YEAR 1 FUNDED PROPOSALS – FIRST INTERIM REPORTS
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Developing Noninvasive Sensors for Wireless Monitoring and Transmission of Physiological Status

Principal Investigator
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Primary NSRDEC Scientific Collaborators
Tad Brunyé
Program Type
Full
Funding period
6/1/2015 – 5/31/2016

Summary: The center for Applied Brain and Cognitive Sciences seeks to find paths to monitor and characterize cognitive and non-cognitive states (Topic B). The proposed approach hinges on the development of a skin mounted system sensing platform that will serve as a universal starting point to monitor physiological parameters. While we aim to leverage the large expertise existent at the nutrition school to validate a real-life scenario on markers of dietary anomalies through sweat monitoring, we will extend the approach to fatigue by adapting the platform to relevant markers such as lactic acid (in sweat) and look to extend to trace hormone detection in saliva. An electronic interface of this kind would provide continuous feedback on heath state of an individual under duress or intense physical activity allowing monitoring of the well-being of an individual/a troop. The overall objective of this proposal is to develop a platform for a surface-mounted, conformal RF antenna and an associated readout/data interpretation system that will be able to extract physiological information from bodily fluids such as sweat and saliva.

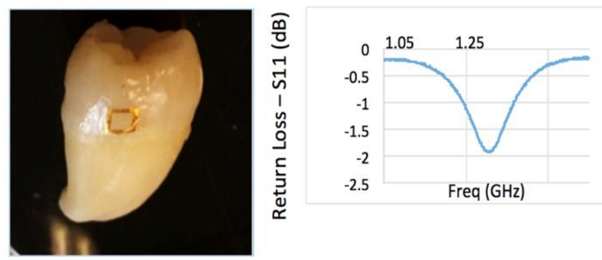

Figure 1. Broadside-coupled split-ring resonator affixed on a tooth and its measured RF response

Reported Progress: In the first period of investigation, we have started designing new formats of passive antennas that can serve as the RF transducers for monitoring. A small format antenna, the broadside coupled split ring resonator (BC-SRR), has been identified as a good sensor for passive RF sensor. This antenna allows for small size (~2mm), easily measureable low frequency resonances (~1GHz), and a strong electric field localized in the substrate between the antenna layers. This antenna has been fabricated on a flexible substrate to verify resonance of the antenna. Next steps include fabrication of high Q factor formats of this antenna using thick electroplated traces, and then fabrication on a silk substrate. Following fabrication of these high Q-factor antennas on silk, they will then be tested for sensitivity to the various sweat biomarkers and saliva biomarkers with the intended goal of using these antennas in the oral cavity. Additionally, we have started to validate principal component analysis by applying it to data sets collected at the time of the marathon running. The data had been collected during the Boston Marathon. Sweat patches composed of a commercial RFID and an absorbent cellulose pad were affixed to 10 marathon runners. Measurements of the patches using a portable network analyzer were taken before the race, at mile 10, and at the finish line. Principal component analysis performed on these measurements show separation of the measurement points, indicating relatively repeatable measurements that could, if training data were available, be used to measure hydration state of the runner. We plan to build on these results further throughout the year, by extending the data set and training the sensor for the detection of specific analytes in both skin-mounted formats and the tooth mounted format describe above.

Using Neuro-cognitive Multi-modal Techniques to Assess Mental Workload in Real-world Language Contexts

Principal Investigator
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Primary NSRDEC Scientific Collaborators
Marianna Eddy
Program Type
Full
Funding period
6/1/2015 – 5/31/2016

Summary: This proposal links directly to Topic B: Monitor, Characterize and Optimize Cognitive and Non-Cognitive States, by establishing and testing EEG/behavioral (i.e., multi-modal) measures of mental workload in ecologically valid cognitive paradigms. Much of the prior work using neuro-cognitive methods (most prominently ERPs) to assess mental workload have used artificial secondary task paradigms (typically the oddball task) and have measured the P300 component. Here we propose to use well worked out naturalistic language processing tasks, which more closely parallel real-world multi-tasking environments, along with multi-modal techniques (behavior and EEG/ERPs) to assess mental workload under varying demand scenarios. One long term goal of this research is use neuro-cognitive measures of naturalistic language processing to optimize language comprehension in demanding scenarios.

