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Outbrief and Results Report

MSAT

Mobile Stress and Anger management Tool

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Abstract

Anger and stress are highly prevalent problems in US military populations, and are associated with significant disability. Cognitive behavioral therapy (CBT) has the potential to attenuate symptoms, but suffers from low compliance. The mobile stress and anger management tool (MSAT) represents a mobile health approach to supplementing CBT, improving symptoms, and increasing patient compliance. A group of twenty symptomatic active duty Service members were randomized to a group using MSAT or undergoing standard CBT, and were compared to an asymptomatic population using MSAT. The use of MSAT significantly improved symptoms of stress, anxiety, depression, anger, and post traumatic stress disorder (PTSD) in symptomatic participants who used MSAT, and significantly decreased CBT dropout rates. Given the prevalence of disorders of stress and anger in active duty and Veteran populations, MSAT represents promising technology to mitigate risk and increase deployability.

Introduction

Concern has been raised over the prevalence of behavioral health disorders in military personnel returning from deployment to the Middle East. While not appearing as an overt physical injury, disruptions of a psychological nature are often as debilitating, and present with a variety of symptoms. Approximately 1/3 of combat Veterans returning from Iraq and Afghanistan suffer from post-traumatic stress disorder (PTSD), depression, a traumatic brain injury (TBI), or a combination of states [1]. Anger, hostility, and aggression have been associated with PTSD and sub-threshold PTSD (some symptoms of PTSD but not all required for a clinical diagnosis), which in turn have been associated with alcoholism, depression, poor overall health, and increased suicidality [2; 3]. The number of suicides in active-duty soldiers in the US military has doubled over the past 10 years. Historically, the number of suicides in the military was well below the civilian population rate [4]. Among military veterans, 70% of all suicides are in the population 50 years or older, approximately twice the rate in the non-Veteran civilian population [5]. Many factors can increase the risk for suicide ideation or attempt, including substance abuse, mental health disorders, post-traumatic stress disorder (PTSD), and early life stress/abuse.

Anger is a prevalent problem within the military as found by Rand's 2015 Health-Related Behaviors Survey [6]. For Veterans returning from the post 9/11 conflicts, problematic anger has been identified as one of the most common and pressing conditions requiring treatment [7]. Survey responses from 16,699 Service members showed almost 47% demonstrating significant aggressive behaviors over the past 30 days (becoming angry and yelling, hitting or smashing something, making violent threats, or fighting/hitting someone) [6]. Taken together, anger and stress represent highly prevalent problems in active duty Service members and Veterans.

Cognitive behavioral therapy (CBT) is one of the most effective psychotherapy modalities used to treat a range of emotional and physiological symptoms such as anger and stress. CBT is generally administered by mental health professionals, and consists of a structured, collaborative process that helps individuals consider and alter their thought processes and behaviors associated with stress or anger, usually administered weekly over several months. Homework is an integral component of CBT, but homework compliance in CBT remains problematic in real-life practice. Homework in CBT provides opportunities to practice skills. In prior studies, homework adherence was associated with improved outcome across a variety of disorders [8]. However, standard CBT does not offer the provider information regarding the utilization of therapeutic skills outside of office visits, specifically the relaxation and behavioral strategies shown to be the most effective component of anger treatment [9].

A recent study incorporated mobile technology and social support into CBT for anger in veterans [10]. The application provided both information about CBT skills and the opportunity to practice the skills patients learned during the course of treatment. Experimental participants readily used the application, found it valuable and were more likely to practice CBT skills taught in treatment than the control participants [10]. The utilization of technology has been well accepted by veterans and its facilitation of therapeutic skill utilization has resulted in reductions in anger, stress, and depression symptoms [11]. Such tools should allow for mitigation of anger and stress outside of face-to-face treatment by increasing the utilization of therapy skills taught in treatment and enhance the overall treatment plan for individuals struggling with psychological health issues.

Emerging mobile applications have the potential to enhance CBT treatment outcomes by improving adherence to homework and reminding patients when it is best to use interventions taught in therapy in real world situations. The integration of data from a commercially available wrist-worn smartwatch paired with an application that provides reminders to the participant to engage in cognitive and behavioral skills taught in session will significantly improve the adherence with CBT homework and result in significant reductions in anger and stress in subjects receiving standard CBT compared to CBT alone without reminders [12]. The mobile stress and anger tool (MSAT) is a mobile application that can support CBT by reminding users to practice stress and anger reduction techniques, such as deep breathing exercises, biofeedback, and relaxation. MSAT reminds participants to relax and practice CBT techniques by pairing with commercially available smartwatches to monitor participant heart rate, and remind participants to practice stress and anger reduction techniques when heart rate rises. MSAT also provides journaling capabilities to support CBT.

