Introduction to the Special Issue on Physiological Computing for Human-Computer Interaction

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Physiological data in its different dimensions—bioelectrical, biomechanical, biochemical, or biophysical—and collected through existing sensors or specialized biomedical devices, image capture, or other sources is pushing the boundaries of physiological computing for human-computer interaction (HCI). Although physiological computing shows the potential to enhance the way in which people interact with digital content, systems remain challenging to design and build. The aim of this special issue is to present outstanding work related to use of physiological data in HCI, setting additional bases for next-generation computer interfaces and interaction experiences. Topics covered in this issue include methods and methodologies, human factors, the use of devices, and applications for supporting the development of emerging interfaces.

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1. INTRODUCTION

In the past decade, new classes of applications for human-computer interaction (HCI) mediated by physiological data (or biosignals) have emerged [Fairclough 2009], alongside novel devices that enable a more mundane use of input modalities that would otherwise be circumscribed to medical scenarios [Silva et al. 2014]. In parallel with the proliferation of such devices, new interaction styles have been explored. Among these new styles are augmentative communication [Helal et al. 2008], affective interfaces [Sano and Picard 2013; Petta et al. 2011], silent speech [Denby et al. 2010], air-writing [Amma and Schultz 2013] and gesture-based interaction [Saponas et al. 2008], human enhancement using exoskeletons [Herr 2009], brain computer interfaces (BCI), and non-BCI interfaces such as electrocardiography (ECG), electromyography (EMG), electro-oculography, galvanic skin response (GSR), force, accelerometry, and eye gaze, among many others.

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As a result of this increasing diversity of devices and interaction styles, researchers exploring next-generation interfaces mediated by physiological computing experience difficulties associated with the lack of appropriate algorithms and methods for interaction design, the need to understand the applicability of different modalities to the design of HCI interfaces, and the integration of novel hardware. As part of the research effort to address these difficulties, the concept of HCI mediated by physiological computing, which has its foundations in computer science, biomedical engineering, and psychophysiology, is emerging as a promising approach. Physiological computing allows HCI researchers to specify and design novel interfaces supported by biosignal acquisition devices and algorithms at different levels of the design process.

Several physiological computing interfaces have been developed in recent years, mostly within the BCI community [Graimann et al. 2011] and which are starting to get limited use outside of the laboratory. However, many questions regarding the usefulness and effectiveness of physiologically driven user interfaces remain open, especially as novel applications beyond BCIs emerge. This special issue presents a diversity of outstanding research and development from those working in the creation of novel interaction methods, adaptable interfaces, algorithms, and tools through the study, planning, and design of interfaces between people and computers supported by biosignal data.

2. ENHANCING THE USER EXPERIENCE

An interesting use of physiological computing explored in this issue is the augmentation of the HCI experience, by providing or presenting information in ways that would otherwise be unavailable to the user. Decision making is a compelling example of how information extracted from biosignals can enhance the user experience. Zhou et al. present a work that uses GSR and pupillary analysis to design intelligent interfaces with performance indicators derived from biosignal data. Using such a system, users can better perceive the quality of their decisions in real time, as well as the difficulty level associated with the decision.

Knowledge about physiological limitations of the users is an important design factor when seeking to enhance the user experience during HCI. Color blindness, for instance, is a condition that affects millions of people worldwide, characterized by the inability of impaired users to distinguish certain colors. As shown by Chua et al., existing digital aids that work by substituting colors or applying visual patterns for information augmentation have a set of practical limitations. In this issue, the authors present a work that integrates and builds on what is known about the binocular luster effect to create unobtrusive visualization overlays prone to be used as more effective HCI aids for the colorblind users.

3. DESIGNING PHYSIOLOGICALLY DRIVEN INTERFACES

Biosignal analysis can also play a major role in informing the design of HCI interfaces, particularly by providing objective data that one can use to assess how different options compare with respect to ergonomics, fatigue, workload, and other factors. Bachynskyi et al. bring us their experience in the summarization of biomechanical and task performance data as a tool for user interface designers. The work reports a spatial pointing task where users were requested to cover the full reachable space of the arm, targeting the application to in-air and large-scale interface design. Biomechanical data, collected by means of optical motion tracking devices, is used to examine muscle load and user performance indicators.

Besides the perspective of using biosignals to validate interface options during the design stage, HCI systems can also benefit from incorporating physiological data related to the state of the users at a given point in time for the purpose of continuous adaptation. This has a set of guidelines and practical considerations that need to be taken into account, as described in the work by Solovey et al., which provides an overview and discussion specific to the design of adaptable interfaces that have biosignals as an implicit input channel. The authors share their results on the use of functional near-infrared spectroscopy (fNIRS) as a BCI to better support the user during the interaction.

4. HUMAN-COMPUTER INTERACTION MEDIATED BY BIOSIGNALS

Historically, HCI mediated by biosignals is perhaps the most classical and widely known use of biosignals in the field of HCI, where state-of-the-art work has been mostly focusing on capturing minutiae from the data. In this issue, Caramiaux et al. address the problem of understanding gesture expressivity from muscle signals. Gestures alone are already interesting for HCI due to their role in nonverbal communication. However, complementing the standard information with measures of expressivity has the potential to add yet another layer that can contribute to richer interaction experiences. The authors use EMG and mechanomyography (MMG) data as input modalities for their work.

On a different dimension, Karran et al. present a framework that uses multimodal biosignal data, namely heart rate (HR), electroencephalography (EEG), and GSR, as a part of a biocybernetic loop designed to adapt content delivery to visitors during a cultural heritage experience. The authors develop a psychophysiological construct of interest inferred from the data with the purpose of sustaining visitor interest. Experimental results point toward the feasibility of delivering personalized contents in real-time through the perceived manifestations of interest derived from selected biosignal features.

5. CONCLUDING REMARKS

Physiological data has been extensively used in the medical domain for centuries. Ever since 1887, with the first practical implementation of what is known today as ECG [Besterman and Creese 1979], the application of computer science and engineering principles to the field has proven to be of paramount importance, leading to remarkable technical, methodological, and scientific achievements. Today, biosignals are a popular topic within the global research community, and potential applications extend beyond medical arena, paving the way for the emerging field of physiological computing.

This special issue was encouraged by the fact that interface between physiological computing and HCI is attracting an interdisciplinary and growing research community. The study and development of interactive software and hardware systems capable of sensing, processing, reacting, and interfacing the digital and physiological worlds drives interesting and challenging opportunities for HCI researchers.

We have included several examples in this special issue that show how much the field has progressed, as well as the topical nature of this matter, although many questions remain open for future work. What information can be extracted from each modality and used for HCI? How can the systems be easy to use and a part of the user's daily life? How should the usefulness and effectiveness of physiological interfaces be evaluated? What physiological computing approaches will result in practical and powerful interfaces for real-world deployment? How will the collaboration between HCI and physiological researchers affect the architectural framework of the next generation of interfaces?

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