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TPM: Cloud-based Tele-PTSD Monitor Using Multi-Dimensional Information

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Abstract. An automated system that can remotely and non-intrusively screen individuals at high risk for Post-Traumatic Stress Disorder (PTSD) and monitor their progress during treatment would be desired by many Veterans Affairs (VAs) as well as other PTSD treatment and research organizations. In this paper, we present an automated, cloud-based Tele-PTSD Monitor (TPM) system based on the fusion of multiple sources of information. The TPM system can be hosted in a cloud environment and accessed through landline or cell phones, or on the Internet through a web portal or mobile application (app).

Keywords. PTSD, voice, cloud, mobile health

Introduction

Individuals who have been traumatized by extreme stressors that threatened or caused great physical harm often develop an anxiety disorder, called Post-Traumatic Stress Disorder (PTSD) [1]. It has been reported that nearly 10 percent of Iraq veterans have screened positive for PTSD [2]. It is a challenge to perform accurate and timely psychological assessment of PTSD patients due to the diversity of PTSD symptoms, time-consuming assessment in a clinic environment, and truthful responses required from patients. An automated system that is able to remotely and non-intrusively screen individuals at high risk for PTSD and to monitor their progress during treatment alleviates many of the barriers to cost-effective PTSD assessment and progress monitoring.

In the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) Criteria D [1], PTSD patients may experience increased anxiety and emotional arousal as well as symptoms related to negative emotions (anger, fear, sadness, etc.). Also, individuals with PTSD may feel detached or disconnected from friends and family, leading to depression, which is one of the most commonly comorbid disorders with PTSD. Because PTSD may be reflected in voice changes through negative emotions/ depression, and the voice data can be easily accessible, the TPM system is mainly based on voice pattern changes. Myriad studies have been performed for voice-based, negative emotion/depression analysis [3][4], which can be leveraged for PTSD assessment.

Researchers are also trying to utilize other sources of information for PTSD screening and monitoring. One example is the ongoing DARPA BAA program, entitled

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"Detection and Computational Analysis of Psychological Signals (DCAPS) [5]". In this program, DCAPS tools are being developed to analyze patterns in daily behaviors and to correlate them with distress. The behavioral markers of interest include text entry (online posts/tweets), voice communications, activity patterns (sleeping/eating), social interactions, facial expression, posture, and body movements.

In this paper, we present an automated, cloud-based Tele-PTSD Monitor (TPM) system utilizing multi-dimensional information to remotely screen, monitor, and to provide assistance to clinicians in diagnosing a patient at high risk for PTSD. The system supports multiple types of client connections, including landline/cell phones through an Interactive Voice Response (IVR) server, apps on users' mobile platforms (Apple iOS and Android), and a web-based interface. In the next section, we describe the conceptual architecture of the TPM system. Then, we present the TPM prototype, including the server and different types of clients. The final section concludes with the potential benefits of using such a system.

1. Methods and Materials

A soldier (or other service man/woman likely to suffer from PTSD) can access the TPM system via a Public Switched Telephone Network (PSTN), as well as the Internet. With PSTN, a soldier only needs to call a phone number to engage with an IVR server. With the Internet, the soldier can access the TPM system via a web browser or a mobile app (iOS or Android platforms) to initiate the process. The architecture is shown in Figure 1. The TPM system is designed to utilize different sources of information, including voice patterns, speech content (reflecting linguistics features of negative emotions and verbal communication problems), attention/memory test outcomes, and self-report results.

1.1. Voice Patterns

A wide range of existing research has been devoted to investigating different acoustic features for negative emotion and for depression detection. Vocal analysis is commonly used for emotion detection, examining the nonverbal elements present during normal speech [6]. Analysis of these features does not rely on the word content of the acoustic sample, increasing the robustness of the method when faced with a subject attempting to hide their feelings and emotions. Examples of acoustic features for emotion and depression detection include speech rate, pitch, intensity, voice quality, articulation, Gabor filter features, and Glottal features [7][8].