The ability of CBT to reduce symptoms of stress, anger, and associated effects on other behaviors (e.g., sleep) with and without additional reminders was evaluated with 20 active duty Service members reporting stress or anger who are undergoing CBT. Ten active duty Service members were randomized to receive the MSAT mobile application as part of their CBT (experimental group; “MSAT”), and ten were randomized to receive standard CBT without the MSAT system (active control group with a Garmin smartwatch without access to the MSAT application; “control”). An additional ten active duty Service members that were not reporting stress or anger, (asymptomatic control group; “asymptomatic”) received the smartwatch and MSAT mobile application to determine the ability of the system to detect anger and stress in a healthy cohort and to compare any changes that occur from using MSAT alone to CBT with MSAT in a symptomatic population. The primary objective was to measure the effectiveness of MSAT in tandem with CBT to reduce anger and stress in active duty Service members. We hypothesize that MSAT will result in significantly less anger, anxiety, depression, and PTSD symptoms following CBT treatment as compared to standard CBT therapy in an active duty population.

Methods

Study design: The study design was a parallel, randomized controlled trial with active duty populations to test the effectiveness of MSAT in conjunction with CBT (MSAT group) compared to CBT alone (control group), and to an additional psychologically asymptomatic control group (asymptomatic group) that used MSAT. Symptomatic participants were randomly assigned to a treatment group via block randomization to ensure equal and random groups. Asymptomatic controls were recruited outside the behavioral health clinic and were not randomized. Asymptomatic controls were compared against the other groups at baseline and at study completion (4, 8, or 12 weeks, representing the end of CBT completion for the

symptomatic groups). Mixed within (timepoint)/between (group) repeated measures ANOVA were used to analyze results.

Subjects: A total of 30 participants (10 per group) were recruited for this study based on a power analysis using data from prior work (d=1.0, α=0.1, β=0. 8, Wilcoxon-Mann-Whitney test) [12]. Only subjects who completed the initial clinical session were counted in the study pool of 30 subjects. Symptomatic subjects were recruited at Brooke Army Medical Center (BAMC) from active duty personnel who presented to the nonemergency, outpatient mental health clinic. Potential participants were processed through the standard clinic intake or triage protocol. Clinic providers were briefed on the study availability and inclusion criteria. Patients that met the initial inclusion criteria (diagnosis or complaint of stress and anger), were offered to schedule with the project coordinator. The project coordinator explained the protocol and completed the consent if the subject was appropriate and volunteered for inclusion. Asymptomatic subjects were recruited in Orlando FL using flyers.

Inclusion criteria: Symptomatic participants: active duty Service members, aged 18-64, who have concerns about managing their stress, and were willing to participate. Asymptomatic participants: active duty Service members, aged 18-64 who are not in treatment for a behavioral health condition or diagnosed with a chronic mental health disorder and willing to participate.

Exclusion criteria: Symptomatic participants: severe mental impairment or unstable psychiatric illness such as active psychosis, recent hospitalization, currently suicidal/homicidal, etc.; functional limitations that would keep them from using a mobile or sensing device (e.g., amputations, hearing/vision loss); and/or treating clinician judges that participation in the study would interfere with the individual's treatment. Asymptomatic participants: current self-reported difficulties with anger and/or stress management per their report to their provider; candidate for CBT for anger and/or stress; severe mental impairment or unstable psychiatric illness; functional limitations that would keep them from using a mobile or sensing device (e.g., amputations, hearing/vision loss); and/or treating clinician judges that participation in the study would interfere with the individual's treatment.

Procedure: After obtaining written informed consent for participation from the participant, subjects were given a unique 4-digit study participant ID number and were asked to complete self-report questionnaires including: demographics information, the Depression, Anxiety, Stress Scale (DASS) [13], Patient-reported outcomes measurement information scale (PROMIS)-Anger Scale [14], PTSD Checklist for DSM-5 (PCL-5) [15], and Epworth Sleepiness Scale (ESS) [16]. Subject were then randomly assigned to treatment condition (CBT Alone [control] or CBT+MSAT [MSAT]) and engaged in the protocol treatment with a study therapist. Patients not interested or deemed not appropriate for the study, were scheduled for a routine follow up appointment consistent with the clinic policy. Subjects randomized to the MSAT group received a smartwatch (Garmin Vivoactive 4) along with instructions in its use, and downloaded the MSAT application to their phone. Subjects randomized to the control group received a smartwatch only and instructions in its use but were not provided with the download of the MSAT application.

