Enhancing Decision-Making Under Stress Among Sailors

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EXECUTIVE SUMMARY

Problem: For crews of naval ships, effective decision-making during stressful situations is essential to successful performance of their operational missions. Recent mishaps at sea have shown that fatigue, communication deficits, and other factors can have deleterious consequences for decision-making during unexpected or emergency events. One strategy for improving safety and readiness at sea involves identifying minimally intrusive methods to increase resilience among crew members, enhance their ability to make optimal decisions effectively during urgent situations, and improve their ability to manage stress during normal operations.

Purpose: The purpose of this study was to deliver an enhanced version of an existing Stress Resilience Training System (SRTS) and to evaluate its effects on cognitive performance, stress-related physiology, and psychological health. As delivered in this study, SRTS involves an initial 2-hr in-person classroom training, augmented by ongoing use of an SRTS mobile app, and continued mentoring by selected crew members who received additional training in SRTS. This system has been previously used to teach stress management and self-regulation strategies in other military, first responder, and elite athlete populations. We hypothesized that SRTS would improve resilience, psychological health, decision-making, and other areas of executive functioning among shipboard Sailors.

Method: Using a single-group, time series design, 92 crew members from a single naval vessel received the SRTS intervention, and were measured at three different time points: baseline, 8-week follow-up, and 10-week follow-up. Study assessments measured cognitive performance, heart rate variability (HRV), and self-reported psychological health.

Findings: At the 8-week follow-up, relative to baseline, participants demonstrated increased information processing speed and improved decision-making, and reported decreased depression and anxiety. Furthermore, there was a marginally significant increase in resilience across the study period. Overall, Sailors perceived increased stress at the 8-week follow-up relative to baseline; however, these changes were not sustained at the 10-week follow-up. Increases in perceived stress were statistically significant only among Sailors reporting low levels of app usage, suggesting that using the SRTS app component may have protective effects on perceived stress. There was also a positive relationship between training-related HRV coherence and a relative increase in cognitive processing speed among those reporting higher use of the self-regulation techniques taught in the intervention. However, neither app utilization nor self-reported use of the self-regulation techniques taught in the intervention were related to any other outcome found significant in the current study. Furthermore, no significant changes over time were found in the HRV-based physiological measures, in cognitive assessments of sustained attention or planning, or in self-reported psychological outcomes in sleep, anger, social support, or coping styles.

Conclusions: In this pilot study, some methodological challenges were encountered, which will be remedied in subsequent administrations of the training and evaluation. In addition, statistical power was limited by relatively high rates of attrition between baseline and follow-up. Nonetheless, initial findings were encouraging. This study showed that a command can feasibly integrate a resilience intervention into its training schedule and command culture for the purposes of improving the resilience and well-being of its crew. The results indicated that SRTS has promise as a foundation for enhancing decision-making and resilience among shipboard Sailors to ultimately enhance their readiness and ability to successfully complete their missions.

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TABLE OF CONTENTS

I. Introduction

a. Statement of the Problem

Since January 2017, there have been four collisions involving Navy ships that have garnered national attention, including one in which seven Sailors were killed. As part of a multipronged solution to optimize operations at sea and enhance the readiness of each Sailor on every ship, the then-Commander of Naval Surface Forces implemented several new policies that included changes to training, equipment, and work schedules. However, additional efforts are needed to comprehensively address this issue and to ensure that Sailors are as well-trained and well-equipped as possible to conduct their missions safely and successfully (U.S. Government Accounting Office, 2017). Evidence suggests that problems in decision-making among the ships' crew members may have been an important contributing factor in these collisions (Office of the Chief of Naval Operations, 2017). Additionally, stress may have played a role. Shipboard Sailors encounter high levels of stress, as shipboard operations come with unique and often intense stressors that affect the readiness of service members. Although stress can sometimes be motivating, exposure to intense or prolonged stressors has well-documented adverse effects on decision-making (Morgado, Sousa, & Cergueira, 2015; Wemm &Wulfert, 2017) and operational performance (Hancock & Szalma, 2008), and can adversely impact both psychological (Guille, Clark, Amstadter, & Sen, 2014; Walker, McKune, Ferguson, Pyne, & Rattray, 2016) and physical health (Donatelle & Ketcham, 2007; Gianaros & Wager, 2015; Vickery & Fries, 2004). Managing stress, maintaining the ability to think clearly and make decisions calmly under duress, and enhancing resilience are critical to optimizing the readiness and enhancing the safety of Sailors, particularly in hazardous or challenging conditions.

b. Background

To combat the stress of shipboard operations and prevent the development of stress-related illnesses and injuries, it is imperative that Sailors possess high levels of resilience—the ability to adapt, or "bounce back," in the face of adversity. Individuals innately differ in their resilience, as well as in their ability to manage stress and to make sound decisions under the pressure of stressful situations. Various strategies for increasing the resilience of Sailors and other service members have been developed, either as direct resilience interventions or as part of broader efforts (Bowles & Bates, 2010; Meredith et al., 2011). For example, Master Resilience Training (MRT) is one component of the U.S. Army's Comprehensive Soldier Fitness program. MRT is based on positive psychology and teaches military leaders skills associated with resilience; the intention is that, after learning and practicing these skills, leaders will then teach and model them for their subordinates (Reivich, Seligman, & McBride, 2011). A 2013 cross-sectional study of MRT found that service members who received the training reported a perceived increase in character strengths, self-awareness, optimism, mental agility, and connection (Griffith & West, 2013).

A 2011 RAND review of 23 resilience programs (Meredith et al., 2011), such as the Navy Operational Stress Control Program, Mindfulness-based Mind Fitness Training, Navy Senior Leader Seminar on wellness enhancement, and Warrior Resiliency Program, revealed that several common elements were used in many of these programs. Specifically, 19 programs involved positive thinking, 17 taught coping skills, 16 trained for realism, 16 taught behavioral control skills, and 14 taught positive affect. Most programs also focused on both individual and unit-level factors.

Resilience efforts by HeartMath, founders of the Stress Resilience Training System (SRTS), were among the programs reviewed by Meredith and colleagues (2011), although they were not described as a single program. HeartMath's focus on behavioral controls was noted, as was the use of positive affect and community cohesion. Newer programs that were not part of the RAND review included the Marine Corps' Reaction Control program (Komnick, 2016), which is based on rational emotive behavioral therapy (REBT). To date, there is no published evidence of Reaction Control's efficacy. Moreover, while REBT does have an evidence base, the evidence base for cognitive behavioral therapy (CBT), which forms the basis for the program selected for this evaluation, is even stronger.

c. Approach

The Stress Resilience Training System (SRTS; de Visser et al., 2016) is one promising approach to increasing resilience and operational performance under stress. SRTS involves multiple components. It begins with an in-person training that describes (1) effects of stress on readiness and performance, and (2) techniques for managing stress to improve readiness, resilience and performance. The training also includes two components designed to increase uptake and continued use over time of the techniques taught in the training. The first is a mobile application that reinforces the content of the initial training and allows users to practice the techniques they have learned; the second is regular consultations with a shipboard mentor who has received additional in-depth training in SRTS.

The development of the core components of SRTS was informed by the content of Stress Exposure Training, a program previously used to build resilience and performance under stress, including in U.S. Navy combat teams, by teaching users effective coping skills and having them practice those skills under gradually increasing levels of stress (Driskell & Johnston, 1998; de Visser et al., 2016). SRTS was designed specifically for service members to use, and includes content and features that enhance the acceptability and effectiveness of the program specifically among this group of elite occupational athletes. For example, the program is presented to service members as a way to enhance performance rather than mitigate potential mental health challenges, which reduces the potential for mental health-related stigma (de Visser et al., 2016; Meredith et al., 2011). Additionally, the app engages the participant as a learner and uses progressively more difficult scenarios (i.e., games) as a means to practice the techniques, potentially increasing its appeal to a younger, tech-savvy audience. This is an effective, yet somewhat underutilized tool for adults (DeWitte, Buyck, & Van Daele, 2019).

SRTS teaches two primary types of skills. The first involves practicing regulated breathing accompanied by biofeedback to learn to control heart rate variability (HRV); the second consists of using cognitive behavioral techniques to improve stress management by improving the ability to recognize and self-regulate emotional responses.

<u>HRV Regulation Through Biofeedback</u>

Recent research suggests that HRV may provide an objective measure of individuals' ability to regulate their responses to stressful situations (Appelhans & Luecken, 2006). HRV refers to the amount of variation in the time interval between an individual's consecutive heartbeats (i.e., beat-to-beat changes in heart rate). HRV reflects the interplay between sympathetic and parasympathetic control of cardiovascular activity and the central nervous system at large; as such, it is a marker of cardiovascular adaptability, or the ability to shift cardiac activity to meet changing situational demands.

Building on the concept of HRV is the related measure of HRV coherence. HRV coherence is also based on the duration of time between consecutive heartbeats, but it is a more complex calculation (McCraty, Atkinson, Tomasino, & Bradley, 2009). Greater HRV coherence is evidenced by the smoothness and regularity of the HRV pattern, as well as an increase in physiological entrainment, as marked by synchronization of various bodily systems (e.g., heart rate, respiration, blood pressure).

In general, higher levels of both HRV and HRV coherence are associated with an array of positive, adaptive outcomes, including improved executive function (i.e., planning, decision-making, working memory capacity, ability to inhibit inaccurate responses; Hansen, Johnsen, & Thayer, 2003; Huang et al., 2019; Hugdahl et al., 2000; Johnsen et al., 2003), greater situational awareness (Johnsen et al., 2003, as cited in Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Saus et al., 2006a, 2006b), and reduced mental health symptoms (Berry et al., 2014; Cohen et al., 2003; Karavidas et al. 2007; Siepmann, Aykac, Unterdörfer, Petrowski, & Mueck-Weymann, 2008; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). Additionally, studies of performance under stressful conditions reveal better outcomes for individuals with higher levels of HRV, including better performance on tests of executive function (e.g., Hansen et al., 2009), reduced distress in response to stressors (Fabes, Eisenberg, & Eisenbud, 1993), and increased use of constructive coping strategies (O'Connor, Allen, & Kaszniak, 2002; Pauls & Stemmler, 2003).

Given that military personnel encounter high levels of stress, it is not surprising that many studies examining the effects of HRV and HRV coherence on performance have focused on service members or others in high-stress professions such as police (for a review, see Thayer et al., 2009). Gamble and colleagues (2018) reported that service members who were considered experts in performing under high-stress conditions (e.g., infantry and full-time special reaction team members), compared with those who were not considered experts, displayed higher HRV. This may reflect either selection effects (with individuals with higher HRV being more likely to seek out or qualify for high stress occupations) or training effects (i.e., training for high-stress occupations may increase individuals' HRV). In either case, it is adaptive that service members in high-stress occupations have high levels of HRV, given that this is associated with greater cognitive flexibility and therefore greater ability to adapt to unpredictable situations.

In addition to the effects on decision-making and situational awareness discussed above, studies have also shown that higher HRV is associated with better performance in simulated operational tasks (e.g., shooting accuracy, navigation; Johnsen et al., 2003, as cited in Thayer et al., 2009; Saus et al., 2006a, 2006b). Similarly, research, including studies in military personnel and veterans (Berry, Ginsberg, & Powell, 2010), has supported links between HRV coherence and both cognitive functioning and emotion regulation (McCraty, 2015).

Although individual differences in HRV and HRV coherence exist (Li et al., 2009; Thayer & Lane, 2007), a substantial and growing body of research confirms that these physiological responses are also modifiable. HRV can be affected by various types of interventions, including pharmacology and exercise (Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004; Sandrone et al., 1994; Stein, Ehsani, Domitrovich, Kleiger, & Rottman, 1999; Stein & Kleiger, 1999) as well as biofeedback (e.g., Lehrer, Vaschillo, E., & Vaschillo, B., 2000; Lehrer et al., 2003; Nolan et al., 2005). Importantly, interventions that change an individual's HRV also have been shown to produce changes in their cognitive performance (Hansen et al., 2004), mental health (Karavidas et al. 2007; Siepmann et al., 2008; Zucker et al. 2009), and physical health (Lehrer et al., 2003, McCraty, Atkinson, & Tomasino, 2003; Nolan et al., 2005). For example, in a randomized clinical trial of military veterans receiving treatment for chronic pain (Berry et al., 2014), veterans who also received HRV coherence biofeedback, compared with those who did not, not only demonstrated increased levels of HRV coherence but also showed greater improvements in self-reported pain, stress, negative affect, and level of physical restriction. Furthermore, several studies have shown that benefits attributed to these interventions are sustained even after participants disengage from the active condition (Lemaire, Wallace, Lewin, de Grood, & Schaefer, 2011; Penzlin et al., 2017; Pyne et al., 2018; Teufel et al., 2013).

Emotional Awareness and Self-Regulation

In addition to teaching individuals to monitor and regulate their HRV and HRV coherence through practicing paced breathing with biofeedback, SRTS includes techniques designed to increase Sailors' awareness of their current emotional states and to modify those states as necessary to increase readiness and resilience. The proposed multifaceted approach reflects evidence-based strategies drawn from regulatory skills training, which involves the use of behavioral and cognitive strategies to help individuals acknowledge and change the duration and intensity of their emotional responses (Gross, 2013). The strategies include cognitively directed (or attention focused) paced breathing and evidence-based techniques from CBT, both of which have been shown to have consistent benefits for stress management within occupational settings (Richardson & Rothstein, 2008). This multifaceted approach also included structured activities that afford opportunities to practice these strategies using mental imagery techniques.

