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ORIGINAL PAPER

The Effect of a Brief Mindfulness Practice on Perceived Stress and Sustained Attention: Does Priming Matter?

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Abstract

Objectives The objective of the current study was to investigate the effect of a brief mindfulness practice on perceived stress and sustained attention, and to determine whether priming the benefits of mindfulness meditation enhances this effect.

Methods Two hundred and twenty undergraduate students were randomly assigned to a control condition (CC), a meditation condition (MC), or a priming + meditation condition (PMC). Baseline and post-treatment measures included subjective stress ratings on a visual analog scale (VAS) and performance on a Sustained Attention to Response Task (SART), determined by reaction time coefficient of variability (RTCV) and three measures of accuracy: correct responses, errors of commission, and errors of omission.

Results Repeated measures analyses revealed that both the MC and the PMC displayed a decline in perceived stress relative to the CC. Analyses further revelated that the MC and PMC displayed fewer errors of omission relative to the CC. However, only the PMC displayed better performance relative to the CC with respect to total correct response and errors of commission. There were no significant between-group differences for RTCV.

Conclusions These findings are novel and provide a foundation to further investigate the effect of priming on mindfulness engagement and its potential benefits.

Keywords Mindfulness · Meditation · Attention · Stress · Priming

Over the last three decades, research on the benefits of mindfulness meditation has emerged as a prominent field of focus across a number of disciplines including, but not limited to, education, psychology, and neuroscience (Van Dam et al., 2018). Grounded in Buddhist philosophy, mindfulness may be defined as purposely paying attention to thoughts, emotions, and sensations as they arise moment-to-moment, with an open and accepting attitude (Kabat-Zinn, 2003). Meditation is the formal practice used to cultivate mindfulness, through the practice of specific mind–body techniques that facilitate the awareness of and skillful responding to internal and external experiences as they arise (Kabat-Zinn, 2003). Although findings are mixed, research suggests that mindfulness training may reduce stress and improve psychological indices of well-being, perceptions of pain, and cognitive functioning (Gill et al., 2020; Hilton et al., 2017; Im et al., 2021; Khoury et al., 2015; Pascoe et al., 2017).

The development of attentional skills has been a fundamental focus in the literature, thought to underlie the observed benefits of mindfulness training in reducing stress and stress-related ailments (Cheisa & Malinowski 2011; Lutz et al., 2008). The two common styles of meditation practice include focused attention (FA), which entails focusing and sustaining attention on a chosen object, such as the breath; and open monitoring (OM), which entails the conscious awareness of moment-to-moment experiences as they arise. While both practices are commonly embedded within a standard mindfulness-based intervention, the novice practitioner commonly begins with FA to reduce distractibility and build equanimity, before moving to open monitoring with a reflective awareness (Lutz et al., 2008).

While a majority of research has examined the benefits of multi-week mindfulness-based intervention programs, a growing area of research is starting to examine the effects of brief meditation practice, for example, those that are less than an hour long (Heppner & Shirk, 2018; Jankowski &

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Holas, 2020; Norris et al., 2018; Somaraju et al., 2021). Specifically, there has been exploration into the benefits of brief mindfulness practice for outcomes of emotion regulation and cognitive control, as both are skills that employ similar neural networks and have been suggested to improve following long-term interventions (Lutz et al., 2008). In a study by Friese et al. (2012), participants were invited to participate in an experimental study following a 3-day introductory meditation seminar. Participants were randomized to a self-control depletion condition (i.e., emotional suppression task) or a neutral condition. Those exposed to the depletion condition were then further randomized to a subsequent 5-min meditation condition, or a non-meditation condition. All participants were then invited to complete a test of attention and concentration. Results showed that the meditation group performed as well as the non-depletion group on the attention task, whereas participants randomized to the depletion condition without meditation displayed poorer performance. Accordingly, brief meditation may restore the ability for sustained attention following resource depletion (Friese et al., 2012). A brief 15-min mindfulness practice has also been found to partially moderate provoked aggression following resource depletion (Yusainy & Lawrence, 2015). However, the effect of a brief mindfulness practice on reducing negative affect has been mixed (Arch & Craske, 2006; Erisman & Roemer, 2010).

In examining the effect of a 10-min breath-focused meditation practice on attention performance among meditation-naïve college students, Norris et al. (2018) reported enhanced accuracy on a measure of sustained attention following meditation relative to an active control condition. Furthermore, Mrazek et al. (2012) found that an 8-min mindful breathing exercise contributed to marginally less variable reaction time and fewer errors of commission (i.e., failing to respond when one should respond, or misses) relative to controls, indicating reduced mind-wandering in the meditation group (Mrazek et al., 2012). Still, other studies have reported null associations following brief meditation practice (Johnson et al., 2015; Larson et al., 2013).