All symptomatic subjects were scheduled for a clinical session with a study therapist. Only subjects who completed this first clinical session were counted in the study pool. All symptomatic participants received standard Cognitive Behavioral Therapy (CBT) consistent with the U.S. Department of Health and Human Services Substance Abuse and Mental Health Services Administration (SAMHSA) CBT therapy manual targeting stress management and anger management [17]. The interventions used in this study are manualized treatments published by the US Department and Health and Human Services for anger and

stress management and are widely used in both civilian and military/Veteran populations and represent the current standard of care. The expected treatment course lasted for approximately eight to twelve sessions. All subjects completed the study measures (DASS, PROMIS-Anger, PCL-5, ESS) at every 4th session and upon the completion of treatment. The study terminated after the 12th scheduled appointment although subjects were allowed to continue with the study therapist or referred to another treating provider if continued treatment was indicated. Subjects were considered a "dropout" if they leave treatment after having completed the first appointment. Subjects were considered "completed" at the 12th session or if the subject and therapist agreed that clinical goals were met at any point prior to the 12th session. Regardless of the session number, in order to be considered "completed" the subject must have completed an agreed upon "termination" session, completed the study measures and returned the smartwatch. Symptomatic subjects who received the MSAT device also completed the MSAT Mobile Application questionnaire in addition to the assessment measures at the final appointment.

Prior to appointments with subjects assigned to the MSAT group, the study therapist accessed the subject MSAT data (times and locations [if enabled] of situations that are associated with stress/anger events and any journal entries) in the secure cloud server using the provider portal. The MSAT data since the last appointment was discussed in the course of the treatment session as an adjunct to the standard CBT protocol.

Asymptomatic controls were recruited from other sites through the use of fliers. Interested participants met with the project coordinator and, if they met inclusion criteria, the project coordinator explained the protocol and completed the consent process. Subjects were then asked to fill out self-report questionnaires including demographics information, the Depression, Anxiety, Stress Scale (DASS), PROMIS Anger Scale, PTSD Checklist for DSM-5 (PCL-5), and Epworth Sleepiness Scale (ESS).

All asymptomatic control participants completed the same behavioral health assessment measures and received a wrist-worn smartwatch (unless they already owned a compatible smartwatch) and the MSAT mobile application along with instructions in its use, and downloaded the patient mobile application to their phone. Data from the asymptomatic controls was uploaded from the subject phone to the secure cloud server. Asymptomatic controls received a text or email reminder and link to complete the assessment measures online using their subject ID at week 4, 8, and 12.

MSAT Tool: The MSAT mobile application provided reminders to prompt participants to utilize CBT skills such as breathing exercises they learned in treatment. The wrist-worn sensor sends heart rate and movement data to an Android or iOS device, which runs the MSAT application. Stress classification is calculated using the operational stress index (OSI) based on physiological data from the wearable device, consisting of pulse plethysmography (PPG), used to derive frequency and temporal domain metrics of heart rate variability, and an embedded inertial measurement unit (IMU) to give context to the cardiovascular data. The OSI is 97.1% accurate in capturing stress [12]. The OSI is scaled from 1 to 10, with 1 to 3 representing low stress, 4 to 7 representing moderate stress, and 8 to 10 representing severe stress.

Results

The sociodemographic factors in the evaluation are listed in (

Table 1). The average age of the participants was 37.4 ± 7.7 (SD) years, and most were active duty Service members in the Army.

Table 1. List of sociodemographic factors of study sample

	Study sample % (*n*)
Gender	
Male	80.0 (24)
Female	20.0 (6)
Age Group	
20-29	16.7 (5)
30-39	43.3 (13)
40-49	33.3 (10)
50-59	6.7 (2)
Military Branch	
Army	53.3 (16)
Navy	13.3 (4)
Air Force	10.0 (3)
Marines	23.3 (7)

Among the symptomatic groups receiving CBT, five individuals dropped out prior to completion of therapy, all of which were assigned to the control group. Welch's t-test indicated that individuals in the symptomatic-experimental group completed a significantly greater number of therapy sessions ($p = 0.001$, $F = 14.039$) at an average of 11.2 ± 1.8 (SD) sessions as compared to 4.8 ± 3.5 (SD) in the symptomatic control group.

Depression, anxiety, and stress scale (DASS) scores are shown in Table 2. For the initial assessment, the asymptomatic group was considered normal, while the control group reported stress and anxiety in the 96th percentile (severe), and depression in the 92nd percentile (mild) as compared to a normative sample (Crawford, 2003). The MSAT group reported stress in the 91st percentile (moderate), anxiety in the 95th percentile (moderate), and depression in the 86th percentile (mild) [13].

