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Practice Is Protective: Mindfulness Training Promotes Cognitive Resilience in High-Stress Cohorts

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Abstract Attention is critical for successful performance in demanding real-world situations. Yet, protracted periods of high demand may compromise attention and increase off-task thinking. Herein, we investigate if mindfulness training (MT) may promote cognitive resilience by curbing attentional lapses in high-stress cohorts. Two military cohorts were recruited during their high-stress predeployment interval. Mindfulness-based Mind Fitness Training (MMFT)® was provided to one group (MT, $N=31$) but not the other group (military control group, MC, $N=24$). The MT group attended an 8-week MMFT® course and logged the amount of out-of-class time spent practicing formal MT exercises. The Sustained Attention to Response Task (SART) was used to index objective attentional performance and subjective ratings of mind wandering before (T1) and after (T2) the MT course. In the MT group, changes in SART measures correlated with the amount of time spent engaging in MT homework practice, with greater objective performance benefits (indexed by A', a sensitivity measure), and reduced subjective reports of mind wandering over time in those who engaged in high practice vs. low practice. Performance measures in the low practice and MC groups significantly declined from T1 to T2. In contrast, the high practice group remained stable over time. These results suggest that engaging in sufficient MT practice may protect against attentional lapses over high-demand intervals. Based on these results, we argue that MT programs emphasizing greater engagement in mindfulness practice should be further investigated as a route by which to build cognitive resilience in high-stress cohorts.

Keywords Mind wandering · Attention · Mindfulness · Stress · Resilience · Military

Introduction

While there is growing interest in cognitive training within the fields of cognitive psychology and cognitive neuroscience, there is a paucity of research on the utility of cognitive training in promoting cognitive resilience in high-stress cohorts. *Cognitive resilience* is the ability to maintain or regain cognitive capacities at risk of degradation, depletion, or failure in the face of situational challenges experienced over protracted time periods. Growing evidence suggests that executive control processes such as attention and working memory are necessary for real-world performance success (Cheyne et al. 2006; see also Meyer and Kieras 1999; Miloyan et al. 2013). Individuals must attend to their environment while keeping behavioral goals in mind. In addition, they must remain aware of their relationship to and functioning within their surroundings before appropriate responses can be activated. Yet, subjective reports of mind wandering (i.e., off-task, stimulus-independent thought during an ongoing task) correspond to attentional performance lapses (e.g., Smallwood et al. 2004; Stawarczyk et al. 2011), suggesting that episodes of mind wandering can impede goal-directed behavior. Furthermore, negative mood (Smallwood et al. 2009), dysphoria (Murphy et al. 2013), stereotyped threat (Mrazek et al. 2011), sleep deprivation (Chua et al. 2014), and craving (Sayette et al. 2010) promote attentional performance lapses and correspond with greater self-reported mind wandering. For high-stress

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cohorts experiencing physical, psychological, and situational challenges, the very circumstances necessitating attention to ensure performance success may also diminish its availability.

One emerging area of research involves offering high-stress cohorts mindfulness training (MT) as a form of cognitive training by which to protect against attentional performance lapses and promote performance stability (see Stanley and Jha 2009; Stanley 2014). Mindfulness is described as "a mental mode characterized by attention to present - moment experience without judgment, elaboration, or emotional reactivity" (Jha et al. 2010, p. 54, see also Kabat-Zinn 2013). Typical MT programs offer didactic content and formal exercises on how to stabilize and focus attention on one's present-moment experience. Most programs for novices emphasize concentrative exercises that direct participants to focus on a target object, such as a body sensation or sound. During a breath-focused practice, for example, participants are instructed to sit in a relaxed, upright posture and direct their full attention to the sensations of breathing. When they notice that their attention has wandered, they are to gently return it back to those sensations. Novice participants report noticing that their attention has wandered off task during this exercise, and many report feeling frustrated when this occurs. In these instances, they may upregulate attentional control processes to ensure that they stay on task. If such processes are indeed centrally and repeatedly engaged while performing MT exercises, more time spent engaging in MT practice may result in corresponding strengthening of attentional control. Repeated and sufficient engagement in MT practice may bolster attentional control commensurate with the amount of time spent engaging in MT practice. In line with the notion that MT may strengthen such control processes, several prior studies have established that MT improves performance on measures of attention (e.g., Allen et al. 2012; Jensen et al. 2012; Jha et al. 2007; MacLean et al. 2010; Zanesco et al. 2013) and working memory (Jensen et al. 2012; Mrazek et al. 2013; van Vugt and Jha 2011) and reduces attentional lapses associated with mind wandering (Morrison et al. 2014), as well as subjective reports of mind wandering (Mrazek et al. 2013).

Recent findings also suggest that MT is *protective* against degradation of attentional control over protracted periods of high stress and high demand (Jha et al. 2010, 2015; Leonard et al. 2013; Morrison et al. 2014). While high-stress intervals may increase attentional lapses over time, two recent studies suggest MT may protect against this increase (Leonard et al. 2013; Morrison et al. 2014). For example, while a group of undergraduates who did not receive MT had greater performance lapses and self-reported mind wandering on the Sustained Attention to Response Task (SART: Robertson et al. 1997) over the academic semester, a group receiving a 7-hour, 7-week MT course decreased their SART performance lapses and remained stable over time in self-reported mind wandering over the same 7-week interval of the semester (Morrison et al. 2014). In a study of incarcerated adolescents, Leonard et al. (2013) reported that over a 3- to 5-week period of incarceration, all adolescents in the study showed impaired attentional performance and increased reaction time (RT) variability over time on a behavioral laboratory-based attention task. Yet, those who completed an MT course embedded in a cognitive behavioral therapy (CBT) framework showed significantly less decline in performance than adolescents in an active comparison condition. Further, a "dose–response" relationship was observed between time spent engaging in mindfulness exercises outside of the formal class context and the magnitude of performance benefits. Within the CBT/MT group, those who practiced outside of class performed better on the attention task at T2 than those who did not practice.