Although inconsistent findings are commonly attributed to issues of study design (Cheisa et al., 2011; Davidson, 2010), researchers have also acknowledged the importance of individual difference factors, such as trait mindfulness (Carpenter et al., 2019; Laurent et al., 2015). However, the influence of individual differences in motivation and preconceived assumptions of mindfulness meditation have not been evaluated. According to Shapiro et al. (2006), mindfulness is comprised of three pillars: intention, attention, and attitude (IAA). These three pillars interact to facilitate a perspective shift contributing to the achievement of benefits commonly associated with the practice (Shapiro et al., 2006), while attention and attitude are commonly evaluated through changes in attentional processing and the cultivation of acceptance and non-judgment following mindfulness meditation (Lykins et al., 2012; Rahl et al., 2017; Teper & Inzlicht, 2013; Verhaeghen, 2021), examination of one's motivation or intention for engaging in mindfulness practice, and subsequently the mindset that one brings to the experience is often not considered (Shapiro et al., 2006). More recently, the Liverpool Mindfulness Model was proposed as an expansion of the IAA model, which structures the progression of mindfulness into five tiers (Malinowski, 2013). *Motivational factors* determine whether and how the individual engages in the *mental training* of mindfulness, which in turn refines *core processes* of attentional and emotional regulatory skills. The development of such skills may result in a more balanced overall *mental stance* and achievement of *positive outcomes* for overall physical and mental well-being. The initial motivational factors of the Liverpool Model consider the interplay of motivations, intentions, expectations, and attitudes that facilitate purposeful engagement in mindfulness practice (Malinowski, 2013). The literature to date, especially in the context of brief mindfulness training, has primarily focused on the emotional and cognitive benefits of the practice in absence of the novice practitioner's mindset or preconceived notions.

A potential framework that may provide insight into the motivational factors of mindfulness proposed by Malinowski (2013) is through the lens of Expectancy-Value Theory, which posits that achievement on a given task can be predicted by whether the individual values the task and the extent to which they believe they can perform well (Wigfield & Eccles, 2000). In the context of mindfulness meditation, value of the practice may be questioned, depending on the individual's knowledge and preconceived notions of the practice (McKenzie et al., 2012). Indeed, the "buy in" may be challenged with preconceived notions of mindfulness practice being "airy fairy," a waste of time, too difficult, or a religion (Harrison et al., 2019). Expectancy-Value Theory has been applied to educational psychology, finding that course-related task value and self-efficacy in students are predictive of achievement outcomes (Meyer et al., 2019; Vinni-Laasko et al., 2019).

Task value and achievement may be synthesized through a priming technique that frames mindfulness meditation as an achievable and valuable practice. Priming has been applied to various health domains to increase the frequency and fidelity of health behavior engagement through cultivation of a health goal-oriented mindset. Findings from prior research have been mixed; however, this technique has been shown to hold value in influencing behaviors such as food selection, vaccination perception, and exercise engagement (Brown et al., 2016; Courtney et al., 2022; Papies, 2016; Petzel & Noel, 2021; Schlegel et al., 2021). More specifically, supraliminal priming is a technique whereby individuals are aware of the exposure of an environmental cue but are naïve to the effect it may have on their behavior (Stajkovic et al., 2006). Employment of such techniques may in turn translate to benefits for task performance (Engeser et al., 2016). In a study by Hogue (2019), male college students were exposed to a 15-min lecture on achievement goal perspective theory, highlighting the importance of *caring task-involving* and *mastery motivation*, before being exposed to an ego-involving instructional juggling session. Results showed that, relative to the non-primed group, primed participants displayed lower levels of stress following the juggling session, evidenced by lower cortisol secretion, a primary stress hormone in humans (Hogue, 2019).

In regard to the benefits of priming for mindfulness, one study to date has investigated priming to foster an intentional mindset related to mindfulness practice. Rowe et al. (2016) primed 117 meditation-naïve participants with either a self-compassion, attachment security, or neutral control prime before engaging in a mindfulness practice. Each priming condition entailed visualization (compassion towards self, close secure relationship, or solo shopping trip) and writing down the visualization. Following the meditation practice, willingness to participate in future mindfulness training was assessed. Relative to the control priming condition, both the self-compassion and the attachment security prime resulted in greater self-report willingness to engage in future mindfulness practice (Rowe et al., 2016). Consequently, it may be surmised that priming may be employed to address barriers to receptivity and foster task value and self-efficacy in the context of mindfulness meditation. More specifically, it may be postulated that a priming effect may enhance engagement in the meditation practice when the benefits of mindfulness are presented as valuable, attainable, and empirically supported.

To this end, the objective of this study was two-fold: (1) to determine whether a brief mindfulness meditation practice decreases momentary perceived stress and enhances sustained attention, and (2) to determine whether priming the benefits of mindfulness meditation using a mindfulness infographic enhances the aforementioned effects. It was hypothesized that participants who engage in a 10-min mindfulness meditation condition would display lower perceived momentary stress and better performance on an attention task relative to a non-meditation control condition. Furthermore, it was hypothesized that participants who were primed via a mindfulness infographic prior to meditation would display lower perceived momentary stress and better performance on the attention task relative to a control and meditation-only condition.

