
Main Sample	0.09	[-0.09, 0.28]	1.01	115	.315	0.17	5.92
Full Sample	0.04	[-0.13, 0.21]	0.48	130	.629	0.11	9.18
Linear Integrated Speed-accuracy Score							
Main Sample	0.14	[-0.05, 0.32]	1.49	115	.140	0.30	3.33
Full Sample	0.13	[-0.04, 0.30]	1.51	130	.133	0.29	3.40
Task-switching							
Original Results							
Main Sample	0.02	[-0.16, 0.20]	0.21	116	.832	0.10	9.53
Full Sample	-0.08	[-0.25, 0.09]	-0.90	131	.371	0.14	6.97
Binning Procedure 2							
Main Sample	0.01	[-0.17, 0.19]	0.08	116	.936	0.10	9.71
Full Sample	-0.05	[-0.22, 0.13]	-0.52	131	.605	0.11	9.06
Binning Procedure 3							
Main Sample	-0.09	[-0.27, 0.09]	-0.99	116	.326	0.16	6.07
Full Sample	0.02	[-0.15, 0.19]	0.21	131	.831	0.10	10.10
Binning Procedure 4							
Main Sample	-0.09	[-0.27, 0.09]	-0.98	116	.331	0.16	6.13
Full Sample	0.03	[-0.14, 0.20]	0.32	131	.748	0.10	9.82
Reaction Time Difference Score							
Main Sample	-0.01	[-0.19, 0.17]	-0.11	116	.909	0.10	9.68
Full Sample	-0.004	[-0.17, 0.17]	-0.05	131	.962	0.10	10.32
Inverse Efficiency Score							
Main Sample	-0.05	[-0.23, 0.13]	-0.51	116	.608	0.12	8.57
Full Sample	-0.004	[-0.17, 0.17]	-0.04	131	.967	0.10	10.32
Linear Integrated Speed-accuracy Score							
Main Sample	-0.03	[-0.21, 0.15]	-0.31	116	.760	0.11	9.31
Full Sample	0.01	[-0.16, 0.18]	0.14	141	.889	0.10	10.32

effect of Mindfulness ($F(1, 115) = 0.09$, $p = .760$, $\eta^2 = .001$) and Order ($F(1, 115) = 1.40$, $p = .240$, $\eta^2 = .012$). However, similar to inhibitory control, we found a significant interaction effect between Order and Mindfulness on repeat condition RTs in color-shape switching task ($F(1, 115) = 74.99$, $p < .001$, $\eta^2 = .395$). Participants who were first assigned to the Mindful Breathing condition had significantly faster repeat condition RTs in the color-shape switching task during the Mind Wandering condition (M = 808.68) as compared to the Mindful Breathing condition (M = 918.16), $p < .001$, whereas participants who were first assigned to the Mind Wandering condition had significantly faster repeat condition RTs in the color-shape switching task during the Mindful Breathing condition (M = 849.85) as compared to the Mind Wandering condition (M = 951.86), $p < .001$. Overall, the results showed that participants had faster reaction time during their second session as compared to the first, indicating that there was a practice effect for the flanker task and color-shape switching task.

Discussion

There is an accumulating body of evidence in the literature that mindfulness-based practices provide cognitive benefits such as improvement in executive functioning (Creswell et al., 2012; Doorley et al., 2021; Gardi et al., 2022). However, most of these mindfulness-based practices require the participants to be involved either an extended immersive experience or repeated daily practice that may span over multiple weeks or months (Allen et al., 2012; Quach et al., 2016; Ron-Grajales et al., 2021; Wong et al., 2017). In contrast, although several recent studies have suggested that a single session of brief mindfulness exercise is sufficient to enhance cognitive functions (Jankowski & Holas, 2020; Mrazek et al., 2012), the empirical findings were not always consistent (Quek et al., 2021). In view of the potential practical implications of brief mindfulness intervention, the goal of the current study was to revisit the effectiveness of a single session brief mindfulness breathing exercises on executive functions. Specifically, we conducted a within-subject experiment to test the effect of a 15-minute brief mindfulness breathing exercise in enhancing the performance of individuals on inhibitory control and task-switching using flanker task and color-shape task-switching paradigm.