Paced breathing has much in common with well-established focused-meditation practices that involve actively directing and focusing attention on specific areas of the body. It is well established that such techniques can help the individual pay attention to their physiological and emotional states in order to regulate them, which has been recently termed "mindful emotion regulation" (Guendelman, Medeiros, & Rampes, 2017). This strategy requires focused attention, which involves actively choosing a stimulus upon which to focus while engaged with paced breathing practices, similar to strategies deployed within mindfulness-based stress reduction training (MBSR; Kabat-Zinn, 2003). Specifically, the cognitively directed paced breathing approach that serves as a foundation of the SRTS approach promotes directed attention toward a stimulus, namely the bodily sensations surrounding the heart, with the goal of promoting mindfulness to these senses and broadened awareness to emotional states. A capacity for directed, self-focused attention facilitates adaptive responses across varying situations and has been proposed as an adaptive ability to improve behavioral self-regulation (Baer, 2009)

The CBT strategies taught within SRTS are largely based on the framework of appraisal theories of emotion regulation, which suggest that it is an individual's cognitive appraisal of an event, rather than the event itself, that leads to an emotional response (Lazarus & Folkman, 1984). The core of the SRTS strategy is to teach individuals how to reconsider and change their appraisals of emotionally intense situations (reframing), which may allow them to reinterpret the meaning of the situation, thereby shifting their emotional response and protecting against negative effects associated with stress (Troy, Wilhelm, Shallcross, & Mauss, 2010).

Mental imagery is defined as the experience of perception without sensory input (Kosslyn, Thompson, & Ganis, 2006). It has been used as a structured strategy for imagining previous or future experiences to allow the individual to regulate his or her behavior in similar situations (Heyes, Lau, & Holmes, 2013; Taylor & Wilson, 2005), specifically those within high-stakes environments (Holmes & Collins, 2001). From a cognitive performance perspective, mental imagery works as a proactive filter for incoming perceptual information (Diekhof et al., 2011). Thus, repeated preparation or (mental) exposure to a targeted event (e.g., future operational drill) generates a predictive perceptual bias that facilitates apprehension of the targeted event with the goal of regulating it and simulating potential actions and their consequences in order to improve performance (Frith & Dolan, 1997). The use of mental imagery is a highly flexible strategy for regulating emotional states and enhancing performance across a variety of contexts, including military operational environments.

The SRTS components that focus on physiological and emotional self-regulation are not discrete and separate; they are intertwined. SRTS teaches that the ability to recognize and regulate emotional states will be enhanced if one is in an optimized physiological state marked by HRV coherence. The use of biofeedback is a core element of the training, given research suggesting that individuals may be better able to regulate their stress if they are able to monitor it (DeWitte et al., 2019); that is, biofeedback may help Sailors to identify when they are in a physiological state that is conducive to effective emotion recognition and regulation. The personalized biofeedback is designed to assist users in understanding the connection between their physiological processes and their emotional responses. Enhanced awareness of their personal response to stress is then used to teach the user to control their response, thus improving the ability to perform under stress.

d. Purpose of Present Work

The purpose of this study was to assist Navy leadership in strengthening the performance and resilience of shipboard Sailors. To this end, Sailors were provided with an enhanced version of the multifaceted SRTS intervention, which included instruction about and practice in using a variety of adaptive, evidence-based, cognitive and behavioral strategies for responding to stressful situations. The present study extended previous SRTS-based research by (a) tailoring the system to fit the unique needs and circumstances of shipboard Sailors, and (b) investigating the acceptability and effectiveness of the new, adapted intervention to Sailors in a shipboard environment. Ultimately, this study addressed a specific military need to improve Sailors' ability to adapt to stressful situations and to optimize their decision-making and performance under stress.

i. Hypotheses

(1) Following receipt of SRTS training, we hypothesized that crew members would:

(a) Show improvement on measures of decision-making and cognitive performance

(b) Report reduced stress and stress-related symptoms

(c) Demonstrate increased HRV

(2) We further hypothesized that crew members who spent more time using the SRTS app or otherwise practicing the techniques taught within SRTS would demonstrate greater improvements in the outcomes of interest.

ii. Objectives

(1) To assess the effectiveness of the SRTS intervention.

(2) To determine the acceptability of the SRTS intervention to Sailors working in a shipboard environment.

II. Methods

a. Study Setting

The training sessions and assessments took place in facilities and classrooms on and near the base of operations. The SRTS mobile application was made available to all members of the command on Apple iPads® distributed by study staff during the consent process.

b. Participants

The participants in this study were crew members (N = 92) from a single naval vessel. The study was conducted at the behest of the ship's leadership as a preventive measure to enhance crew members' decision-making under stress. Leadership augmented their current command training by adding the SRTS intervention. Accordingly, all crew members received the training and the materials necessary for training participation; however, all study-specific tasks (i.e., assessments at baseline, 8-week follow-up, and 10-week follow-up) were voluntary.

c. Study Design

This study utilized a single-group time series design. This design was selected because it was not feasible to randomize participants to an intervention and a control group, given that the command required all crew members receive the SRTS intervention. Because the SRTS intervention was command-directed, each crew member was provided with a 2-hr in-person training, assigned to a shipboard mentor, and given a study iPad on which the SRTS app had been installed as well as an ear sensor that could be used with the app to monitor HRV. The repeated measures design included a baseline assessment before the training, a follow-up assessment 8 weeks after the training, and an additional follow-up assessment 10 weeks after the training.

A group-based consent process was initiated prior to the start of any study activities. All crew members were required to muster in one room; at that time, study staff made a verbal announcement about the study and explained study procedures. Crew members were given paper consent forms and time to review the forms and ask questions of study staff, who were dispersed about the room. They were also provided with a check-out form that they had to complete in order to receive an iPad.

All crew members, regardless of whether they chose to participate in the study, were directed to return their paperwork to study staff posted at distribution tables. In order to allow the decision of whether to participate in the evaluation to be anonymous, all participants turned in consent forms and equipment check-out forms, and only study staff had information about whether each crew member consented to participate. All crew members, regardless of whether they consented to participate in the program evaluation, received iPads that included the SRTS app. However, only the iPads of consenting participants contained the assessments used for the program evaluation.

Over the next few days, multiple baseline assessment sessions were held; these employed a small-group format to allow consenting participants to attend any session that fit into their schedules. Similar small-group sessions, distributed over several days, were held to conduct the 8- and 10-week follow-up assessments.

d. Data Collection and Procedures

All data were collected anonymously but linked to a unique random identification number assigned to each participant during the consent process. All assessments were administered via iPad. In each assessment phase (i.e., baseline and 8- and 10-week follow-ups), assessments were conducted across several proctored sessions, each including a maximum of 20 participants. The initial follow-up assessments were scheduled for approximately 8 weeks after the training sessions to allow participants time to use the strategies and integrate the training in their daily lives. The second (10-week) follow-up assessment occurred approximately 2 weeks after the 8-week follow-up assessment. Due to the staggered nature of the training sessions, in some cases, the gap between the two follow-up assessments was as brief as 1 week.

e. Intervention

The command-directed SRTS intervention used in this study consisted of several components, including the introductory training, 8 weeks of using the app, and weekly meetings with an assigned shipboard SRTS mentor. Each intervention component is described in detail below.

Introductory SRTS training

All crew members received initial psychoeducational training during a 2-hr in-person session led by a certified SRTS trainer and a Navy co-trainer. Certification is provided by the HeartMath organization, which owns the copyright to the techniques used in SRTS. Approximately 20 crew members attended each introductory training session; in total, eight training sessions were held to accommodate all crew members. The initial SRTS training session informed Sailors about the physiology of stress and resilience. They were taught about HRV and its association with performance, and they were instructed in specific cognitive–behavioral techniques for recognizing and regulating emotional states. These techniques, which overlap with other resilience building strategies such as focused attention within mindfulness and meditation practices, included Heart-Focused Breathing™ (HFB) (i.e., engaging in paced breathing while focusing on the area of the body around the heart), Prep (i.e., using mental imagery in preparation for an upcoming situation to sustain composure and readiness), Freeze Frame® (i.e., engaging in HFB while using cognitive reappraisal and restructuring to seek the most effective solution to a problem), the Depletion to Renewal™ Grid (i.e., a visual tool used to determine one's current emotional state and its relation to states in the sympathetic and parasympathetic nervous system), Coherent Communication™ Technique (i.e., engaging in HFB with nonjudgmental active listening), and Quick Coherence (i.e., engaging in HFB with regenerative attentional focus to promote positive affect).

SRTS app

Each crew member was provided with an iPad equipped with the SRTS app, which was meant to be used as a supplement to the introductory training and mentor guidance (described below). Each crew member was also provided with a heart rate monitoring device to be used in conjunction with the app. This device is designed to be clipped to a participant's earlobe to collect heart rate data (earlobe photoplethysmography), which are used to calculate HRV and to provide biofeedback regarding HRV coherence within the SRTS app. The SRTS app included four main sections:

1. Know How: The Know How section of the SRTS app included nine brief videos that provided basic information about the physiology of the stress response and the effects of stress on performance.
2. Techniques: The Techniques section of the app included seven videos that instructed users in a variety of cognitive–behavioral- and biofeedback–based techniques for maintaining resilience under stress. The cognitive–behavioral techniques included in this section were evidence-based HeartMath® strategies for improving coping, adaptation, and decision-making under stress (de Visser et al., 2016; Edwards, 2015; Meredith et al., 2011). The biofeedback-based techniques taught the user how to achieve HRV coherence via controlled breathing and biofeedback.
3. Games: The Games section included 5 increasingly challenging games in which performance was determined by the participant's own HRV coherence. While playing these games, the user saw a graphic depicting their personal physiological response to stress (e.g., HRV), and had the opportunity to practice self-regulation of HRV coherence.
4. Review: The Review section of the app contained quizzes, scenario-based self-tests, and graphic visualizations of changes in performance over time.

Mentorship in SRTS

Eleven Sailors from the ship's crew were provided with additional specialized training in SRTS to enable them to serve as SRTS mentors. Mentors attended one of two 2-day workshops provided by HeartMath in order to receive Coach/Mentor certification. At these trainings, mentors acquired the knowledge and skills necessary to effectively lead their Sailors in practicing use of SRTS strategies and techniques, in order to increase HRV coherence and both their awareness and ability to regulate emotional states. In addition to the 11 Sailors from the ship's crew who were trained as mentors, two Naval Health Research Center (NHRC) staff members (both former Navy corpsmen) completed the Coach/Mentor Certification training in order to support the participating crew mentors. The NHRC mentors had ongoing contact with the shipboard mentors over the course of the study period and assisted them with the mentorship process, answered questions, and brainstormed solutions to obstacles hindering effective use of the training among the ship's crew.

Each shipboard mentor worked with approximately 10–15 crew members over the course of the 8-week intervention period. Sailors met individually with a mentor for about 15 min each week during the 8-week intervention period to discuss how the program was working for them. During these meetings, mentors reinforced use of the SRTS app and techniques and provided individualized guidance to crew members on how to incorporate the SRTS strategies and techniques into their daily lives. Finally, the ship's leadership also provided supportive messages to Sailors to practice the strategies and incorporate them into their daily routine, and integrated them into some of the ship's activities. This reinforced the work of the mentors.

f. Measures

Outcome measures spanned multiple domains of overall health and performance, including physiological functioning (i.e., autonomic tone and HRV coherence), psychological well-being, and cognitive performance. Each domain was evaluated before and after training. In addition, measures of HRV coherence and app usage were acquired during the training phase of the study.

i. Physiological Measures: HRV and HRV Coherence

Evaluation of baseline autonomic tone

HRV was calculated based on the time interval between heartbeats, or inter-beat interval (IBI). This information was obtained using earlobe photoplethysmography during each evaluation phase of the study. Specifically, for each participant, 5 min of continuous IBI data were recorded and used to calculate HRV during each of the three assessment points (baseline, 8- and 10-week follow-ups). Measures of HRV allowed for the direct assessment of individual differences in trait-specific profiles of HRV (i.e., autonomic tone), independent of any event-related modulations of HRV (in contrast to training-related HRV coherence described below). Standard preprocessing of time-domain IBI data and time-frequency decomposition were conducted using modified scripts from freely available HRV analysis software (https://anslabtools.univ-st-etienne.fr; for details, see Pichot, Roche, Celle, Barthélémy, & Chouchou, 2016). Using IBI data acquired during the evaluation phases of the study, additional HRV-based physiological outcomes including vagal tone and adaptation were also computed. HRV coherence was computed during HRV-based biofeedback within the (Games section) SRTS app during the training phase of the study (see below).

HRV as vagal tone (high-frequency component of HRV)

Vagal tone was measured as the high-frequency component of the HRV signal, which captures the more rapid changes in HRV. This high-frequency component is thought to directly reflect parasympathetic activity (i.e., vagal tone). Individuals' (preprocessed) 5-min IBI data were decomposed into the frequency domain using fast Fourier transform (256-s windows with 50% overlap) and was measured as the sum of the power spectral densities (PSDs) between 0.15 and 0.40 Hz. The units of measure, PSDs, were computed as ms^2/Hz.

HRV as adaptation

HRV adaptation was measured as the overall variability of the continuous HRV time-series data. This measure was calculated using the 5-min continuous (preprocessed) time-domain IBI data as the standard deviation of normal-to-normal intervals (SDNN). SDNN represents the overall variability of autonomic functioning, regardless of sympathetic or parasympathetic dominance. Because SDNN is the overall standard deviation of the IBI time series, the units of measure were in IBI (ms).