Indeed, evidence is growing of a dose–response relationship between time spent engaging in MT exercises outside of class and MT's salutary effects on a variety of outcome measures. Higher levels of well-being and lower levels of stress and psychological symptoms have been reported with MT, with benefits corresponding to the amount of time spent practicing MT (Carmody and Baer 2008; Rosenzweig et al. 2010). In addition to psychological and clinical variables, the amount of MT practice is tied to the amount of weight loss in a mindfulness-based eating study (Kristeller and Wolever 2011), as well as changes in brain activity profiles (Allen et al. 2012; Farb et al. 2013). Collectively, these results converge on the view that MT may improve functioning above baseline levels, with benefits commensurate with the amount of time spent engaging in MT practice (see Carmody and Baer 2008).

In contrast to a growing literature on functional improvements with MT, where more practice time corresponds with greater salutary changes above baseline, less is known about the relationship between practice time and MT's ability to build cognitive resilience and promote functional stability among individuals enduring high-demand intervals. For military servicemembers, there may be periods of heightened demand and psychological stress due to the cyclical nature of military deployments and associated training. As such, building cognitive resilience may be particularly important for this profession.

The military deployment cycle increases the likelihood of servicemembers enduring psychological and physical harm, as well as suffering degradation in cognitive functioning (Tanielian and Jaycox 2008; Vasterling et al. 2006; Marx et al. 2009). In the several months prior to deployment, to habituate themselves to stressors they may experience during their impending mission, servicemembers engage in mission-critical operational training and "stress-inoculation" training, which has been linked to degradation in cognitive performance (Lieberman et al. 2002, 2005; Morgan et al. 2004, 2006; Stanley 2014). All the while, they must prepare to leave loved ones behind and face uncertain and potentially dangerous situations during their deployment. Thus, several studies document increases in troops' distress and emotional disturbances over this interval (Bolton et al. 2001; MacDonald et al. 1998; Maguen et al. 2008).

A recent study investigated MT's ability to build cognitive resilience when offered over the intensive period of predeployment training (Jha et al. 2010). Two questions were examined: (1) Does the high-demand predeployment interval negatively impact performance on a measure of working memory capacity? (2) If so, can MT prevent or dampen working memory depletion over this interval? MT participants received a 24-hour, 8-week program, called Mindfulness-based Mind Fitness Training (MMFT). Military servicemembers in the MMFT course who also practiced more regularly outside of class (an average of ~12 min/day) maintained or improved working memory task performance compared to those who practiced less frequently or not at all and relative to servicemembers in the no-training control group. As such, MMFT was shown to protect working memory performance from depletion over the predeployment interval, and this protection corresponded with the amount of time spent practicing MT exercises.

Moreover, in line with recent findings suggesting that working memory capacity supports the ability to regulate mood (Schmeichel and Demaree 2010; Schmeichel et al. 2008; Pe et al. 2013), servicemembers who practiced MT exercises more regularly outside of class, and maintained or improved their working memory task performance, saw stable levels of negative emotion over the predeployment interval. In contrast, those who practiced less frequently outside of class as well as those in the no-training control group saw increases in negative emotions during this interval. Thus, sufficient MT practice was associated with functional stability in working memory capacity, which may in-turn have helped preserve servicemembers' psychological health in the face of known vulnerabilities associated with their profession.

In addition to the established relationships between working memory and emotion regulation (e.g., Schmeichel and Demaree 2010), working memory capacity is also related to the prevalence of attentional lapses associated with self-reported mind wandering (Kane et al. 2007; Levinson et al. 2012; McVay and Kane 2012). As such, further investigation is warranted to determine if MT can curb such lapses, which may increase over high-stress intervals (e.g., Leonard et al. 2013). The SART is an established metric by which to index attentional performance lapses associated with mind wandering (Cheyne et al. 2009; Robertson et al. 1997; Smallwood and Schooler 2006). Theoretical models suggest that these lapses may be due to the "perceptual decoupling" of attention (Kam and Handy 2013; Schooler et al. 2011, but see Head and Helton 2013). During off-task episodes, attentional resources necessary for task-related cognitive and perceptual analysis of environmental stimuli are proposed to be decoupled from the task at hand as attention is hijacked by internally generated thought. Attentional lapses driven by off-task thinking could have particularly deleterious effects when experienced by military servicemembers, civilian first responders, and others whose jobs require situational awareness, surveying environmental input to detect low-probability events or rapidly changing circumstances (Endsley 1995; Stanton et al. 2001).

The SART involves frequent "go" and infrequent "no-go" responses such that commission errors occur quite readily. In a recent attempt to relate this laboratory task to more ecologically valid circumstances, Wilson et al. (2013) designed a SART variant to simulate a battlefield scenario that troops might encounter during combat operations. In this variant, firearms were to be deployed to respond to frequent "go" trials, and fire was to be withheld for "no-go" trials. They found that similar to the computer-based button press version of the SART, the firearm version produced a high rate of commission errors.

As highlighted by the firearm version of the SART, performance errors are ubiquitous and curbing their occurrence in real-world scenarios could be beneficial. Wilson et al. (2013) note that their results suggest that more research is warranted to determine if training or technological countermeasures can help reduce commission errors. This could be extremely important during combat, when battle requires quick action to shoot at "frequently occurring targets amongst rarely occurring neutrals, e.g., comrade or civilians" (Wilson et al. 2013, p. 1248). Thus, training or other solutions to curb commission errors may help reduce "friendly fire" incidences or the killing of innocents. In addition, such training may also help servicemembers better preserve their own psychological health as they return to civilian life. Psychological and physical health challenges among servicemembers returning from deployment are at unprecedented levels (Tanielian and Jaycox 2008) and have been attributed, in part, to engaging in behavior while deployed that violates servicemembers' own ethical code (Drescher et al. 2011; Johnson 2012). As such, a far-reaching benefit of offering training to curb attentional lapses (e.g., reduce commission errors) and reduce mind wandering may be to help servicemembers better maintain discerning control so that regrettable behavior and its psychological costs are mitigated.