Findings of our experiment suggests that a 15-minute brief mindfulness breathing exercise may not have an immediate effect on inhibitory control and task-switching. In both flanker task and color-shape task-switching paradigm, cognitive performance in the mindfulness condition were not significantly different than the control condition. Our Bayesian t-tests further supported our null hypothesis. The results are consistent with Quek et al. (2021) who did not find any evidence that a 15-minutes brief mindfulness breathing exercise may enhance working memory capacity. Thus, the current study extends the null results of Quek et al. (2021) to the domain of inhibitory control and task-switching.

Although a number of existing studies on mindfulness intervention have found considerable evidence to support the positive effect of mindfulness training on inhibitory control (Isbel et al., 2020; Ron-Grajales et al., 2021; Viglas & Perlman, 2018) and task-switching (Moore & Malinowski, 2009; Zou et al., 2020), it is likely that a short duration of mindful intervention is not sufficient to immediately enhance higher-order cognitive processes such as inhibitory control and task-switching. Our null finding further suggests that single-session brief mindfulness breathing exercise should not be used as a standalone tool for immediate cognitive enhancement and may not be suitable as a rapid intervention for patients needing immediate cognitive improvement. This could be particularly relevant for patients with cognitive impairment or disorders characterized by deficits in executive functions. More importantly, our results underscore the need for realistic expectations regarding the effect of brief mindfulness breathing intervention, especially for therapists and educators.

Nevertheless, several limitations of the current study are noteworthy. Notably, the current study may lack of generalizability given that the sample was mostly consisted young adults. Existing studies have showed that young adults tend to have better performance than children and older adults in flanker task and task-switching paradigm (Eppinger et al., 2007; Kray et al., 2002; Mahoney et al., 2010; Rueda et al., 2004). Given that young adults are likely at the peak performance in term of its ability to exercise cognitive control (Åberg et al., 2009; Hartanto et al., 2016; Kramer et al., 1999), it is possible that the effect of single session brief mindfulness is more restricted to other age groups such as children and older adults. This is consistent with studies that found near transfer of task-switching training is more prominent in children and older adults than young adults (Karbach & Kray, 2009; Kray & Fehér, 2017). Furthermore, the executive function measures in the current study might be vulnerable to task impurity due to the use of single task for inhibitory control and task-switching. Although flanker task and color-shape task-switching paradigm are two of the most common measures for inhibitory control and task-switching (Friedman & Miyake, 2004; Gärtner & Strobel, 2021; Miyake et al., 2000; Monsell, 2003), it is plausible that the null finding observed in the current study is task-specific. As such, it is important for future studies to replicate the finding of the current study using multiple tasks to increase the task generalizability In addition, in our experimental procedure, we used a manipulation check item asking participants about their level of absorption, a method widely adopted in prior brief mindfulness studies (Clinton et al., 2018; Mrazek et al., 2013). However, we acknowledge that the wording might be vague and difficult to interpret for some participants. Future studies should consider using more concrete and easily understandable items for manipulation checks. Lastly, it is noteworthy that, while similar to Quek et al. (2021), the current experimental paradigm had slightly different configuration than those of Mrazek et al. (2012) and Jankowski & Holas (2020). For instance, our 15-minute brief mindful breathing intervention is slightly longer than the 8-minute mindful breathing exercise conducted by Mrazek et al. (2012) and 10-minute mindful exercise by Jankowski & Holas (2020). Variations also existed in the active control condition. Therefore, the current study could not rule out the possibility that the mixed findings regarding the effectiveness of brief mindfulness intervention on cognitive functions were partly driven by differences in the administration of the experimental paradigm.

In summary, despite the promising practical implications of brief mindfulness intervention, the current study did not find any evidence that a single-session 15-minutes brief mindfulness breathing exercise is effective in improving inhibitory control and task-switching in young adult participants. Corroborating the recent finding from Quek et al. (2021), our study suggests that a single-session brief mindfulness intervention is too short to temporarily improve higher-order cognitive functions such as inhibitory control and task-switching.