Method

Participants

According to a priori power calculation using G*Power3.1 for an analysis of covariance (ANCOVA, considering main effect, interaction, and covariate) assuming an effect size of $\eta_p^2 = 0.242$ (Norris et al., 2018) with a statistical power of $\beta = 0.90$ and a significance level of $a = 0.05$, a total of 202 participants were required to detect a significant between-groups difference. However, due to the possibility of unusable data from an online study, the authors chose to oversample, keeping the study portal open for two academic semesters. A total of 329 participants were initially recruited from an undergraduate psychology participant pool between November 2020 and March 2021, to participate in an online experimental study for course credit. To be eligible for the study, participants were required to have access to a computer and high-speed internet. Participants with a history of trauma were excluded.

A total of 109 participants were removed from the dataset. Thirty-eight participants asked to withdraw their data after being debriefed (reasons for withdrawal of data are unknown) and 71 participants met the a priori elimination criteria for unusable data (see five criteria below). Accordingly, the remaining sample entailed 220 participants: 79 participants were randomized to the CC, 78 were randomized to the MC, and 63 were randomized to the PMC. The relatively fewer number of participants in the PMC resulted from technical difficulties with the online platform link. Table 1 displays baseline characteristics of the study sample.

Procedures

Participants were sent a study link through the recruitment platform. Following the provision of consent, participants were randomized to one of three experimental conditions: the priming + meditation condition (PMC), wherein participants read the mindfulness infographic prior to meditating for 10 min; the meditation-only condition (MC), wherein participants meditated for 10 min; or the control condition (CC), wherein participants read the mindfulness infographic but did not meditate. The experiment began with the completion of a baseline visual analog scale (VAS) to measure perceived stress and the Sustained Attention to Response Task (SART), followed by experimental condition exposure (PMC, MC, or CC), and a post-exposure VAS and SART. A 5-min break was offered immediately before condition exposure and immediately following post-exposure VAS and SART completion. Finally, participants completed the demographic and

Table 1 Baseline characteristics of the entire study sample and across condition

Measure, mean (SD) or %	**Total ($n = 221$)**	**PMC ($n = 63$)**	**MC ($n = 78$)**	**CC ($n = 79$)**	***p***
Demographics					
Sex (% female)	84%	87%	74%	90%	**0.21**
Age	20.04 (4.46)	20.10 (5.00)	20.65 (5.05)	19.39 (3.16)	.207
Race/Ethnicity (%)					.378
Caucasian	25%	19%	29%	25%	
Asian	45%	46%	45%	44%	
Black	12%	14%	9%	13%	
Middle Eastern	12%	13%	15%	8%	
Hispanic/LatinX	2%	2%	1%	4%	
Other	4%	6%	0%	6%	
Health diagnosis (%)					
Depression	21%	21%	18%	24%	.642
Anxiety	22%	19%	22%	25%	.666
ADHD	4%	5%	5%	1%	.370
Meditation experience (%)					
Time spent meditating per week					.348
0 min	80%	81%	79%	80%	
1–30 min	19%	19%	18%	18%	
31–60 + min	1%	0%	3%	1%	
Likeliness to practice mindfulness in the future					.547
Not likely	29%	20%	28%	34%	
Somewhat likely	34%	38%	37%	28%	
Moderately likely	24%	30%	18%	23%	
Extremely likely	6%	5%	8%	6%	
Already practice	7%	5%	9%	8%	
Questionnaire					
MAAS	3.45 (0.80)	3.41 (0.79)	3.39 (0.92)	3.53 (0.68)	.491

ADHD, attention-deficit hyperactivity disorder; *CC*, control condition; *MAAS*, Mindful Attention and Awareness Scale; *MC*, meditation condition; *p*, *p* value; *PMC*, priming plus meditation condition; *RTCV*, reaction time coefficient of variability; *SART*, Sustained Attention to Response Test; *SD*, standard deviation; *VAS*, visual analog scale

meditation habit questionnaire and the MAAS, followed by debriefing on the study hypotheses. Once debriefing was complete, participants had an option to withdraw their data (i.e., prompted to click on submit data or withdraw data).

Measures

The experimental study was delivered online using Pavlovia. Experimental stimuli were created and administered through PsychoPy and questionnaires were administered through Qualtrics™.