1.2. Linguistics

Linguistic features have been used to detect negative emotions and stress/deception. Depressed and suicidal individuals are more self-focused, and express more words related to negative emotions and death. Studies on depression and suicide show that language features can be markers of mental health [9]. One pattern that has been observed is the more frequent use of first-person singular and negative emotion words by depressed people [10]. A good example of linguistic features is the Linguistic Inquiry and Word Count (LIWC) [9], which measures the cognitive and emotional properties of a person based on the words they use. To utilize the linguistic features for

PTSD assessment, we perform voice recognition and extract linguistic features from the transcripts.

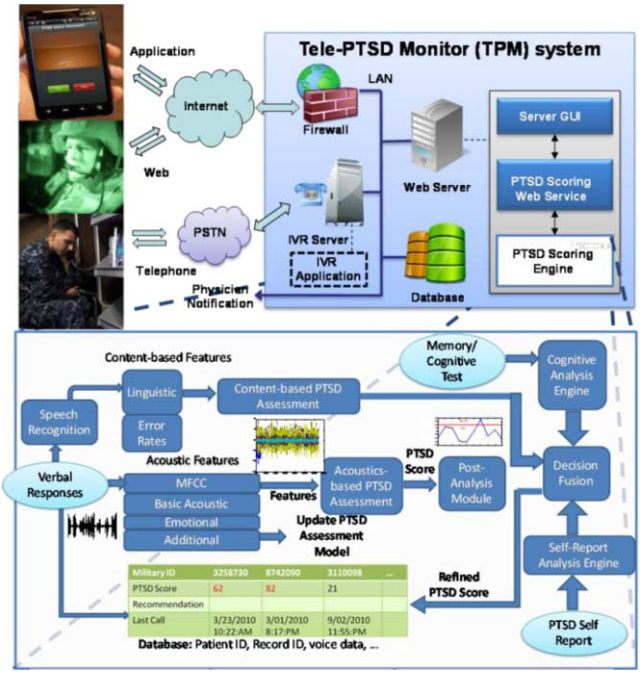

Figure 1. A system diagram of TPM.

1.3. Verbal Communication

PTSD patients often complain that they are unable to speak fluently and/or correctly. According to a PTSD forum survey [11], over 93% of PTSD patients are affected by verbal communication issues when symptomatic. Therefore, another possible way to utilize the voice signal is to perform voice recognition and combine the transcripts and the acoustic signals to investigate verbal communication issues. We can utilize captured audio from a subject reading a standardized piece such as the Grandfather passage, a 132 word passage commonly used for the assessment of communication disorders.

1.4. Attention & Memory Tests

Attention and memory deficits are seen as core elements of PTSD and are reflected in the DSM-IV criteria (C3, D3 & D4) [1]. For example, C3 indicates avoidant/numbing leading to the inability to recall an important aspect of the trauma. These deficits can be measured in different ways; for example, the Weschler memory scale, a neuropsychological test designed to measure different memory functions in a person. We can select one or more effective and simple cognitive test and integrate them into the current TPM system.

1.5. Self-Report

The PTSD self-report, PTSD Checklist-Military version (PCL-M), has shown a strong correlation (0.929) with Clinician Administered PTSD Scale (CAPS, the gold standard for diagnosing PTSD). Because it can also be easily implemented, we can enhance the PTSD screening and monitoring by integrating the PCL-M self-report into the TPM system.

The TPM supports a plug-in framework for different models. Based on the user responses, different modeling techniques are being investigated, such as the Gaussian Mixture Model (GMM), sparse coding, deep learning, and other machine learning methods.

2. Results: Prototype of TPM

In the TPM prototype, the soldier is greeted and asked questions that are related to PTSD symptoms and their impact on social and occupational functionality. TPM can be used as both a PTSD screening tool and a monitoring tool. Furthermore, it can be used by clinicians as a tool to manage PTSD patients. For example, during a screening process, a user can log in to the TPM system through different clients. After being authenticated, the user performs a PCL-M self-report to answer 17 questions corresponding to the PTSD symptoms (e.g., choose from 1-5 for each question through a touch panel, keyboard, mouse click, telephone keypad, or voice). Then, the user is prompted to read the Grandfather passage (on the screen or print-out) and the voices will be collected and transmitted to the TPM server. A simple attention/memory test is then presented to the user before he/she answers via voice the 17 questions related to the PTSD symptoms. The user's responses are stored in a database for future analysis by a clinician (see Figure 2). At the same time, the data is sent to the TPM server to be processed by the scoring engine (PTSD-SE), which computes mental health scores for the soldier. The scores are also saved in the database and accessible by clinicians. During the screening process, if the score indicates that the user is likely to have identifiable PTSD symptoms, the system notifies clinicians for further confirmation via email or text messaging. During the monitoring process for a PTSD patient, clinicians will be notified if the trend of the PTSD worsens to a certain extent.