A one-way between-groups analysis of variance (ANOVA) was used to assess differences in self-reported depression, anxiety, and stress (DASS) between groups at the initial assessment. There was a statistically significant difference in stress scores [$F(2,27) = 24.21$, $p < 0.001$]. The effect size, calculated using eta squared (η^2), was 0.64. Post-hoc comparisons using Tukey HSD indicated that the mean for the asymptomatic group was significantly lower than the control group ($p<0.001$) and the MSAT group ($p = 0.001$). No difference was observed between the symptomatic groups. For depression, there was also a statistically significant difference at the initial assessment [$F(2,27) = 5.29$, $p = 0.011$, $\eta^2 = 0.28$]. Post-hoc comparisons indicated that the asymptomatic group reported a significantly lower depression score than the control group ($p = 0.033$) and the MSAT group ($p = 0.017$). No differences were observed between the symptomatic groups ($p = 0.958$). Finally, there was a statistically significant difference in self-reported anxiety [$F(2,27) = 8.19$, $p = 0.002$, $\eta^2 = 0.38$]. Post-hoc comparisons indicated that the asymptomatic group

reported significantly less anxiety than the control group (p= 0.002) and the MSAT group (p = 0.013). No differences were observed between the symptomatic groups (p = 0.748).

At the follow-up assessment, the MSAT group reported levels of stress, depression, and anxiety that did not differ statistically from the asymptomatic group, indicative of successful therapy, while the control groups reported values which were indistinguishable from the initial assessment. There was a statistically significant difference in self-reported stress between groups at follow-up [$F(2,27) = 7.69$, $p = 0.002$, $\eta^2 = 0.36$]. Post-hoc comparisons indicated a significant difference in stress between the asymptomatic group and the control group ($p = 0.002$) and between the MSAT group and control group ($p = 0.002$), but not between the asymptomatic group and the MSAT group ($p = 0.645$). There was also a significant difference between groups in self-reported depression [$F(2,27) = 5.59$, $p = 0.009$, $\eta^2 = 0.29$]. Post-hoc comparisons indicated a significant difference in depression between the asymptomatic group and the control group ($p = 0.007$), but not between the MSAT group and the asymptomatic group ($p = 0.272$) or the control group ($p = 0.200$). There was also a significant difference in self-reported anxiety at follow-up between groups [$F(2,27) = 5.83$, $p = 0.008$, $\eta^2 = 0.30$]. Post-hoc comparisons indicated a significant difference in anxiety between the asymptomatic group and the control group ($p = 0.007$), but not between the MSAT group and the asymptomatic group ($p = 0.649$) or the control group ($p = 0.058$).

Within groups, the asymptomatic group had no statistically significant changes in stress ($p = 0.255$, $\eta^2 = 0.14$), depression ($p = 0.734$, $\eta^2 = 0.01$), or anxiety ($p = 0.656$, $\eta^2 = 0.02$). Similarly the control group had no statistically significant changes in stress ($p = 0.051$, $\eta^2 = 0.36$), depression ($p = 0.768$, $\eta^2 = 0.010$), or anxiety ($p = 0.060$, $\eta^2 = 0.34$). However, the MSAT group, which used MSAT for up to 12 weeks in conjunction with CBT had a statistically significant decrease in stress ($p = 0.039$, $\eta^2 = 0.39$), depression ($p = 0.009$, $\eta^2 = 0.55$), and anxiety ($p = 0.014$, $\eta^2 = 0.99$).

Table 3. Mean (SD) DASS assessment scores; *$p \leq 0.05$

	Initial assessment			**Follow-up**		
DASS Scale	**Stress**	**Anxiety**	**Depression**	**Stress**	**Anxiety**	**Depression**
Asymptomatic	7.3 (3.5)	1.6 (3.1)	3.1 (3.5)	9.7 (7.6)	2.2 (2.4)	2.5 (3.8)
Control	29.8 (7.1)	17.2 (9.4)	10.8 (8.9)	24.2 (11.7)	11.2 (9.3)	11.6 (8.6)
MSAT	21.0 (9.8)	14.2 (12.4)	11.6 (5.8)	13.2 (5.3)*	4.6 (4.5)*	6.8 (4.8)*

In addition to self-reported data, the operational stress index (OSI) calculated by MSAT showed a gradual decrease in stress events (OSI > 4) as a function of time for the MSAT group (Figure 1). The number of stress events in the asymptomatic group remained low throughout the study, and by approximately 45 days (6 weeks of CBT for the MSAT group), the number of daily events were similar between groups.