Contributions

Contributed to conception and design: AH, NMM, FYXQ

Contributed to acquisition of data: JAN, JSYO, FYXQ, NMM

Contributed to analysis and interpretation of data: KTASK, YJC, JAN, JSYO, FYXQ, NMM

Drafted and/or revised the article: AH, KTASK, YJC, JAN, JSYO, FYXQ, XCS, NMM

Approved the submitted version for publication: AH, KTASK, YJC, JAN, JSYO, FYXQ, XCS, NMM

Competing Interests

The authors declared no potential conflict of interest.

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Data Accessibility Statement

Materials, data, and code are publicly available on ResearchBox: https://researchbox.org/825

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References

Åberg, M. A. I., Pedersen, N. L., Torén, K., Svartengren, M., Bäckstrand, B., Johnsson, T., Cooper-Kuhn, C. M., Åberg, N. D., Nilsson, M., & Kuhn, H. G. (2009). Cardiovascular fitness is associated with cognition in young adulthood. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(49), 20906–20911. https://doi.org/10.1073/pnas.0905307106

Ainsworth, B., Eddershaw, R., Meron, D., Baldwin, D. S., & Garner, M. (2013). The effect of focused attention and open monitoring meditation on attention network function in healthy volunteers. *Psychiatry Research*, *210*(3), 1226–1231. https://doi.org/10.1016/j.psychres.2013.09.002

Allen, M., Dietz, M., Blair, K. S., van Beek, M., Rees, G., Vestergaard-Poulsen, P., Lutz, A., & Roepstorff, A. (2012). Cognitive-affective neural plasticity following active-controlled mindfulness intervention. *The Journal of Neuroscience*, *32*(44), 15601–15610. https://doi.org/10.1523/jneurosci.2957-12.2012

Arch, J. J., & Craske, M. G. (2006). Mechanisms of mindfulness: Emotion regulation following a focused breathing induction. *Behaviour Research and Therapy*, *44*(12), 1849–1858. https://doi.org/10.1016/j.brat.2005.12.007

Auguie, B. (2017). *gridExtra: Miscellaneous Functions for "Grid" Graphics*. R package version 2.3. https://CRAN.R-project.org/package=gridExtra

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), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive Therapy and Research*, *32*(3), 303–322. https://doi.org/10.1007/s10608-007-9119-0

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior & Organization*, *81*(1), 1–8. https://doi.org/10.1016/j.jebo.2011.08.009

Chiesa, A., & Serretti, A. (2009). Mindfulness-based stress reduction for stress management in healthy people: A review and meta-analysis. *The Journal of Alternative and Complementary Medicine*, *15*(5), 593–600. https://doi.org/10.1089/acm.2008.0495

Clinton, V., Swenseth, M., & Carlson, S. E. (2018). Do mindful breathing exercises benefit reading comprehension? A brief report. *Journal of Cognitive Enhancement*, *2*(3), 305–310. https://doi.org/10.1007/s41465-018-0067-2

Creswell, J. D., Irwin, M. R., Burklund, L. J., Lieberman, M. D., Arevalo, J. M. G., Ma, J., Breen, E. C., & Cole, S. W. (2012). Mindfulness-Based Stress Reduction training reduces loneliness and pro-inflammatory gene expression in older adults: A small randomized controlled trial. *Brain, Behavior, and Immunity*, *26*(7), 1095–1101. https://doi.org/10.1016/j.bbi.2012.07.006

de Vibe, M., Solhaug, I., Rosenvinge, J. H., Tyssen, R., Hanley, A., & Garland, E. (2018). Six-year positive effects of a mindfulness-based intervention on mindfulness, coping and well-being in medical and psychology students; Results from a randomized controlled trial. *PloS One*, *13*(4), e0196053. https://doi.org/10.1371/journal.pone.0196053

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Doorley, J., Greenberg, J., Stauder, M., & Vranceanu, A.-M. (2021). The role of mindfulness and relaxation in improved sleep quality following a mind-body and activity program for chronic pain. *Mindfulness*, *12*(11), 2672–2680. https://doi.org/10.1007/s12671-021-01729-y