Sustained Attention

The primary outcome of interest was performance on a brief Sustained Attention to Response Task (SART; Robertson et al., 1997). The SART is a computerized GO/NO-GO task that entails pressing the computer spacebar for non-target stimuli (e.g., numbers 1–8, respond) and inhibiting a response when presented with an infrequent target (e.g., number 9, withhold response). The SART is a commonly used cognitive task to assess changes in 5 performance following brief mindfulness practice and short-term interventions (Bauer et al., 2020; Morrison et al., 2014; Mrazek et al., 2012). To accommodate an online study and to reduce risk of fatigue, the pre-exposure SART was 2 min in length (33 No-Go trials, 77 Go trials), to assess baseline performance. The post-exposure SART was approximately 4 min in length (54 No-Go trials, 144 Go trials). Stimuli were 1.2 inches in height and 0.8 inches in width, were in white font, and were presented in the center of the screen on a dark gray background. Numbers one through nine were flashed on the screen sequentially, in random order for 1500 ms. Participants were instructed to press the space bar for GO stimuli and withhold a response for the NO-GO stimulus.

Immediately following response to the stimulus, the next number flashed on the screen; if no response was recorded, the number remained on the screen for the full duration of 1500 ms.

Performance was determined by reaction time (RT) coefficient of variability (CV) (RTCV; defined as standard deviation divided by mean response time), and three accuracy scores (Van Schie et al., 2012): correct response (sum of correct hits for GO stimuli and correct misses for NO-GO stimuli); errors of commission (sum of incorrect hits for NO-GO stimuli; i.e., respond when should not respond); and errors of omission (sum of incorrect misses for GO stimuli; i.e., failure to respond).

Momentary Perceived Stress

The secondary outcome of interest was momentary perceived stress, which was assessed using a visual analog scale (VAS). The VAS is a validated measure of momentary stress (Barré et al., 2017). Before and after experimental exposure, participants were asked to rate their current stress along a 10-cm line from "not at all" to "extremely."

Trait Mindlessness

The Mindful Attention and Awareness Scale (MAAS; Brown & Ryan, 2003; Carlson & Brown, 2005) is a 15-item scale that assesses propensity towards inattention, or *mindlessness* (Grossman, 2011). Items are rated from one (*almost always*) to six (*almost never*), and items include statements such as "I find it difficult to stay focused on what's happening in the present" and "I rush through activities without being really attentive to them." The scale is reported to have good validity and strong reliability (Black et al., 2012; Carlson & Brown, 2005; Kotzé & Nel, 2016; Phang et al., 2016). The total score on the MAAS ranges from one to six, with lower scores indicating a greater propensity towards mindlessness. The MAAS was administered to ensure that the three experimental groups did not differ on trait mindlessness. McDonald's omega in the current sample ($\omega = 0.873$) suggests good reliability of the scale.

Demographics and Meditation Habits

A questionnaire designed by the researchers was administered to index demographic factors, health status, and whether participants had an existing meditation practice. Demographic questions indexed age, gender, biological sex, and race/ethnicity. Health-related questions assessed for any conditions which may confound the results of the study, including depression, anxiety, and attention-deficit hyperactivity disorder (ADHD). Finally, participants were asked to report their engagement in contemplative practices (i.e., On average, how many minutes do you meditate each week?). Finally, at the end of the study, before debriefing, participants were asked the likelihood of incorporating meditation into their daily practice.

Ten-Minute Guided Meditation

Participants assigned to the meditation conditions (with or without priming) completed a 10-min FA meditation. Participants were invited to rest attention on the breath, followed by a body scan in which participants were invited to systematically shift attention to different parts of the body (Lippelt et al., 2014). The auditory instructions were to comfortably sit in a chair with closed eyes or with an unfocused gaze towards the floor. To ensure compliance with the guided meditation, two attention tests were displayed at the 3-min and 8-min mark, prompting a response by pressing the space bar. The rationale was that participants who pressed the space bar did not comply with the instructions to close their eyes or soften their gaze towards the floor, in which case their results were removed ($n = 36$).

Priming Mindfulness Infographic

Priming was facilitated using a mindfulness infographic. The material was presented as one continuous infographic with sub-sections pertaining to (1) an overview of mindfulness, (2) neuroplasticity associated with mindfulness, and (3) behavioral changes associated with mindfulness. Empirical evidence was provided on the effects of mindfulness meditation on the amygdala, the prefrontal cortex, the anterior cingulate cortex, and the hippocampus. The behavioral subsection informed on changes in domains of stress resilience, cognitive function, and emotion regulation. Please see Supplementary Materials to view infographic.

Data Analyses

Data were first cleaned for potential unusable data. Due to the unsupervised, online administration of the experiment, five strict elimination criteria were established. Participants were removed from the data set if they (1) completed the experiment between 1 and 5 am; (2) pressed the spacebar during the 10-min meditation segment; (3) did not engage with the SART (i.e., had greater than four consecutive errors of omission); (4) responded indiscriminately to the SART (e.g., continuous pressing of button regardless of stimulus); or (5) took longer than 30 min to complete the questionnaires. As noted above, this resulted in the removal of 71 participants from the dataset.

