Remote Anger Management Support using Mobile Technology

An Android Phone Application for persons with Post Traumatic Stress Disorder (PTSD)

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Abstract— **Continuous Anger Level Monitoring (CALM) is a prototype for Android smartphones addressing the needs of persons with Post Traumatic Stress Disorder (PTSD) or emotion/impulse control problems. The application combines physiological monitoring and evidence-based group psychotherapy (Anger Management Therapy, developed by O'Reilly and Shopshire). CALM allows the recording of highly emotional and stressful events and for monitoring of these events by remote therapists. The system helps identify undesirable response behaviors and patterns by creating awareness around one's own behaviors, triggers and coping strategies. The application integrates with the Zephyr BioHarness BT belt to allow for continues physiological monitoring, biofeedback and Respiratory Sinus Arrhythmia (RSA) breathing exercises.**

Keywords: Mobile Mental Health Application, Biofeedback, PTSD, Remote Monitoring, Cognitive Control of Emotions, Anger Management Therapy, Virtual Avatars.

I. INTRODUCTION

Each of us has, at one point or another, experienced difficulty feeling, processing or expressing anger appropriately. For some of us, however—particularly returning veterans attempting to reintegrate into civilian life, sometimes with co-morbidities such as Post Traumatic Stress Disorder (PTSD)—the problem is so serious as to be debilitating ([1], [2], [3], [4]). Studies have associated anger with hyper-arousal symptoms like sleep problems, being "on guard", irritability and difficulty concentrating and as a common symptom of PTSD. Anger is a reaction to perceived environmental threat and a warning sign that consists of 3 components: physical sensations (i.e., increased heart rate), cognitive (i.e., perceived unfairness) and behavioral expressions of anger (i.e., slam a door). We developed a tool that can facilitate and enhance clinical practice in the treatment of anger control issues. Effective treatment of anger in veterans has to address all components of anger - physiology, destructive thinking patterns and behavioral change. The only form of treatment addressing these issues and currently offered at VAs throughout the country is "Anger Management Therapy" developed by Patrick Reilly and Michael Shopshire [5]. The Minneapolis VA Medical Center Mental and Behavioral Health Patient Service Line offers this group based treatment to all Veterans with anger dysregulation who have been clinically determined to be able to benefit from this treatment. It is a 12-session manualized intervention that uses Cognitive Behavioral Therapy (CBT) techniques to teach patients to monitor their anger and identify triggers and cues as well as develop coping strategies and skills.

CALM not only integrates evidence-based therapy specifically targeting "anger", but also remote physiological monitoring. The completely wireless collection (via the Zephyr BioHarness BT3 belt), analysis and storage of physiological data in a single application allows for unobtrusive real-time tracking. In particular, CALM looks at heart rate variability (HRV) because 1) HRV is an excellent marker for cognitive control of emotions [6] and 2) HRV biofeedback in Respiratory Sinus Arrhythmia (RSA) breathing exercises has been shown to reduce symptoms of PTSD [7], chronic stress and anger [8].

CALM is a smart phone application specifically designed to be integrated with ongoing Anger Management Therapy, addressing all components of anger and hostility. The system also provides completely new ways to facilitate and enhance communication and therapeutic work between patients and providers. With CALM we are introducing a well-defined prototype with detailed specifications able to address post-deployment mental health problems and ready to be used for clinical testing. Finally, CALM is not only a phone application, but a patient-therapist system that allows tracking of a number of treatment efficacy and performance metrics in a simple, timesaving, user-friendly and easily modifiable way.

The application provides, for example, an interface for patients to record and track anger events, create awareness of cues and triggers and identify personal coping strategies.

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Furthermore, the application enhances existing Anger Management Therapy by providing feedback (general and specific visualizations of recorded metrics) and motivation (personalization of application, avatars, etc.). Most importantly, CALM provides a meeting point for therapists and patients, allowing common reviews of subjective and objective measures indicative of changes to mental health and personal progress.