Training-related HRV coherence

The HRV coherence score was computed during HRV-based biofeedback gameplay training within the SRTS app. HRV coherence is based on the energy distribution (PSDs) over a period of time, quantifying the extent to which the power of the signal spreads across a range of frequencies (centered at 0.1 Hz). It is calculated as a percentage between 0 and 100, where higher scores indicate that the HRV signal is clustered around a small band of frequencies near 0.1 that represent coherence, and lower scores indicate greater spread in the power distribution (de Visser et al., 2016). For each participant, the grand average HRV coherence was calculated both *within* and *across* each of the HRV-based biofeedback gameplay training sessions for the entire duration of the study.

ii. Self-Report Questionnaire Measures

Self-report questionnaires were administered via the study iPad at baseline and at 8- and 10-week follow-ups. General demographics, military characteristics, and information about history of traumatic brain injury (TBI) were collected at baseline only. Several measures of psychological health, behavioral health, social support, and coping skills were assessed at all three study time points. Other self-reports were assessed at the 8-week follow-up only (i.e., participant satisfaction with the training and app) or at the 8- and 10-week follow-ups only (i.e., knowledge and use of self-regulation strategies).

Demographics

Participants were asked to provide their gender, age, race/ethnicity, education level, and marital/relationship status.

Military characteristics

Participants were asked to provide their pay grade/rank and deployment history (total number of previous deployments, including both combat and peacekeeping missions).

Resilience

The 10-item version of the Connor–Davidson Resilience Scale (CD-RISC; Campbell-Sills & Stein, 2007) was used to assess dispositional resilience. This widely used measure of resilience is a shortened version of the 25-item Connor–Davidson Resilience Scale (Connor & Davidson, 2003) and has been found to have good internal consistency and construct validity (Campbell-Sills & Stein, 2007). Like the full CD-RISC, the 10-item CD-RISC assesses the individual’s ability to adapt and thrive despite stress and adversity. Each item was rated on a 5-point scale ranging from 0 (*not true at all*) to 4 (*true nearly all the time*).

Total scores were computed as the respondent's mean rating across the 10 items (Cronbach's α = .88 at baseline).

Sleep health

Sleep health was assessed with the 19-item Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). This measure assesses sleep quality and duration over the past 2 weeks. Response formats vary from open-ended to 4-point rating scales. The measure is widely used and has moderate reliability and validity (Mollayeva et al., 2016). The PSQI provides a global sleep score and seven individual sleep component scores for areas such as subjective sleep quality, sleep latency, and sleep disturbance. A global sleep score is created by summing the seven individual sleep component scores (range = 0–21); higher scores indicate poorer sleep quality (Cronbach's α = .59 at baseline).

Perceived stress

Stress was assessed using the 4-item Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983), which has adequate reliability and validity and has been recommended for use in studies where questionnaire length is a concern (Lee, 2012). This brief scale measures how often situations in one's life over the past 2 weeks have been appraised as stressful (0 = *never* to 4 = *very often*). For each participant, a total PSS score was computed as their mean rating across the 4 items (Cronbach's α = .71 at baseline).

Posttraumatic stress disorder symptom severity

Posttraumatic stress disorder (PTSD) symptoms were assessed using the abbreviated PTSD Checklist (PCL; Price, Szafranski, van Stolk-Cooke, & Gros, 2016). This 8-item scale is a subset of the PTSD Checklist for DSM-5 (PCL-5; Weathers et al., 2013) and has demonstrated good reliability and validity (Price et al., 2016). Severity of each symptom in the past 2 weeks was rated on a 5-point scale ranging from 0 (*not at all*) to 4 (*extremely*). Total PTSD symptom severity scores were computed as the respondent's mean rating across the 8 items (Cronbach's α = .85 at baseline).

Traumatic brain injury

Traumatic brain injury (TBI) was assessed at baseline with the 3-item Brief Traumatic Brain Injury Screen (BTBIS; Schwab et al., 2006). The three questions that comprise this measure assess for (a) an event during deployment that could have produced a TBI (e.g., blast, fall), (b) symptoms following the event that suggest a possible TBI (e.g., headache, loss of consciousness), and (c) current symptoms that could be the result of a prior head injury (e.g., headaches, dizziness). Endorsement of all three screening items suggests probable TBI. The BTBIS has demonstrated good sensitivity (78.2%) and specificity (90.3%) for identifying previously deployed service members who sustained a TBI (Schwab, Brenner, Terrio, Lewis, & Scher, 2013).

Anger

A modified version of the 6-item Brief Anger-Aggression Questionnaire (BAAQ, Maiuro, Vitaliano, & Cahn, 1987) was used to assess anger during the past 2 weeks. This measure is brief, fairly widely used, and has satisfactory reliability and validity (Maiuro et al., 1987).

Participants rated how frequently they experienced each symptom on a 5-point scale ranging from 0 (*none or almost none of the time*) to 4 (*all or almost all of the time*). A total BAAQ score was computed as the respondent's mean of rating across the 6 items (Cronbach's α = .83 at baseline).

Depression and anxiety

Symptoms of depression and anxiety in the past 2 weeks were measured with the brief Patient Health Questionnaire 4 (PHQ-4; Kroenke, Spitzer, Williams, & Löwe, 2009), which has been shown to be a reliable and valid measure (Löwe et al., 2010). Two items assess symptoms of depression and the other two assess symptoms of anxiety. Symptom frequency was rated on a 4-point scale ranging from 0 (*not at all*) to 3 (*nearly every day*). Total scale scores were computed as the mean rating across the four items (Cronbach's α = .79 at baseline).

Coping strategies

Coping strategies were assessed using the 28-item Brief COPE (Carver, 1997), a shortened version of Carver's 60-item COPE inventory (Carver, Scheier, & Weintraub, 1989). The Brief COPE is widely used and has been shown to have adequate reliability for the majority of its 14 subscales (Carver, 1997) and adequate validity of its broader composite factors (Cooper, Katona, & Livingston, 2008; Snell, Siegert, Hay-Smith, & Surgenor, 2011). Participants rated the extent to which they used specific coping strategies over the past 2 weeks (0 = *I haven't been doing this at all* to 3 = *I've been doing this a lot*). This measure assesses 14 specific types of coping: self-distraction, active coping, denial, substance use, use of emotional support, use of instrumental support, behavioral disengagement, venting, positive reframing, planning, humor, acceptance, religion, and self-blame.

In order to simplify and reduce the number of coping variables, a principle component analysis with varimax rotation was computed using participant responses on the 14 subscale scores during the baseline assessment. Various factor solutions were examined, and the three-factor solution was selected because it yielded the most theoretically interpretable factors. Appendix A provides eigenvalues and factor loadings for each factor; factor loadings less than .55 are omitted from the table. The first factor included 4 subscales tapping problem-focused coping (positive reframing, planning, active coping, and religion). The second factor included 6 subscales reflecting emotion-focused coping (venting, humor, self-distraction, acceptance, use of emotional support, and use of instrumental support). The third factor included 3 subscales that assessed maladaptive coping (denial, behavioral disengagement, and self-blame). Scores on each subscale were created by computing the mean rating across subscale items. At baseline, internal consistencies were good for problem-focused coping and emotion-focused coping factor (Cronbach's α = .87 and .81, respectively). Not surprisingly given its smaller number of items, reliability for the maladaptive coping scale was lower (α = .54).

Social support

Social support was assessed using two items from the interpersonal problems domain of the Behavior and Symptom Identification Scale (BASIS-24®; Eisen, Normand, Belanger, Spiro, & Esch, 2004). This subscale has been shown to have acceptable reliability and validity among a sample of mental health clinic outpatients (Eisen et al., 2004). Participants were asked to indicate how often, during the past 2 weeks, they were able to (a) "feel close to another person," and (b) "feel like you had someone to turn to if you needed help." Response options ranged from 0 (*none of the time*) to 4 (*all of the time*). Total social support scores were computed as the respondent's mean rating across the two items (Cronbach's α = .82 at baseline).

Use of self-regulation strategies

At the 8-week and 10-week follow-up assessments, participants were asked about specific self-regulation strategies or tools taught in SRTS: Prep, Freeze Frame, Coherent Communication, and the Depletion to Renewal Grid. Seven questions were asked about each technique. One multiple choice item assessed participants' knowledge of strategy. Three items assessed how often participants had used the strategy in the past 2 weeks before, during, and after a stressful event (0 = *never* to 4 = *very often*). One item assessed the total number of times each technique was used in the past 2 weeks, and another item asked how many times in the past 2 weeks they had encountered a situation where the technique would have been helpful; response options for these items ranged from 0 to 30 times. A final item gauged intent to use the techniques; participants were asked to rate how likely they were to use each strategy in the future (1 = *extremely unlikely* to 4 = *extremely likely*). In order to identify participants who endorsed using these techniques during stressful situations compared with those who used them less, a median split was calculated for this variable, splitting the high and low self-regulation groups.

Satisfaction with the training and app

Participants' satisfaction with specific aspects of SRTS was assessed at the 8-week follow-up assessment only. Unless otherwise noted, all questions were rated on a 5-point Likert-type scale ranging from 1 (*strongly agree*) to 5 (*strongly disagree*). Five items assessed satisfaction with the introductory workshop (I am satisfied with the workshop; the workshop instructors were credible; the length of the workshop was appropriate; the workshop was relevant to readiness; and the workshop was useful). Ten items assessed satisfaction with the SRTS app. Six of these items assessed overall satisfaction with the app (I am satisfied with the app overall; the app was useful; I learned new information from this app; the app was easy to use; I feel that this app is appropriate for military service members; and I would recommend this app to a civilian friend) and four items asked about the usefulness of each of the four sections of the app (Know How, Techniques, Games, and Review). One item assessed satisfaction with the mentorship component of the SRTS program. A final item asked participants to rate how much technical difficulty they experienced with the app, ranging from 1 (*no technical difficulty*) to 5 (*nearly constant technical difficulty*).

iii. Cognitive Assessments

Cognitive performance tests were administered to assess key cognitive domains involved in executive function and decision-making (i.e., decision-making, planning, attention, and processing speed). An additional cognitive test assessed participants' level of effort. All cognitive tests were administered on study iPads via the Inquisit app (www.millisecond.com). To minimize practice effects, cognitive assessments were given only twice, at baseline and 8-week follow-up.

Processing speed

An iPad version of the Symbol Search task (Wechsler, 2008) was used to assess cognitive processing speed. On each trial, participants were presented with two columns of target symbols on the left of the screen and five columns of search symbols on the right. For each row, their task was to determine whether any of the target symbols on the left matched any of the search symbols on the right as accurately and quickly as possible. Participants indicated their response by selecting a button corresponding to match or a corresponding nonmatch button on the iPad touchscreen. Participants moved from trial to trial (each trial was unique) until the end of the 120-s task period. Errors were subtracted from the total number of correct responses; the resulting total was used as a measure of cognitive processing speed.

Planning

Planning was assessed by an iPad version of the Tower of London task (Krikorian, Bartok, & Gay, 1994; Shallice, 1982). In each trial, participants were presented with a display consisting of three rods, with three disks of different colors stacked on the rods in a particular configuration. Their task was to move the disks, one at a time, to create a different target configuration within a limited number of moves. Across 13 trials, the target configuration became more difficult, the puzzle became more complicated to execute, and the number of moves necessary to achieve the goal increased. For each target configuration, participants were allowed three attempts to successfully complete the problem within the allowed number of moves. Three points were awarded for successful completion on the first attempt, two points for successful completion on the second attempt, and one point for successful completion on the third attempt. Failure on the third attempt resulted in a score of zero points. The total score across the 13 trials could thus range from 0 to 39, with higher scores indicating better planning.

Letter memory test

The letter memory test (LMT; Inman et al., 1998) was administered to evaluate the level of effort participants expended in completing the cognitive battery. The LMT is a computerized test that was reconfigured for use on an iPad. Participants were presented with 18 trials that contained a series of letters from the first 10 consonants in the alphabet (i.e., B, C, D, F, G, H, J, K, L, M). In initial trials, three letters were presented; this increased over trials to four and then five letters. Participants were asked to remember the group of letters presented during each trial; after a 5-s delay, they were presented with several letter groups and asked to choose the one previously presented. The number of options from which they had to choose the previously presented stimulus increased over time from two to three to four. The LMT has been shown to be a good measure of effort, since most test takers can complete the entire test with few errors. In accord with standard practice, number of errors made was used as a measure of effort; scores could range from 0 to 18, with lower scores indicating greater participant effort.

Decision-making

Decision-making was measured using an iPad version of the Iowa Gambling Task (Bechara, 2007). Four decks of playing cards were displayed on the screen, and participants were asked to pick one card at a time from any of the four decks. On each of the 100 trials on this task, participants were charged a "fee" to choose a card, and they either won or lost "money" once a card was chosen. Some decks were reliably more profitable than others. The participant is encouraged to make as large of a profit as possible by the end of the game. The overall number of disadvantageous selections were subtracted from the overall number of advantageous selections (possible scores range from −100 to 100, with higher scores indicating better decision-making).

Attention

An iPad version of the continuous performance test (CPT) was used to assess attention. Our CPT paradigm had two phases. In the first (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), a series of single letters appeared on the iPad screen, each for a fraction of a second, on each of 620 trials; participants' were instructed to press a button whenever they saw an "X." The letter X was presented on 10% of the trials. In the second phase of the task (AX-CPT; Marcora, Staiano, & Manning, 2009), participants were presented with four letters on each of 100 trials. They were asked to attend only to the first and the fourth letters (which were red) and to ignore the second and third letters (which were white). Participants were asked to press one key when the letter "A" was in the first position and the letter "X" was in the fourth position; if any other combination of letters appeared in the first and fourth positions, they were to press the other key. Overall errors of omission and commission were examined to identify possible outliers and/or participants not following task instructions, exemplified by simply pressing the response button on every trial (or missing every target). This led us to exclude the CPT score of one participant at baseline (2% of the sample); at follow-up, no CPT scores were excluded for this reason. Each participant's mean reaction time to target pairs was computed to evaluate attentional performance.

g. Statistical Analyses

All statistical analyses were performed using SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, NY).