Data were then assessed for assumptions of normality. The outlier labeling rule was used to identify significant outliers in the data. Observed outliers were then winsorized to reduce the effects of possible outliers while maintaining the sample size. Descriptive statistics were analyzed using analyses of variance (ANOVAs, for continuous variables) and chi-square analyses (for categorical variables) to identify potential confounding variables. Sample characteristics that significantly differed between conditions were treated as covariates in subsequent statistical models.

To address the study hypothesis pertaining to SART performance, multiple analysis of covariance (MANCOVA) was conducted. Of note, a repeated measures analysis was not possible as the baseline SART task was shorter in duration than the post-exposure task. Condition (PMC, MC, CC) was entered as the independent variable; sex and baseline performance (RTCV, three accuracy scores) were entered as covariates; and post-exposure SART performance scores (RTCV, three accuracy scores) were entered as the dependent variables. To address the study hypothesis pertaining to perceived stress, a repeated measures ANCOVA was conducted, with condition entered as the between-subjects factor, sex entered as the covariate, and VAS stress scores at pre- and post-exposure entered as the within-subjects variables. Statistically significant omnibus tests were followed by post hoc comparisons between the three conditions with Bonferroni correction to control for multiple comparisons. All statistical analyses were conducted using IBM SPSS Statistics version 27, with a two-tailed significance value set at $p < 0.05$.

Results

Baseline Performance

Analyses showed that groups did not significantly differ on health status (p value range = 0.370–0.916), prior meditation experience (p value = 0.348), trait mindlessness ($p = 0.491$), or demographic variables (p value range = 0.207–0.378), with the exception of sex. Chi-squared analyses revealed a significant group difference by sex ($X^2(2) = 7.70$, $p = 0.021$). Specifically, the MC had a greater proportion of males (26%), relative to the PMC (13%) and the CC (10%). Accordingly, sex was entered as a covariate in all subsequent analyses. Of note, trait mindlessness did not associate with any of the outcome variables ($p = 0.491$).

No significant between-group differences were observed for baseline stress rating ($p = 0.142$) or baseline SART performance scores (p value range = 0.191–0.681). Nonetheless, all statistical models included baseline performance as an a priori covariate.

Effect of Condition on Change in Self-reported Stress

Controlling for sex, repeated measures ANCOVA using Greenhouse–Geisser correction revealed a significant effect of condition on change in perceived stress from baseline to post-exposure assessment ($F(2, 216) = 38.47$, $p < 0.001$, $\eta_p^2 = 0.261$). At post-exposure assessment, multiple comparisons using Bonferroni correction showed that the CC reported significantly higher perceived stress relative to the MC ($M_{difference} = 2.58$, $SE = 0.34$, 95% CI = 1.92, 3.25, $p < 0.001$) and the PMC ($M_{DIFF} = 2.34$, $SE = 0.35$, 95% CI = 1.48, 3.19, $p < 0.001$). The MC and PMC did not differ on post-exposure perceived stress ($M_{difference} = 0.25$, $SE = 0.36$, 95% CI = − 0.61, 1.11, $p = 1.00$). See Fig. 1 for change in perceived stress by condition.

Effect of Condition on Post-exposure SART Performance

Controlling for sex and mean baseline performance scores, MANCOVA revealed a significant effect of condition on SART performance ($V = 0.082$, $F(8, 418) = 2.24$, $p = 0.024$, $\eta_p^2 = 0.041$). Subsequent between-groups effects failed to reveal an effect of condition on RTCV ($F(2, 212) = 1.49$, $p = 0.227$, $\eta_p^2 = 0.014$). However, a significant effect of condition was found for correct response score ($F(2, 212) = 3.73$, $p = 0.025$, $\eta_p^2 = 0.034$), omission errors ($F(2, 198) = 4.39$, $p = 0.014$, $\eta_p^2 = 0.040$), and commission errors ($F(2, 212) = 4.48$, $p = 0.012$, $\eta_p^2 = 0.041$).

Subsequent multiple comparisons with Bonferroni correction were conducted for SART accuracy scores. With respect to SART correct response scores, analyses revealed that the CC did not differ from the MC

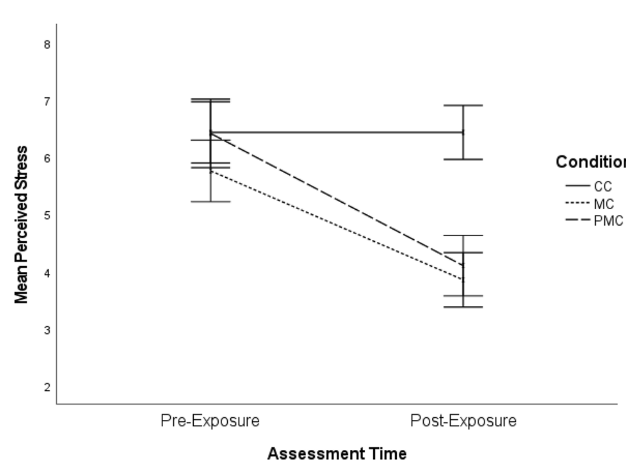

Fig. 1 Change in perceived stress by condition. *Note:* CC, control condition; MC, meditation condition; PMC, priming + meditation condition. Error bars: ± 2 standard error