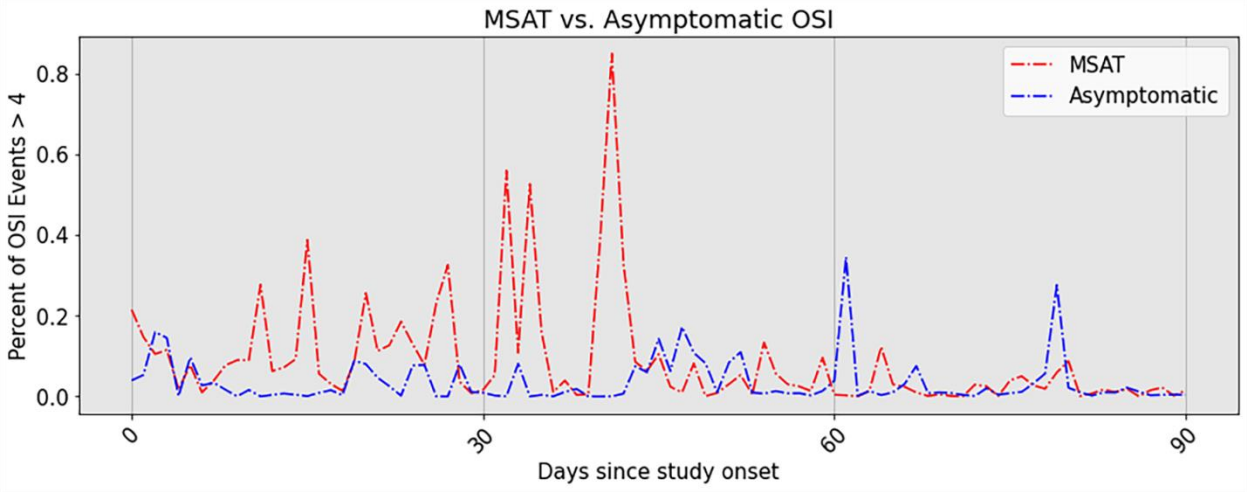

Figure 1. Average number of daily OSI events over the course of the study

PROMIS-anger scores are show in Table 4. At the initial assessment, asymptomatic participants reported none to slight anger, while the symptomatic groups reported moderate anger [14]. There was a statistically significant difference at the initial assessment [$F(2,27) = 14.15$, $p < 0.001$, $\eta^2 = 0.51$]. Post-hoc comparisons indicated that the asymptomatic group reported significantly less anger than the control group ($p < 0.001$) and the MSAT group ($p = 0.002$). No differences were observed between the symptomatic groups ($p = 0.348$).

At follow-up, there was a statistically significant difference in self-reported anger between groups [$F(2,27) = 7.79$, $p = 0.002$, $\eta^2 = 0.37$]. Post-hoc comparisons indicated a significant difference in anger between the asymptomatic group and the control group ($p = 0.002$), but not between the MSAT and asymptomatic group ($p = 0.249$) or between the MSAT and control groups ($p = 0.07$). At follow-up, the MSAT group's average level of anger decreased from moderate to mild.

Within groups, no difference in anger was observed for the asymptomatic group ($p = 0.821$, $\eta^2 = 0.01$), control group ($p = 0.324$, $\eta^2 = 0.11$), or MSAT group ($p = 0.076$, $\eta^2 = 0.31$).

Table 4. Mean (SD) PROMIS Anger scores

	Initial assessment	**Follow-up**
Asymptomatic	50.5 (7.1)	50.0 (9.2)
Control	69.7 (6.4)	66.9 (9.8)
MSAT	64.4 (10.8)	57.0 (9.8)

PTSD checklist-military scores are shown in Table 5. At the initial assessment, the asymptomatic group did not meet criteria for PTSD, while both symptomatic groups scored in a range that suggests the participants would benefit from PTSD treatment [15]. There was a statistically significant difference at the initial assessment [$F(2,27) = 13.10$, $p < 0.001$, $\eta^2 = 0.49$]. Post-hoc comparisons indicated that the asymptomatic group reported significantly less anger than the control group ($p < 0.001$) and the MSAT group ($p = 0.001$). No differences were observed between the symptomatic groups ($p = 0.823$).

At follow-up, there was a statistically significant difference in self-reported PTSD symptoms between groups [$F(2,27) = 10.82$, $p < 0.001$, $\eta^2 = 0.45$]. Post-hoc comparisons indicated a significant difference in

anger between the asymptomatic group and the control group ($p < 0.001$), and between the MSAT and asymptomatic group ($p = 0.050$), but not between the symptomatic groups ($p = 0.091$).

Within groups, no difference in PTSD symptoms was observed for the asymptomatic group ($p = 0.662$, $\eta^2 = 0.02$), control group ($p = 0.900$, $\eta^2 = 0.002$), or MSAT group ($p = 0.108$, $\eta^2 = 0.26$).