Relatedly, performance on the standard, computerized button-press version of the SART corresponds with psychological health outcomes of particular relevance to military populations, such as sleep (Gobin et al. 2015), depression (Murphy et al. 2013), and PTSD (Koso et al. 2012). Consistent with prior findings that executive functioning may subserve successful emotion regulation (see Hofmann et al. 2012 for a review), these studies report that poorer SART performance corresponds with worse sleep quality, as well as higher depression and PTSD symptom severity. As such, the SART may be a useful metric by which to evaluate the impact of MT in military cohorts who are engaged in predeployment training, which is known to compromise psychological health.

In the current study, we investigated the impact of MT on performance of the computerized SART in predeployment cohorts of U.S. Marine reservists. An 8-week MT course was offered to one but not a second cohort (military control group, MC). Within the MT cohort, we asked participants to log their time spent practicing mindfulness exercises assigned as homework during the course. SART performance was indexed for both the MT and MC groups at two time points (time 1: T1; time 2: T2) separated by 9 to 10 weeks over the predeployment interval. We predicted performance degradation over the T1 to T2 interval in the MC group, as well as among those in the MT cohort who engaged in very little or no MT practice outside of class. In contrast, we predicted that those in the MT cohort with sufficient amounts of MT practice outside of class would be protected from performance degradation over time. From this perspective, a dose–response relationship was predicted where greater practice time would correspond with less performance degradation from baseline. Such a pattern would support the hypothesis that MT practice is protective and builds cognitive resilience by promoting functional stability in those facing intensive, high-demand intervals.

Method

Participants

The MT group comprised 31 male participants (*M* age = 30, standard deviation (*SD*) = 8.06) recruited from a detachment of U.S. Marine Corps reservists to complete an 8-week MT (MMFT) course designed specifically for military servicemembers before deployment. The group's commanding officers offered access to the unit in response to a recruitment flyer. More information about the MT group's characteristics and history can be found in Stanley et al. (2011).

The MC group comprised 24 male participants (*M* age = 25, SD = 4.30) recruited from a separate detachment of U.S. Marine Corps reservists, drawn from the same parent unit as the MT group. While the MC group had a different deployment date than the MT group, they were tested at the same time points relative to their own deployment date and they were preparing for the same mission in Iraq.

None of the participants in either cohort had any prior experience with mindfulness techniques. The study was approved by the University of Pennsylvania Institutional Review Board, and informed consent was obtained from each participant prior to entry into the study.

Procedure

The MT course, MMFT, was created and delivered by a former U.S. Army officer, with many years of experience and training in mindfulness practice, Mindfulness-Based Stress Reduction (MBSR), and trauma resilience. The MMFT course contained some features of the well-known MBSR program (Kabat-Zinn 2013) but differed in its approach to mindfulness training and the scope of the didactic content. Similar to MBSR, the MMFT course involved 24 h of class instruction over 8 weeks with weekly 2-h meetings (on average) and a day-long silent workshop. Distinct from other mindfulness-based approaches, the MMFT course blended mindfulness skills training with concrete applications for the operational environment (e.g., decision making under pressure, such as during counterinsurgency operations, and maintaining self-awareness and emotion regulation during difficult encounters with local populations), information about stress, trauma and resilience, and body-based self-regulation skills incorporating concepts from sensorimotor psychotherapy (Ogden et al. 2006) and Somatic Experiencing® (Levine 1997). This blend of mindfulness skills training with body-based self-regulation and resilience skills is unique to MMFT, with a gradual developmental sequence of exercises to move an individual from dysregulation to regulation. MMFT emphasizes interoceptive awareness by cultivating attentional control and tolerance of challenging experiences, both external (e.g., harsh environmental conditions) and internal (e.g., distressing thoughts, physical pain, intense emotions). Integrating these different course components, each class session consisted of didactic instruction, group discussion of the didactic topics applied concretely to the deployment environment, and interactive mindfulness-based exercises. For more details about the 24-h MMFT course taught in this study, and its distinctions from MBSR, see Stanley et al. (2011).

MMFT was delivered by the trainer via a manualized program and was taught on site at the unit's various training locations during their predeployment training. Marines were divided into two class groups, organized around the unit's organizational teams, which remained constant throughout the course. Because of conflicts with their predeployment training field exercises, 12 participants missed some of the class sessions. Some participants were able to attend make-up classes with the other group, while others received personal instruction through phone interview, so that all participants received all course instructions and content. Participants were also instructed to complete up to 30 min of "homework" each day outside of class, practicing MT exercises with audio CDs specifically created by the instructor for this cohort. The recorded exercises, ranging from 5 to 30 min, were shorter than MBSR's recorded exercises, with out-of-class MT practice often completed in a group setting and in short sessions throughout the day.

All participants took part in two testing sessions, occurring 9 weeks apart for the MC group and 10 weeks apart (1 week before and 1 week after the MMFT course) for the MT group. Stimuli were presented via E-Prime (Version 1.2, Psychology

Software Tools, Pittsburgh, PA), using Dell Vostro 1000 laptops. They sat in a quiet room approximately 57 cm from a PC laptop display and performed the SART (Robertson et al. 1997). A trained experimenter proctored the session during which groups of no more than ten participants, each at his own PC laptop workstation, completed the SART as well as other measures outside the scope of this report.

Measures

Sustained Attention to Response Task

All participants performed a practice block consisting of 313 target and non-target trials, immediately followed by the experimental session consisting of 3 blocks of 313 trials, totaling 939 trials (48 of which were targets). The task took approximately 35 min to complete.