($M_{\text{difference}} = -0.91$, $SE = 1.04$, CI 95% = −0.3.42, 1.59, $p = 0.100$), but displayed a lower mean correct response score than the PMC ($M_{\text{difference}} = -2.85$, $SE = 1.10$, CI 95% = −5.50, −0.20, $p = 0.031$). The MC did not display a statistically significant lower correct response score relative to the PMC ($M_{\text{difference}} = -1.93$, $SE = 1.10$, CI 95% = −4.59, 0.73, $p = 0.243$). Subsequent comparisons for SART omission errors revealed that the CC displayed significantly greater errors of omission relative to both the MC ($M_{\text{difference}} = -0.24$, $SE = 0.09$, CI 95% = −0.46, −0.02, $p = 0.025$) and the PMC ($M_{\text{difference}} = -0.28$, $SE = 0.09$, CI 95% = −0.51, −0.05, $p = 0.010$); however, omission errors did not differ between MC and PMC ($M_{\text{difference}} = -0.04$, $SE = 0.09$, CI 95% = −0.27, 0.19, $p = 1.00$). Finally, with respect to commission errors, analyses revealed that the CC displayed significantly more errors of commission than the PMC ($M_{\text{difference}} = 2.89$, $SE = 1.03$, 95% CI = 0.40, 5.39, $p = 0.017$); however, errors of commission were not significantly different between the CC and the MC ($M_{\text{difference}} = 0.96$, $SE = 0.98$, 95% CI = −1.40, 3.32, $p = 0.987$), or between the MC and the PMC ($M_{\text{difference}} = 1.94$, $SE = 1.04$, 95% CI = −0.57, 4.44, $p = 0.19$). See Fig. 2 for mean accuracy scores by condition.

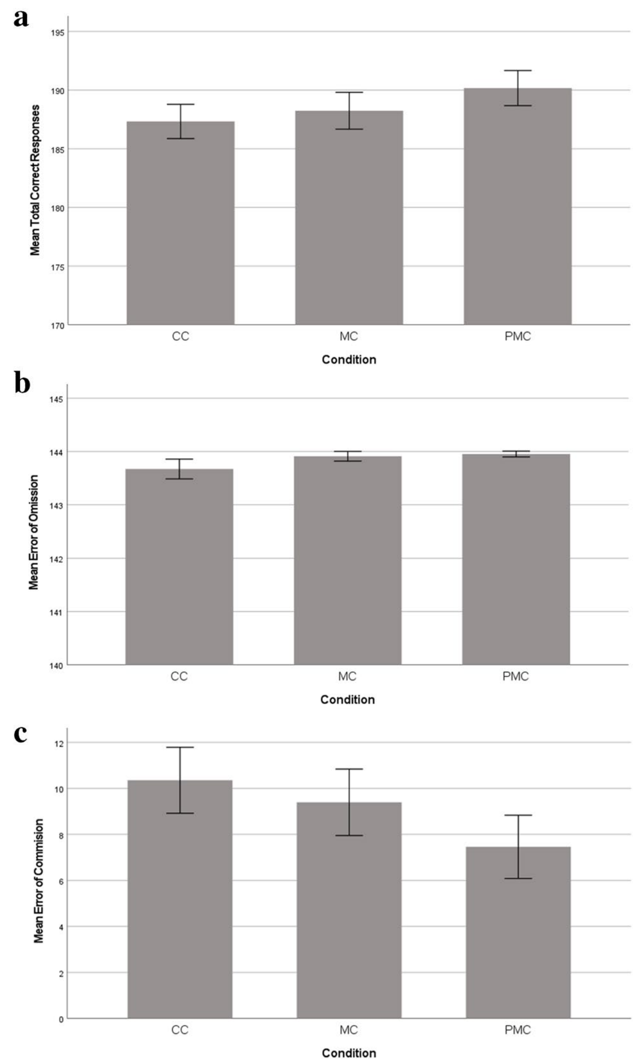

Fig. 2 Post-exposure SART accuracy scores by condition for **a** mean (standard error) total correct responses by condition, **b** mean (standard error) error of omission, and **c** mean (standard error) error of commission. *Note:* CC, control condition; MC, meditation condition; PMC, priming + meditation condition. Mean total correct response = greater score indicates better performance; error of omission = lower score indicates greater error; error of commission = higher score in indicates greater error. Error bars: ± 2 standard error

Discussion

The present study sought to evaluate the effect of a brief mindfulness meditation practice on momentary stress and attentional performance, and to determine whether priming the benefits of meditation before practice may augment performance outcomes. It was hypothesized that priming may enhance the effects of a mindfulness practice when the benefits of mindfulness are presented as valuable, attainable, and empirically supported. Results suggest that priming does not enhance the effects of a brief mindfulness practice in reducing momentary perceived stress; however, priming may enhance the effects of a brief mindfulness practice on elements of attentional performance.

