Mobile Biofeedback Therapy for the Treatment of Panic Attacks: A Pilot Feasibility Study

Ryan S. McGinnis
Electrical and Biomedical Eng.
University of Vermont
Burlington, VT, USA
ryan.mcginnis@uvm.edu

Ellen W. McGinnis
Psychiatry
University of Vermont
Burlington, VT, USA
ellen.mcginnis@uvmhealth.org

Christopher J. Petrillo
Electrical and Biomedical Eng.
University of Vermont
Burlington, VT, USA
chrisjpetrillo@gmail.com

Matthew Price
Psychological Science
University of Vermont
Burlington, VT, USA
matthew.price@uvm.edu

***Abstract*—Panic attacks are an impairing mental health problem that affects 11% of adults every year. Those who suffer from panic attacks often do not seek psychological treatment, citing the inability to receive care during their attacks as a contributing factor. Herein, we introduce a mobile health (mHealth) biofeedback system that enables treatment of panic attacks wherever and whenever they occur and describe the results of an initial feasibility study. We find that only three of nine chronic panic attack sufferers experienced a panic attack during the study, potentially suggesting a preventative placebo effect common to similar pharmacological interventions. Of the four panic attacks observed, subjects noted that the act of using their phone to record their physiology during the attack helped to stop the attack. While preliminary, these results point toward the need for future development of this mHealth system and a future clinical study to assess its efficacy for preventing panic attacks.**

Keywords—mental health, mHealth, biofeedback, panic attack

I. Introduction

Every year, 11% of adults, or over 27.5 million Americans, have at least one panic attack [1]. However, only 16% of panic attack sufferers seek treatment [1], citing barriers such as long wait times for outpatient services [2], and the inability to receive treatment in real time during an attack [3]. Left untreated, panic attacks predict the onset of mental illnesses including social and specific phobia, generalized anxiety disorder, depression [4], and substance use disorders [5] as well as greater persistence, co-morbidity, and functional impairment of mental disorders [6], [7]. In short, panic attacks are a significant problem that require early intervention to prevent the development of future psychopathology.

According to cognitive-behavioral theories of panic, emotional activation leads to hyperventilation, which increases blood pH. This increase leads to a cascade of uncomfortable somatic symptoms developing abruptly and peaking within 10 minutes [8]. Individuals experiencing these symptoms often feel helpless and scared, thus exacerbating their hyperventilation [9].

Those who seek treatment for panic attacks receive either pharmacological intervention and/or psychotherapy. Pharmacological interventions, such as antidepressants or benzodiazepines, suffer from significant side effects [10], exhibit relatively high patient drop-out rates compared to psychotherapies [11], and only prevent panic attacks while a patient is taking the medication. The most common psychotherapy referral is to cognitive behavioral therapy (CBT, [12]). However, CBT alone only improves symptoms in up to two-thirds of patients, and efficacy tends to decline as treatment intensity decreases or the therapy ends [13], [14].

Mediation studies suggest that the active ingredient in effective psychotherapy appears to be the reappraisal of bodily sensations, which decreases catastrophic beliefs and urgent attempts to avoid sensations, and increases the patient's sense of perceived control over their body [15], [16]. Ultimately this decreases the frequency and intensity of panic attacks. Thus, supplemental behavioral approaches that directly target decreasing avoidance and increasing perceived control (in addition to cognitive reappraisals) increase the efficacy of CBT-based psychotherapy. For instance, interoceptive exposure is a behavioral component which can supplement the cognitive reappraisals within CBT. It involves inducing physiological symptoms associated with panic attacks by spinning quickly or running in place. By inducing these symptoms, the idea is to be able to decrease the urgent sense of avoidance and to practice reappraisals. As a supplement to CBT, this combination has demonstrated significant improvements in 81% of patients who remain panic-free 2 years later [17].

Biofeedback therapy, or *applied psychophysiological feedback,* works using similar principles as interoceptive exposure in helping patients experience and understand the connection between thoughts and bodily sensations. Typically, biofeedback involves displaying audio, visual, or tactile measurements of a patient's autonomic arousal via one or more modalities including heart rate and respiratory rate. Biofeedback has several additional benefits over interoceptive exposure in that it provides personalized, *in vivo* information about a patient's physiological arousal during their panic attacks without having to induce symptoms in artificial circumstances. It is thought that biofeedback likely helps patients achieve the connection of thoughts and bodily sensations taught in typical CBT, faster [18]. Studies demonstrating the efficacy of self-exposures [19] and selfmonitoring sessions for panic [20] suggest that biofeedback can be employed outside of the clinic. However, until now, this effective therapy has been inaccessible because it requires the use of specialized equipment to quantitatively track heart and respiratory rate during an attack.

To answer this limitation, we propose to develop, and assess the feasibility of a mobile health (mHealth) system to provide personalized biofeedback therapy for treating panic attacks wherever and whenever they occur. If feasible, mobile biofeedback could be a beneficial response to patient requests for accessible, *in vivo* panic attack intervention [2], [3]. Herein, we describe this mHealth system and the results from our initial efforts to assess the feasibility of using a mobile phone for making heart rate recordings during a panic attack.

