WARFIGHTER ANALYTICS USING SMARTPHONES FOR HEALTH (WASH)

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Proposer’s Day
16 May 2017

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WARFIGHTER ANALYTICS USING SMARTPHONES FOR HEALTH (WASH)

PROGRAM GOALS

Develop algorithms that use raw data from smartphone sensors to enable continuous and real-time assessment of warfighters and determine mission readiness.

1. Apply analytic techniques to smartphone sensor raw data to link observed behavior to user physiological and cognitive state for warfighter assessment.

2. Determine warfighter combat/mission readiness and lead to better diagnosis.
SENSING WARFIGHTER
PHYSIOLOGICAL AND COGNITIVE STATE

How it's done today

- **Intrusive** and disparate health sensors requiring expert.
  - Thermometer (Temperature)
  - Microphone (Speech Parameters)
  - ECG (Heart Rate & Cardio Health)
  - Blood Pressure Sensor (Blood Pressure)
  - Inertial Measurement Unit (Gait, Load, Balance)
- **Non-Continuous** Assessment
- Heavy reliance on self-reporting
- Industry supports disparate medical wearable devices since wearable medical device market size was valued at USD 3.9 billion in 2014

Program focus:

- Passive and continuous assessment of physiological and cognitive state of the warfighter using ubiquitous sensor platform
- Determine combat/mission readiness and lead to better diagnosis
WARFIGHTER ANALYTICS USING SMARTPHONES FOR HEALTH (WASH) THEORY

TA1: Phase 1 & 2

PERSONAL BEHAVIOR/CHARACTERISTICS
- Eye Movements
- Voice
- Device Orientation & GPS location
- Finger images
- Finger pressure
- Gait, speed & body motion

SMARTPHONE SENSORS
- Camera
- Pedometer
- Light Sensor
- Thermometer
- Fingerprint Sensor
- Proximity Sensor
- Magnetometer
- Accelerometer
- Gyroscope
- Microphone

TA2: Phase 1

CONTEXT OF USE

TA2: Phase 2

DISEASE BIOMARKERS
- Physiological and Cognitive Symptoms
  - Excessive Sweating
  - Shaking Voice
  - Hands Shake
  - Muscle Tension
  - Facial Tics
  - Racing Heartbeat
  - Blood Pressure Rising
  - Facial Freezing
  - Gait Variance
  - Decreased Attention and Concentration
  - Communication Variance
  - Diminished Reasoning Ability
  - Poor Decision-Making
  - Impulsive Actions

==>

Biologic Onset of Disease/Illness

WASH Symptom Detection

Noticeable Emergence of Symptoms

Preclinical Health Determination
WARFIGHTER ANALYTICS USING SMARTPHONES FOR HEALTH (WASH) PROGRAM OVERVIEW

**User Sensing**

**Data Collection**

**Raw Data**

**PHASE 1: Useful Signal Extraction**

**Context of Usage**

**PHASE 2: Physiological and/or cognitive state assessment**
- TBI
- Infectious Disease
- Others

**Actions**

**CHALLENGES:**
- Acquire Data (with ground truth)
- Establish Context
- Extract Weak Signal
- Deconflict Multiple Hypotheses

**TA1**

**TA2**

**Physical & Behavioral Indicators**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Facial Characteristics</th>
<th>Eye movement</th>
<th>Heart Rhythm</th>
<th>Gait, speed &amp; body motion</th>
<th>Grasping Pattern &amp; Hand Movement</th>
<th>Hand/Arm Gestures</th>
<th>Finger Images</th>
<th>Speech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious Disease</td>
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<tr>
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<td>High Blood Pressure</td>
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</table>
1. Identify and sign up medical cohorts to participate with data providers
2. Coordinate with, monitor, and manage diverse cohorts (DoD and private)
3. Communication plan with cohort management, cohort participants, and TA2 performers
4. Issue resolution plan
1. Infrastructure specifications, including access latency, storage capacity, and scalability in terms of number of users, number of TA2 performers, and computational analytics supported

2. Data protection and privacy (in accordance with cohort IRB requirements)

3. Accommodations for public, private, and hybrid cloud environments

4. Component and data failure recovery strategy
1. List of sensors collected on Android and iOS operating system
2. Overhead management of the collection application inclusive of power, storage management, data transfer bandwidth/timing, and scalability
3. Application management for periodic updates and modifications (bug fixes, new features)
4. Server-based database development for data collection, storage requirements, and protection
TA2 performers will develop the data analytics for:

- extracting context from TA1-provided data identifying useful digital biomarkers that are predictive or indicative of physiological conditions
- demonstrating the correct anticipation and identification of said conditions.