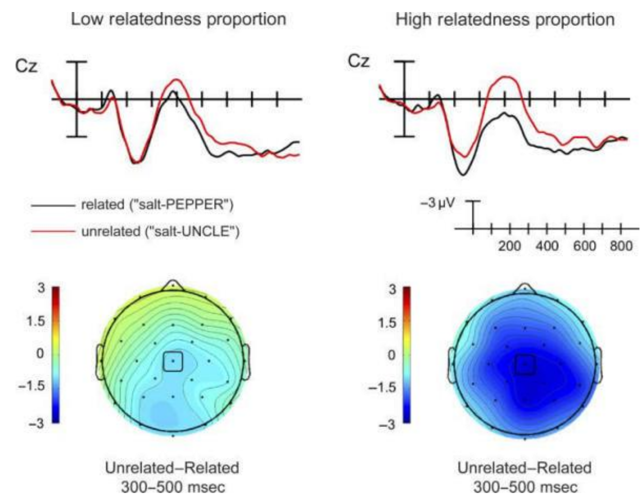

Figure 1. Waveforms and scalp distributions of a prototypical N400 response evoked during reading.

Reported Progress: Our project is making good progress. We have received IRB approval from Tufts and the Army and are currently preparing the first experiments for execution in the lab. The graduate student running the empirical studies is currently piloting the experiment (a simultaneous dual-task paradigm involving a video game portion and an auditory language comprehension portion) and should be running the first participants in the coming weeks. We are also working with Prof Scheutz and his grad student Andy Valenti on the modeling component of the project.

Neuromodulation of the Anterior Cingulate Cortex (ACC) via transcranial Direct Current Stimulation

Principal Investigator
Lisa Shin, Professor of Psychology
Primary NSRDEC Scientific Collaborators
Tad Brunyé
Program Type
Pilot
Funding period
6/1/2015 – 5/31/2016

Summary: Our research project is directly linked to Topic B of the Center's topics of interest. Our project will entail establishing and testing multi-modal measures (i.e., combined tDCS and EEG) and metrics for monitoring and characterizing relevant cognitive states (i.e, behavioral tasks assessing cognitive and emotional interference). Furthermore, our project will foster collaborations to advance the field of neuromodulation and cognitive neuroscience. The results from this pilot study will provide a novel basis of comparison between two popular neurostimulation techniques and inform us which technique, traditional tDCS or HD-tDCS, may allow for stimulation of medial regions of the brain. Furthermore, the behavioral tasks will provide a basis for understanding the relationship between brain stimulation and cognitive and emotional interference. The next step would be to take the knowledge from the pilot study to assess whether it is possible to facilitate or inhibit specific medial frontal brain regions (i.e., dorsal and rostral ACC) and to assess the effects on cognitive and emotional interference by using tDCS combined with precise brain coordinates and computational models.