II. Description of thr mHealth System

Mock screens from the mobile application are shown in Fig. 1. The application will enable real-time tracking of heart rate and respiratory rate, provide users the ability to view data about their previous attacks and triggers, and include mechanisms for providing audio, visual, and vibro-tactile biofeedback during a panic attack. We have implemented a prototype version of this app on the Android platform that provides a subset of these features, including real-time heart rate tracking, visual biofeedback, and the ability to view and summarize information about previous attacks.

To track heart and respiratory rate, the app requires that users place the tip of their finger against the phone's camera lens with the flash enabled. A video recorded by the phone is able to capture subtle temporal color variations that correspond to the passing of blood through the capillary bed in the user's fingertip and thus is a direct measure of cardiac activity. This measurement modality is functionally similar to the recordings made by photoplethysmography, and has been shown to enable estimation of a user's heart and respiratory rates [21]–[23]. Future work will explore the integration of wearable devices that capture continuous measures of heart and respiratory rate (from companies such as Fitbit and Apple) into the app.

Fig. 1. Home screen (left), screen used for reporting physiological measures and providing video biofeedback (middle), and screen used for tracking panic attack history and common triggers (right). Reported data are simulated.

There are a variety of algorithms for estimating heart and respiratory rate from mobile phone video that employ both time and frequency domain approaches. Herein, as proof of principal, we will focus on heart rate estimation, where we employ a simple time-domain approach. Specifically, the intensity values of each pixel from the red color channel are averaged for each video frame. This yields a noisy one-dimensional time series with roughly periodic oscillations that occur at a frequency corresponding to the user's heart rate. This time series is bandpass filtered with cutoffs selected to pass physiologically relevant frequencies (0.4 to 3.15 Hz). A simple peak detection algorithm identifies fiducial points that can be used to extract beat-beat time intervals. The inverse of these intervals corresponds directly to the user's instantaneous heart rate. Intervals are passed through an outlier removal process where values more than 2 standard deviations from the mean are discarded. These methods are used to process video data collected during the feasibility study described next.

III. Methods

A. Participants

To assess the feasibility of using a mobile phone to record video of your fingertip during a panic attack, we recruited a sample of N=20 panic attack sufferers from the community (19-34 y/o). To be eligible for the study, subjects had to own a smart phone, have experienced a panic attack in the last two weeks, not be diagnosed with psychosis or schizophrenia, not be opioid dependent, and be able to record video of the fingertip twice daily and whenever a panic attack occurred.

B. Protocol

These volunteers were phone screened to check that they met eligibility criteria. Twelve of the original N=20 were brought to the university-based laboratory for a one-hour lab visit. During this visit, study staff collected written informed consent and conducted a Structured Clinical Interview (SCID – Panic Module [24]) to quantify the volunteer's typical panic attack frequency. Subjects were trained to complete the protocol which included collecting a 30-second video of their fingertip twice daily and whenever the user had a panic attack in the seven days following their lab visit. After collecting each video, each volunteer completed an online questionnaire related to the recording and uploaded the video to a google drive link provided by the study coordinator. Volunteers were compensated for their participation. This protocol was approved by our Institutional Review Board (CHRBS#18-0414).

The questionnaire included items to identify the type of recording (normal daily or panic attack). If the recording was identified as a panic attack, items included questions about ability to record a video of their fingertip, if the recording was difficult to make, and if so what made it difficult. Additionally, the subject was asked to rate the intensity of their panic attack. Finally, the subject was asked if the act of recording the video stopped the panic attack or made it less severe. As a means of assessing feasibility, we summarize the data reported by volunteers and examine in detail several reported panic attacks. This examination includes both analysis of their written responses and the uploaded video files.

IV. Results

Following the lab visit, nine subjects completed the questionnaire and uploaded a video at least once (median=8, range=28). In total, the questionnaire was completed 83 times and accompanied by a video 80 times. Compliance issues (attrition of N=11) are common in studies of patients with heightened anxiety, and thus not unexpected in this sample.

Three subjects suffered five panic attacks while on study. Two subjects were able to record a video of the panic attack four out of these five times. In the one instance when the video was not recorded, the subject noted that he "did not remember to record" the video during the attack. The remaining four instances (median intensity 7 of 10) were triggered by pending exams (two attacks) or interpersonal relationships (two attacks). Subjects indicated that it was difficult to make the recordings in three of the four attacks citing external ("other people being around wondering what I was doing", one attack) and internal factors such that "focusing on something else" besides their feeling of helplessness and worries was difficult (two attacks). Despite subjective reports of difficulty, both users successfully captured and uploaded their videos. One volunteer was able to record three panic attacks, indicating that it was difficult to make recordings during the first two, but responded that "it wasn't" difficult on the third, possibly suggesting a relatively fast learning curve to video recording panic attacks. Importantly, for three out of the four panic attacks, the volunteer indicated that the act of recording their fingertip stopped their panic attack. This included positive responses from each of the two subjects.