The SART consisted of a continuous array of single digits (0 through 9) presented visually. Each trial consisted of a digit displayed for 250 ms on a gray screen followed by a fixation cross displayed for 900 ms. Stimulus timing, identical to that used herein, has been used in several prior reports (e.g., Robertson et al. 1997; Manly et al. 1999). Participants were instructed to withhold responses (i.e., not pressing space bar) to the number 3 (target) and to respond as quickly as possible to all other numbers (non-targets). Participants could respond either during the stimulus display or during the intertrial interval (ITI). Targets were presented on 5 % of trials. Trial order was pseudo-randomized so that target trials were always separated by at least one non-target trial.

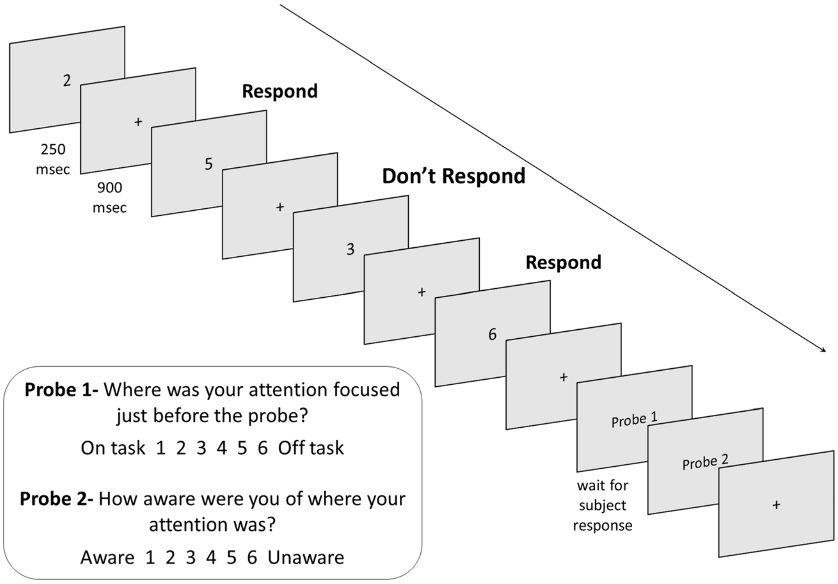
On occasion, two probe questions were presented in succession. The first asked, “Where was your attention focused just before the probe?” Participants responded on a 6-point Likert scale, where 1 represented “on task” and 6 “off task.” A second question asked, “How aware were you of where your attention was?” Participants responded on a similar scale, where 1 represented “aware” and 6 “unaware.” The probe questions were displayed until a response was made. Upon entering a response to the second probe, participants immediately advanced to the next trial. The set of two probes appeared a total of 48 times and were separated by a sequence of trials varying in length from 4 to 33 trials. See Fig. 1 for a visual depiction of the task.

Objective performance measures and subjective ratings of mind wandering were assessed to provide a comprehensive picture of participants’ behavior during the SART. Objective task performance measures included A prime (A') and target accuracy. Target accuracy is the percentage of correctly withheld responses to the number 3 (i.e., 100 %–% of commission errors). A' is a non-parametric measure of sensitivity and was calculated from hits (accuracy in response to targets) and false alarms (errors in response to non-targets) to account and correct for unequal weighting of both error types as described in Stanislaw and Todorov (1999). Speed of response was evaluated with both average RT and the intraindividual coefficient of variation (ICV). RTs below 100 ms were removed from analysis, with average RT including responses to correct non-target trials only. ICV was calculated by dividing the standard deviation of an individual’s RTs by his mean RT for correct non-target trials, with trials under 100 ms also removed. Greater ICV reflects a more variable response speed and has been implicated as a marker of off-task thinking (see Bastian and Sackur 2013). The subjective experience of mind wandering during the SART was measured through a participant’s average response to probe 1 and probe 2, separately. These imbedded experience-sampling probes explore the online (rather than retrospective) subjective experience of mind wandering.

Data Analyses

Of the 31 MT participants, one was excluded from the analysis for failing to submit any practice logs and two others were excluded for failing to follow task instructions (e.g., falling asleep, providing no behavioral responses), and thus 28 MT participants were included in the final analysis. Of the 24 MC participants, five participants were excluded from analysis because they did not follow task instructions. Of the 19 remaining participants, data from trials 1–546 were reported previously in Jha et al. (2015). Full data from 939 trials was not available for two participants resulting in inclusion of 17 MC participants herein.

Participants in the MMFT group were assigned up to 30 min of daily MT practice outside of class and asked to log their practice. They were informed that the instructor would not see their logs and asked to report actual practice time as honestly as possible. Logs were submitted to the research team without instructor access. The range of practice time was 25 to 1685 min of total practice outside of class over the 8-week course (overall, $M = 400$ min; SD = 377). Participants were classified as high practice or low practice using the same strategy as Jha et al. (2010), which described group differences in measures of working memory capacity and affect in the same group of participants investigated herein. MT subgroups were established by performing a median split of practice time. Fifteen participants were classified as high practice (high practice group, $M = 634$ min; SD = 401) and 13 as low practice (low practice group, $M = 151$ min; SD = 62). Two individuals reporting the same practice time as the median value were assigned to the high practice group, leading to unequal group sizes. While the subgroups differed in the amount of homework completion, the high practice ($M = 20.3$ h, SD = 7.2 h) and low practice group ($M = 17$ h, SD = 7.3 h) did not significantly differ in the number of course hours they attended in person ($p > .1$).



Probe 1- Where was your attention focused just before the probe?

On task 1 2 3 4 5 6 Off task

Probe 2- How aware were you of where your attention was?

Aware 1 2 3 4 5 6 Unaware

Fig. 1 The Sustained-Attention-to-Response Task (SART). Participants viewed a continuous string of single digits and were instructed to button press to all digits besides 3 (non-targets) while withholding response to the 3 (targets). Intermittently, they were probed about their mind wandering and awareness (probe 1, probe 2)

To address our critical hypotheses of interest regarding dose–response relationships between MT practice time and training-related changes in SART metrics over the training interval, a series of correlations were conducted for the MT group. To reduce a severe right skew in the distribution of minutes of practice, correlational analyses were conducted using the square root of each participant’s total minutes of reported practice; we refer to this transformed measure as practice time.