In this paper we will explain the overall structure of the system and its components, i.e. evidence-based therapy, the integration of remotely monitored physiological measures and a socially intelligent avatar (section II.), as well as the various functions the application is able to perform (section III.). We will end this paper with the conclusions section (IV.).

II. OVERALL SYSTEM ARCHITECTURE

Only two hardware components are needed in order to provide full functionality to the patient: 1) a mobile phone (to date, we have implemented versions for Android) with installed CALM application, and 2) a physiological monitoring belt (for example, BioHarness BT by Zephyr) with the ability to transfer Bluetooth data between the phone and the monitoring belt.

The data transfer happens between the phone and the monitoring belt; the application transforms the data to provide easy-to-use readings of physiological indicators of mental health and also provides real-time biofeedback if patients choose to do a breathing exercise. Patients, on the other hand, are asked to provide subjective inputs of well-being by answering a few questions. Both objective and subjective metrics are presented back to patients. These metrics can also be shared with a therapist. Figure 1. shows the components required for the CALM application and the information flow between monitoring device, mobile phone application, patient and clinician.

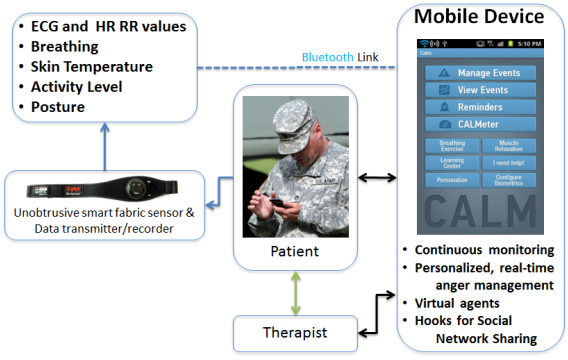

Figure 1. CALM System Architecture

A. *Evidence-based Therapy*

A number of evidence-based therapies address the needs of post-deployment mental health issues. These include: trauma desensitization, hypnotherapy, psychodynamic therapy, image exposure, cognitive restructuring, eye movement desensitization and reprocessing, biofeedback-assisted relaxation, exposure therapy, stress inoculation training, wait-list control condition, individual or group CBT, and possibly other forms. However, CALM's approach focuses on the following criteria:

- Integration with physiological monitoring and biofeedback options
- The ability to provide help remotely
- Specific needs of patients with anger/stress/emotion control issues
- Allows integration with final application and meets technical requirements

Given these criteria, we decided that Anger Management Therapy (AMT) is most suitable to integrate with our system. AMT provides a conceptual framework for addressing specific and concrete emotional states along with strategies for coping with the inability to control emotions (anger), which is the primary symptom among our patient population. The therapy's manual and workbook are suitable for easy integration with biofeedback and physiological monitoring in a phone application.

Specific enhancements that CALM can provide over paper-based delivery of AMT are summarized in Table 1.

TABLE I. BENEFITS OF CALM

Manual-guided AMT	CALM-enhanced AMT
Printed workbook	Phone application can serve as workbook
Homework assignments with pencil and paper	Homework assignments with few taps on phone
Anger Events recorded after they happen	Anger Events can be recorded in real-time
No feedback to patients	Feedback in form of logs and visualizations of objective and subjective data
No feedback to therapist about efficacy of AMT Anger Control Plan and its application to real-life anger events.	Physiological and behavioral efficacy metrics of real-life application of AMT Anger Control Plan
No objective feedback to therapists about frequency of workbook usage, time spent on assignments, how often relaxation exercises are done, etc.	Therapist is able to monitor therapeutic progress outside of group meetings
Simple breathing exercise: no knowledge about effectiveness	HRV-Biofeedback enhanced breathing exercise: guided visualization and real-time HRV biofeedback teach and guide correct RSA breathing [16]/
Anger Control Plan is written on piece of paper	Anger Control Plan is easy to modify and lives in phone.
No build in motivational enhancement	Increased motivation via fun app, reminders and personalized avatars that can be injected with desired human characteristics expressed in language.