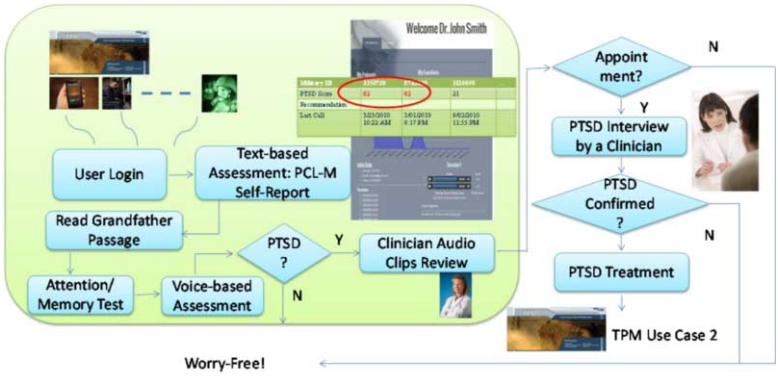

Figure 2. PTSD screening in TPM

The aforementioned different sources of information reflect multiple aspects of PTSD and can all be easily collected. An appropriate fusion of data sources is required to enhance the overall PTSD assessment performance. For example, although PCL-M self-report has shown a strong correlation with CAPS, the PCL-M score depends on honesty. If a user lies, the PCL score may not be trusted. On the other hand, although objective, the PTSD assessment based on voice patterns may be negatively impacted by many variables, such as sickness and the recording environment. The performance may not be guaranteed if based solely on voice patterns. Therefore, a decision fusion needs to be implemented to combine the decisions from these difference sources by considering the advantages and disadvantages of each option. Possible fusion techniques include the Dampster Shafer and Transferable Belief Model (TBM) [12].

We have implemented the key TPM components hosted on a Windows IIS web server using XML-RPC as the web service protocol for the communication between the web service clients and the web service host, employing the named pipe Inter Process Communication (IPC) as the communication protocol.

We are developing web service clients running different target platforms such as PC, Apple's iOS devices (iPhones & iPads), the IVR server and Android devices using the XML-RPC communication protocol. As an example, some snapshots of the Android-based client are shown in Figure 3. The left side of the figure shows the main TPM window on the phone with text-based, audio-based, and cognitive test-based (attention/memory) assessment options. The right side of the figure shows a snapshot of the audio-based assessment user interface. Another example is the IVR-based TPM client. Figure 4 shows the logic using the IVR to perform PTSD screening.