Results

Correlations were examined to investigate whether, similar to previous findings (Smallwood and Schooler 2006), there was a significant correspondence between objective performance measures (A') and subjective ratings of mind wandering (probe 1, probe 2) on the SART. Indeed, at T1 in all 45 participants, A' was negatively correlated with probe 1 ($r(43) = -.560$, $p < .0005$) and probe 2 ($r(43) = -.510$, $p < .0005$), suggesting that better task performance during the SART corresponded with lower degrees of self-reported “off-task” and “unaware” thinking, respectively.

Table 1 shows participants’ performance by group on all outcome measures at T1 and T2. Because group assignment to MT vs. MC was based on convenience vs. matched selection, and because the MT high and low practice subgroups were determined by self-reported practice time, analyses of variance (ANOVA) were performed to determine if there were baseline group differences at T1 in any of the six SART outcome variables. Of particular interest was seeing if the high and low practice groups might have differed at T1, which might have suggested intrinsic vs. practice-related differences being revealed at T2. Significant results were followed with planned contrasts comparing the MT practice groups to each other and the MC group.

At T1, there were significant group differences in A' ($F(2, 42) = 3.330$, $p = .045$), where MT outperformed MC ($t(42) = 2.465$, $p = .018$), but the high and low MT practice groups did not differ from each other ($t(42) = .656$, $p = .516$). Similarly, there were significant group differences in target accuracy ($F(2, 42) = 4.113$, $p = .023$), where MT performed better than MC ($t(42) = 2.866$, $p = .006$), but the high and low MT practice groups again did not differ ($t(42) = .028$, $p = .978$). There were no T1 group differences in average RT, ICV, probe 1, or probe 2 (all $p > .10$). Thus, while baseline group differences were observed, these were between MT and MC, not between the MT practice subgroups.

Nonetheless, to determine if there were group differences *after* the training period and to adjust for the noted baseline differences, T1 scores were included as covariates in analysis of covariance (ANCOVA) analyses of T2 scores, with group membership as a fixed factor. This ANCOVA analysis strategy was used for each measure. Significant group effects are detailed below, followed by contrasts designed to answer specific questions about the putative costs of the predeployment interval on attentional performance and the role of MT practice time outside of class on the ability to protect against such costs. Due to the planned nature of these comparisons, we employed uncorrected tests using the least significant differences method; for each contrast, we report the p value as well as the 95 % confidence interval around the contrast estimate.

Groupwise Differences After the Training Period

A series of ANCOVA were conducted to investigate group differences following the training period and to adjust for baseline differences in SART performance at T1. For each

Table 1 Performance prior to and following the training period

	MC		Low practice		High practice	
	T1 M (SD)	T2 M (SD)	T1 M (SD)	T2 M (SD)	T1 M (SD)	T2 M (SD)
A'	0.744 (0.119)	0.600 (0.188)	0.827 (0.150)	0.653 (0.219)	0.860 (0.125)	0.867 (0.094)
Target accuracy (%)	34.1 (19.0)	25.9 (16.9)	55.0 (25.9)	39.4 (30.9)	54.7 (26.0)	58.3 (28.3)
RT (ms)	362 (129)	352 (80)	383 (86)	400 (90)	375 (99)	374 (82)
ICV	0.413 (0.144)	0.544 (0.228)	0.413 (0.249)	0.482 (0.237)	0.295 (0.129)	0.283 (0.101)
Probe 1	2.66 (1.25)	2.86 (1.46)	2.14 (1.02)	3.06 (1.25)	2.39 (1.36)	2.21 (1.11)
Probe 2	2.45 (1.18)	2.93 (1.49)	2.25 (1.08)	3.04 (1.19)	2.36 (1.53)	2.053 (1.17)

of the SART measures, a separate ANCOVA examined the effect of group membership on T2 scores, with T1 scores included as a covariate. Significant group effects were followed by planned contrasts comparing the three experimental groups (high practice, low practice, and MC).

There was a significant effect of group for A' ($F(2, 41)=8.026$, $p=.001$) where the high practice group (adj. mean = .823) outperformed both the low practice (adj. mean = .636; $p=.001$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.292$ to $-.082$) and MC groups (adj. mean = .652; $p=.002$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.276$ to $-.067$), but the low practice and MC groups did not differ ($p=.767$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.120$ to .089, Fig. 2a). Target accuracy also differed between groups ($F(2, 41)=3.924$, $p=.028$), with greater accuracy in the high practice group (adj. mean = .540) vs. low practice (adj. mean = .349; $p=.028$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=.022$ to .359) and MC (adj. mean = .331; $p=.017$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.377$ to $-.040$) groups. Target accuracy did not differ between the low practice and MC groups ($p=.837$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.193$ to .157).

While average RT showed a non-significant effect of group ($F(2, 41)=1.059$, $p=.356$), ICV differed between the groups ($F(2, 41)=4.806$, $p=.013$). Specifically, ICV was marginally lower in the high practice group (adj. mean = .338) vs. the low practice group (adj. mean = .455; $p=.065$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.241$ to .008) and significantly lower in the high practice group vs. the MC group (adj. mean = .516; $p=.004$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=.062$ to .296). ICV did not differ between the low practice and MC groups ($p=.291$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-.055$ to .179, Fig. 2b).

The effect of group on T2 probe 1 response was marginal ($F(2, 41)=2.895$, $p=.067$), while the effect of group on T2 probe 2 response reached significance ($F(2, 41)=4.113$, $p=.023$). The high practice group (adj. mean = 2.055) reported being more "aware" during the SART than the low practice (adj. mean = 3.117; $p=.010$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-1.859$ to $-.264$) and MC (adj. mean = 2.874; $p=.032$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=.073$ to 1.564) groups. The low practice and MC groups did not differ from each other ($p=.532$, 95 % $\mathrm{CI}_{\text{contrast estimate}}=-1.019$ to .534, Fig. 2c).

