Detection and Computational Analysis of Psychological Signals (DCAPS)

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DCAPS Goal

- Develop computationally-based, networked tools to assess and analyze psychological behavioral states in a DoD medical environment.
  - Analyze verbal and nonverbal cues, online activities, and indicators of social behavior
  - Employ approaches both individually and in concert
  - Use novel sources of data: iPhone, Android, Kinect, social-networks, synthetic environments, EEGs, web cams, etc.
  - Leverage expertise from MIT, Dartmouth, Boston University, Vanderbilt, USC, & UCLA
DCAPS: BLUF

High-level contributions:

• Early recognition of indicators of psychological distress (e.g., depression, anxiety or PTSD)
• More effective triage of potentially distressed service members
• Facilitate clinician training
• Share DCAPS insights and data with scientific community
• Virtual humans may reduce stress and fear of judgment

Specific Applications:

• Behavioral assessment and monitoring of military personnel, pre-, during, and post-deployment
• Deployed to clinician training sites
• Call Centers/Hotlines
DCAPS Approach

- Used “Honest Signal” theory as a start point (Dr. Sandy Pentland, MIT)

- Data Analyzed
  - Spoken and written communications (including metadata)
  - Online behaviors: email, surfing habits, games, and social networking
  - Nonverbal cues such as facial expression, posture, movement patterns
  - Creative content of artistic expression in art and writing (SBIR)
  - Response to stimuli obtained through sensors such as EEG, EKG, GSR

- “Products”
  - Reality Analysis: two applications that use the “honest signals” analysis
    - Clinician (TRL 9) and Mobile (TRL 6)
  - MINAT: text and voice analytics tools for early detection of PTSD, depression, and suicidality (TRL 6)

  - SimSensei: an avatar-based tool to perform “honest signal” analysis that examines a combination of nonverbal cues using Kinect technologies (TRL 4)
REALITY ANALYSIS

Mobile

Clinician
Reality Analysis Mobile: Overall Description

- Goal: Using data from mobile phone usage provide individuals (**and clinicians**) by with a high-level assessment of an individual’s mental health state
- Individuals have the option to share data

- Data analyzed:
  - Activity / location
  - Sleep patterns
  - Audio Diary content
  - Call and text metadata
  - Call and text content (when used with MINAT)

- Analysis produced are qualitative assessments in four areas:
  - Travel, Social, Sleep, Mood
Reality Analysis Mobile: Results

- Participants’ behavioral and voice data were passively gathered then assessed using predictive models
- Assessments were completed using data from clinical and non-clinical field trials*
  - Clinical trial
    - 95 participants over a 3-month period, included weekly audio diary entries
    - Trial included a 30K weekly survey questions and over 51M data points of bio-behavioral markers
    - Protocol adherence was 96%
  - Non-Clinical trial
    - Two focus groups, totaling 21 participants
    - Participants were comfortable with the level of privacy of the mobile app
    - Participants were also comfortable sharing their mental health status
    - Gather data on adoption, usability, and privacy concerns
- The predictive models produced 0.6 to 0.9 AUC (ROC curves) for a variety of symptoms [1]

## Symptoms

<table>
<thead>
<tr>
<th>Description</th>
<th>Physical isolation</th>
<th>Social isolation</th>
<th>Fatigue</th>
<th>Inability to concentrate</th>
<th>Sleep disturbance</th>
<th>Sounds depressed (mono)</th>
<th>Sounds depressed (stereo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A behavioral metric measuring if a person is exhibiting diminished interest or pleasure in their normal activities. This metric aligns with a symptom of depression.</td>
<td>A behavioral metric measuring if a person is attempting to avoid thoughts, feelings, or conversations associated with their trauma.</td>
<td>A behavioral metric measuring if a person is exhibiting fatigue or loss of energy in their everyday life. This metric aligns with a symptom of depression.</td>
<td>A behavioral metric measuring if a person is having difficulty concentrating on their daily activities. If they are distracted and unable to focus. This metric aligns with a symptom of depression.</td>
<td>A behavioral metric measuring if a person is having major sleep disturbances. This could include either insomnia or hypersomnia. This metric aligns with a symptom of depression.</td>
<td>A vocal acoustic metric associated with major depressive disorder. The metric utilizes data from only one person (mono recording).</td>
<td>A vocal acoustic metric associated with major depressive disorder. The metric utilizes data coming from both sides of a conversation, involving two people (stereo recording), however the metric is for only one speaker.</td>
<td></td>
</tr>
</tbody>
</table>

| Range of accuracy | AUC= .66 | AUC = .85 | AUC= .79 | AUC ranging from .70 to .73 | AUC ranges from .67 to .74 | AUC ranging from .61 to .88 | Predict: Depression at 1.38 to 1.54x chance or AUC=0.64 |

| Model covariates | gender | age, gender | gender | none | age, gender | none | age, gender |

Reality Analysis Mobile: Privacy Ratings [1]

**Privacy Rating by Veteran Status**

- Extremely Comfortable
- Moderately Comfortable
- Not at all comfortable

- Non Veteran
- Veteran

**Privacy Rating by Age**

- 18-24
- 24-34
- 35-44
- 45-54
- 55-64

Reality Analysis Mobile: Data Shared with Other Entities/Groups [1]