Draheim, C., Hicks, K. L., & Engle, R. W. (2016). Combining reaction time and accuracy: The relationship between working memory capacity and task switching as a case example. *Perspectives on Psychological Science*, *11*(1), 133–155. https://doi.org/10.1177/1745691615596990

Eppinger, B., Kray, J., Mecklinger, A., & John, O. (2007). Age differences in task switching and response monitoring: Evidence from ERPs. *Biological Psychology*, *75*(1), 52–67. https://doi.org/10.1016/j.biopsycho.2006.12.001

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General*, *133*(1), 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Gallant, S. N. (2016). Mindfulness meditation practice and executive functioning: Breaking down the benefit. *Consciousness and Cognition*, *40*, 116–130. https://doi.org/10.1016/j.concog.2016.01.005

Gardi, C., Fazia, T., Stringa, B., & Giommi, F. (2022). A short mindfulness retreat can improve biological markers of stress and inflammation. *Psychoneuroendocrinology*, *135*, 105579. https://doi.org/10.1016/j.psyneuen.2021.105579

Gärtner, A., & Strobel, A. (2021). Individual differences in inhibitory control: A latent variable analysis. *Journal of Cognition*, *4*(1), 17. https://doi.org/10.5334/joc.150

Hafenbrack, A. C., Kinias, Z., & Barsade, S. G. (2014). Debiasing the mind through meditation: Mindfulness and the sunk-cost bias. *Psychological Science*, *25*(2), 369–376. https://doi.org/10.1177/0956797613503853

Hartanto, A., Chua, Y. J., Quek, F. Y. X., Wong, J., Ooi, W. M., & Majeed, N. M. (2023). Problematic smartphone usage, objective smartphone engagement, and executive functions: A latent variable analysis. *Attention, Perception, & Psychophysics*, *85*(8), 1–16. https://doi.org/10.3758/s13414-023-02707-3

Hartanto, A., Ong, N. C. H., Ng, W. Q., & Majeed, N. M. (2020). The effect of state gratitude on cognitive flexibility: A within-subject experimental approach. *Brain Sciences*, *10*(7), 413. https://doi.org/10.3390/brainsci10070413

Hartanto, A., Toh, W. X., & Yang, H. (2016). Age matters: The effect of onset age of video game play on task-switching abilities. *Attention, Perception, & Psychophysics*, *78*(4), 1125–1136. https://doi.org/10.3758/s13414-016-1068-9

Hartanto, A., & Yang, H. (2020). The role of bilingual interactional contexts in predicting interindividual variability in executive functions: A latent variable analysis. *Journal of Experimental Psychology: General*, *149*(4), 609–633. https://doi.org/10.1037/xge0000672

Henriksson, J., Wasara, E., & Rönnlund, M. (2016). Effects of eight-week-web-based mindfulness training on pain intensity, pain acceptance, and life satisfaction in individuals with chronic pain. *Psychological Reports*, *119*(3), 586–607. https://doi.org/10.1177/0033294116675086

Holas, P., & Jankowski, T. (2013). A cognitive perspective on mindfulness. *International Journal of Psychology*, *48*(3), 232–243. https://doi.org/10.1080/00207594.2012.658056

Huang, S.-L., Li, R.-H., Huang, F.-Y., & Tang, F.-C. (2015). The Potential for Mindfulness-Based Intervention in Workplace Mental Health Promotion: Results of a Randomized Controlled Trial. *PloS One*, *10*(9), e0138089. https://doi.org/10.1371/journal.pone.0138089

Hughes, M. M., Linck, J. A., Bowles, A. R., Koeth, J. T., & Bunting, M. F. (2014). Alternatives to switch-cost scoring in the task-switching paradigm: Their reliability and increased validity. *Behavior Research Methods*, *46*(3), 702–721. https://doi.org/10.3758/s13428-013-0411-5