Thus, collectively at T2, the groupwise differences indicate better objective task performance and greater self-reported awareness during the task in the high practice group vs. the low practice and MC groups.

Change Over Time (T1 to T2)

In order to assess whether performance within each group changed over time, a set of paired t tests was examined in one objective SART measure (A') and one subjective measure (probe 2). These measures were chosen as they showed the most sensitivity between groups in the ANCOVA analyses described above. Examining change over time within each group allowed us to determine if SART metrics demonstrated functional degradation, stability, or improvements over time. A' scores revealed poorer performance at T2 vs. T1 in the MC ($t(16)=4.339$, $p=.001$) and low practice ($t(12)=4.048$, $p=.002$) groups. Yet, A' scores did not significantly differ at T2 vs. T1 in the high practice group ($t(14)=.251$, $p=.805$). Thus, unlike the high practice group, which showed stability in SART measures over time, both the low practice and MC groups demonstrated a pattern of cognitive degradation from T1 to T2. Probe 2 scores revealed a lower degree of being "aware" at T2 than T1 in the low practice group ($t(12)=2.936$, $p=.012$) but no change over time in the MC group ($t(16)=1.368$, $p=.190$) or the high practice group ($t(14)=1.445$, $p=.171$).

Practice Time as a Continuous Variable

To investigate our central hypothesis regarding dose–response effects of MT practice and to ensure that the pattern of results found in the ANCOVA results above was not due to our dichotomization of practice time in the MT participants, we examined correlations between practice time, coded as a continuous variable, and the SART measures. Table 2 details

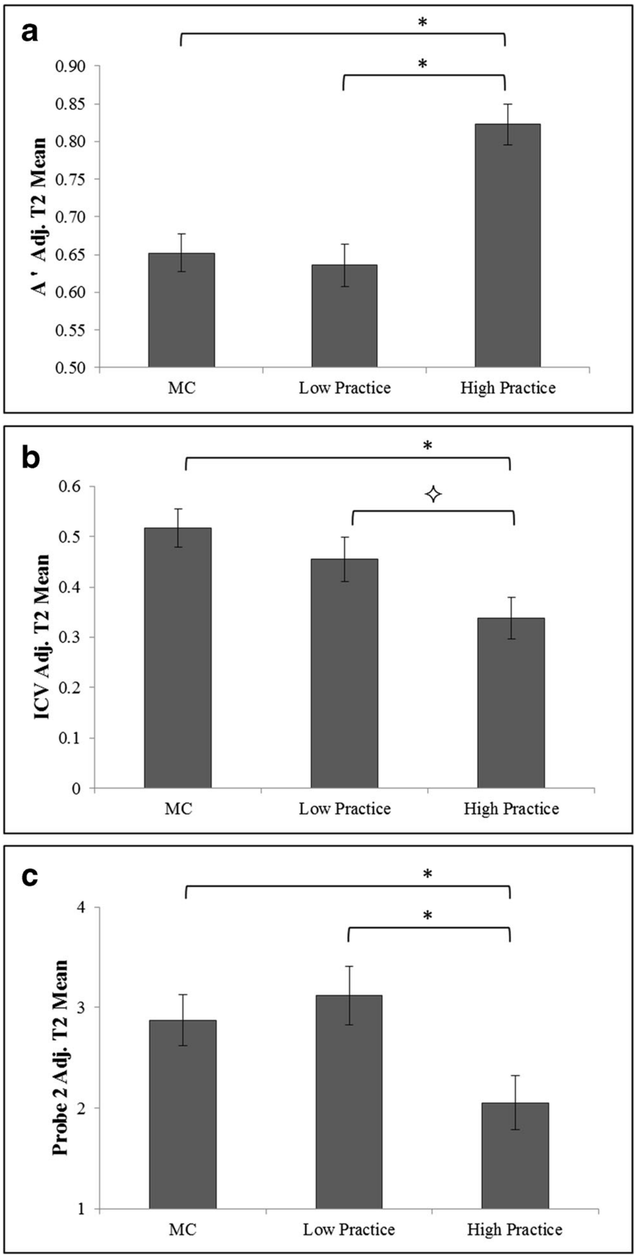


Fig. 2 Time 2 (*T2*) performance in each of the three groups following adjustments for T1 for three SART outcome variables: **a** *A′*, **b** ICV, and **c** probe 2 response. For probe 2, lower scores indicate greater self-reported awareness. *MC* military control group. *Asterisks* indicate a significant contrast at a *p* value of <.05, while ✧ indicate a *p* value of less than .1. *Error bars* show standard error of the mean

correlations between self-reported minutes practiced outside of class and each SART variable at T1, T2, and as a function of change over time (T2–T1). Notably, there was no relationship between practice time and any of the variables at T1. In contrast, at T2, there was a significant positive correlation between practice time and *A′* and a significant negative correlation between practice time and ICV, suggesting that more time spent engaging in MT exercises outside of class was associated with higher levels of task performance and more consistent (less variable) RT at T2. Similarly, there was a significant positive correlation between practice time and the change in *A′* from T1 to T2, such that greater practice time was associated with greater performance benefits. There was a significant negative correlation between practice time and the change in probe 1 and probe 2 responses from T1 to T2, such that greater practice time was associated with being more "on-task" and "aware" over time. No other correlations reached significance (all $p > .1$).