**CHALLENGES:**

- Establish Context
- Extract Weak Signal
TA2-PHASE 1: CONTEXT EXTRACTION

Extract context from TA1-provided data identifying useful digital biomarkers that are predictive or indicative of physiological conditions

- Use sensors to determine what the user is doing and where
- Conclude usability of the data for assessment prediction
- Establish sensing limits

CHALLENGES:

- Establish Context
- Extract Weak Signal

Vertical Axes: Meters per second squared
Horizontal Axes: Seconds

Accelerometer signals for four activities. The first row shows the signal in XYZ dimensions, and the second row shows its magnitude. Signals are very different for different activities.

Physical & Behavioral Indicators

<table>
<thead>
<tr>
<th>Physical &amp; Behavioral Indicators</th>
<th>Actionable</th>
<th>Forceful</th>
<th>Forward</th>
<th>Incident</th>
<th>Impact</th>
<th>Index</th>
<th>Opposition</th>
<th>Passage</th>
<th>Pursue</th>
<th>Impact</th>
<th>Pressure</th>
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<th>Selective</th>
<th>Stateful</th>
<th>Touching</th>
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<td>PHASE 2: Physiological and/or Cognitive State Assessment</td>
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</table>
Psychomotor Impairment Detection via Finger Interactions with a Computer Keyboard During Natural Typing
TA2-PHASE 2: ASSOCIATING SYMPTOMS WITH THE USER STATE AND AMBIENT CONTEXT

Medical Literature → Hypothesis

Collect User Sensing Data Collection from Cohorts

Content Extraction and Noise Reduction → Validate Hypothesis

Medical Ground Truth

Technical Areas
- TBI (2 performers)
- Infectious Disease (2 performers)
- Other Illnesses and Diseases (1-2 performers)

CHALLENGES:
- Deconflict Multiple Hypotheses
- Acquire Data (with ground truth)

<table>
<thead>
<tr>
<th>Medical Characteristics</th>
<th>Eye Movement</th>
<th>Heart Rhythm</th>
<th>Sound/Noise Sensors</th>
<th>Location/Geolocation</th>
<th>Hand/Finger Movements</th>
<th>Finger/Hand Spacing</th>
<th>Speech</th>
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<tbody>
<tr>
<td>TBI</td>
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<td>Neurological Disease</td>
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<td>Musculoskeletal Disease</td>
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<td>Acute Illnesses</td>
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</table>

TA1

Mobile Device Sensors → User Sensing Data Collection → Raw Data → PHASE 1: Useful Signal Extraction → Context of Usage

PHASE 2: Physiological and/or cognitive state assessment
- TBI
- Infectious Disease
- Others

TA2

Content Extraction and Noise Reduction → Validate Hypothesis

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TA2-PHASE 2: ASSOCIATING SYMPTOMS WITH THE USER STATE AND AMBIENT CONTEXT (TBI)

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TA2-PHASE 2: ASSOCIATING SYMPTOMS WITH THE USER STATE AND AMBIENT CONTEXT (INFECTION DISEASE)

Bilateral isolated facial palsy with fast recovery in infectious mononucleosis.
Ford B^1, Noreen A^2, Soleima A^2, Soto S^2.