Videos uploaded daily and during each panic attack allow analysis of the subject's heart rate. Fig. 2a provides an example filtered average pixel intensity time series during one subject's panic attack. Detected beats are indicated with black circles, the timing of which can be used to estimate instantaneous heart rate. Fig. 2b provides the distribution of instantaneous heart rates observed during 60-second daily life (blue) and panic attack (red) recordings.

V. Discussion

We aim to advance a new mobile health solution that provides accessible, *in-vivo* biofeedback therapy for treating panic attacks. As a first step toward this aim, we present results from a pilot study demonstrating the feasibility of using a mobile phone to record a video of a user's fingertip while having a panic attack. We show that this video data can be used to estimate the user's heart rate. We further discuss results from a self-report questionnaire completed following each attack that capture the user's perception of this approach.

The results of Fig. 2 demonstrate that data can be successfully recorded during a panic attack. For the example data provided, the median heart rate during the reported attack was 8 beats per minute (bpm) higher (86 vs. 78 bpm) than the daily recording taken at the same time of day. While this difference is moderate, it is also worth noting the difference in the distribution of heart rates observed during this time. The daily life recording has a narrow peak in the distribution centered at 78 bpm. In contrast, the panic attack recording has a much wider peak centered at 82 bpm with a long tail indicating observed instantaneous heart rates as high as 200 bpm. This is likely a function of both increased heart rate variability during the panic attack as well as additional artifacts in the recording (see callout in Fig. 2).

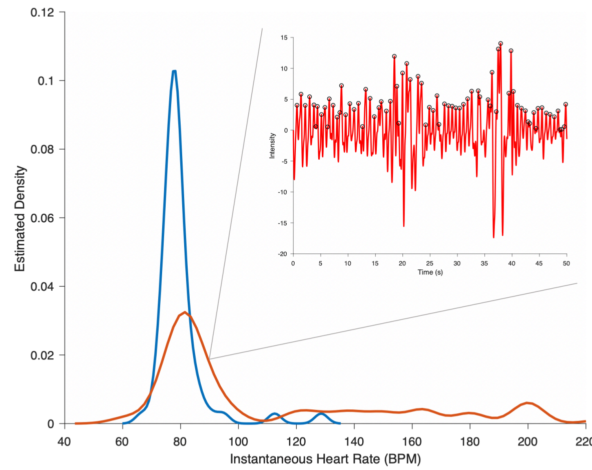

Fig. 2. The distribution of instantaneous heart rates observed during 60s daily life (blue) and panic attack (red) recordings. The callout shows filtered data recorded by a user while experiencing a panic attack. Detected heart beats are indicted with black circles enabling estimation of instantaneous heart rate.

According to subject responses from the SCID, the nine users who participated in the daily life portion of the study experienced between three and nine panic attacks each month. However, during the study, only three users reported attacks. One user who typically experiences between five and seven attacks each week only experienced three attacks while on study. The reduction in the number of attacks experienced by users suggests that there may be a placebo effect associated with this mode of treatment. This phenomenon is similarly observed in placebo-controlled interventions for preventing panic attacks [25].

In three out of the four recorded panic attacks, the user indicated that the act of recording their fingertip stopped the attack. This is a promising result, especially given that biofeedback was not being applied, and supports the use of mobile biofeedback as a treatment for panic attacks. This result is also supported by cognitive-behavioral theories of panic such that encouraging a panic attack sufferer to approach their symptoms instead of avoid them (i.e. via distraction) is shown to be an active mediator of CBT intervention [15], [16].

Users indicated that it was difficult to record a video of their fingertip during the panic attack. However, results suggest that there may be a learning effect. Specifically, one subject experienced three attacks while on study. They indicated difficulty recording videos for the first two of these attacks, but not for the third. She also indicated that the act of recording the video stopped all three of her attacks. This may suggest that users can learn how to easily make these measurements during their panic attacks, and without impacting the potential efficacy of the treatment modality.

Wrist-worn and other wearable devices are increasingly able to capture heart rate continuously. However, these devices come with additional cost that may be prohibitive to some users. Moreover, as suggested above, it may be that the act of pressing one's finger against the camera lens is important for treatment.

Future work should explore the use of wearables for making these measurements, and specifically examine if patients are able to achieve similar benefits from this continuous monitoring technology.

These promising preliminary results should be explored further in a larger sample and with applied biofeedback. Additional efforts should be made to reliably extract respiratory rate from these mobile video recordings, and potentially data from wearable devices, and that these algorithms are able to capture heart rate and respiratory rate accurately during unconstrained daily life.

VI. Conclusion

We describe initial efforts in developing a mobile biofeedback therapy for treating panic attacks and demonstrate preliminary feasibility of the measurement modality in a small sample of individuals who suffer from panic attacks. We find that the measurement modality is feasible and that there is an apparent placebo effect associated with the measurement procedure as subjects report that the act of taking the measurement acts to stop their ongoing panic attack. These results point toward the need for future studies exploring this new treatment modality for preventing panic attacks wherever and whenever they occur.

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