Table 5. Mean (SD) PCL-M scores

	Initial assessment	**Follow-up**
Asymptomatic	7.2 (5.6)	8.0 (6.9)
Control	32.6 (13.3)	32.2 (14.8)
MSAT	29.4 (15.1)	20.8 (11.7)

Epworth sleepiness scale (ESS) scores are shown in Table 6. At the initial assessment, the asymptomatic group reported lower normal daytime sleepiness, while the symptomatic groups reported higher normal daytime sleepiness [16]. There was not a statistically significant difference at the initial assessment [$F(2,27) = 2.14$, $p = 0.138$, $\eta^2 = 0.14$]. At follow-up, there was a statistically significant difference in sleepiness symptoms between groups [$F(2,27) = 4.95$, $p = 0.015$, $\eta^2 = 0.27$]. Post-hoc comparisons indicated a significant difference in sleepiness between the asymptomatic group and the MSAT group ($p = 0.011$), but not between the control group and asymptomatic group ($p = 0.214$) or MSAT group ($p = 0.346$). Within groups, no difference in sleepiness was observed for the asymptomatic group ($p = 0.413$, $\eta^2 = 0.08$), control group ($p = 0.903$, $\eta^2 = 0.002$), or MSAT group ($p = 0.332$, $\eta^2 = 0.10$).

Table 6. Mean (SD) Epworth Sleepiness Scale (ESS) scores

	Initial assessment	**Follow-up**
Asymptomatic	4.6 (2.6)	4.1 (3.5)
Control	7.5 (6.0)	7.7 (5.1)
MSAT	8.7 (4.6)	10.7 (5.4)

In addition to self-reported sleep, sleep fragmentation was calculated using data from the IMU on the wrist-worn sensor (Figure 2). During sleep epochs, each minute is classified as “asleep” or “awake,” with fragmentation defined as a ratio of awake minutes vs. total minutes in a sleep epoch, expressed as a percentage. As is seen in Figure 2 and the self-reported data from Table 6, the symptomatic group experienced lower sleep quality throughout the study, which was not affected by the use of MSAT.

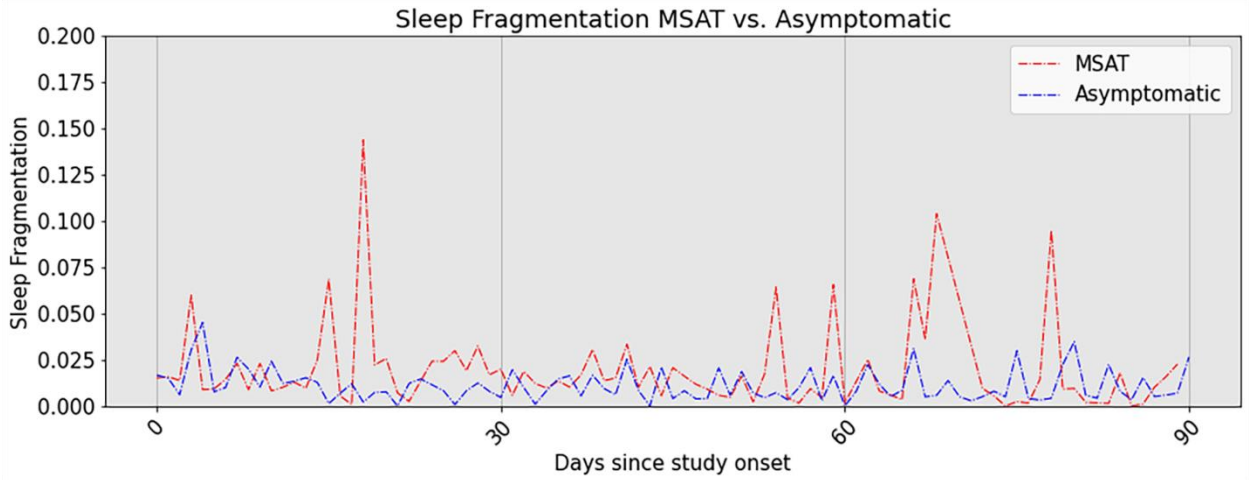

Figure 2. Daily average sleep fragmentation over the course of the study for the MSAT and asymptomatic groups.

Participants in the asymptomatic and MSAT groups rated various aspects of the MSAT application. On a scale of 1 to 5, participants rated the overall experience with the application at 3.7 ± 0.5 (SD), the user interface at 3.3 ± 1.2 (SD), the intuitiveness of the application at 4.2 ± 0.8 (SD), and the loading speed at 4.2 ± 0.8 (SD). Participants rated the stress alerts and relaxation strategies as features they liked most, and application crashes as the experience they liked least. Participants used the application 1.1 ± 1.2 (SD) times daily, and most participants indicated that using MSAT helped them to achieve their goals.

Discussion

The current study indicates that the use of the MSAT tool in conjunction with CBT is able to significantly improve both self-reported and objectively measured stress, anxiety, depression, and anger in active duty Service members. Throughout the course of the study, symptomatic subjects who used MSAT were able to reduce symptoms of stress, anxiety, depression, and anger until they approximated asymptomatic active duty Service members after approximately 6 weeks of use. In a previous RCT with military Veterans, subjects who used the MSAT system were significantly less likely to discontinue therapy (p=0.016, d=1.34) and significantly improved on measures of stress (p=0.032, d=1.61), anxiety (p=0.050, d=1.26), and anger (p=0.046, d=1.41) compared to controls undergoing CBT alone [12].