Isokinetic trunk and knee muscle strengths and gait performance in walking patients with T-cell lymphotrophic virus type 1-associated myelopathy/tropical spastic paraparesis (HAM/TSP).
Munemura H^1, Sakakima H^1, Goto T^2, Kugimiya H^2, MinatsuMI T^2, Imai S^2, Yoshida Y^3.
Competitive TA2 proposals should address the following topics:

1. How to establish context from the data gathered
2. Method of extraction of a weak signal over varying ambient conditions
3. Deconfliction of multiple hypotheses for different medical conditions
4. Level of confidence in sensing limits and data granularity and
5. The ability to acquire data with ground truth
# PROGRAM STRUCTURE AND METRICS

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Phase</th>
<th>Duration Start</th>
<th>Duration End</th>
<th>Evaluation Criteria</th>
<th>Metrics</th>
<th>Target Goals</th>
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<tr>
<td>Infrastructure (TA1: Phase 1)</td>
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<td>M0</td>
<td>M18</td>
<td>Power consumption overhead</td>
<td>&lt;5%</td>
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<td>Scale</td>
<td>&gt;100K Users</td>
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<td>Data Access and Availability</td>
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<tr>
<td>Infrastructure (TA1: Phase 2)</td>
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<td>M19</td>
<td>M48</td>
<td>Power consumption overhead</td>
<td>&lt;5%</td>
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<td>Scale</td>
<td>&gt;1M Users</td>
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<td>Data Access and Availability</td>
<td>99.9%</td>
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<tr>
<td>Determine Context to Extract Relevant Data (TA2: Phase 1)</td>
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<td>M0</td>
<td>M18</td>
<td>Accuracy of Context Identification</td>
<td>80% accurate identification</td>
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</table>
| Associating Symptoms with the User State and Ambient Context (TA2: Phase 2) | 2     | M19           | M48          | Biomarker Identification with Multiple Hypothesis Classifications | • TP: 70% accurate identification of condition family (relative to ground truth) at .3t  
• TP: 80% accurate identification of condition family (relative to ground truth) at .8t  
• FP: 10% on a monthly basis  
• FN: 20%  
Where t=T the emergence of symptoms |                                   |                                   |

<table>
<thead>
<tr>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
<th>YEAR 4</th>
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<tbody>
<tr>
<td>PHASE 1</td>
<td>PHASE 2</td>
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<tr>
<td>TA1</td>
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<td>TA2</td>
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</table>
• Each performer conducts their own evaluation for each phase
  • Provide prototypes to DARPA and AFRL to conduct an independent validation
  • Government reserves the right to engage third parties to independently validate the results

• DARPA will pursue access to unclassified data sets
  • Proposers strongly encouraged to pursue their own data sets that will facilitate initial development
  • Particularly important for Phase 1 goals
  • TA1 cohort and data management performers are expected to work with providers of such data sets (cohorts)
• The program will be conducted at the UNCLASSIFIED level
  • Technical development
  • Performer-internal testing
• Depending on technical approach, proposers may need to consider HSR implications

• DARPA encourages proposers to consult their IRB and address this matter in their proposals
  • Ideal scenario: proposal includes letter with IRB determination
  • Second best scenario: proposal includes submission to IRB

• Proposers are requested to separate human subject research (HSR) tasks from those that do not require human-use within their Statement of Work. The intention is for awards to be structured in each Phase with a base task comprised of non-HSR work followed by an option that will award the HSR affected tasks.
DARPA anticipates the work done in this program to be fundamental research.

Proposals due on June 23, 2017, 12:00 noon (ET).

Anticipated program start date: 1 December 2017.

One proposal per organization as Prime.

Procurement Contracts (no Grants).

To expedite award contracting, proposers are encouraged to have sub-award agreements in place ahead of award notification.

Anticipated number of awards:
- TA1: one or more
- TA2: multiple

Proposals may address any combination of TAs:
- Technical work and cost must be separable to enable partial selection.
MEETINGS AND REPORTING REQUIREMENTS

- Two Annual Principal Investigator (PI) Meetings
- Quarterly Technical Reviews between PI Meetings
- Monthly Progress Reports
  - Technical Report describing progress, resources expended and issues requiring Government attention, provided 10 days after the end of each month
- Financial/Technical Progress Reporting to the DARPA reporting system (Contracting Execution Reporting Services)
- Final Technical Report
- See BAA for full details

- Anticipate high frequency interactions with DARPA technical team

- Agent: AFRL/RIGB