While the workbook is divided into several sessions where patients learn about the causes and effects of anger, our application has adapted and enhanced the most important features that patients will need throughout the course of therapy. For example, an "Anger Meter," a way to visualize anger levels, is similar to our idea of the "CALMeter," a way to not only visualize anger levels continuously, but also to

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provide meaningful objective feedback. The application provides audio files of "learning material," which are updated forms of coping strategies, as well as personal customization of the application. Most importantly, in comparison to the workbook, CALM can be used for recording an anger event in a simple and fast way whenever and wherever needed. Another enhancement over conventional Anger Management Therapy is the integration of biofeedback into a breathing exercise. The strongest evidence for Anger Management Group Therapy, however, is that it is the only form of therapy addressing anger control issues offered at VA Medical Centers nationwide.

B. Heart Rate Variability, Biofeedback and RSA Breathing

A growing body of psychological research supports an association between parasympathetically mediated HRV and outcome measures relevant to regulated emotional responding (e.g., coping). Heightened levels of resting respiratory sinus arrhythmia have been associated with greater self-reported emotion regulation and the use of constructive coping strategies, and lower HRV is associated with greater negative emotional arousal in response to stress [10]. Conversely, greater HRV is a physiological indicator of adaptive emotion regulation and a decreased mental load [9]. A meta-analysis of HRV and neuroimaging studies by Thayer et al. [6] links HRV to markers of stress and health, and shows correlations between HRV and brain regions involved in emotion control. Cerebral blood flow increases during emotion control tasks and can peripherally—via the vagal nerve—be linked to HRV. HRV is therefore not only an excellent index for a person's ability to regulate responses to threatening environments, but baseline HRV is a good indicator of mental health since it is depressed in patients suffering from psychopathologies such as PTSD, anxiety and depression.

A typical ECG tracing of the cardiac cycle (heartbeat) consists of a P wave, a QRS complex, a T wave and a U wave, which is normally visible in 50-75% of ECGs. The RR signal is the interval between two R waves and is obtained by detecting the R peak in the QRS complex of an ECG trace. It is a stepwise constant with transitions at the quasi-periodic occurrences of the peak R. There is consensus in the literature that the high-frequency (HF) components of HRV are related to respiratory rhythm and are a marker of vagal modulation [11], and that the low-frequency (LF) components are thought to be under both sympathetic and parasympathetic control. Sympathovagal balance is characterized by the relationship between these two rhythms [12].

HRV analysis is commonly based on non-parametric methods such as Fourier or wavelet frameworks, or parametric methods like Autoregressive Models (AR) [13, 14]. For CALM, the power spectrum of the RR signal in the range of 0.015-0.5 Hz (LF to HF) is computed by describing the RR with a p order AR model. To limit computation time, the signal is downsampled while allowing access to spectral information in the range of interest.

CALM provides visualizations that integrate objective data, such as heart rate, breathing rate and HRV data from use of the BioHarness belt with subjective measurements from the subject. In particular, CALM presents summarized data representing the movement of power from the LF to HF frequency bands of the HRV over time, because HF activity has been found to decrease under conditions of emotional strain and during states of elevated anxiety, in individuals reporting a greater frequency and duration of daily worry and in those suffering from PTSD [8]. HRV and its HF component are reduced whilst the LF component is elevated.

HRV biofeedback and RSA breathing. Biofeedback is the process of displaying involuntary physiological processes and learning to voluntarily influence processes "feed" them back to users by making changes in cognition. This approach provides a transparent and empirical demonstration of consciously manipulating autonomic functions for improving health. Biofeedback instruments measure and transform information from physiological processes into simple, direct and easy-to-read signals. HRV biofeedback training includes instruction in breathing at a frequency related to optimal low-frequency band power, i.e. resonant frequency [7].