Preliminary analyses

Several preliminary analyses were undertaken prior to conducting statistical testing. First, the distributional properties of all variables were examined to ensure that they met the normality assumption required for most parametric statistical tests. For variables that displayed substantial departures from normality based on Shapiro–Wilk and Kolmogorov–Smirnov tests (cutoff, $p > 0.05$), possible improvements in normality following nonlinear transformations were explored to best restore and approximate normality. Three variables were found to have distributions that exhibited substantial positive skew, and were therefore subjected to a transformation prior to conducting statistical testing: vagal tone (natural log (ln) transformed), planning (square root transformed), and decision-making (log transformed).

Multivariate evaluation of mean changes in outcomes across time

To examine differences from baseline to 8-week follow-up and 10-week follow-up, while covarying on demographics of interest (i.e., age, gender, number of deployments, and probable TBI history), a series of repeated measures analyses of variance (ANOVAs) were computed for all outcomes. Four independent models were computed to account for changes in sample sizes for the baseline to 8-week follow-up and 10-week follow-up comparisons and the inclusion of covariates. More specifically, the first set of repeated measures ANOVAs compared baseline and 8-week follow-up scores, the second set of models compared baseline and 8-week follow-up while adjusting for covariates, the third was a comparison between 8-week follow-up and 10-week follow-up, and lastly, 8-week follow-up and 10-week follow-up with covariates. This conventional approach, combined with the evaluation of the relative change scores described earlier, allowed for identification of the most reliable and robust within-subject outcome differences. Omnibus tests of change across time were evaluated first and if statistically significant ($p < 0.05$), the pairwise comparisons were evaluated.

Relative changes across outcome variables

To assess changes in scores between baseline and the 8-week follow-up, outcome scores were converted into relative change scores based on the following formula:

$$[\text{Score}_{(\text{8-week follow-up})} - \text{Score}_{(\text{Baseline})}] / [\text{Score}_{(\text{Baseline})} \times 100]$$

In effect, this computation produces a standardized difference score for each outcome, allowing for direct comparisons of the magnitude and direction of change across outcomes. Change scores are interpreted as a percent change relative to baseline, such that a score of 0 reflects no change in 8-week follow-up responses relative to baseline, and a positive (or negative) score reflects the proportional “gain” (or “loss”) after training relative to baseline. In order to determine whether the degree of change between baseline and follow-up is statistically significant, one-sample *t* tests (H_0: $\mu = 0$) were computed for each outcome variable.

Multiple comparison correction

Given the large number of multiple comparisons, corrected *p* values were obtained for all analyses using the false discovery rate (FDR) with the Benjamini and Hochberg method (Benjamini & Hochberg, 1995). The FDR threshold was set to 25% to ensure that any important effects for this initial small-scale study were captured.

Supplementary analyses

Possible differences in statistically significant change scores as a function of SRTS app usage

SRTS app usage was extracted to assess whether significant change scores (from the relative change analysis) differed as a function of app usage. Total amount of time participants spent in the SRTS app was collected and used to group the entire sample into three groups: low (<10 min; $n = 16$), medium (10–28 min; $n = 18$), and a high usage group (31–96 min; $n = 20$). Using the same methods described previously, significant relative change scores were assessed as a function of SRTS app usage groupings.

Possible difference in statistically significant change scores, HRV coherence, and use of self-regulation techniques

This exploratory analysis was conducted to establish a possible relationship between use of the self-regulation techniques, HRV coherence, and changes in outcomes. A self-regulation usage grouping variable was calculated based on the self-report questions described in the “Use of self-regulation strategies” section. Those in the “high” self-regulation usage group utilized the self-regulation techniques in times of stress at least “fairly often” in the past 2 weeks (score >2) and the “low” self-regulation group corresponded to those who “sometimes” , or never, utilized the self-regulation techniques during stress in the last 2 weeks (score ≤2). Based on the self-regulation usage grouping variable, Pearson correlations were computed for each of the self-regulation groups across any significant relative change gains scores observed in the previous analysis and HRV coherence scores.

Satisfaction with the SRTS intervention

Descriptive statistics of satisfaction ratings of the SRTS program were calculated.

App usage

Each participant’s time spent in the app during the study period was retrieved when the assessment data were downloaded from the individual iPads. These data included the amount of time spent in the different modules of the app and measures of HRV and coherence while the participants were using the games. These data were stored in the iPad in a manner that was not accessible to participants using the iPads and required connection to the original provisioning server via Wi-Fi to be downloaded.

III. Results

a. Participants

Study participants were crew members of a U.S. naval vessel (*N* = 92). The total number of crew members who consented and completed both the baseline and 8-week follow-up assessments was *N* = 56 (39% attrition from baseline; note: *N* varies across analyses due to missing data). The total number of crew members who completed assessments at all three time points was *N* = 22 (76% attrition from baseline). Demographic data are summarized for the sample with baseline and 8-week follow-up data, and for the sample with all three time points in Table 1. Among the larger, baseline and 8-week follow-up data sample, military rank ranged from E1 to O2, with 55% of the sample represented by E5–E6; 59% of the sample were between the ages of 26 and 35 years old; 80% of this sample were males. On average, Sailors reported about two (*M* = 2.33, *SD* = 1.63) deployments prior to enrolling into this study. For the sample with complete data, military rank ranged from E1 to O2, with 50% represented by E5–E6; 59% were between the ages of 26 and 35 years old; and 82% were males. On average, Sailors in this smaller sample reported *M* = 2.09 (*SD* = 1.60) deployments prior to enrolling into this study.

Table 1

Demographic Characteristics of Participants who Completed Baseline and 8-Week Follow-Up, and Baseline, 8-Week Follow-Up and 10-Week Follow-Up

Variables	Baseline and 8-week follow-up sample (N = 56)		Baseline, 8-week follow-up and 10-week follow-up sample (N = 22)	
	N	%	N	%
Age, years				
18–25	11	19.6	4	18.2
26–29	14	25.0	5	22.7
30–35	19	33.9	8	36.4
36+	10	17.9	5	22.7
Gender				
Male	45	80.4	18	81.8
Female	8	14.3	4	18.2
Ethnicity				
Hispanic or Latino	9	16.1	2	9.1
Not Hispanic or Latino	45	80.4	20	90.9
Race				
Asian	3	5.4	1	4.5
Black or African American	13	23.2	4	18.2
Native Hawaiian or Other Pacific Islander	1	1.8	0	0.0
White	25	44.6	15	68.2
Multiracial	8	14.3	2	9.1
Other/unknown	2	3.6	0	0.0
Marital status				
Divorced/separated/widowed	12	21.4	7	31.8
Never married	20	35.7	8	36.4
Married	22	39.3	7	31.8
Education				
Did not complete HS/GED	1	1.8	0	0.0
Completed HS/GED	14	25.0	4	18.2
Some college or tech school	18	32.1	6	27.3
Associate degree	5	8.9	1	4.5
Bachelor’s degree or higher	13	23.2	9	40.9
Graduate degree	2	3.6	1	4.5
Pay grade/rank				
E1–E4	7	12.5	3	13.6
E5–E6	31	55.4	11	50.0
E7–E9	7	12.5	2	9.1
O1–O3	9	16.1	6	27.3
Total deployments	54		22	
0	14	25.0	6	27.3
1	3	5.4	2	9.1
2	8	14.3	4	18.2

3	9	16.1	4	18.2
4+	20	35.7	6	27.3

Note. Percentages do not add to 100% due to missing data.

b. Attrition

To assess whether attrition was affected by differences across demographic and military characteristics (i.e., age, gender, marital status, rank/pay grade, and number of deployments), mental health (i.e., perceived stress, depression and anxiety, and resilience), and all cognitive performance variables assessed at baseline, a grouping variable was computed to designate those who only completed the baseline assessment ($n = 8$), those who only completed both the baseline and 8-week follow-up assessment ($n = 35$), and those who completed all three assessments, including the 10-week follow-up ($n = 22$). Thereafter, for categorical variables (including all of the demographic variables), χ^2 tests were obtained, and for all continuous variables, one-way ANOVAs were computed, with the attrition grouping variable (three groups) defined as the between-subjects factor.

To test whether attrition was affected by preexisting differences, demographics, mental health, and neuropsychological variables assessed at baseline were examined among attriters and non-attriters using χ^2 tests and ANOVAs. While there were no differences across the attrition groups on measures of mental health or cognitive performance (*p*s > 0.05), there was a difference in marital status. More specifically, attriters at the 10-week follow-up were less likely to be married than study completers ($\chi^2 = 14.64$, $p = 0.005$).

c. Cognitive Performance

All participants performed within acceptable standards on the effort test that was included in the cognitive performance measures. As such, no participants' cognitive performance test results were eliminated. To test hypothesis 1(a) that following the SRTS training, crew members would show improvement in decision-making and other executive functions, we determined if 8-week follow-up relative changes in the four cognitive performance measures were statistically different from baseline scores ($N = 56$) and relative to 10-week follow-up ($N = 22$), by computing independent comparisons for each time point assessment. Figure 1 displays the results for the cognitive performance outcomes tested on the relative change scores (FDR corrected), their mean and 95% confidence intervals (CI). The statistically significant effects at 8-week follow-up (relative to baseline) were improved processing speed, $t(56) = 5.31$, $p < 0.001$, and decision-making, $t(56) = 2.97$, $p = 0.004$. There were no significant differences observed in 10-week follow-up scores for any of the cognitive performance outcomes in this analysis. Appendix B contains all results for baseline to 8-week follow-up and 10-week follow-up analyses for all outcomes examined using relative change scores.

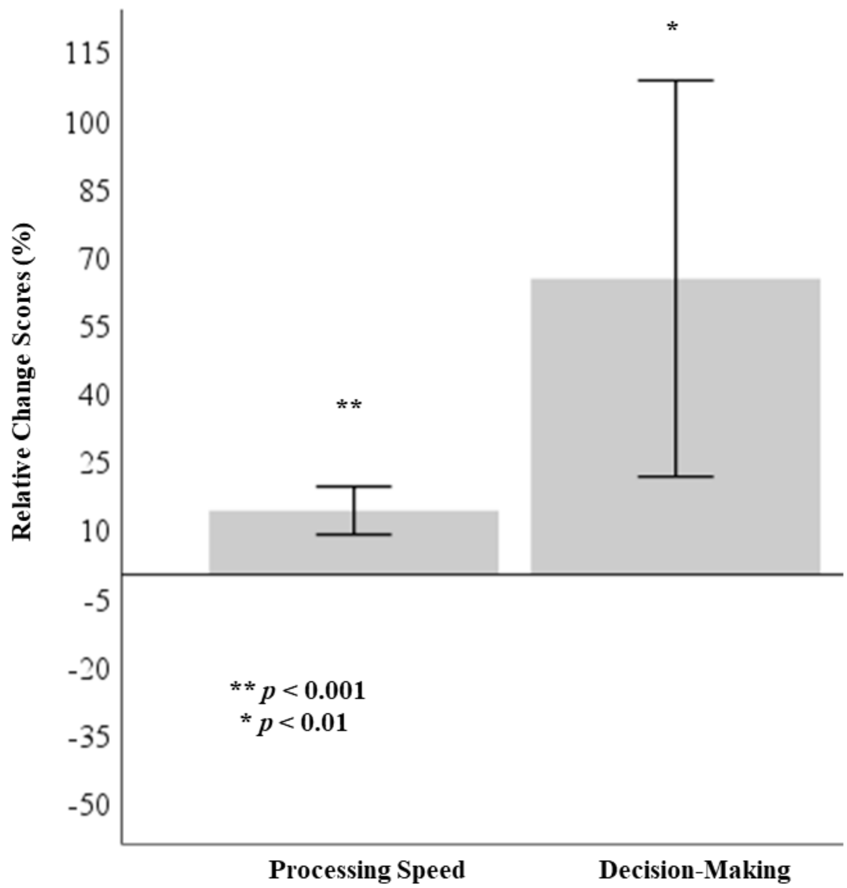

Figure 1. Statistically significant effects in cognitive performance change scores**.**

To determine if mean raw scores changed across time, from baseline to 8-week follow-up (N = 56) and 8-week follow-up to 10-week follow-up (N = 22), with and without the inclusion of covariates (age, gender, number of deployments, and probable TBI history), four independent comparisons were computed across the four cognitive performance outcomes. Similar, but not identical to the results of the relative change score results described above and in Figure 1, the statistically significant differences from baseline to 8-week follow-up were in improved processing speed, $F(1, 54) = 21.042$, $p < 0.001$, and decision-making, $F(1, 52) = 83.26$, $p < 0.001$. However, these effects did not hold once covariates were included into the model. There were no statistically significant effects at the 10-week follow-up (relative to 8-week follow-up) in any of the cognitive performance outcomes. Appendices C and D contain all results for baseline to 8-week follow-up and 10-week follow-up analyses for all outcomes examined using repeated measures ANOVA, without and with covariates, respectively.

d. Stress and Stress-Related Symptoms

To test hypothesis 1(b) that following the SRTS training, crew members would report reduced stress and stress-related symptoms, we used the same two analysis strategies used in the immediate previous section to assess relative changes in stress and stress-related symptoms over time, and by conducting a multivariate evaluation of mean changes across time points. The stress outcomes examined were resilience, perceived stress, depression and anxiety symptoms, PTSD, anger, sleep health, social support, and coping. Figure 2 displays the statistically significant results among the stress and stress-related outcomes tested on the relative change scores, their mean and 95% confidence intervals. The statistically significant effects at 8-week follow-up (relative to baseline) were an unexpected increase in perceived stress, $t(51) = -2.28$, $p = 0.03$, and decreased depression and anxiety, $t(38) = 2.09$, $p = 0.04$. There were no significant differences observed in 10-week follow-up scores for any of the stress outcomes in this analysis.