Distribution Statement A - Approved for Public Release, Distribution Unlimited
Reality Analysis Clinician: Overall Description

- Goal: Analyze verbal interactions between clinician and patient to infer:
  - Degree of engagement
  - Empathy
  - Active listing
- Graphical representations:
  - Tone maps
  - Conversational balance bar
  - Conversational flow gauge
  - Speech pattern timeline
- Supports both real-time and post analysis

Dialog Display:
1. **Tone Maps** plots the distribution of dynamic variation and speaking rate
2. **Conversational Balance Bar** indicates the relative participation of each speaker
3. **Conversational Flow Gauge** measures the fluidity of the conversation
4. **Speech Pattern Timeline** captures the pattern of speech during the call.
Reality Analysis Clinician: Real-time Interface [1]

MINAT
(Medical Informatics and Analytics Toolkit)
MINAT: Overall Description

• Goal: Assign a patient’s communication into zero, one, or more “codes” that are potential indicators for PTSD, depression, & suicidality
  • Assist with triage
• Communication with the patient performed using transcribed audio and written text
• Analysis produced is zero, one, or more “indicators”
• Categories of indicators:
  • Stress Exposure
  • Affect
  • Behavior
  • Cognitive state
  • Degrees of Impairment
• Runs as a deployable web service
MINAT: Indicator Codes

- 70 indicator codes in five categories
  - Categories of indicator codes
    - Behaviors
    - Stress Exposure
    - Affect
    - Cognitive states
    - Degrees of Impairment
  - DSM-IV inspired
    - Criteria, symptoms, indicators
  - Indicator codes continually refined with experience
    - Reduces ambiguity
    - Increases inter-annotator agreement
    - Supports machine learning

Distribution Statement A - Approved for Public Release, Distribution Unlimited
<table>
<thead>
<tr>
<th>Patient</th>
<th>well i guess it started a little while ago but mostly i am i have a lot of trouble sleeping</th>
<th>Sleep problems - not specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>i guess it all kind of started since a little while after i got back from iraq but i have nightmares a lot and um you know i've been having trouble with with work and them you know and well i mean i got divorced so i guess thats that's most of it</td>
<td>Anger/Rage/Frustration/Contempt Nightmares/unpleasant dreams of the event</td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinician</td>
<td>okay so there's there's a lot there</td>
<td></td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinician</td>
<td>let's go back a seconds and maybe you can tell me a little bit about your experience in iraq</td>
<td></td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>well um you know i've back when i was in iraq i was some weeks to go out on patrols a lot um</td>
<td>Warzone exposure</td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinician</td>
<td>when we there</td>
<td></td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient</td>
<td>in two thousand five um two thousand five two thousand six um and in that time part of our duties would be caught on convoys for my congress support and sometimes go out on patrols and things like that which was always always very you know stressful dangerous because we are like sitting ducks the whole time we're out there you don't know who's your friend and who's not your friend and we were constantly especially or out on the road we're always looking up right peace he improvised explosive device and um well i mean those are on the good days we didn't find any um but i guess the worst of it was we did we did take a few we did take a few id bombs we got hit me and we took some a lot of wounded and some casualties and one was one was especially bad it was in the and the humvee right in front of me they got hit directly so i saw it i saw the explosion and it just ripped it to shreds</td>
<td>Warzone exposure</td>
</tr>
<tr>
<td>Jan 18, 2012</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SIMSENSEI

MultiSense / TeleCoach
SimSensei: Overall Description

• Goal: Create an avatar-based tool that senses nonverbal cues that are potential indicators of mental distress

• Communicates with an individual via conversational interaction

• Data analyzed:
  • Body movement
  • Gestures & other physical movements
  • Facial displays
  • Voice
  • Response latency

• Real-time analysis produced:
  • Horizontal gaze, smile level, voice, attention, body movement

SimSensei: Ellie
SimSensei / Telecoach Results

- **Goal:** Assess the clinical states of interest through a multimodal analysis of a patient’s verbal and nonverbal communication
- Communication with the patient is with clinician, through shared video
- **Training**
  - 300+ 20-minute interviews with Ellie
  - Participants’ behavioral profiles were indicative of PTSD and depression
- Demonstrated potential as an alternative clinician support tool
*Person in image is a veteran participant, who has consented to sharing his image.
Psychological Distress Indicators (IEEE FG 2013, Interspeech 2013, MMVR 2013)

- Joy – Facial expr.
- Sad – Facial expr.
- Vertical eye gaze
- Smile intensity
- Hand self-adaptor
- Legs fidgeting
- Voice energy std.
- Voice quality

Distress Assessment Interview Corpus (DAIC)

Distribution Statement A - Approved for Public Release, Distribution Unlimited
Individuals are able to incorporate the TeleCoach indicators into their assessments of a patient’s mental distress. Specifically, providing individuals with TeleCoach indicators cues improved the accuracy of their assessments.