Isbel, B., Lagopoulos, J., Hermens, D., Stefanidis, K., & Summers, M. J. (2020). Mindfulness improves attention resource allocation during response inhibition in older adults. *Mindfulness*, *11*(6), 1500–1510. https://doi.org/10.1007/s12671-020-01364-z

Jankowski, T., & Holas, P. (2020). Effects of Brief Mindfulness Meditation on Attention Switching. *Mindfulness*, *11*(5), 1150–1158. https://doi.org/10.1007/s12671-020-01314-9

JASP Team. (2023). *JASP* (Version 0.17.3). https://jasp-stats.org/

Jha, A. P., Morrison, A. B., Dainer-Best, J., Parker, S., Rostrup, N., & Stanley, E. A. (2015). Minds "At Attention": Mindfulness Training Curbs Attentional Lapses in Military Cohorts. *PLOS ONE*, *10*(2), e0116889. https://doi.org/10.1371/journal.pone.0116889

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion*, *10*(1), 54–64. https://doi.org/10.1037/a0018438

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Karbach, J., & Kray, J. (2009). How useful is executive control training? Age differences in near and far transfer of task-switching training. *Developmental Science*, *12*(6), 978–990. https://doi.org/10.1111/j.1467-7687.2009.00846.x

Kassambara, A. (2023). *ggpubr: 'ggplot2' Based Publication Ready Plots*. R package version 0.6.0. https://CRAN.R-project.org/package=ggpubr

Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., Chason, J., Vakil, E., Bardell, L., Boileau, R. A., & Colcombe, A. (1999). Ageing, fitness and neurocognitive function. *Nature*, *400*(6743), 418–419. https://doi.org/10.1038/22682

Kray, J., & Fehér, B. (2017). Age differences in the transfer and maintenance of practice-induced improvements in task switching: The impact of working-memory and inhibition demands. *Frontiers in Psychology*, *8*, 410. https://doi.org/10.3389/fpsyg.2017.00410

Kray, J., Li, K. Z., & Lindenberger, U. (2002). Age-related changes in task-switching components: The role of task uncertainty. *Brain and Cognition*, *49*(3), 363–381. https://doi.org/10.1006/brcg.2001.1505

Larson, M., Steffen, P., & Primosch, M. (2013). The impact of a brief mindfulness meditation intervention on cognitive control and error-related performance monitoring. *Frontiers in Human Neuroscience*, *7*. https://doi.org/10.3389/fnhum.2013.00308

Mahoney, J. R., Verghese, J., Goldin, Y., Lipton, R., & Holtzer, R. (2010). Alerting, orienting, and executive attention in older adults. *Journal of the International Neuropsychological Society*, *16*(5), 877–889. https://doi.org/10.1017/s1355617710000767

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex 'Frontal Lobe' tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*(3), 134–140. https://doi.org/10.1016/s1364-6613(03)00028-7

Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and Cognition*, *18*(1), 176–186. https://doi.org/10.1016/j.concog.2008.12.008

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological Science*, *24*(5), 776–781. https://doi.org/10.1177/0956797612459659

Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and mind-wandering: Finding convergence through opposing constructs. *Emotion*, *12*(3), 442–448. https://doi.org/10.1037/a0026678

Pascoe, M. C., Thompson, D. R., Jenkins, Z. M., & Ski, C. F. (2017). Mindfulness mediates the physiological markers of stress: Systematic review and meta-analysis. *Journal of Psychiatric Research*, *95*, 156–178. https://doi.org/10.1016/j.jpsychires.2017.08.004

Quach, D., Jastrowski Mano, K. E., & Alexander, K. (2016). A randomized controlled trial examining the effect of mindfulness meditation on working memory capacity in adolescents. *Journal of Adolescent Health*, *58*(5), 489–496. https://doi.org/10.1016/j.jadohealth.2015.09.024

Quek, F., Majeed, N., Kothari, M., Lua, V., Ong, H., & Hartanto, A. (2021). Brief mindfulness breathing exercises and working memory capacity: Findings from two experimental approaches. *Brain Sciences*, *11*(2), 175. https://doi.org/10.3390/brainsci11020175