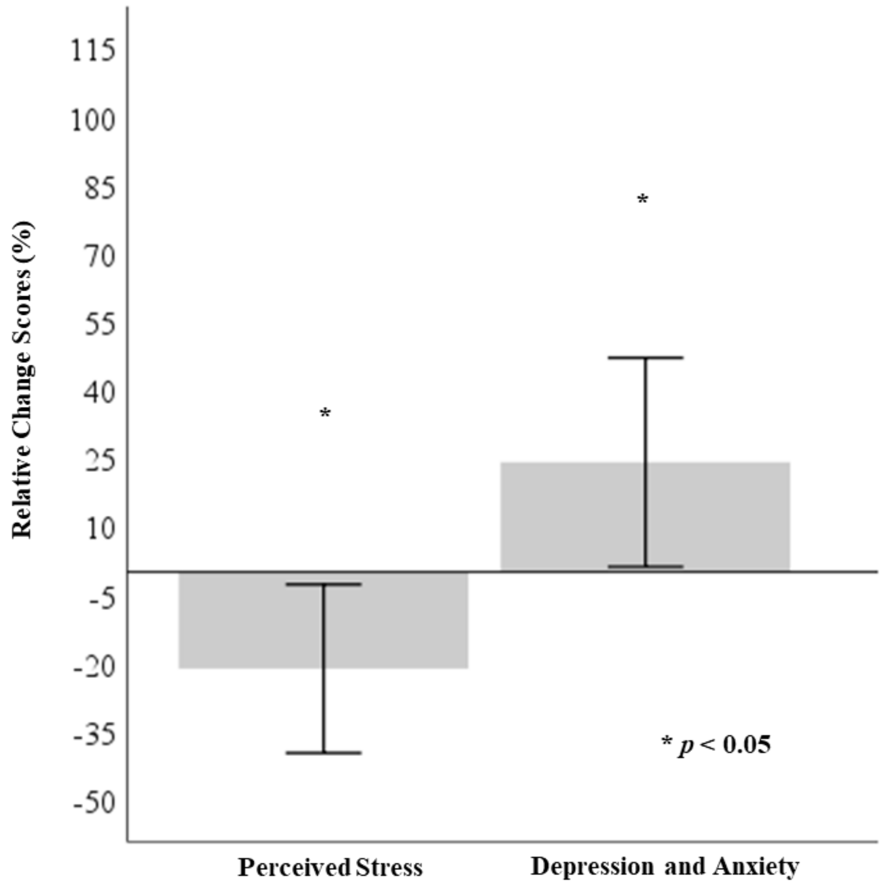

Figure 2. Statistically significant effects in stress and stress-related symptoms change scores.

To determine if mean raw scores of the stress outcomes changed across time, from baseline to 8-week follow-up and 8-week follow-up to 10-week follow-up, with and without the inclusion of covariates (age, gender, number of deployments, and probable TBI history), the four independent comparisons described earlier were computed for the stress outcomes. The only outcome with a significant omnibus change in time (across the entire duration of the study) was resilience (Figure 3). While this effect did not survive FDR threshold, it was indeed the only statistically significant finding in the sample with all three assessment time points, and it was also a primary outcome of interest for this study, thus we present this result as a post hoc result. There was a main effect of time, $F(2, 18) = 3.84$, $p = 0.04$, with a linear increase in scores from baseline to

10-week follow-up. Pairwise comparisons between each time point showed that this effect was driven primarily by increased resilience scores at the 10-week follow-up, with marginal increases in 10-week follow-up compared with baseline ($p = 0.109$) and 10-week follow-up compared with 8-week follow-up ($p = 0.107$), with no difference between baseline and 8-week follow-up ($p = 0.544$).

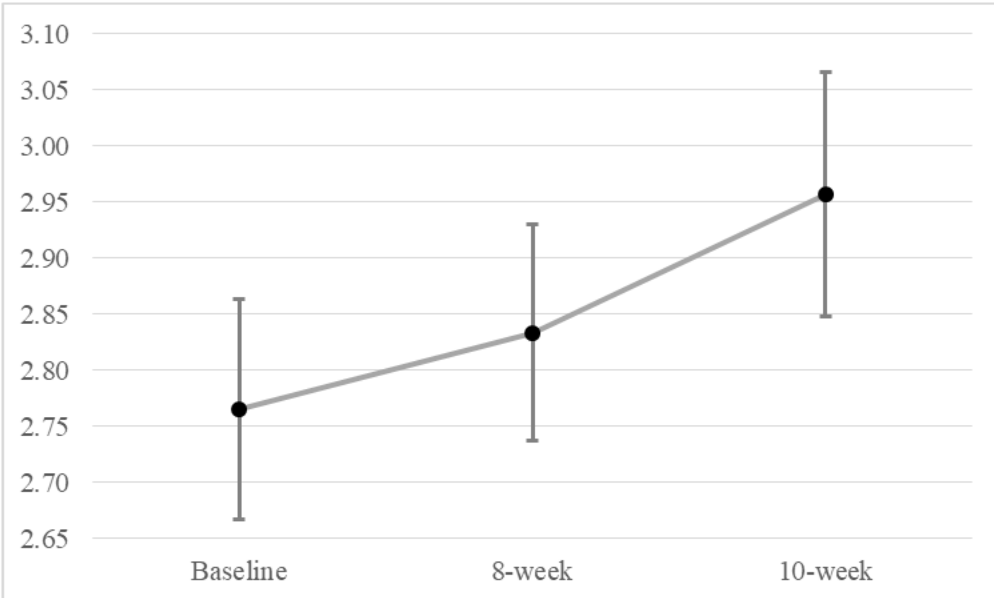

Figure 3. Self-reported resilience across duration of study.

e. Heart Rate Variability

To test hypothesis 1(c) that following the SRTS training, crew members would demonstrate increased HRV, we performed the two analytical approaches of assessing relative changes in the HRV measures over time, and by conducting a multivariate evaluation of mean changes in the HRV measures across time points. To determine if 8-week follow-up relative changes in the three HRV outcomes (HRV as vagal tone, HRV as adaptation, and HRV coherence) were statistically different from baseline scores and relative to 10-week follow-up, independent comparisons were computed for each time point assessment for these outcomes (Figure 4). There were no statistically significant effects at the 8-week follow-up or 10-week follow-up for the HRV measures. Similarly, the multivariate evaluation of mean changes across time points did not yield significant results for the HRV measures.

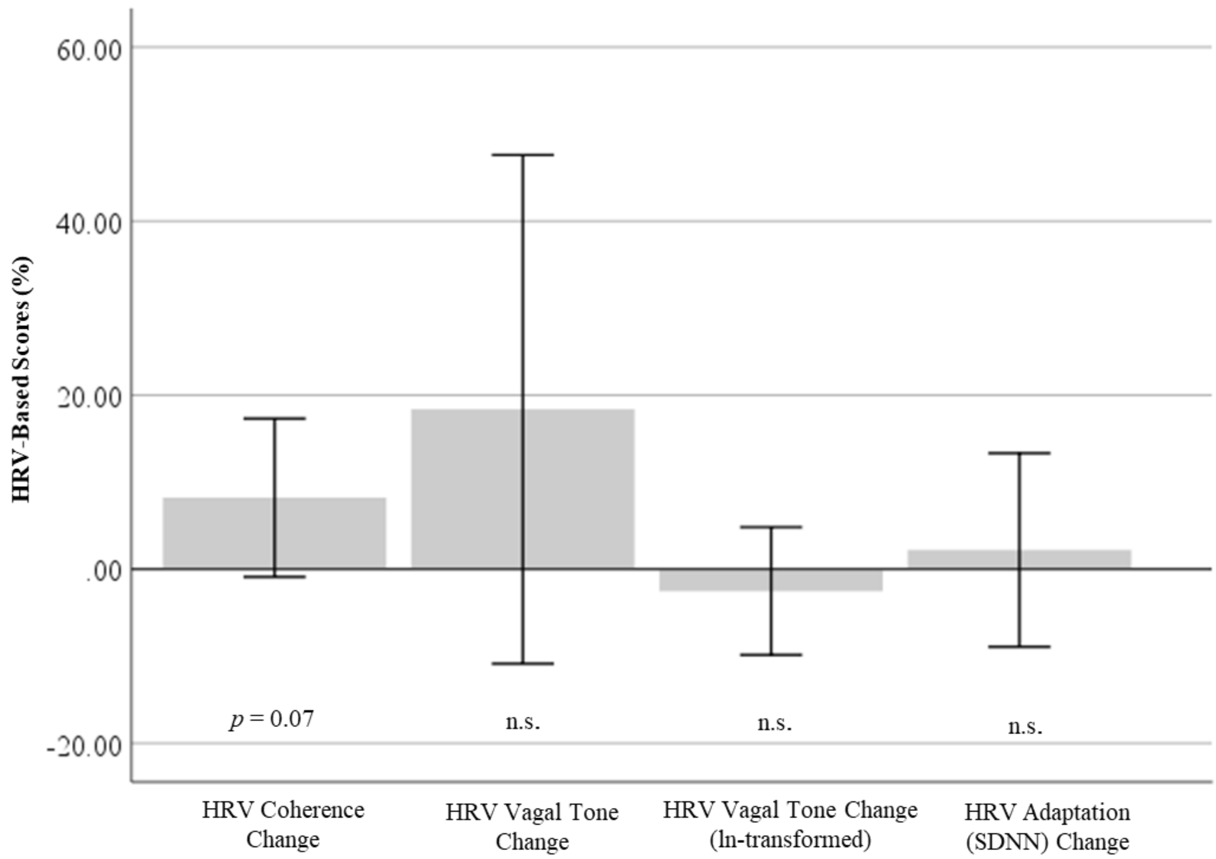

Figure 4. Relative change scores of HRV measures. Both the raw HRV vagal tone scores and natural log (ln)-transformed scores are presented. Ln-transformed vagal tone scores were used for all statistical analyses based on the shape of the distribution, and are presented for easier comparison with previous studies reporting ln-transformed HRV vagal tone scores. SDNN = standard deviation of normal-to-normal intervals.

f. Intervention Usage and Outcomes

To test hypothesis 2, that crew members who spend more time using the app will demonstrate greater improvements in the outcomes of interest, the following analyses were conducted using different levels of app usage.

Comparison of Significant Change Scores as a Function of SRTS App Usage

In order to determine if relative change scores found to be significant in the previous analyses were statistically different across app usage groupings, a one-sample *t* test was conducted to assess changes from zero within each of the groups (low, medium, and high usage). The only outcome variable that showed a differential change as a function of app usage was the perceived stress change scores (after FDR correction). For the low app usage group, there was a statistically significant increase in perceived stress at 8-week follow-up compared with baseline ($p = 0.006$), but there were no statistical changes in perceived stress for the medium and high app usage groups (*p*s > 0.05). Figure 5 displays the mean and 95% confidence intervals of perceived stress across the three different app usage groups. There were no other statistically significant changes observed for the other outcomes examined in this analysis (decision-making, processing speed, and anxiety and depression).

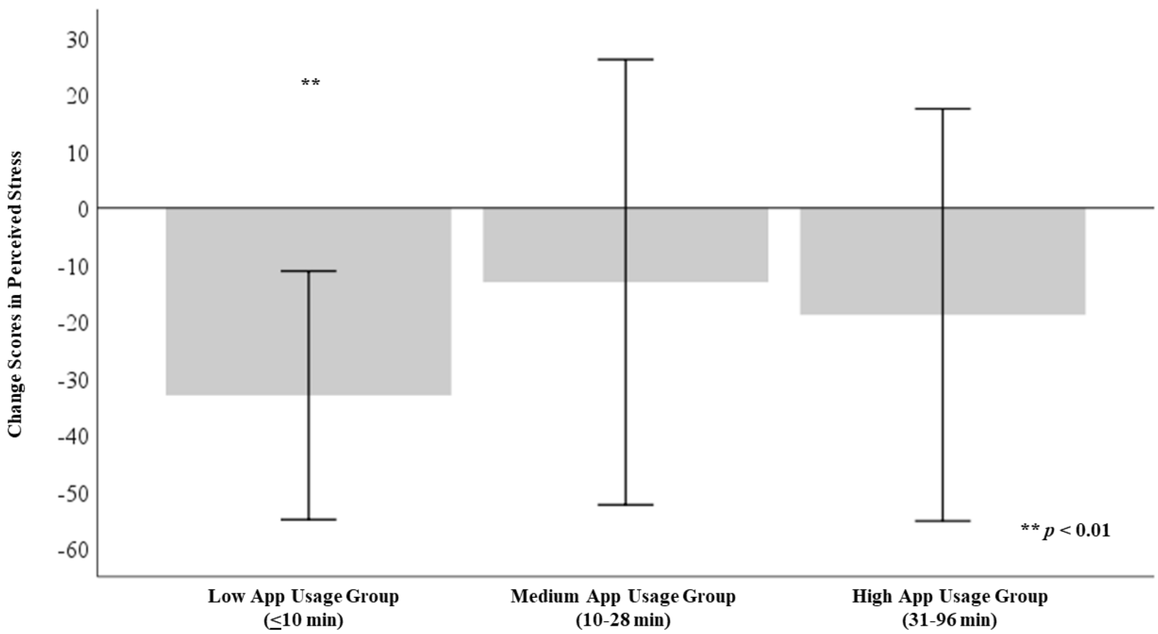

Figure 5. Changes in perceived stress as a function of SRTS app usage.

