Brain, Body and Bytes: Psychophysiological User Interaction

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Abstract
The human brain and body are prolific signal generators. Recent technologies and computing techniques allow us to measure, process and interpret these signals. We can now infer such things as cognitive and emotional states to create adaptive interactive systems and to gain an understanding of user experience. This workshop brings together researchers from the formerly separated communities of physiological computing (PC), and brain-computer interfaces (BCI) to discuss psychophysiological computing. We set out to identify key research challenges, potential global synergies, and emerging technological contributions.

Keywords
Brain-computer interfaces, physiological computing, psychophysiological signals, affective computing

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies; B.4.2 Input/Output Devices: Channels and controllers;

General Keywords
Experimentation, Human Factors, Measurement

Introduction
It is an exciting time for the emerging field of psychophysiological computing: with blooming research

activity encompassing the collection and analysis of data obtained from physiological signals (such as electromyography) or with neuro-imaging techniques (such as functional near-infrared imaging), we obtain new input sources providing additional information about the user's mental and emotional state. Such signals can be used to gain a deeper understanding of user experience, and to create adaptive interactive systems. They can enhance and enrich the overall interactive experience, be it in a functional, entertainment, therapeutic or other context.

Traditionally explored from a neuroscience, a medical or a biomedical engineering point of view, physiological and neurological signals have already been introduced to the HCI community, and many HCI research challenges emerge from this new source of information. Minnery and Fine point out in a recent *interactions* article that "only a small percentage of current neuroscience research is explicitly aimed at understanding aspects of HCI" [3]. Therefore, psychophysiological research in HCI needs to be coordinated to effectively tackle research questions inherent to the field of HCI. Only by the efforts of such a task force can we identify key research challenges, possible global synergies, and emerging technological contributions.

Psychophysiological computing [6] emerges from the communities of Physiological Computing (PC) [2], and Brain-Computer Interfaces (BCI) [7]. While these two communities share similar methodologies, application areas, interests and viewpoints, they have been formerly separated. The necessity of tackling emerging user experience issues by harnessing the power of new psychophysiological technologies is a call to action for uniting these fields to establish a common ground that psychophysiological HCI research can prosper upon.

This disconnect could be attributed to the relatively young age of these research fields, which have been growing up under different conditions. "Classical" BCI researchers focused on getting as many bits and bytes as possible out of the head to permit physically disabled individuals to intentionally control devices and communicate with the world around them, while HCI researchers, mainly doing PC, have been interested in providing value to the healthy consumer by passively sensing user state and adapting human-computer interaction systems.

These new inputs can be applied to many types of applications, users and contexts. While the common BCI is designed to assist disabled patients (for whom brain input is a viable alternative to otherwise unavailable inputs), there is a growing research interest to use psychophysiological signals for healthy users. Applications designed to use such signals as input also show variety. For instance, interfaces can be controlled directly by the user's psychophysiological signal, or they can take a signal as an additional source of input, reacting in a passive manner, the former being traditionally done with BCI, and the latter with PC. We also mention the use of psychophysiological signals to evaluate user experience as a non-invasive, real-time objective measure.

We therefore identify three basic areas that would benefit from cross-pollination: (1) direct (and natural) input mechanisms, (2) evaluation, and (3) adaptive interfaces. We think the largest untapped opportunities are in adaptation for healthy users and that it is also

the most difficult set of challenges, because it requires tight interaction between various fields. It would also be interesting to consider multidimensional or multimodal monitoring of a user's cognitive and emotional states through psychophysiological computing.

Workshop Goals

This workshop will bring together researchers interested in psychophysiological computing. The main goals of the workshop are:

1. Provide a platform for creating synergies between two related and emerging HCI disciplines (PC and BCI).
2. Kick-start psychophysiological research in HCI by identifying key research questions and application areas
3. Enhancing HCI methodologies by adding these new methods and techniques to the toolbox of HCI researchers

We identified research questions relevant to both communities, listed below. To answer them, we are inviting researchers to submit position papers that describe how HCI researchers can leverage brain and body signals. The researchers do not need to have measured such signals at this time, but should provide background indicating the possibility of measuring the signal, and using it in a real interface, user experience evaluation or HCI setting with appropriate literature. The goal is to propose ways how software or technology can adapt to provide enhanced user experiences for humans. Proposed adaptive interfaces should to take into account the constraints of the measurement, and of the analysis (i.e. if signal measured with functional near-infrared spectroscopy, the adaptation needs to consider the slowness of the signal measured).

Workshop Questions

- What is psychophysiological computing good for? How can we think systematically about this space?
- What are the major themes of HCI that can be explored using PC and BCI?
- What specific psychophysiological sensing modalities are interesting and how can we use them? What are most innovative technologies in this space? How do these compare with existing practices (NASA-TLX, Likert-style questionnaires, etc)?
- How can BCI and PC be defined within an HCI context? How is a HCI context different from neuropsychology, biomedicine or biomedical engineering? How does HCI contribute to psychophysiological computing (or more specifically neural engineering, bio-engineering, etc)?
- If we could measure anything on brain and body, what would we want to measure and why? What cognitive states and emotions have been investigated with sensors? What methodologies are best for what signals?
- How can accurate physiological, psychological and neurophysiological measurements improve HCI?
- With what software techniques and hardware technologies could these signals be optimally processed? How can software account for the combination of user actions taken to accomplish a

task versus actions that would surprise the user, yet optimize their experience?

- What are the issues that must be considered when using psychophysiological computing for direct control, passive sensing, adaptation, etc?

Participants and Expected Community Interest

There is much overlap in both the methods used and challenges faced in the fields of physiological computing and brain-computer interfaces in relation to HCI and user experience. They involve collecting noisy data from various sensors on or around the user, as well as analyzing and interpreting this data. In addition, researchers in both fields must determine the appropriate use of this complex data for evaluation or adaptation of software, user interfaces, or interaction technologies. However, to date, these two topics have mostly been investigated separately. This workshop will bring together researchers from both communities. We also extend the invitation to researchers interested in discussing how psychophysiological signals can be used to evaluate, augment or adapt interfaces.

A number of workshops were held in recent years on topics relevant to sub groups of this emerging community: Allanson and Wilson [1] discussed physiological computing in 2002, while Nijholt and Tan's workshops [4, 5] looked at brain-computer interfaces for games in 2007 and 2008. These workshops show individual community interest. We believe it is time to connect researchers from these areas in order to identify key challenges facing this new community, to jointly develop new approaches aimed at solving them and consider future spaces for psychophysiological research.

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