The cardiovascular system is characterized by specific resonance frequencies of HRV that exist at a particular frequency for an individual, within the low-frequency range of the HRV spectra. The resonance frequency for an individual lies at the frequency at which the system, when rhythmically stimulated, produces the maximum HRV, usually around 0.1 Hz or about 6 breathing cycles per minute. When a person breathes at about 6 breaths per minute, the respiratory stimulus causing HR to rise occurs precisely at the same time as the baroreflex impulse. This causes a persistence of the augmented HR oscillation at the resonant frequency; only at this frequency are HR and respiration in sync with each other and HR oscillations become very large. HR and blood pressure oscillate in opposite direction and the baroreflex is stimulated with every breath, causing an increase in HR oscillation. Baroreflex training, which uses RSA breathing, can be achieved with HRV biofeedback. CALM provides HRV biofeedback visualization on how to slow down breathing to meet a patient's personal resonance frequency. Patients learn how to the control color and size of a circle using biofeedback.

Breathing exercises carried out over long periods of time

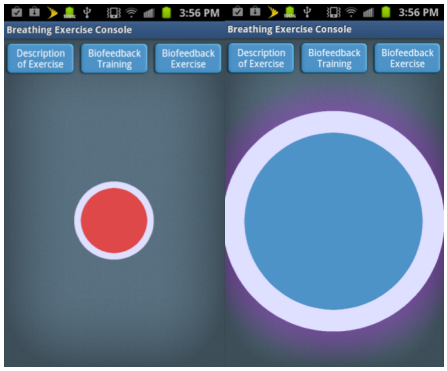

Figure 2. CALM visualizations of RSA breathing exercise

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with HRV biofeedback have been shown to positively affect asthma, hyperventilation, anxiety, depression or pain. Figure 2 indicates how CALM will facilitate breathing exercises, specifically addressing increases in HRV. Patients learn how to control the color, edge size, and radius of a filled circle via biofeedback. The filled circles represent where the HRV data is most powerful: red in the LF range and blue in the HF range. As patients successfully move their HRV towards the desired range, the color will transition from red to blue. The thickness of a white border around the filled area represents patient heart rate. A thinner border corresponds to a faster the heart. The circle's radius represents patient breathing rate, where a larger circle represents a slower breathing rate. A slowly increasing purple glow around the outside of the white edge signifies that a patient is maintaining their biofeedback statistics at a near constant and near optimal value. The time of participation, exercise length, and all biofeedback data are recorded for later analysis.

C. Motivation via Personalization and Avatars

Personalization as motivation. Many forms of psychotherapy require a therapist's guidance precisely because they demand highly individualized approaches. While CALM does not replace a human clinician, its customization features provide a unique selection of settings that fit a particular user's needs. On a therapeutic level, CALM allows users to create a truly personalized Anger Control Plan. Users will be able to modify and add cues, triggers and strategies, add personal notes with written or audio-recorded memos, set reminder features informed by SIFT's Etiquette Engine ™ (shown to increase compliance [15]) or set gender preferences for virtual avatars and audio files. The purpose of CALM's personalization is two-fold: (1) to build a therapeutic alliance between a user and therapist using CALM as a tool for structured communication, and (2) to facilitate pattern recognition for users and their therapists. For example, by recording a user's individual triggers as episodes occur, the user can then share this information with the human therapist. Therapists can retrieve greater detail from these records, rather than purely relying on an individual's recall, making therapists better equipped to tweak a patient's treatment plan. Although the same result may be achieved by patients using a pencil and a notepad, therapists and patients alike agree anecdotally that this method usually fails because (1) it requires patients to recognize anger events as they are occurring and be organized enough to physically have the notepad and pencil on hand, and (2) although they understand the benefits of the recording activity, patients are not always motivated to do it because they do not experience the benefits directly. Often, patients forget to do this type of therapeutic homework assignment, making it difficult to retroactively share important information with their therapists. By facilitating information recording and sharing by providing highly customizable options, CALM connects therapists with users' day-to-day experiences.