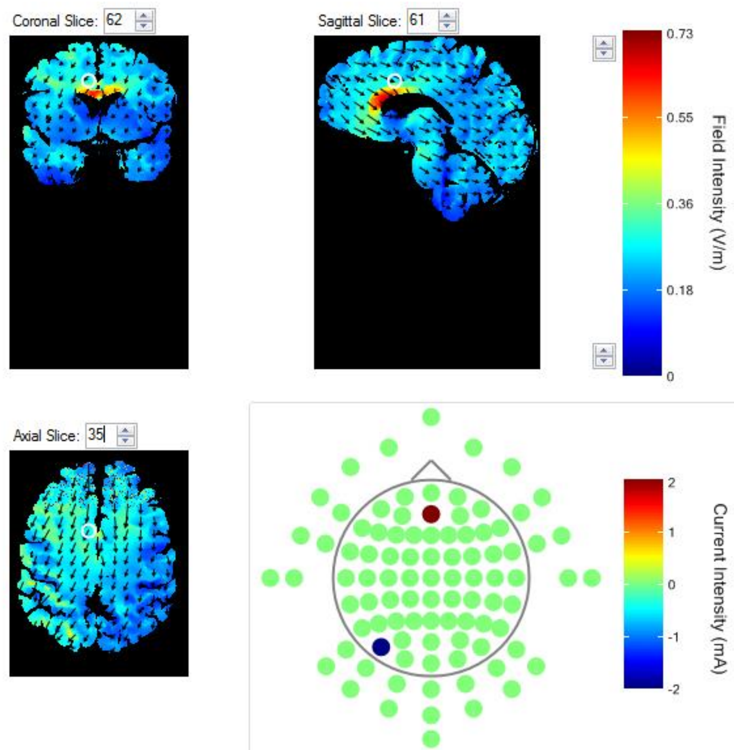

Figure 1. Predicted current propagation through dorsal and rostral ACC with bipolar tDCS.

Reported Progress: Approval for this protocol was granted by the Tufts IRB on August 10, 2015 and submitted for secondary Army review on the same day. The two behavioral tasks are finalized and are ready to use. Dr. Shin's lab has been equipped with tDCS equipment for testing and project staff have received refresher training with Dr. Brunye on setting up, maintaining, and running the equipment. Investigators have met with Dr. Brunye various times at the Center to create finalize specific electrode montages for use during high-definition and traditional tDCS via modeling software. We are waiting for Army approval to begin recruiting and running participants.

Measuring and Applying Cognitive Load

Principal Investigator
Holly Taylor, Professor of Psychology
Primary NSRDEC Scientific Collaborators
Joe Moran
Program Type
Full
Funding period
6/1/2016 – 5/31/2016

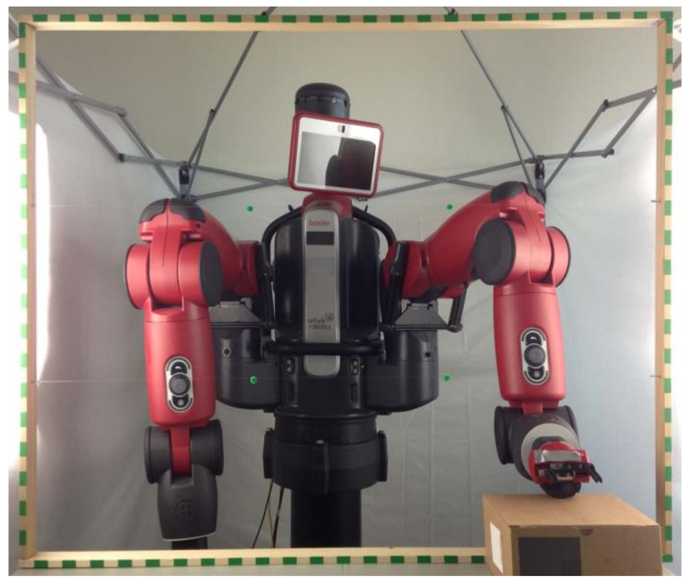

Figure 1. The robotic platform to be employed in Phase II of our

Summary: In our first Phase, most applicable to the Center's Topic B, we develop a technique for assessing multiple dimensions of cognitive load applicable to a wide range of situations. Using a mobile eye tracker, we will monitor performance through think aloud and eye movements. Co-registration provides insights into specific mental processes underlying cognitive load. The data will allow us to model the relationship between the ambient light and pupillary responses. We will obtain a clear signal of cognitive load that accounts for ambient light by developing a mathematical model to remove the noise related to the light reflex. Relying on a lightweight mobile eye tracker for data collection and accounting for environmental noise during data analysis will enable assessment of cognitive load in real life settings. This will expand the range of possible experimental paradigms from strictly controlled laboratory studies to naturalistic designs. In our second Phase, most applicable to the Center's Topic A, we use the pupillometric signal developed in Phase I as a real-time reflection of cognitive load within an interactive user interface. The interactive system uses an adaptive learning system recognizing patterns of cognitive load in supporting multitasking during a human-robot activity.