Among the various interventions available to treat stress, anxiety, depression, anxiety, and PTSD, cognitive behavioral therapy (CBT) has emerged as standard practice for reduction of psychiatric symptoms, with previous studies indicating that CBT has similar therapeutic effects as anti-depressant medication [18]. However, high dropout rates from CBT programs have been reported to span from 25% to as high as 40% [19]. Challenges to therapy compliance in the military health system include the fact that many Service members choose not to seek care [20], may experience long wait times in the military health system [21], and generally show low participation rates in clinical studies [22]. In the current study, 50% of the participants undergoing standard CBT dropped out of therapy, while no participants that used MSAT dropped out of therapy. All participants were given a compatible Garmin smartwatch, so the need to return equipment was likely not the reason for high compliance in the MSAT group.

The success of CBT depends largely on participants' compliance with practicing the coping strategies and relaxation techniques they learn in each session. While CBT sessions are useful for learning the techniques,

much of the work required to achieve successful outcomes occurs between sessions. A primary function of the MSAT system in the present study is to provide resources in support of this work between sessions. Alerts triggered by the stress classifier, for instance, help users learn how to recognize the physiological symptoms of stress they might otherwise miss or ignore. Similarly, the in-app biofeedback tool provides users with increased awareness of stress—and of the positive effects that relaxation techniques have on stress—through the use of visualizations that are synced with real-time data from the sensor band. The goal is to help users gain conscious awareness, and eventually control, over physiological functions that are normally subconscious.

Unsurprisingly, the asymptomatic control participants exhibited low stress levels on average over the course of the study. However, the number of identified stress events did vary greatly within this group. While this may be explained by individual differences in stress experienced, it is also at least partially due to the way MSAT determines suprathreshold stress events for each user. Because of individual differences, accurate stress classification is not possible by simply comparing an individual's physiology to population-level data. Instead, the classifier must be "calibrated" to some fixed, baseline level for each individual so that stress can be determined as a function of the difference from said baseline. The implementation of the stress classifier in the current study requires participants to manually calibrate their baseline by remaining at rest for a fixed, 5-minute period. This led to reliability issues, as it required user input. Even otherwise compliant users may not remain still for long enough to allow for an accurate baseline to be measured. A too-high baseline results in a less sensitive (but more specific) classifier, reducing the number of identified stress events. On the other hand, if the baseline was too low—e.g., the user calibrated the baseline immediately after waking up, near their resting heart rate—then the classifier can become too sensitive, increasing the number of identified stress events and thus the number of false alarms. Done correctly, individualized baselining can improve classifier performance on the order of 30 percentage points over using a population-level baseline [23]. The next step for improving the stress classifier is therefore to develop an algorithm that can automatically and adaptively determine the physiological baseline for each user.

Future work

Beyond traditional approaches to human state quantification via body-worn or remote biosensors, machine learning is being pursued to infer meaning from the increasingly sophisticated sensors embedded in modern smartphones. The inclusion of passive digital phenotypes is expected to improve user compliance and system ease of use by eliminating the need for a separate wearable device, increase data security by removing the need for wireless communication between a wearable and mobile device, and more seamlessly integrate with smartphone functions such as contacting support groups.

In addition, integrating additional data input sources, such as questionnaires, fitness testing, or other applications will expand the scope of the system beyond stress and sleep into general health and wellness. This aggregate data dashboard can provide better insights and inform treatment decisions to improve individual and team effectiveness while also providing a unique and personalized approach for each Service member.

References

[1] T.C. Holdeman, Invisible wounds of war: Psychological and cognitive injuries, their consequences, and services to assist recovery. Psychiatric Services 60 (2009) 273-273.