Relationship Between Significant Change Scores, HRV Coherence, and Use of Self-Regulation Techniques

This exploratory analysis was conducted to examine if outcomes differed by level of use of the self-regulation techniques taught in the training. To determine if there were any relationships between relative change scores in the significant outcome variables in the previous analyses and HRV coherence scores as a function of low and high users of the self-regulation techniques taught in the training, Pearson correlations were computed. After FDR correction, there was a statistically significant correlation between improvements in processing speed and increases in HRV coherence that was specific to the high self-regulation usage group (Figure 6).

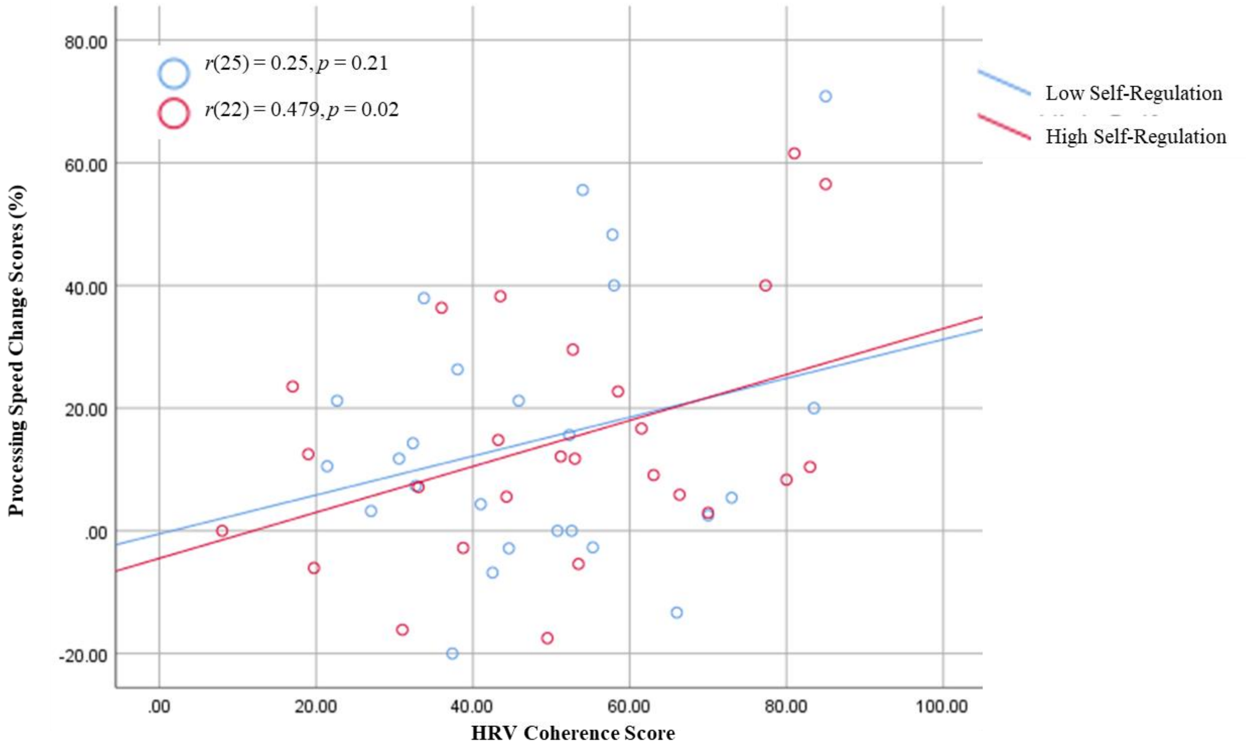

Figure 6. Relationship between HRV coherence and changes in processing speed by low and high use of self-regulation techniques.

g. Satisfaction With the SRTS Intervention

Figure 7 displays the mean and 95% confidence intervals of Sailor satisfaction with the stress and resilience training program. On average, Sailors "agreed" that the workshop instructors were credible ($M = 3.22$, $SD = 0.92$), and that the overall workshop was somewhat satisfactory ($M = 2.50$, $SD = 1.04$) and relevant to readiness ($M = 2.68$, $SD = 0.95$), and that they learned information from the SRTS app itself ($M = 2.66$, $SD = 1.08$), using a scale ranging from 0 (*disagree*) to 4 (*strongly agree*). In addition, participants somewhat agreed that the app was appropriate for military service members ($M = 2.51$, $SD = 1.14$), they would recommend the app to fellow service members ($M = 2.53$, $SD = 1.03$), and they agreed that they were satisfied with the mentoring associated with use of the app ($M = 2.58$, $SD = 0.99$) (data not shown in Figure 7).

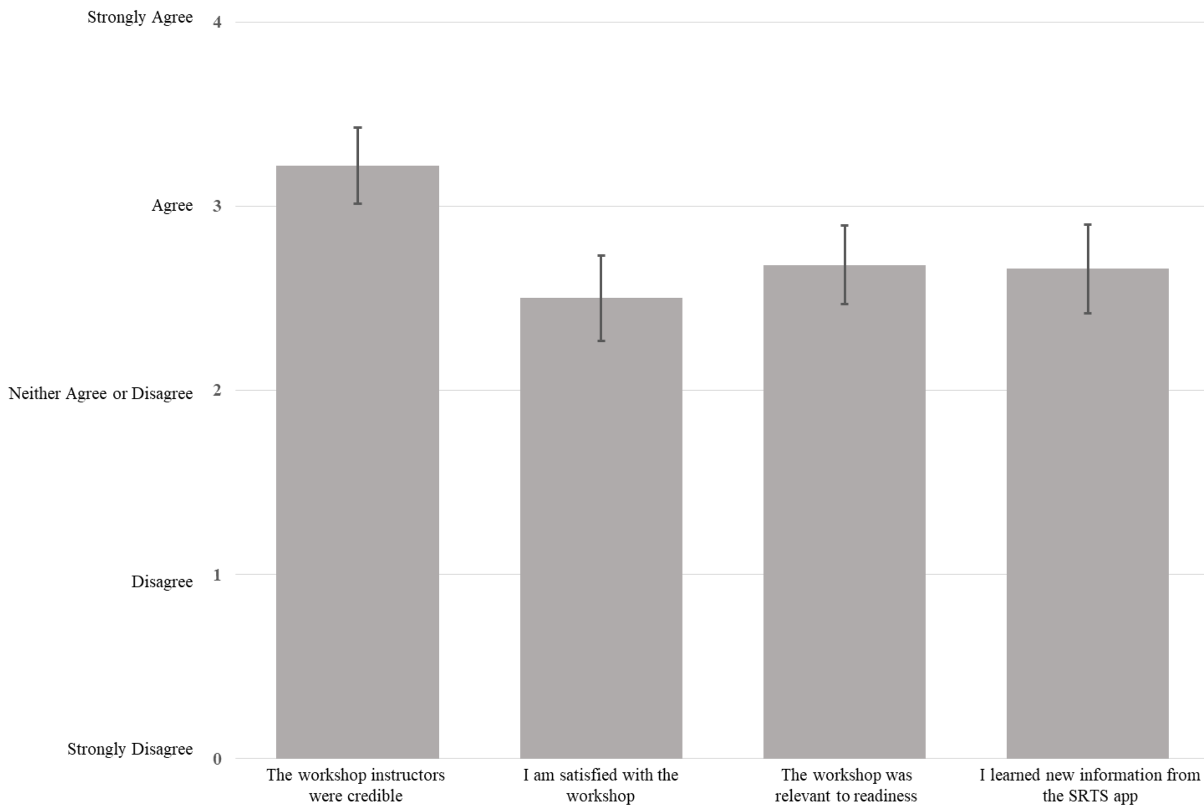

Figure 7. SRTS satisfaction ratings.

h. App Usage

The total amount of time that participants spent using the SRTS app during the approximate 10-week study period was *M* = 42.26 min (*SD* = 60.53; range = 0–312.54). Participants spent the most time in the Games section (Figure 8).

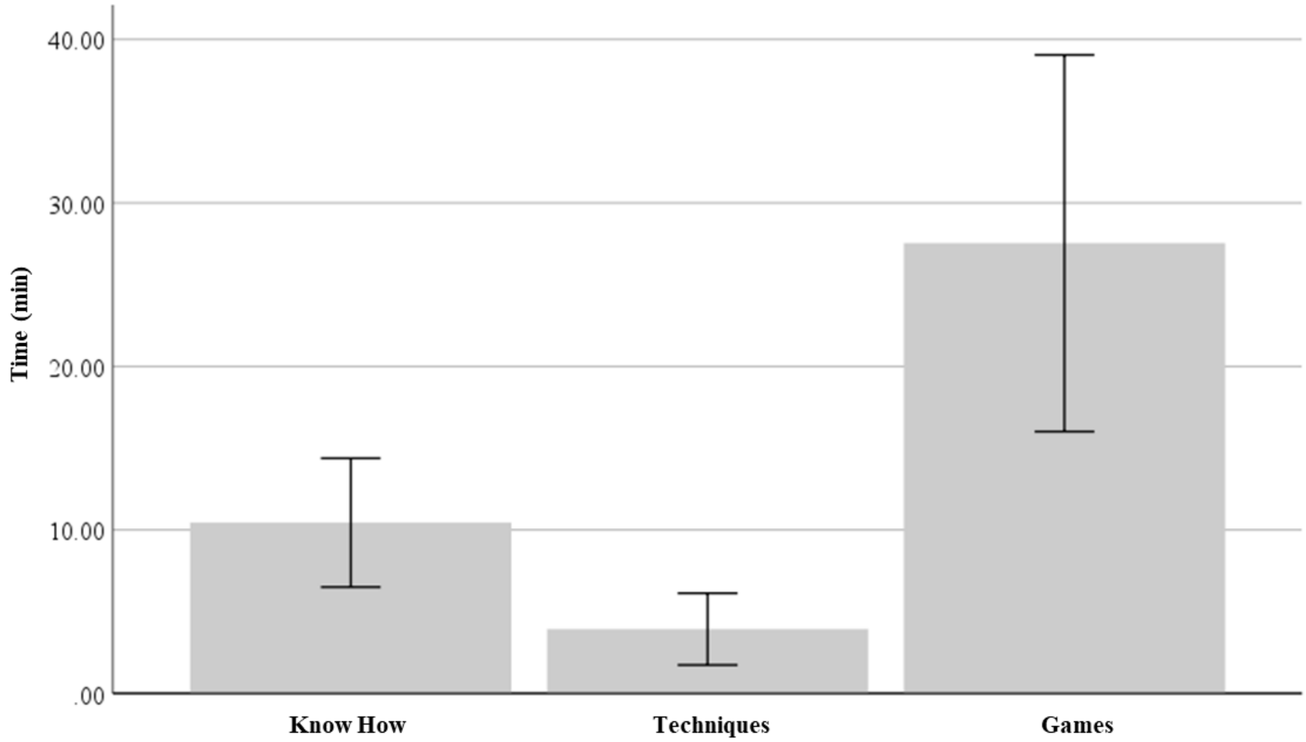

Figure 8. Total amount of time spent using SRTS app-based modules over the course of the 10-week study period.

IV. Discussion

a. Overview of Findings

This effort evaluated a training program to enhance resilience and decision-making under stress in a shipboard field setting. Participants demonstrated improved processing speed and decision-making, and reported decreased depression and anxiety symptoms but increased perceived stress at the 8-week follow-up; however, these changes were not sustained at the 10-week follow-up. In addition, there was a marginally significant increase in resilience over the study period. There were no significant changes found in physiological HRV measures, cognitive performance measures of attention and planning, or in the other self-reported psychological and social outcomes. There were, however, demonstrated benefits among participants with higher usage levels of the app and the self-regulation techniques taught in the intervention. Specifically, app usage was associated with perceived stress, with those reporting low usage of the app having a significant increase in perceived stress, while those with medium and high use of the app did not exhibit such an increase. Additionally, an exploratory analysis revealed a dose-response relationship such that that the relationship between HRV coherence and processing speed was significant among those reporting higher use of the self-regulation techniques taught in the training but not among participants with low use of these techniques. Regarding participants' rating of the SRTS training, Sailors were generally satisfied with the initial training workshop, trainers, and the app.

The overarching purpose of this effort was to enhance resilience among Sailors to improve their performance and decision-making under stress. The results of this study indicate a marginally significant increase in resilience over time. This finding, which is consistent with results of other studies evaluating SRTS (de Visser et al., 2016; Weltman, Lamon, Freedy, & Chartrand, 2014), indicates that this tool could be used in future resilience programs for service members. Specifically, this study also sought to improve HRV and cognitive performance as indicators of resilience. While the intervention did not produce significant changes in HRV-related measures, our results showed improvements in decision-making and processing speed, two of the performance indicators highlighted as critical in shipboard settings by ship leadership. However, consistent with previous research (Byrd, Reuther, McNamara, Delucca, & Berg, 2015; Luque-Casado, Perales, Cárdenas, & Sanabria, 2016), significant differences in the executive functions of planning or attention were not observed in this study, indicating a need for continued examination of additional indices of cognitive performance.