Reported Progress: We are in the process of modifying our existing Tufts IRB-approved protocol to encompass the full scope of this project. The project, previously funded by a Tufts Innovates award, had approval for a portion of the fully planned work. We should be submitting this modification to the Tufts IRB soon. With the previous Tufts funding, we can look at the data from the pilot work. This includes some of the participants from Phase 1. Data includes mobile eye tracking, pupillometry, verbal protocols, and questionnaire results. This data should inform specifics of moving forward.

Analyzing Users' Gaze and Mouse Interactions in Bayesian Reasoning Tasks

Principal Investigator
Remco Chang, Assistant Professor of Computer Science
Primary NSRDEC Scientific Collaborators
Tad Brunyé, Joe Moran
Program Type
Pilot
Funding period
6/1/2015 – 2/1/2016

Summary: In addition to establishing measures and characterizing risk decision making behaviors (Topic Area B), our long term goal is to develop an operational decision-making support tool (Topic Area A) to improve people's Bayesian reasoning skills in high-stakes situations. Specifically, if combining visual illustration with textual description leads to worse performance in reasoning tasks, what is a better strategy? Furthermore, could this strategy be generalized to both printed (static) information as well as dynamic (computer-based) interactive tools? Through the eye-tracking and mouse-tracking experiments, we will collect large-scale data that can be used to derive quantitative models that will lead to the development of usable and operational decision-making support tools.

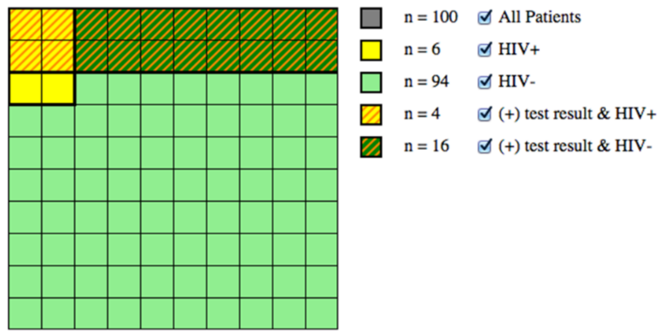

Figure 1. Design of the visualization to be used in the first-stage replication experiment.

Reported Progress: For the eye tracking portion of the project, as originally proposed, we have designed and developed an experiment for assessing how users reconcile text and visualization elements when they are presented together. We plan to conduct an in-person experiment where we will be recording participants' eye movements and gaze positions as they perform statistical problems. For this study we will focus on the interaction between text and visualization when they are presented together. To test this, we will have three conditions: 1) text only, 2) visualization only and 3) combined text and the visualization. Using an online experiment deployment tool, we have developed and have ran several test experiments. The procedure and material needed for this experiment have been completed. Early steps in a pilot study have been conducted. For the mouse interaction portion of the project, we are in the process of designing and developing an interactive visualization for communicating Bayesian reasoning. Following the experiment design of previous research, will be using a 10 by 10 interactive grid and users will be able to view or hide sets. Prior research has found that such grid has been effective for communicating Bayesian reasoning. For this portion of the project, our goal is to first extend and replicate the prior work by using online, crowdsourced participants. Then, we will collect and analyze mouse interaction data as participants interact with the visualization (see Figure 3). While much of the work is still in its design and development stage, our primary goal for the next phase of the project is to complete pilot testing.