Aligned with previous research (Borchardt & Zoccola, 2018; Call et al., 2014; de Sousa et al., 2021), brief engagement in a mindfulness meditation practice associated with a decrease in perceived stress. In the current study, both the meditation and the meditation with priming condition displayed a significant decrease in perceived stress, relative to the non-meditation control condition. However, priming did not reduce perceived stress above and beyond that which was observed following meditation alone. The lack of a priming enhancing effect on perceived stress may be due to the relative robust effect of mindfulness meditation on stress sensitive systems (Borchardt & Zoccola, 2018; Tang et al., 2009). During the mindfulness practice, participants were invited to engage in diaphragmatic breathing, which entails contraction of the diaphragm and expansion of the abdomen wall on the inhalation, facilitating efficient movement of oxygen into the lungs and body; and relaxation of the diaphragm and abdomen wall on the exhalation, releasing carbon dioxide (Ma et al., 2017). Through the regulation of vagal activity, diaphragmatic breathing regulates sympatho-vagal balance, enhancing parasympathetic activity (Bordoni et al., 2018; Russo et al., 2017). Indeed, deep breathing interventions, including acute deep breathing exercises (Joshi et al., 2020), are found to improve physiological and self-reported measures of stress (Hopper et al., 2019; Tsiouli et al., 2014). Given the strong association between diaphragmatic breathing and reduced sympathetic activity, it is possible that priming the meditation practice was superfluous in the context of perceived stress. It is also possible that the current study protocol did not provide a suitable context to assess priming enhancing effects on perceived stress. Research has shown that brief mindfulness training may alter reactivity to the Trier Social Stress Test (TSST), a laboratory psychosocial stressor (Creswell et al., 2014). Accordingly, priming within the context of a psychosocial stress challenge may allow for greater sensitivity in measuring priming effects on meditation-induced stress inoculation to a psychosocial stressor.

The effect of a brief mindfulness meditation practice on attention has been more variable, with some studies resulting in null findings (Johnson et al., 2015; Larson et al., 2013; Norris et al., 2018) and others suggesting attention enhancing effects of a brief mindfulness practice (Jankowski & Holas, 2020; Mrazek et al., 2012). The current study examined performance on the SART to assess variability in reaction time, overall accuracy in performance, and errors of commission and omission. In the context of mindfulness, the SART provides an interesting tool to assess sustained attention and mind-wandering. Variable reaction time and errors of commission present two different measures of mind-wandering, with the former reflecting fluctuations in speed of response and the latter reflecting distinct failure of sustained attention, marked by automatic rather than controlled response behavior (Cheyne et al., 2009; Robertson et al., 1997). Errors of omission reflect the ability to remain engaged with the task at hand and further contribute to overall sustained attention performance (Cheyne et al., 2009).

Although there is limited research examining the benefits of acute mindfulness exposure on errors of omission, the current findings are aligned with previous research examining errors of omission following longer term (e.g., 8-week program) mindfulness programs (Bauer et al., 2020; Morrison et al., 2014). Specifically, the current findings suggest that engaging in a brief mindfulness practice may facilitate engagement with a targeted task, evidenced by fewer errors of omission in the mindfulness-only condition, relative to the control condition. Although the mindfulness with priming condition also resulted in fewer errors of omission relative to the control condition, priming did not associate with fewer errors of omission relative to the mindfulness-only condition, suggesting no added benefit of priming above and beyond meditation alone in fostering the ability to remain "on task" (Morrison et al., 2014). Although additional research is required, reduced perceived stress across meditation groups may have facilitated the ability to remain on task. This postulation is supported by a significant bivariate correlation between post-exposure stress scores and errors of omission (results not presented). Indeed, previous research suggests that stress may modulate mental resources, which may influence attentional control (Dehais et al., 2019; Vinski & Watter, 2013).

Although a 10-min mindfulness practice reduced errors of omission, the mindfulness-only condition did not associate with better variable reaction time score, overall accuracy, or commission errors, relative to the control condition. This finding is in contrast with Mazrek et al. (2012), who reported a significant effect of mindful breathing on errors of commission and a marginal effect for response variability, relative to a passive relaxation condition and a reading condition. Discrepant results may be attributed to the difference in SART duration (4-min vs 10-min SART). The current study employed a shorter SART paradigm to facilitate feasibility of the online study and to minimize participant attrition. As longer attention tests have been associated with decreased performance over time, which may be offset by mindfulness training, it may be surmised that the 4-min SART employed in the current study was not long enough to invoke a difference in target response patterns following mindfulness meditation alone (Bauer et al., 2020; Morrison et al., 2014; Mrazek et al., 2012). However, mindfulness training over a 3-day period has been found to enhance performance on SART paradigms as short as 6 min in length (Rahl et al., 2017). Given the small number of studies to date that examine brief mindfulness protocols on indices of attention and mind-wandering, additional research is needed.