In addition to resilience, HRV, and cognitive performance, symptoms of depression and anxiety were assessed in this study because psychological distress is associated with reduced resilience. Reductions in depression and anxiety symptoms were observed in this study, and these findings are both consistent with prior studies and indicate that interventions that seek to manage physiological stress response may benefit overall psychological health. Specifically, other studies that have used the same HRV system that is a core component of the intervention used in this effort have also reported reduction in psychological symptoms (Beckham, Greene, & Meltzer-Brody, 2013; Lee, Kim, & Wachholtz, 2015; McAusland & Addington, 2018), as have other interventions that integrated an HRV biofeedback component (Goessl, Curtiss, & Hofmann, 2017; Karavidas et al., 2007; Knox et al., 2011; Nolan et al. 2005; Sutarto, Wahab, & Zin, 2012; Ratanasiripong, Kaewboonchoo, Ratanasiripong, Hanklang, & Chumchai, 2015). While research in this area lacks consistency in methodology, taken together, the results show promise for the use of HRV-based interventions.

Perceived stress was also assessed as a potential indicator of resilience. For the entire study sample, self-reported perceived stress levels did increase over the study period. The operational setting during the latter data collection points was likely a contributor to the stressors that participants were experiencing, and it is possible that this is reflected in the unanticipated result of overall increased perceived stress at the 8-week follow-up when compared with baseline, as well as the lack of an increase in the use of traditional coping strategies during this time. The increasing operational tempo over the course of the study may have also led to an overall low level of sustained practice of the strategies taught in the SRTS training. For example, perceived stress varied as a function of app use. Sailors with the lowest levels of app usage reported significant increases in perceived stress, while no significant change in perceived stress was detected among Sailors with greater usage. This finding suggests a possible dose-response benefit in using the app such that app usage may have protected against increases in stress; however, the sample size is insufficient to determine this in the present study.

Other possible dose-response relationships were observed. Specifically, when we compared participants who used the self-regulation techniques with greater frequency and those who used them less frequently, there were demonstrated benefits among the high-level users. Specifically, the positive relationship between HRV coherence and processing speed was significant among those reporting higher use of the self-regulation techniques taught in the training but not among participants with low use of these techniques. This suggests that use of self-regulation techniques enhanced the association among HRV coherence and the cognitive performance measure of processing speed. However, there were no significant direct improvements observed in the HRV physiological outcomes overall. The increasing operational tempo during the study and the probable lack of sustained practice of the SRTS strategies over time are likely important contributors to the absence of significant changes in HRV physiological outcomes.

b. Limitations and Future Research

The two major limitations of this study were the high levels of attrition and the lack of a control group. The attrition levels were higher than anticipated, even in an operational setting, which led to statistical power dropping below 80% for anything less than a large effect size (.5 or greater). There were several issues that likely contributed to the decrease in participation in the evaluation over time. The one that the researchers anecdotally heard about was related to the high operational demands of the command participating in the study during the final month of data collection, which included the 8-week and 10-week follow-up assessments. High operational demands combined with the time commitment and additional effort required to complete the cognitive performance and psychological assessments may have contributed to decreased continued participation and led to less than 24% retention at 8-week follow-up and 14% at the final time point. This made it impossible to statistically detect smaller effects among the sample with data at all three time points. Additionally, the high attrition made it difficult to generalize significant results to nonmarried service members or to service members at large, who, as a group, may have different stressors, as attriters at the 10-week follow-up were less likely to be married than study completers.

Furthermore, the current quasi-experimental design is inherently limited to infer direct causation, making it difficult to determine the presence of confounding factors, or if use of the intervention program might have had some protective effect against the deterioration of HRV coherence over time. The ad hoc finding that perceived stress levels increased for participants with low use of the intervention app is consistent with the operational demands over time, and the lack of change in groups with medium or high app usage may indicate a protective effect. This merits further examination over a longer period of time with a sample sufficient to detect medium and small effects.

In addition, the internal consistency of some outcome measures was low, specifically for the maladaptive coping factor derived from analysis of the Brief COPE, and the PSQI, used to measure sleep health. The low Cronbach's α for the maladaptive coping factor is consistent with the low factor loadings for this factor in the current sample. The low reliability estimate for the PSQI is consistent with a previous meta-analysis on its reliability, where lower Cronbach's αs (below 0.70) were observed in nonclinical samples and a sample featuring patients with chronic fatigue syndrome (Mollayeva et al., 2016).

c. Recommended Implementation

Based on the data gathered in this study, a modified program and a larger scale evaluation is recommended. Because the present study suggested that increased use of the app and the corresponding stress management techniques was associated with some benefits, a modified program should incorporate new ways to encourage and enable increased use. For example, the app component of the intervention should be modified for use on personal smartphones operating on both iOS and android platforms to make it more user-friendly and accessible than the iPad version that was used in this study. Another modification to the app to motivate increased use would be the addition of new games, badges and points for progress, and better alignment of the lessons in the app with the classroom training to reinforce the program's main principles. Additionally, tailoring the content of the app and the overall intervention more heavily toward the specific concerns in a shipboard environment is recommended.

In addition to improvements to the app, a modified program should be structured to rely more heavily on the mentoring process. Given that independent app usage can range substantially across users, as was observed in the present study, mentors can consistently reinforce and foster learning the techniques. It is anticipated that more emphasis on mentoring would likely increase the uptake and practice of the principles and strategies of the intervention prior to the times of increased stress and operational tempo so they will be more likely to become rote.

Several additional implementation and methodological improvements should be considered in future evaluations of this intervention or a modified intervention. These include increasing the exposure to the intervention to greater than 8 weeks, which would allow for more practice of the skills and techniques; integrating an increased period of time between the 8-week follow-up and the final follow-up (which was not possible given the timing in the present study); executing simulated assessments during shipboard training evolutions (to assess effects during active stress situations); and thoroughly documenting external factors that influence stress levels (e.g., operational tempo, training exercises, afloat vs. shore time) to better factor in their influence on the outcomes of interest. In addition, future research should integrate a control group to assess whether exposure to the intervention has an effect compared with controls in the same shipboard environment. Additional research should also assess which intervention components (e.g., techniques, biofeedback) has a greater influence on outcomes.

d. Conclusion

This study demonstrated that a naval vessel could integrate into its operations a training program aimed at enhancing decision-making under stress and that it could have some positive impact on a variety of outcomes related to resilience and performance. The intervention was integrated into the participating ship's training rotation for the purposes of improving the well-being of its crew, and its principles were embraced by the Commanding Officer as part of the command culture beyond the evaluation period. While there was some support for the hypothesis that there would be improvement in measures of decision-making over time, other hypotheses such as improved HRV coherence were not supported. Still other hypotheses, including a reduction of stress-related symptoms, had mixed support most likely due to increasing operational tempo over the course of the study affecting the entire sample. Despite mixed results, the study's demonstrated feasibility, acceptability, and effects on resilience remains a good initial effort at assessing SRTS in a shipboard setting, and sets the foundation for future research that can overcome some of the challenges and limitations of this endeavor.

In summary, the results of this evaluation indicate SRTS has the potential to enhance shipboard Sailors' mission effectiveness by improving the quality of their mission-relevant decisions, thereby potentially ultimately reducing critical errors in judgment and enhancing mission performance. The intervention also has promise to reduce stress injuries among Sailors deployed at sea, thereby also enhancing readiness and potentially reducing costs associated with stress injury.

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Appendix A

Factor Loadings From Principal Components Analysis of the Brief COPE Scale

	Problem-focused coping factor	Emotion-focused coping factor	Maladaptive coping factor
Positive reframing	.869	–	–
Planning	.840	–	–
Active coping	.800	–	–
Religion	.676	–	–
Venting	–	.773	–
Humor	–	.753	–
Self-distraction	–	.750	–
Acceptance	–	.661	–
Use of emotional support	–	.569	–
Use of instrumental support	–	.562	–
Denial	–	–	.827
Behavioral disengagement	–	–	.771
Self-blame	–	–	.737
Substance use	–	–	–

Note. These factor values are based on a principal components analysis with varimax rotation. Factor loadings less than .55 are omitted from the table.

Appendix B

Relative Change Score Descriptive and Inferential Statistics Across all Outcomes

Outcomes	Time	Mean change score (%)	*SD*	*N*	CI (lower)	CI (upper)	*df*	*t*	*p*
Stress and stress-related symptoms									
Resilience[a]	8-week - baseline	3.69	25.59	57	-3.10	10.47	56.00	1.09	0.28
	10-week - 8-week	6.64	15.33	24	0.16	13.11	23.00	2.12	0.05
Perceived stress[b]	**8-week - baseline**	**-21.23**	**66.49**	**51**	**-39.93**	**-2.53**	**50.00**	**-2.28**	**0.03***
	10-week - 8-week	42.20	159.39	22	-28.47	112.87	21.00	1.24	0.23
Posttraumatic stress symptoms[c]	8-week - baseline	-18.42	80.83	38	-44.99	8.15	37.00	-1.41	0.17
	10-week - 8-week	-15.26	31.57	17	-31.50	0.97	16.00	-1.99	0.06
Depression and anxiety[d]	**8-week - baseline**	**24.08**	**71.11**	**38**	**0.71**	**47.45**	**37.00**	**2.09**	**0.04***
	10-week - 8-week	-6.28	75.10	13	-51.67	39.10	12.00	-0.30	0.77
Anger[e]	8-week - baseline	-6.27	94.02	45	-34.51	21.98	44.00	-0.45	0.66
	10-week - 8-week	8.62	99.73	19	-39.45	56.69	18.00	0.38	0.71
Sleep[f]	8-week - baseline	-10.00	42.99	50	-22.22	2.22	49.00	-1.65	0.11
	10-week - 8-week	2.27	39.27	22	-15.14	19.68	21.00	0.27	0.79
Coping – Problem focused[g]	8-week - baseline	10.52	62.06	50	-7.12	28.16	49.00	1.20	0.24
	10-week - 8-week	-2.71	48.30	21	-24.69	19.28	20.00	-0.26	0.80
Coping – Emotion focused[g]	8-week - baseline	6.87	37.72	37	-5.71	19.44	36	1.11	0.28
	10-week - 8-week	-17.76	44.35	20	-38.51	2.99	19	-1.79	0.09
Coping – Maladaptive[g]	8-week - baseline	41.18	128.95	19	-20.97	103.34	18	1.39	0.18
	10-week - 8-week	-6.54	60.67	13	-43.20	30.12	12	-0.39	0.70
Social support[h]	8-week - baseline	24.57	112.18	52	-6.66	55.80	51	1.58	0.12
	10-week - 8-week	20.17	61.73	20	-8.72	49.06	19	1.46	0.16
Physiological outcomes									
HRV as vagal tone[i]	8-week - baseline	14.83	102.62	54	-13.19	42.84	53	1.06	0.29

Outcomes	Time	Mean change score (%)	*SD*	*N*	CI (lower)	CI (upper)	*df*	*t*	*p*
	10-week - 8-week	31.11	162.12	19	-47.03	109.25	18	0.84	0.41
HRV as vagal tone (ln-transform)[i]	8-week - baseline	-3.31	25.90	54	-10.38	3.76	53	-0.94	0.35
	10-week - 8-week	-1.67	22.88	19	-12.70	18.71	18	-0.32	0.75
HRV as adaptation[j]	8-week - baseline	2.44	40.05	57	-8.19	13.07	56	0.46	0.65
	10-week - 8-week	3.08	32.43	19	-12.55	18.71	18	0.41	0.68
HRV coherence[k]	Last-First login	9.39	36.26	49	-1.03	19.80	48	1.81	0.07
Cognitive performance									
Decision-making[l]	**8-week - baseline**	**65.04**	**163.79**	**56**	**21.18**	**108.90**	**55**	**2.97**	**0.004***
Processing speed[m]	**8-week - baseline**	**14.07**	**19.82**	**56**	**8.76**	**19.38**	**55**	**5.31**	**<0.001***
Planning[n]	8-week - baseline	2.12	10.98	56	-0.82	5.07	55	1.45	0.15
Attention[o]	8-week - baseline	2.43	14.72	56	-1.51	6.37	55	1.24	0.22

One-sample *t* tests were performed ($H_0 = 0$).
Exact *P* values are presented.
*The effect remained significant after false discovery rate correction.
[a] 10-item Connor-Davidson Resilience Scale, ranging from 0 (*not true at all*) to 4 (*true nearly all the time*).
[b] Cohen's 4-item Perceived Stress Scale, ranging from 0 (*never*) to 4 (*very often*).
[c] Abbreviated PTSD Checklist, ranging from 0 (*not at all*) to 4 (*extremely*).
[d] Patient Health Questionnaire-4, ranging from 0 (*not at all*) to 3 (*nearly every day*).
[e] The 6-item Brief Anger-Aggression Questionnaire, ranging from 0 (*not at all*) to 4 (*very frequently*).
[f] 9-item Pittsburgh Sleep Quality Index, ranging from 0 (*poor sleep quality*) to 21 (*optimal sleep quality*).
[g] Brief COPE, composite scores range from 0 (*I haven't been doing this at all*) to 3 (*I've been doing this a lot*).
[h] 2-item measure of social support, ranging from 0 (*none of the time*) to 5 (*all of the time*).
[i] The high-frequency component of the HRV signal, original units expressed as power spectral density, ms^2/Hz.
[j] Standard deviation of normal-to-normal intervals, original units expressed as inter-beat intervals in ms.
[k] HRV coherence score was generated from SRTS app, original scores range from 0 (broad spectral coherence) to 100 (narrow spectral coherence).
[l] Iowa Gambling Task (net total, reward-cost scores), original scores range from −100 to 100.
[m] Symbol Search task (accuracy), sample ranges from 18 to 57.
[n] The Tower of London task (total score square root-transformed), original scores range from 0 to 39.
[o] The continuous performance test (reaction times), original scores measured in ms.