[2] R.D. Marshall, M. Olfson, F. Hellman, C. Blanco, M. Guardino, and E.L. Struening, Comorbidity, impairment, and suicidality in subthreshold PTSD. American Journal of Psychiatry (2001).
[3] J.S. Yarvis, and L. Schiess, Subthreshold posttraumatic stress disorder (PTSD) as a predictor of depression, alcohol use, and health problems in veterans. Journal of Workplace Behavioral Health 23 (2008) 395-424.
[4] C.A. LeardMann, T.M. Powell, T.C. Smith, M.R. Bell, B. Smith, E.J. Boyko, T.I. Hooper, G.D. Gackstetter, M. Ghamsary, and C.W. Hoge, Risk factors associated with suicide in current and former US military personnel. JAMA 310 (2013) 496-506.
[5] J. Kemp, and R. Bossarte, Suicide Data Report, 2012, Department of Veterans Affairs, Mental Health Services, Suicide Prevention Program.
[6] S.O. Meadows, C.C. Engel, R.L. Collins, R.L. Beckman, M. Cefalu, J. Hawes-Dawson, M. Doyle, A.M. Kress, L. Sontag-Padilla, and R. Ramchand, 2015 Department of Defense health related behaviors survey (HRBS). Rand health quarterly 8 (2018).
[7] K.H. Dillon, E.F. Crawford, H. Kudler, K.A. Straits-Troster, E.B. Elbogen, and P.S. Calhoun, An Investigation of Treatment Engagement among Iraq/Afghanistan Era Veterans with Problematic Anger. The Journal of nervous and mental disease 205 (2017) 119.
[8] S.E. Decker, B.D. Kiluk, T. Frankforter, T. Babuscio, C. Nich, and K.M. Carroll, Just showing up is not enough: Homework adherence and outcome in cognitive–behavioral therapy for cocaine dependence. Journal of consulting and clinical psychology 84 (2016) 907.
[9] A.H. Lee, and R. DiGiuseppe, Anger and aggression treatments: a review of meta-analyses. Current opinion in psychology 19 (2018) 65-74.
[10] E.B. Elbogen, H. Aralis, C.F. Cassiello-Robbins, P. Lester, W. Saltzman, and G. Barish, Integrating mobile technology and social support with cognitive behavioral therapy for anger in veterans with PTSD: A pilot study. Military Behavioral Health 9 (2021) 17-26.
[11] L.A. Morland, J. Niehaus, C. Taft, B.P. Marx, U. Menez, and M.-A. Mackintosh, Using a mobile application in the management of anger problems among veterans: a pilot study. Military medicine 181 (2016) 990-995.
[12] B.D. Winslow, G.L. Chadderdon, S.J. Dechmerowski, D.L. Jones, S. Kalkstein, J.L. Greene, and P. Gehrman, Development and Clinical Evaluation of an mHealth Application for Stress Management. Frontiers in Psychiatry 7 (2016).
[13] T.A. Brown, B.F. Chorpita, W. Korotitsch, and D.H. Barlow, Psychometric properties of the Depression Anxiety Stress Scales (DASS) in clinical samples. Behaviour research and therapy 35 (1997) 79-89.
[14] P.A. Pilkonis, S.W. Choi, S.P. Reise, A.M. Stover, W.T. Riley, and D. Cella, Item banks for measuring emotional distress from the Patient-Reported Outcomes Measurement Information System (PROMIS®): depression, anxiety, and anger. Assessment 18 (2011) 263-283.
[15] F. Weathers, and J. Ford, Psychometric review of PTSD Checklist (PCL-C, PCL-S, PCL-M, PCL-PR). Measurement of stress, trauma, and adaptation (1996) 250-251.
[16] M.W. Johns, A new method for measuring daytime sleepiness: the Epworth sleepiness scale. sleep 14 (1991) 540-545.
[17] P.M. Reilly, and M.S. Shopshire, Anger management for substance abuse and mental health clients: A cognitive behavioral therapy manual. Journal of Drug Addiction, Education, and Eradication 10 (2014) 199.
[18] R.J. DeRubeis, S.D. Hollon, J.D. Amsterdam, R.C. Shelton, P.R. Young, R.M. Salomon, J.P. O'Reardon, M.L. Lovett, M.M. Gladis, and L.L. Brown, Cognitive therapy vs medications in the treatment of moderate to severe depression. Archives of general psychiatry 62 (2005) 409-416.

[19] E. Fernandez, D. Salem, J.K. Swift, and N. Ramtahal, Meta-analysis of dropout from cognitive behavioral therapy: Magnitude, timing, and moderators. Journal of Consulting and Clinical Psychology 83 (2015) 1108.
[20] M.R. Spoont, D.B. Nelson, M. Murdoch, T. Rector, N.A. Sayer, S. Nugent, and J. Westermeyer, Impact of treatment beliefs and social network encouragement on initiation of care by VA service users with PTSD. Psychiatric Services 65 (2014) 654-662.
[21] D.o.V. Affairs, Expanded access to non-VA care through the veterans choice program. Final rule. Federal register 80 (2015) 66419-66429.
[22] M.M. Davis, S.J. Clark, A.T. Butchart, D.C. Singer, T.P. Shanley, and D.S. Gipson, Public participation in, and awareness about, medical research opportunities in the era of clinical and translational research. Clinical and translational science 6 (2013) 88-93.
[23] B. Winslow, Z. Huber, and J. Chiang, SMART - Stress Management & Assessment for Responder Training Final Report. DHS/DHA (2019).