Adding Interactivity to Brain Stimulation and Measurement

Principal Investigator
Robert Jacob, Professor of Computer Science
Primary NSRDEC Scientific Collaborators
Tad Brunyé
Project Type
Full
Funding period
6/1/2015 – 5/31/2016

Summary: This undertaking directly relates to Topic B of the center's objectives (Monitor, Characterize and Optimize Cognitive and Non-Cognitive States). Using functional near-infrared spectroscopy as input, we will explore the possibility of teaching machine learning software to automatically infer when a user is mentally taxed. We will dissect the learned patterns of the resulting machine learning algorithms for the purpose of better understanding the characteristics of cognitive workload, but our focus as computer scientists and human-computer interaction researchers will be exploring the engineering aspects of evaluating workload from a filtered fNIRS signal in terms of a minimal set of readily extractable features that can power a machine learning algorithm in real-time. Furthermore, we will explore the nature and time-course of interactions between monitoring, metrics development, and the delivery of optimization strategies such as low-current brain stimulation.

Figure 1. Customized functional near-infrared spectroscopy lights and sensors being positioned over the frontal cortex.

Reported Progress: In the first reporting period, we have been learning more about transcranial direct-current stimulation (tDCS), particularly with respect to the novel way in which we propose to use it. For this project, we are particularly interested in looking for short-term effects from the stimulation, but this has not been the focus of most past work in the literature. In consultation with CABCS personnel we have developed a more detailed plan for the experiments we will conduct, in a logical sequence beginning with non-interactive tests and leading to the interactive system we ultimately seek. We have secured the loan of a tDCS unit for our lab from CABCS and begun informal tests with it. We are also investigating how to mount the tDCS electrodes and fNIRS optodes as near as possible to each other without interference. Over the next few months we aim to begin pilot data collection.

Stereotype Threat and Performance of Mixed-gender Groups on Spatial Reasoning Tasks

Principal Investigator
Jessica Remedios, Assistant Professor of Psychology
Primary NSRDEC Scientific Collaborators
Joe Moran
Program Type:
Full
Funding period:
6/1/2015 – 5/31/2016

Summary: As the Army explores mixed-gender units across operational specializations, the proposed research will examine whether groups as a whole underperform on spatial reasoning tasks when female group members constitute the gender minority. Anecdotes about personal experiences with stereotypes can inform this discussion, but scientific investigations are necessary to provide empirically-vetted strategies for promoting optimal group decision making. Performance in male-majority groups may be impeded (relative to gender-equal and female-majority groups) because women in male-majority groups are expected to contribute fewer and less optimal solutions to spatial problems. In such situations, women may be distracted by stereotypes that others may use to judge their performance. This work links to the objectives of the Center for Applied Brain and Cognitive Sciences (CABCS) because it aims to understand social factors involved in translating optimal individual performance into real-world, team-based contexts (Topic D). Specifically, the findings from this work may contribute to policy designed to address the challenges of gender diversity in groups in order to harness the many benefits of greater gender diversity in the Army.

Figure 1. Mixed gender small unit infantry members training for deployment.

Reported Progress: To date, we have progressed toward our program objectives in several ways. We have prepared for submission the human subjects protocol describing our research for approval by the Tufts IRB. We expect to submit this within the month of October 2015. Samantha Snyder, a PhD student, was instrumental in preparing this protocol. She was funded by this grant during the previous summer semester and will receive funding to support her role on this project throughout the academic year. A part-time research assistant not yet hired will begin preparing the research protocols for pilot data collection and developing a plan for participant recruitment.

A Pilot Study of the Influence of Different Urban Environments on Mental States

Principal Investigator
Justin Hollander, Associate Professor of Urban and Environmental Policy and Planning
Primary NSRDEC Scientific Collaborators
Tad Brunyé, Marianna Eddy
Program Type
Pilot
Funding period
6/1/2015 – 2/1/2016