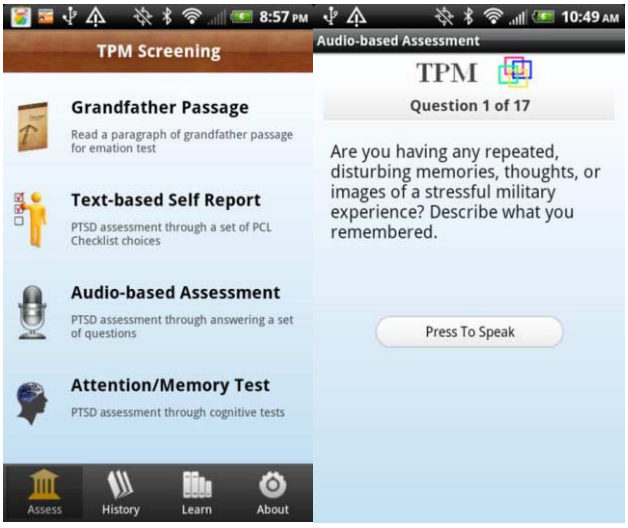

Figure 3. Android phone-based TPM snapshots

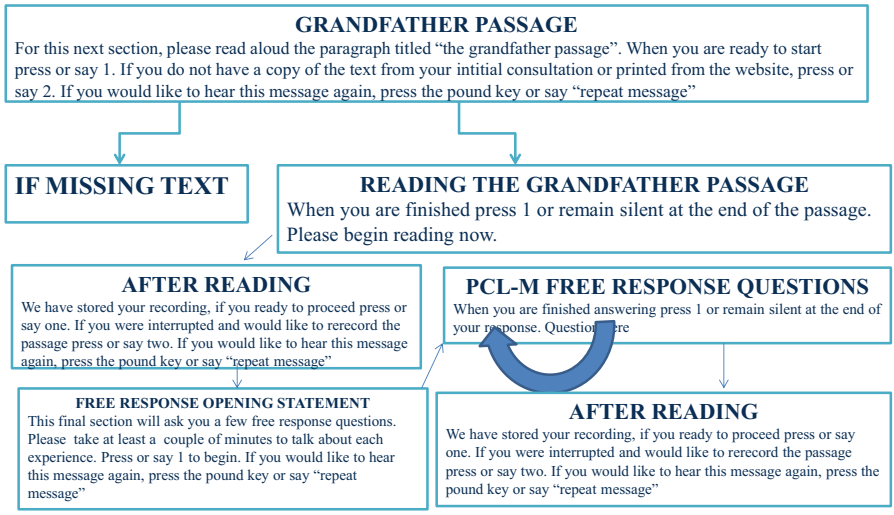

Figure 4. IVR for PTSD screening.

Instead of building the TPM server pools and dealing with their installation, maintenance, and load balancing, it is possible to deploy the web portion of the TPM system in the cloud computing environments such as Amazon Elastic Compute Cloud (Amazon EC2), as shown in Figure 5. With Amazon EC2, we can simply launch as many instances (virtual machines) as needed with a variety of operating systems to choose from, such as Windows Server and Linux. We have full control with these virtual machines as if they were installed locally.

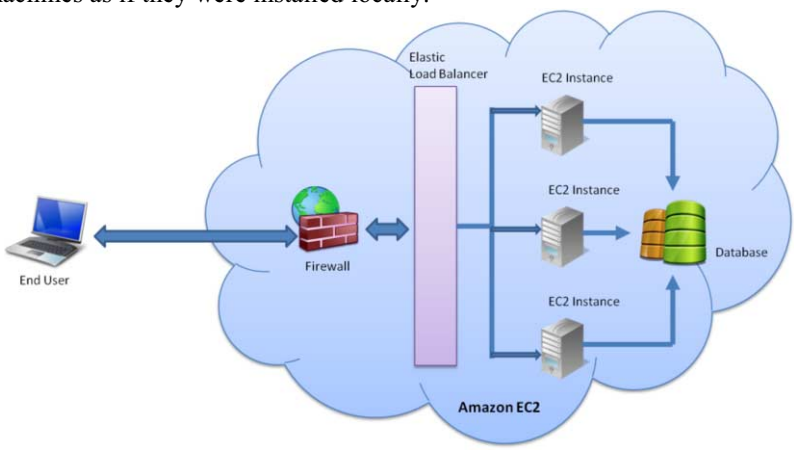

Figure 5. Schematic of cloud-hosting on Amazon EC2.

3. Conclusions & Discussion

We are currently developing an automated cloud-based Tele-PTSD Monitor (TPM) system, which can provide assistance to clinicians in diagnosing a PTSD patient's mental health and readiness in the field. Potential users include soldiers returning from war zones or other service men/women who may suffer from PTSD. The TPM system

provides a variety of user interfaces, including mobile apps (Android and Apple iOS), landline phones/cellphones through IVR, and a web-based interface. It could also be applicable to other types of mental health screening and assessments, such as depression and suicide. The major functions of the key TPM system components are being evaluated. In the future, we will assess the TPM system with a complete experimental dataset.

4. Acknowledgments

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