Table 2 Correlations between SART measures and practice time

SART measure	Time 1		Time 2		Δ over time	
	r	*p*	*r*	*p*	*r*	*p*
A′	.176	.369	.441	.019*	.380	.046*
Target accuracy	.146	.457	.204	.298	.096	.628
RT	.144	.465	−.223	253	−.306	114
ICV	−.268	.168	−.419	.026*	−.188	.337
Probe 1	.230	.239	−.162	.412	−.447	.017*
Probe 2	.168	.394	−.233	.233	−.493	.008**

$^*p < .05$, $^{**}p < .001$

Discussion

In the current study, we investigated the impact of MT on attentional performance lapses and self-reported mind wandering in two military cohorts as they prepared for deployment. Objective and subjective performance measures on the SART were indexed before (T1) and after (T2) a 9 to 10-week interval to determine if MT promotes cognitive resilience and functional stability over the high-stress predeployment interval. We found that objective SART performance measures (*A′* and target accuracy) were greater in the high practice group vs. the low practice and MC groups at T2. In addition, we found that ICV (i.e., RT variability) was significantly or marginally lower in the high practice group vs. the other two groups. Subjective performance measures indicated that the high practice group reported more awareness of where their attention was directed during the SART at T2 relative to the other two groups, who did not differ from each other. An analysis of change-over-time within each group revealed that SART measures degraded in the MC and low practice groups from T1 to T2 but remained stable over time in the high practice group. Importantly, when MT practice time was indexed as a continuous variable in the MT group, more out-of-class time spent engaging in mindfulness exercises over the training interval corresponded with greater functional stability in objective and subjective SART metrics. Thus, together these results suggest that engagement in the MMFT course and sufficient MT practice outside of class may have protected against attentional decline over the high-demand predeployment interval. We consider protection against attentional decline associated with self-reported mind wandering as a salutary effect of MT. Yet, recently, there has been a call for more nuanced consideration of mind wandering, which acknowledges that mind wandering may have benefits in addition to the well-studied costs (e.g., Smallwood and Andrews-Hanna 2013). In fact, conscious internal reflection (i.e., day dreaming), which shares many features with mind wandering, has been associated with benefits such as planning and creative problem solving (McMillan et al. 2013). Key considerations in determining if and when mind wandering is costly or beneficial are tied to the contents of mind wandering (Andrews-Hanna et al. 2013) as well as the other task demands co-occurring with the mind wandering episode (Levinson et al. 2012). The findings regarding attention and mind wandering herein are limited to participants' performance on the SART. To more fully determine if and when mind wandering has salutary vs. deleterious consequences for high-stress cohorts, future studies should examine whether MT influences the content and frequency of mind wandering that may occur during a variety of other experimental tasks, free rest, and ongoing daily activities.

Nonetheless, the current results are promising regarding MT-related protection against degradation in SART measures over time. Prior research on the SART confirms that it is a stable task over repeated testing sessions when offered during typical civilian life (Jha et al. 2015; Robertson et al. 1997). As such, the pattern of decline over time in the MC and low practice groups should not be attributed to task instability. One interpretation of the present results is that having to endure the high-demand predeployment interval may lead to diminished attention to the task at hand. It is well-established that the predeployment interval comprises intensive and persistent demands, requiring individuals to acquire new skills, complete training exercises designed to induce high levels of stress, and prepare for the risks and hardships associated with deployment (see Stanley 2014, for review). Not only are substantial attentional resources required for success during this challenging period, but these resources may be overexerted, leading to increases in attentional failures. Accordingly, declines in performance in the MC and low practice groups in the present study are in line with a resource depletion framework of attention where performing intensive, demanding tasks will deplete cognitive resources over time leading to diminished performance on subsequent demanding tasks (see Persson et al. 2007). Unlike the MC and low practice groups, the high practice group did not demonstrate a pattern of depletion over time, and as described in Table 2, greater practice time in the MT group corresponded with protection from decline in A' scores over time.

While these practice-related results are novel and further our understanding of the putative role MT exercises may play in promoting cognitive resilience, we acknowledge that the present study is limited in multiple ways. Many of these limitations result from the constraints of conducting research in a predeployment military context. The MT group was invited to participate, as a convenience sample, after the leadership responded with interest to recruitment efforts. While the MC group was from the same unit, and was matched on its projected mission during deployment, there was no random assignment or blinding of conditions to units or individuals, and the MC group was recruited after the MT group.

Further, there were baseline group differences in SART variables at T1. Based on prior published reports in these participants (Jha et al. 2010; Stanley et al. 2011), we can confirm that the MT and MC groups did not differ at T1 on the following measures: the Five-Factor Mindfulness Questionnaire (5FMQ: Baer et al. 2006), Perceived Stress Scale (PSS: Cohen et al. 1983), a measure of working memory capacity (the Operation Span Task: Unsworth et al. 2005), and the Positive and Negative Affect Scale (PANAS: Watson et al. 1988). As such, the cognitive and affective factors examined in these participants failed to reveal groupwise differences which could help inform why baseline group differences in SART performance may have been observed. However, interindividual baseline differences in SART performance measures, similar to those observed herein, have been previously documented in healthy, young adults (Manly et al. 1999; McVay et al. 2009).

Other limitations of the present study are that it did not include an active comparison group, and the size of the sample was small. Moreover, while 30 min of daily homework was assigned to all of the MT participants, the degree and manner of homework completion were ultimately determined by the individuals rather than the researchers. We acknowledge that our study design does not allow us to make strong causal inferences about the influence of MT practice (vs. other factors) on SART measures. Nonetheless, a recent study conducted in predeployment U.S. Army Soldiers does provide corroborative evidence regarding the importance of MT practice on attention (Jha et al. 2015). Two short-form variants of MMFT were offered to two cohorts, one emphasizing in-class MT practice instruction and discussion and the other emphasizing didactic content. After the training interval, SART performance measures were better for the practice- vs. didactic-focused variant. Participants in the practice-focused MMFT variant also reported spending a greater (marginally significant) amount of time than didactic-focused participants engaging in MT practice outside of class. As such, it was unclear if the practice-focused group's better SART performance was due to greater in-class practice time or cumulative practice time (Jha et al. 2015). Nonetheless, when the level of in-class emphasis on mindfulness practice (vs. didactic content) was manipulated experimentally (Jha et al. 2015), the results were in line with the findings from the present study.