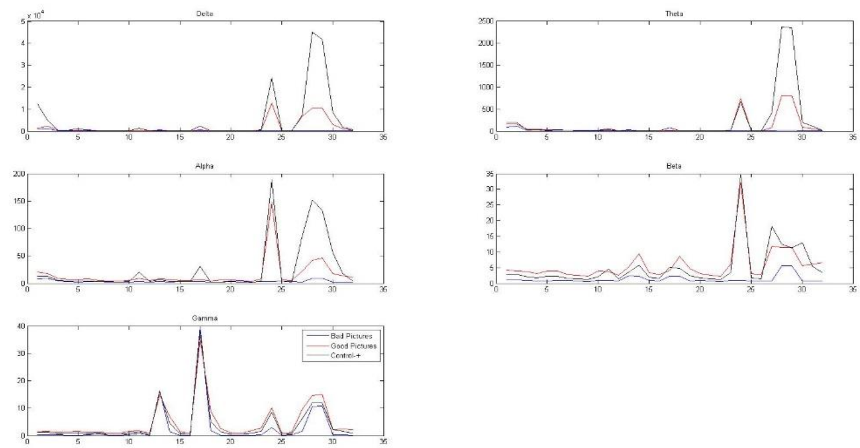

Figure 1. EEG activity across five frequency bands collected while a pilot participant views images of urban environments with varied features.

Summary: Just as the Center's work is around monitoring, characterizing, and optimizing cognitive and non-cognitive states (Topic B), this project will use urban context to frame a series of research questions, including: How does urban context (weighting on four Cognitive Architecture principles) influence a soldier's mental states? Can we predict how certain urban contexts will influence them and their abilities to respond to sudden tasks? In these different contexts, how can we optimize soldier performance by inducing higher levels of attention and meditative state? This research can go far in helping to understand the influence of the built environment on mental states, developing techniques for monitoring these effects, predicting how these effects will influence emotion, cognition and behavior, and seeking to optimize the fit between an individual's task objectives and supporting mental states. There may be strategies for cueing particular emotional and cognitive states that can overcome potential performance decrements induced by environmental context.

Reported Progress: Over the summer, several meetings of the project team convened. A detailed modification to an existing IRB protocol reflecting the new research direction was successfully approved by the Tufts IRB on August 15th and is pending secondary Army review. In the meantime, the project team has ordered the bulk of the needed equipment and supplies. A new lab space has been secured in which to store all project equipment, material, and cleaning supplies, and to meet with research subjects to conduct the in-lab portion of the experiment. In September, the team conducted two testing sessions of the g.Nautilus portable EEG monitor with the assistance of CABCS staff. The project team is working closely with Center staff to get the g.Nautilus to work properly and will continue to test it pending Army approvals. In the event that the technical issues cannot be overcome expediently, the NeuroSky EEG monitor will be used to conduct the experiment.

Mobile sign and gesture recognition system for communication in impoverished environments

Principal Investigator
Ariel Goldberg, Assistant Professor of Psychology
Primary NSRDEC Scientific Collaborators
Tad Brunyé
Program Type
Pilot
Funding period
6/1/2015 – 2/1/2016

Figure 1. The MotionNode Accel, a triaxial accelerometer to track real-time acceleration data

Summary:
This project links to Topic A of the Center goals: Understanding Humans and Supporting Systems. The primary goal of this pilot project is to develop a wearable hardware/software system that can capture gestural data and make classifications from a set of 20 conventionalized gestures. The specific outcomes from this primary goal (apart from the actual system) will be to 1) document the steps necessary to develop the device and train the software, 2) describe the technical properties of the hardware and software (e.g., power consumption, spatial/temporal resolution, the types of recognition capabilities of various learning algorithms, etc.), and 3) provide a taxonomy of existing gestural systems and make recommendations for which hardware/software combinations would work best for each. A secondary goal is to provide experimental validation of the system's classification accuracy using human participants. This is given as a secondary goal in the case that the time necessary to develop the recognition system does not allow for recruiting participants.

Reported Progress: To date, all of the preparatory work for the project has been completed. Specifically, the primary hardware to be used in the project (2 kinds of Inertial Motion Units that capture 3D motion, stretch sensing strips to capture finger flexion) have been purchased and were delivered, the machine learning software that will be used to classify motion data as gestures has been identified and acquired and the team of undergraduates who will be working on the project has been assembled. Additionally, 17 conventionalized gestural systems spanning military, commercial, and civilian uses have been identified.