BUCKNELL UNIVERSITY

A PROPOSAL TO

PROGRAM FOR UNDERGRADUATE RESEARCH

Improving Computer-Mediated Decision-Making via Physiological Signals from Wearable Sensors

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A Project Description

A.1 Background

a. *Decision making and cognitive overload*
People tend to make bad decisions when they are under stress or heavy workload. According to *Thinking, Fast and Slow*, our thought process could be explained by two systems: "System 1" is fast and instinctive, and "System 2" is deliberate and logical. When performing complicated tasks that occupy the limited processing capability of "System 2", people tend to make decisions based on immediate affection instead of logic and cognition. This conflict of affect and cognition in decision-making is presented through a popular experiment involving a choice between chocolate cake and fruit salad (Shiv & Fedorikhin, 1999). When the experiment respondents were asked to memorize long numbers, their mind occupied, they tended to choose unhealthy chocolate cakes over the fruit salad.

In the real world, people face decisions more serious than choosing a desert. Bad decisions made in unsuitable cognitive conditions can have serious consequences. For instance, air-traffic controllers' tasks often entail high cognitive workload involving information processing and logic reasoning. In 2002, a controller, Peter Nielsen, was under heavy workload, and his mistake led to the Überlingen mid-air collision that claimed 71 lives.

b. *Technology has become a mediator for decision-making*
As technology becomes more integrated in people's lives, decisions are often taken in context of some kind of computer; decision-making has become an important aspect in Human-Computer Interaction (HCI) (Zhou, Sun, Chen, Wang, & Taib, 2015). Important mediators as they are, computers generally understand users poorly. By the mere means of keyboards or touch screens, much of the relational information present in social contexts is not perceived by computers. Studies have shown that interruption (by computers) at bad moments could make us stress out and perform worse (Carton & Aiello, 2009). Computers could do better in mediating decision-making by gaining a better understanding in users' state of mind.

c. *Wearable physiological sensor as solution*
Stress could manifest as many characteristic physical signals, such as electrodermal activities (EDA), heart-rate, skin temperature and pupil size. Some of these signals could now be acquired through a variety of burgeoning wearable sensors, such as wristbands and headbands. We could process those physiological signals to decide whether the user is in a stressed state or not. There are several advantages that make wearable sensors suitable for mediating decision-making (Peck, 2014):

(a) As opposed to traditional electroencephalography (EEG), wearable sensors are portable enough to be used in everyday environment, where decisions are made.
(b) Users can provide input to computers via wearable sensors, without interrupting their tasks and thought processes.
(c) Physiological signals provide computers with the previously unaccessible information that we naturally pick up through social cues.

A.2 This Project

Given that wearable sensors could inform computers of our state of mind, we propose to build an "attentive" computer system that could present us with decisions when we are best equipped to handle them. Two recent papers have made initial attempts to utilize physiological signals and tried to use biofeedback to promote better decision making (Carroll et al., 2013; Zhou et al., 2015).

Starting from a big concept, we will combine pre-existing technologies in an innovative way, described in A.3 Methods. As shown in Figure 1, this projects could be encapsulated as a bio-cybernetic loop. A senior design team is currently working on a program framework that could determine whether a user is stressed or not. This part of the system takes physiological signals as input and judges the state of mind of the user.

We will also work with people at Bucknell and beyond. For instance, Professor Joaquin Gomez-Minambres in Economics Department specializes in behavioral economics and decision-making, and has expressed interest in collaborating on this project. Professor Erin Solovey at Drexel University could provide insight into processing physiological data.

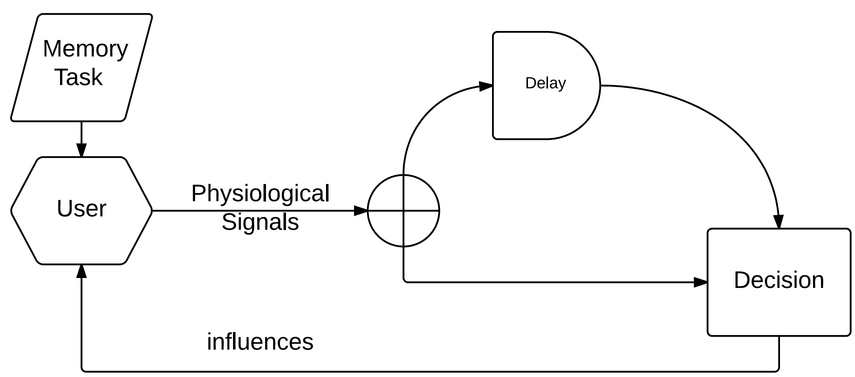

Figure 1: This project viewed as a biocybernetic loop.

A.3 Methods

A.3.1 Sensors

We will potentially use two wearable sensors to acquire physiological signals: *1*) Empatica E4: it is a wristband that contains a heart-rate sensor, 3-axis accelerometer, skin temperature + heat flux sensor, and electrodermal activity sensor. *2*) Muse (potentially): it is a miniature EEG in a headband.

A.3.2 Implementation

In order to assess the effectiveness of our system, we will create controlled stress level and decision-making process. Established psychology tasks will be used to manipulate stress level; examples include the n-back task or digit span. We will also incoporate decision-making questions that have been validated by the psychology community.

We will conduct within-subjects experiments, meaning the same group of participants will be presented with two different decision-making systems:

1. One that deliver decisions immediately, while the participant is still under stress.
2. One that deliver decisions at “good moments”, a judgment made based on the participant’s physiological signals. If the user is stressed, decisions will not be presented immediately.

A.3.3 Time Line

- Weeks 1-4: Construct experimental platform and validate of physiological measures.
- Weeks 5-6: Perform pilot study and review experimental procedures.
- Weeks 7-8: Conduct decision-making experiment with participants.
- Weeks 9-10: Analyze data and compile a research paper.

A.4 Anticipated Outcome

We expect to: *1*) assess how well we can predict a good or bad decision based purely on physiological signals; *2*) evaluate whether we can improve decision making by choosing more opportune moments to deliver decisions; *3*) write a research paper and *4*) submit for ACM Conference on Human Factors in Computing Systems (CHI) 2016. CHI is the most prestigious venue in HCI.

B Research Environment

I will work closely with Professor Peck throughout the research period. Professor Peck will be present and available over the summer, and there will be daily discussions and weekly summarizations. We will collaborate on multiple levels, from generating new ideas to coding. Because of the digital nature of this project, Professor Peck has planned on a practical project management system that includes GitLab, Google Drive, Slack and Trello. This research will be conducted in Dana or Breakiron labs.

References

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