Raffone, A., & Srinivasan, N. (2017). Mindfulness and cognitive functions: Toward a unifying neurocognitive framework. *Mindfulness*, *8*(1), 1–9. https://doi.org/10.1007/s12671-016-0654-1

Revelle, W. (2023). *psych: Procedures for psychological, psychometric, and personality research*. R package version 2.3.6. https://CRAN.R-project.org/package=psych

Ron-Grajales, A., Sanz-Martin, A., Castañeda-Torres, R. D., Esparza-López, M., Ramos-Loyo, J., & Inozemtseva, O. (2021). Effect of mindfulness training on inhibitory control in young offenders. *Mindfulness*, *12*(7), 1822–1838. https://doi.org/10.1007/s12671-021-01643-3

RStudio Team. (2023). *RStudio: Integrated development for R*. RStudio. http://www.rstudio.com/

Rubin, O., & Meiran, N. (2005). On the Origins of the Task Mixing Cost in the Cuing Task-Switching Paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(6), 1477–1491. https://doi.org/10.1037/0278-7393.31.6.1477

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*(8), 1029–1040. https://doi.org/10.1016/j.neuropsychologia.2003.12.012

Shapiro, S. L., Oman, D., Thoresen, C. E., Plante, T. G., & Flinders, T. (2008). Cultivating mindfulness: Effects on well-being. *Journal of Clinical Psychology*, *64*(7), 840–862. https://doi.org/10.1002/jclp.20491

Sharma, M., & Rush, S. E. (2014). Mindfulness-based stress reduction as a stress management intervention for healthy individuals: A systematic review. *Journal of Evidence-Based Complementary & Alternative Medicine*, *19*(4), 271–286. https://doi.org/10.1177/2156587214543143

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. *Dialogue: The Official Newsletter of the Society for Personality and Social Psychology*, *26*, 4–7.

Song, Y., & Lindquist, R. (2015). Effects of mindfulness-based stress reduction on depression, anxiety, stress and mindfulness in Korean nursing students. *Nurse Education Today*, *35*(1), 86–90. https://doi.org/10.1016/j.nedt.2014.06.010

Townsend, J. T., & Ashby, F. G. (1983). *The Stochastic Modeling of Elementary Psychological Processes*. Cambridge University Press.

Vago, D. R., & Zeidan, F. (2016). The brain on silent: Mind wandering, mindful awareness, and states of mental tranquility. *Annals of the New York Academy of Sciences*, *1373*(1), 96–113. https://doi.org/10.1111/nyas.13171

van Vugt, M. K., & Jha, A. P. (2011). Investigating the impact of mindfulness meditation training on working memory: A mathematical modeling approach. *Cognitive, Affective, & Behavioral Neuroscience*, *11*(3), 344–353. https://doi.org/10.3758/s13415-011-0048-8

Vandierendonck, A. (2017). A comparison of methods to combine speed and accuracy measures of performance: A rejoinder on the binning procedure. *Behavior Research Methods*, *49*(2), 653–673. https://doi.org/10.3758/s13428-016-0721-5

Viglas, M., & Perlman, M. (2018). Effects of a mindfulness-based program on young children's self-regulation, prosocial behavior and hyperactivity. *Journal of Child and Family Studies*, *27*(4), 1150–1161. https://doi.org/10.1007/s10826-017-0971-6

von Bastian, C. C., Locher, A., & Ruflin, M. (2013). Tatool: A java-based open-source programming framework for psychological studies. *Behavior Research Methods*, *45*(1), 108–115. https://doi.org/10.3758/s13428-012-0224-y

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. https://ggplot2.tidyverse.org

Wong, W. P., Coles, J., Chambers, R., Wu, D. B.-C., & Hassed, C. (2017). The effects of mindfulness on older adults with mild cognitive impairment. *Journal of Alzheimer's Disease Reports*, *1*(1), 181–193. https://doi.org/10.3233/adr-170031

Zou, Y., Li, P., Hofmann, S. G., & Liu, X. (2020). The mediating role of non-reactivity to mindfulness training and cognitive flexibility: A randomized controlled trial. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01053

Supplementary Materials

Peer Review History

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