<table>
<thead>
<tr>
<th></th>
<th>Without indicators</th>
<th>With indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy of depression ratings</strong></td>
<td>$\beta = 0.59$</td>
<td>$\beta = 0.72$</td>
</tr>
<tr>
<td><strong>Accuracy of PTSD ratings</strong></td>
<td>$\beta = 0.17$</td>
<td>$\beta = 0.43$</td>
</tr>
</tbody>
</table>

$\beta$ represents the size of the effect, or in this case, degree of accuracy, in regression analyses. $\beta$ ranges from 0.0, which would be no accuracy, to 1.0, which represents perfect accuracy.
DCAPS: Bibliography of refereed published papers


- E. Suma, B. Lange, A. Rizzo, D. Krum, and M. Bolas. “FAAST-R: Defining a core mechanic for designing gestural interfaces.” In The 3rd Dimension of CHI: Touching and Designing 3D User Interfaces, 2012. Accepted for publication.


Back-ups
Technology Readiness Levels

• TRL 1: Basic principles observed and reported
• TRL 2: Technology concept and/or application formulated
• TRL 3: Analytical and experimental critical function and/or characteristic proof of concept
• TRL 4: Component and/or breadboard validation in a laboratory environment
• TRL 5: Component and/or breadboard validation in a relevant environment
• TRL 6: System/subsystem model or prototype demonstration in a relevant environment
• TRL 7: System prototype demonstration in an operational environment
• TRL 8: Actual system completed and qualified through test and demonstration
• TRL 9: Actual system proven through successful mission operations.
We can reliably detect severe distress in hotline conversations: 80% recall in most severe cases (TR1) with only 19% False Positive Rate.

TR1: Imminent Danger

TR2: Refer to Clinician

TR3: No Referral

AUC: 0.81

AUC: 0.69

AUC: 0.90
Affect Labels

Affect

Positive Emotions
- Happiness/cheerful
- Hopeful/optimistic
- Gratitude

Negative Emotions
- Sadness/depression
- Pessimistic
- Despair/hopelessness
- Self-doubt
- Worthlessness
- Helpless
- Guilt/remorse/regret
- Shame

- Anger/rage/frustration/contempt

- Fear/anxiety/nervous/worry
- Horror

- Disgust
- Distress, not specified

Other Emotions
- Surprise
- Numb/unable to feel anything
- Emotional lability/mood swings
- Mood disturbance, not specified
Behavior Labels

Hyperactivity
- Trauma-related hyperactivity
  - Physiological distress to trauma reminders
  - Physiological reactivity to trauma reminders
  - Hyperactivity/exaggerated startle

Avoidance
- Avoidance
  - Avoid internal reminders of exposure (thoughts, feelings, physical sensations)
  - Avoid external reminders of exposure (people, places, conversations, activities, objects, situations)
  - Panic behavior

Aggressive/Destructive Behavior
- Aggressive/Destructive Behavior: Other
  - Property destruction
  - Road rage
  - Injury to others
  - Intimate partner violence, physical
  - Intimate partner violence, sexual
  - Intimate partner violence, verbal
  - Intimate partner violence, sexual

- Aggressive/Destructive Behavior: Self
  - Self-destructive behavior/injury to self
  - Attempt to self harm
  - Suicide attempt

- Aggressive/Destructive Behavior: NOS
  - Irritable behavior, other/NOS
  - Aggressive behavior, other/NOS

Substance Use
- Substance Use
  - Excessive drug use
  - Excessive alcohol use
  - Excessive substance abuse, not specified

Negative Symptoms
- Negative Symptoms
  - Detachment/isolation from others
  - Disinterested/passive to experience pleasure
  - Anhedonia
  - Agility
  - Indolence/procrastination/lack of spontaneity
  - Social isolation

Physical Symptoms
- Physical Symptoms
  - Balance problem
  - Dizziness
  - Tinnitus

- Psychomotor Problems
  - Sleep problems
  - Sleep difficulties, not specified
  - Sleep problems, not specified
  - Difficultly falling asleep
  - Difficultly staying asleep
  - Sleeping too much

- Appetite/Weight Problems
  - Unintentional weight loss
  - Unintentional weight gain
  - Appetite increase
  - Appetite decrease

- Sensory Disturbances: Ear
  - Tinnitus
  - Sensitive to noise
  - Hearing loss

- Sensory Disturbances: Eye
  - Visual
  - Sensitivity to light
  - Sensory disturbance, visual, not specified

- Sensory Disturbances: Other
  - Sensory disturbance, olfactory
  - Sensory disturbance, taste
  - Sensory disturbance, touch

Distribution Statement A - Approved for Public Release, Distribution Unlimited
Domains (Degrees) of Impairment

Domains of Impairment

- Social Impairment
  - Social Impairment: Family
    - Family impairment, NOS
    - Intimate partner/core family member impairment
    - Extended family impairment
  - Social Impairment: Friendship
    - Friendship impairment
  - Social Impairment: NOS
    - Social impairment, NOS

- Role Performance Impairment
  - Role Performance Impairment
    - Occupational impairment
    - Educational/academic impairment

- Activities of Daily Living Impairment
  - Activities of Daily Living Impairment
    - Self-care impairment
    - Financial problems
    - Legal problems