Motivation via socially intelligent avatars. Many veterans shy away from face-to-face mental health treatment, but may be open to using more anonymous alternatives (e.g., online forums). To address this, DARPA has recently funded a new project called "SIM Sensai," a virtual therapist that identifies patients who need help most acutely [16]. Virtual therapy and telemedicine are uniquely equipped for wide and cost-effective distribution even to remote locations, especially in environments where care demands can't always be met. The main element of this treatment option is the use of a virtual avatar. While CALM is not intended as virtual therapy, it integrates socially intelligent avatars on the following basis:

1) Avatars, especially those that display socially appropriate behavior (see Figure 3.), can impact human-machine trust which has emerged as having a considerable impact on human-machine performance [17, 18]. Definitions of trust stem from work in sociology associated with human-human trust, and are applicable based on Reeves and Nass' theory that humans regularly anthropomorphize technology, treating machines as social agents. As a result, humans (intentionally or not) react to the social queues displayed by machines. If a machine has been deemed untrustworthy, a human may reject the use of it regardless of its efficiency or reliability [19].

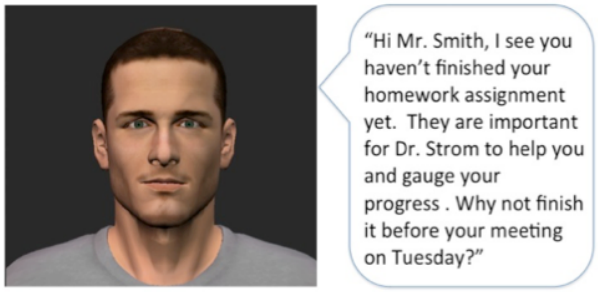

Figure 3. Avatar with adjusted speech level reflective of high-to-medium social distance and imposition.

III. CALM FUNCTIONALITIES

As part of this project, we have implemented and evaluated all features necessary for a fully functioning prototype. Figure 4. provides screenshots for the main functionalities integrated to date. These functionalities include: 1) A CALMeter, allowing the user to record the intensity of an anger event on a scale from 1 to 10, 2) An Anger Control Plan, consisting of the possibility to record the details of a particular anger event, including time, triggers, cue, strategies used, effectiveness of strategies and optional notes, 3) Data Visualizations of subjective recordings of events as well as physiological measures, 4) Breathing and Muscle Relaxation Exercises including Biofeedback, 5) an Education Center providing basic information about anger habits and 6) an Emergency Button.

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Figure 4. Summary of CALM functionalities

For detailed descriptions of all CALM functionalities please contact the authors.

IV. CONCLUSION

This prototype was developed in collaboration with psychotherapists from Minneapolis Veterans Affairs Medical Center (MVAMC) in order to meet the needs of veterans returning from deployment. CALM integrates with ongoing Anger Management Therapy offered at VAs nationwide. Currently, Anger Management Therapy is a manual-based 12-week group therapy. The core of this form of therapy is to become aware of what causes anger. With a mobile application anger triggers, cues and strategies can be recorded in real-time as well as reflected upon later. The application help to gives context a situation that seems difficult to handle – what times of the day or week, which other persons where involved and most importantly how was a situation handled. In addition, physiological measures can provide further cues to recovery progress. For patients, CALM provides opportunities to do therapeutic work at their own pace, it is a cost-effective and widely distributable form of intervention, it can offer support for a large group of people (e.g., in times of disasters of when the resources of clinicians are limited), people who otherwise may not week treatment can be reached and virtual avatars increase motivation and engagement. For clinicians, CALM can help to efficiently and cost-effectively treat a larger number of patients, it increases the realism of the social and environmental components influencing treatment and it offers feedback on efficacy of patient treatment.

To validate and further improve CALM, clinical testing is needed in the future.

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