Replication is largely necessary; however, the current findings provide some evidence that priming may augment the effects of a brief mindfulness practice on elements of attentional performance. Although the mindfulness with priming condition did not significantly differ from the meditation-only condition on SART performance outcomes, mindfulness with priming did associate with better overall accuracy scores and fewer errors of commission relative to the control condition, an effect that was not observed for the mindfulness-only condition. As previous findings on the effect of mindfulness meditation on attentional performance have been mixed (Sumantry & Stewart, 2021), it is possible that addressing the mindset of the individual is key to understanding individual variation for the potential effectiveness of the practice. In line with the Liverpool Model of Mindfulness, the motivational factors of attitude, intention, motivation, and expectation may have been primed via infographic exposure to foster a mindset that structured mindfulness practice for the purpose of achieving the specific goal of sustaining attention (Malinowski, 2013).

It may be argued that the priming condition enhanced expectancy effects on the SART, such that the educational information provided increased motivation to perform well on a future task. Although motivation to perform well on the SART was not measured, previous research has shown that explicit performance-related motivation for the SART does not actually influence performance (Cardeña et al., 2015). As such, it is likely that SART performance among the primed mindfulness participants relative to controls was driven by greater engagement with the mindfulness practice, rather than an increased desire to perform well. This is aligned with Expectancy-Value Theory, which posits that primed participants view the practice as valuable and attainable. However, this interpretation is purely speculative and requires further investigation.

While there were no significant differences between the two meditation conditions, the effect of priming before mindfulness may simply facilitate small incremental benefits over and beyond mindfulness alone. However, results must be interpreted with caution and additional research is needed using controlled laboratory protocols and more complex testing paradigms to assess for potential threshold effects that may differentiate primed conditions from non-primed conditions.

Limitations and Future Research

Although the current study is novel in examining a potential priming effect for mindfulness practice and provides an important stepping stone to evaluating the importance of intention in the context of mindfulness meditation, results must be considered in light of study limitations. Replication is highly recommended to corroborate the validity of the findings, particularly considering the current replicability crisis for priming effects (Sherman & Rivers, 2021). First, although the sample was relatively diverse with respect to racial background, with over half of the sample identifying as non-White, a majority of the sample was female. As such, results from this study cannot be generalized to males with confidence. Additional research is needed to examine potential sex and gender effect modification in the benefits of mindfulness meditation on attention and affect. Second, the participants in this study were undergraduate students, and thus, findings cannot be generalized to a more diverse population with regard to educational background. However, these findings may provide support for bringing mindfulness into the university classroom (Miller et al., 2017). Third, although online research may facilitate the collection of data from a larger sample within a shorter period of time, the limitations of conducting remote research due to the COVID-19 pandemic led to inevitable, uncontrollable factors, such as level of distractibility in the testing environment, the time of day the participant completed the study, lack of consistency across devices on which the experiment was completed, and internet service. It is possible that variability of the testing environment influenced study engagement and underestimated the true effects of meditation priming on sustained attention. Although an attention test was embedded in the experiment during the 10-min meditation session, which eliminated 36 participants, there is no guarantee that participants engaged in the practice or that they read the experiment infographic. Importantly, while there is greater risk for disengagement from study stimuli in an online study, this risk is not completely immune to a laboratory session. Still, future research is needed to examine priming effects in a controlled laboratory setting, with the inclusion of a pure control condition (i.e., no priming or meditation condition). Fourth, questionnaires, including the MAAS were completed following completion of the experiment, which may have resulted in response bias due to carry-over effects. However, this study design was chosen to minimize the potential priming effect of the MAAS and questions pertaining to an existing practice on study outcomes. Furthermore, the MAAS has recently received criticism as a measure of trait mindfulness (Van Dam et al., 2010) as it only measures the facet of acting with awareness, and more specifically *mindlessness*, without considering other distinct facets such as non-judgment, non-reactivity, describing, and observing (Baer et al., 2006). However, the objective of the current study was not to evaluate trait mindfulness among undergraduate students. Finally, the control group was not a pure control condition such that participants in this group were exposed to the mindfulness infographic. Feasibility and time constraints contributed to this final decision. Although it is unlikely that reading a mindfulness infographic would result in a state of mindfulness before task exposure, future research is encouraged to include a non-meditation-plus-non-priming condition.

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Author Contribution RU: designed and executed the study, analyzed data, wrote paper. AJF: supervised RU, and collaborated on design, analyses, and writing of the paper.

Data Availability The data are available at the Open Science Framework (https://osf.io/6j7n4/).

Declarations

Ethics Approval This study was approached by the Toronto Metropolitan University Research Ethics Board (#2020–362) and was therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare no competing interests.

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