We argue that MT-related SART performance benefits are due to strengthening of attention via its repeated engagement during MT practice exercises. We conceptualized MT practice time as a metric to approximate MT-related attentional engagement, such that greater time promotes greater strengthening of attention. Yet, we acknowledge that the variable of practice time may be confounded by other factors that may partially or fully explain the patterns in the SART measures we report. One such factor is mental effort exerted during task performance, which may have varied between individuals and could have systematically varied with the amount of MT practice in which individuals chose to engage. Specifically, those who spent more time and effort engaging in MT exercises may have also applied more effort during the SART at T2. Their level of effort and task engagement may have also been related to a belief in the training program as beneficial or to a desire to adhere to the testing and training instructions for prosocial or organizational reasons. Therefore, a plausible alternative explanation is that the present findings are due to greater applied effort expended during performance of the test battery at T2 rather than benefits to attention deriving from MT practice. If this alternative explanation were correct, we would have expected that changes in mental effort would globally influence all measures on the SART. Yet, in the present study, we did not find significant group differences for either average RT or probe 1. Thus, the lack of generalizability in practice-related effects across multiple SART metrics somewhat undermines the argument that applied mental effort alone can explain our results.

Even so, we acknowledge that effort is a significant factor which warrants further future study. In one prior study, Jensen et al. (2012) elegantly examined this methodological issue by assessing MT-related improvement in attentional performance in comparison to control participants who either received financial incentive or not. They hypothesized that controls with financial incentive would significantly outperform controls without incentive. Indeed, the incentivized control group did outperform the other groups on several measures, and their performance was comparable to an MT group on some measures. Yet, the MT group outperformed the control groups on measures of selective attention, visual working memory ability emphasizing attentional accuracy, and reaction time variability vs. measures of mean reaction time. These findings complement our own findings of MT-related performance advantages in ICV and A'. Because practice time corresponds to only a subset of the SART outcome variables, and in particular those that are not as easily moderated by incentivizing participants (Jensen et al. 2012), the hypothesis that our results are driven exclusively by applied mental effort is somewhat weakened.

Another alternative explanation is that MT practice time may be confounded with an individual's intrinsic level of SART performance and their pre-existing degree of cognitive resilience during high-demand intervals. By this logic, individuals who are cognitively adept or resilient at T1 may also demonstrate improvements or no change in SART scores, while low-resilience individuals might demonstrate decrements in SART scores over time. In the present study, we found that greater MT practice time corresponded with more stable SART scores over time. However, perhaps practice time itself was epiphenomenal and unessential in producing this pattern of results. That is, perhaps high vs. low cognitively resilient or adept individuals choose to spend more time engaging in MT exercises simply because they have the attentional capacity to do so. If the change in SART scores reflects intrinsic cognitive resilience as opposed to MT-related functional changes, we might have expected to see differences in the SART scores between the high and low practice groups at T1, but we did not. Thus, the lack of pre-existing differences between the practice groups somewhat undermines the argument that intrinsic differences alone can explain our results.

Since practice time varied between individuals and corresponded to SART changes over time, it is of interest to understand which factors contribute to how much time an individual spends engaging in MT practice. Here, we demonstrate that SART scores at T1 did not correspond to how much an individual practiced. In a related paper with the same participants (Stanley et al. 2011), demographic differences such as age, education, marital status, military rank, and number of prior deployments were examined and not found to significantly relate to practice time. One instrument, the Personal Outlook Scale (POS: Bodner and Langer 2001), significantly corresponded with practice time. This measure indexes an individual's level of flexibility and openness to new experiences; higher POS scores at T1 corresponded to more time spent practicing MT exercises outside of class over the training interval. Future studies in a larger sample should investigate which factors correspond to the likelihood of higher levels of practice, such as personal history, personality profiles, coping style, and organizational dynamics. These studies should also examine whether these relationships are specific to engagement of MT practice vs. generalizable to other types of resilience or cognitive training.

Beyond the effects of MT on SART measures, data from the MC group highlight the cost of the predeployment interval on attentional performance lapses and self-reported mind wandering. While this interval is meant to prepare troops cognitively, physically, and emotionally for deployment, we found that the MC group was more error-prone—demonstrating more commission errors, more variable RTs, and less self-reported awareness at T2 than T1. This finding corroborates and strengthens Head and Helton's (2013) call for training or technological solutions to reduce performance lapses on the SART, based on their simulated firearm variant of the SART.

Our study examined if MT might promote cognitive resilience from functional impairments experienced in specific military contexts and it adds to a growing number of studies examining MT in these contexts (e.g., Haase et al. 2014; Jha et al. 2010, 2015; Johnson et al. 2014). Yet, the protective cognitive effects of MT practice observed herein to curb objective performance errors and maintain subjective awareness suggest that MT might be effective as a training protocol more generally, especially in professional environments where lacking situational awareness or engaging in behavior driven by prepotent response tendencies could be problematic. As such, future studies should investigate the impact of MT in a broader range of applied settings, such as among first responders, professional athletes, medical professionals, accountants, and financial brokers.

In sum, the current study suggests that MT practice may mitigate the attentional performance lapses and self-reported mind wandering that may increase over high-stress intervals. While preliminary, our results suggest that more research is warranted to determine if MT could be a broadly accessible tool for building cognitive resilience in military cohorts. Not only might MT reduce the likelihood of cognitive and performance failures, but MT could provide greater cognitive resources for servicemembers to preserve their capacity for ethical decision making (Ruedy and Schweitzer 2010), as well as greater cognitive resources for top-down regulation of emotions and impulse control (see Hofmann et al. 2012). MT may promote greater situational awareness in the range of complex, ambiguous, uncertain, and stressful environments in which servicemembers find themselves—from battlefield combat, to peacekeeping operations, to humanitarian missions and disaster relief.

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Compliance with Ethical Standards

Conflict of Interest Elizabeth Stanley is the creator of MMFT and founder of the nonprofit Mind Fitness Training Institute (MFTI), established to support the delivery of MMFT. She was not involved in the data collection or analysis. MMFT and MFTI are registered trademarks.

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