Appendix C

Descriptive and Inferential Statistics and Effect Sizes Across all Outcomes

Outcomes	Time	*M*	*SD*	*N*	CI (lower)	CI (upper)	Contrasts	*t*	*df*	*p*	Hedges' *g*
Stress and stress-related symptoms											
Resilience[a]	baseline	2.93	0.57	57	2.78	3.08	8-week - baseline	0.43	55	0.67	0.05
	8-week	2.95	0.53	57	2.81	3.09	10-week - 8-week	1.45	21	0.16	0.23
	10-week	2.96	0.50	23							
Perceived stress[b]	baseline	1.25	0.71	54	1.06	1.45	8-week - baseline	1.65	52	0.11	0.20
	8-week	1.39	0.69	54	1.21	1.58	10-week - 8-week	1.25	20	0.22	0.22
	10-week	1.45	0.73	22							
Posttraumatic stress symptoms[c]	baseline	0.85	0.71	43	0.63	1.07	8-week - baseline	0.69	41	0.50	0.08
	8-week	0.92	0.85	43	0.65	1.18	10-week - 8-week	-1.23	15	0.24	-0.14
	10-week	0.66	0.72	17							
Depression and anxiety[d]	baseline	0.66	0.65	50	0.47	0.84	8-week - baseline	1.61	48	0.11	-0.17
	8-week	0.54	0.70	50	0.34	0.74	10-week - 8-week	-0.49	19	0.63	-0.04
	10-week	0.40	0.56	21							
Anger[e]	baseline	0.92	0.79	52	0.69	1.14	8-week - baseline	0.95	50	0.35	-0.13
	8-week	0.80	0.87	52	0.56	1.05	10-week - 8-week	-0.61	18	0.55	-0.06
	10-week	0.61	0.65	20							
Sleep[f]	baseline	7.50	3.35	30	6.25	8.75	8-week - baseline	1.56	28	0.13	-0.25
	8-week	6.63	3.52	30	5.32	7.95	10-week - 8-week	-0.35	10	0.73	-0.07
	10-week	5.42	2.97	12							
Coping – Problem focused[g]	baseline	1.16	0.72	55	0.96	1.35	8-week - baseline	1.09	53	0.28	0.13
	8-week	1.24	0.66	55	1.07	1.42	10-week - 8-week	-1.17	19	0.26	-0.18
	10-week	1.13	0.68	21							
Coping – Emotion focused[g]	baseline	1.19	0.66	41	0.98	1.39	8-week - baseline	0.89	39	0.38	0.12
	8-week	1.26	0.55	41	1.09	1.43	10-week - 8-week	-1.18	13	0.26	-0.24
	10-week	1.19	0.72	15							
Coping – Maladaptive[g]	baseline	0.42	0.44	30	0.25	0.58	8-week - baseline	1.19	28	0.24	0.21

Outcomes	Time	*M*	*SD*	*N*	CI (lower)	CI (upper)	Contrasts	*t*	*df*	*p*	Hedges' *g*
	8-week	0.53	0.58	30	0.31	0.74	10-week - 8-week	-0.41	7	0.70	-0.06
	10-week	0.41	0.56	9							
Social support[h]	baseline	2.25	1.20	55	1.93	2.58	8-week - baseline	0.45	53	0.65	-0.06
	8-week	2.18	1.19	55	1.86	2.50	10-week - 8-week	0.97	21	0.35	0.16
	10-week	2.07	1.29	23							
Physiological outcomes											
HRV as vagal tone[i]	baseline	184.97	163.04	54	140.47	229.47	8-week - baseline	0.18	52	0.85	0.03
	8-week	190.76	257.83	54	120.39	261.14	10-week - 8-week	-0.23	16	0.82	-0.03
	10-week	118.53	137.02	18							
HRV as adaptation[j]	baseline	64.64	27.17	57	57.43	71.85	8-week - baseline	0.53	55	0.60	-0.05
	8-week	63.08	30.77	57	54.92	71.24	10-week - 8-week	-0.66	17	0.52	-0.12
	10-week	58.24	20.30	19							
Cognitive performance											
Decision-making[k]	baseline	1.23	0.45	53	1.10	1.35	**8-week - baseline**	**83.27**	**51**	**<0.001 ***	**1.91**
	8-week	1.92	0.24	53	1.85	1.98					
Processing speed[l]	baseline	32.75	7.97	55	30.59	34.90	**8-week - baseline**	**21.04**	**53**	**<0.001 ***	**0.45**
	8-week	36.47	8.44	55	34.19	38.75					
Planning[m]	baseline	2.31	0.79	56	2.10	2.52	8-week - baseline	0.83	54	0.37	-0.12
	8-week	2.22	0.74	56	2.02	2.42					
Attention[n]	baseline	480.56	39.60	55	469.57	491.56	8-week - baseline	0.98	53	0.33	0.18
	8-week	489.01	53.50	55	474.78	503.24					

Repeated measures analyses of variance were performed.
Exact *P* values are presented.
*The effect remained significant after false discovery rate correction.
[a] 10-item Connor-Davidson Resilience Scale, ranging from 0 (*not true at all*) to 4 (*true nearly all the time*).
[b] Cohen's 4-item Perceived Stress Scale, ranging from 0 (*never*) to 4 (*very often*).
[c] Abbreviated PTSD Checklist, ranging from 0 (*not at all*) to 4 (*extremely*).
[d] Patient Health Questionnaire-4, ranging from 0 (*not at all*) to 3 (*nearly every day*).
[e] The 6-item Brief Anger-Aggression Questionnaire, ranging from 0 (*not at all*) to 4 (*very frequently*).
[f] 9-item Pittsburgh Sleep Quality Index, ranging from 0 (*poor sleep quality*) to 21 (*optimal sleep quality*).
[g] Brief COPE, composite scores range from 0 (*I haven't been doing this at all*) to 3 (*I've been doing this a lot*).
[h] 2-item measure of social support, ranging from 0 (*none of the time*) to 5 (*all of the time*).
[i] The high-frequency component of the HRV signal, original units expressed as power spectral density (PSD), ms^2/Hz.
[j] Standard deviation of normal-to-normal intervals, original units expressed as inter-beat intervals in ms.
[k] Iowa Gambling Task (net total, reward-cost scores), original scores range from −100 to 100.

[l] Symbol Search task (accuracy), sample ranges from 18 to 57.
[m] The Tower of London task (total score square root-transformed), original scores range from 0 to 39.
[n] The continuous performance test (reaction times), original scores measured in ms.

Appendix D

Descriptive and Inferential Statistics and Effect Sizes Across all Outcomes (With Covariates)

Outcomes	Time	*M*	*SD*	*N*	CI (lower)	CI (upper)	Contrasts	*t*	*df*	*p*	Hedges' *g*
Stress and stress-related symptoms											
Resilience[a]	baseline	2.92	0.57	56	2.80	3.04	8-week - baseline	1.82	49	0.08	0.07
	8-week	2.96	0.53	56	2.82	3.10	10-week - 8-week	1.66	16	0.11	0.23
	10-week	2.96	0.50	23							
Perceived stress[b]	baseline	1.26	0.71	53	1.08	1.44	8-week - baseline	2.24	46	0.03	0.18
	8-week	1.39	0.70	53	1.20	1.58	10-week - 8-week	1.23	15	0.24	0.22
	10-week	1.45	0.73	22							
Posttraumatic stress symptoms[c]	baseline	0.86	0.71	42	0.63	1.09	8-week - baseline	1.92	35	0.06	0.08
	8-week	0.93	0.86	42	0.66	1.19	10-week - 8-week	– 1.19	10	0.26	-0.14
	10-week	0.66	0.72	17							
Depression and anxiety[d]	baseline	0.67	0.65	49	0.49	0.84	8-week - baseline	0.03	42	0.98	-0.18
	8-week	0.55	0.70	49	0.35	0.74	10-week - 8-week	– 0.50	14	0.63	-0.04
	10-week	0.40	0.56	21							
Anger[e]	baseline	0.92	0.79	52	0.71	1.12	8-week - baseline	1.65	45	0.11	-0.13
	8-week	0.80	0.87	52	0.56	1.05	10-week - 8-week	– 0.63	13	0.54	-0.06
	10-week	0.61	0.65	20							
Sleep[f]	baseline	7.48	3.41	29	6.27	8.69	8-week - baseline	1.24	22	0.23	-0.21
	8-week	6.76	3.51	29	5.33	8.18	10-week - 8-week	– 0.28	5	0.79	-0.07
	10-week	5.42	2.97	12							
Coping – Problem focused[g]	baseline	1.16	0.72	55	0.96	1.35	8-week - baseline	0.25	47	0.81	0.14
	8-week	1.24	0.66	55	1.07	1.42	10-week - 8-week	– 1.30	14	0.21	-0.18
	10-week	1.13	0.68	21							
Coping – Emotion focused[g]	baseline	1.19	0.66	41	0.98	1.39	8-week - baseline	0.78	33	0.44	0.07
	8-week	1.26	0.55	41	1.09	1.43	10-week - 8-week	– 1.33	8	0.22	-0.24
	10-week	1.19	0.72	15							
Coping – Maladaptive[g]	baseline	0.42	0.44	30	0.25	0.58	8-week - baseline	1.92	23	0.07	0.21

Outcomes	Time	*M*	*SD*	*N*	CI (lower)	CI (upper)	Contrasts	*t*	*df*	*p*	Hedges' *g*
	8-week	0.53	0.58	30	0.31	0.74	10-week - 8-week	– 0.40	2	0.71	-0.06
	10-week	0.41	0.56	9							
Social support[h]	baseline	2.24	1.21	54	1.92	2.56	8-week - baseline	2.38	47	0.02	-0.05
	8-week	2.18	1.20	54	1.83	2.52	10-week - 8-week	0.92	16	0.37	0.16
	10-week	2.07	1.29	23							
Physiological outcomes											
HRV as vagal tone[i]	baseline	182.83	162.30	52	140.50	225.16	8-week - baseline	2.06	45	0.05	0.05
	8-week	193.92	261.68	52	131.28	256.57	10-week - 8-week	– 0.20	11	0.85	-0.03
	10-week	118.53	137.02	18							
HRV as adaptation[j]	baseline	64.40	27.63	55	57.69	71.12	8-week - baseline	1.69	48	0.10	-0.04
	8-week	63.10	31.26	55	55.75	70.44	10-week - 8-week	– 0.63	12	0.54	-0.12
	10-week	58.24	20.30	19							
Cognitive performance											
Decision-making[k]	baseline	1.22	0.45	52	1.09	1.36	8-week - baseline	1.39	45	0.24	1.91
	8-week	1.92	0.24	52	1.86	1.98					
Processing speed[l]	baseline	32.74	8.05	54	30.53	34.95	8-week - baseline	0.53	47	0.47	0.46
	8-week	36.54	8.50	54	34.26	38.82					
Planning[m]	baseline	2.28	0.77	55	2.08	2.49	8-week - baseline	0.66	48	0.42	-0.09
	8-week	2.21	0.75	55	2.02	2.41					
Attention[n]	baseline	480.15	39.36	56	469.61	490.69	8-week - baseline	1.08	49	0.30	0.13
	8-week	488.58	53.12	56	474.35	502.80					

Repeated measures analyses of variance (with covariates) were performed.
Covariates included age, gender, number of deployments, probable traumatic brain injury history.
Exact *P* values are presented.
[a] 10-item Connor-Davidson Resilience Scale, ranging from 0 (*not true at all*) to 4 (*true nearly all the time*).
[b] Cohen's 4-item Perceived Stress Scale, ranging from 0 (*never*) to 4 (*very often*).
[c] Abbreviated PTSD Checklist, ranging from 0 (*not at all*) to 4 (*extremely*).
[d] Patient Health Questionnaire-4, ranging from 0 (*not at all*) to 3 (*nearly every day*).
[e] The 6-item Brief Anger-Aggression Questionnaire, ranging from 0 (*not at all*) to 4 (*very frequently*).
[f] 9-item Pittsburgh Sleep Quality Index, ranging from 0 (*poor sleep quality*) to 21 (*optimal sleep quality*).
[g] Brief COPE, composite scores range from 0 (*I haven't been doing this at all*) to 3 (*I've been doing this a lot*).
[h] 2-item measure of social support, ranging from 0 (*none of the time*) to 5 (*all of the time*).
[i] The high-frequency component of the HRV signal, original units expressed as power spectral density, ms^2/Hz.
[j] Standard deviation of normal-to-normal intervals, original units expressed as inter-beat intervals in ms.
[k] Iowa Gambling Task (net total, reward-cost scores), original scores range from −100 to 100.
[l] Symbol Search task (accuracy), sample ranges from 18 to 57.

[m] The Tower of London task (total score square root-transformed), original scores range from 0 to 39.
[n] The continuous performance test (reaction times), original scores measured in ms.

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14. ABSTRACT

Decision-making during stressful situations is a necessity for crews of naval ships to perform their operational missions. Recent mishaps have shown that fatigue, communication deficits, and other factors can have deleterious consequences on decision-making during unexpected or emergency events. Identifying minimally intrusive methods to increase resilience among crew members, enhance their ability to make optimal decisions effectively during urgent situations, and improve their ability to manage stress during normal operations is one strategy for improving safety and readiness at sea. While the study was limited by high attrition and methodological issues, there were encouraging findings for future efforts. This study showed that a command can feasibly integrate a resilience intervention into its training schedule and command culture for the purposes of improving the resilience and well-being of its crew. The results indicated that SRTS has promise as a foundation for enhancing decision-making and resilience among shipboard Sailors to ultimately enhance readiness.

15. SUBJECT TERMS
resilience, stress, training, mobile application, program implementation, technology, shipboard, biofeedback

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