Moving from brain-computer interfaces to personal cognitive informatics

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SIG: Moving from Brain-Computer Interfaces to Personal Cognitive Informatics

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ABSTRACT

Consumer neurotechnology is arriving en masse, even while algorithms for user state estimation are being actively defined and developed. Indeed, many consumable wearables are now available that try to estimate cognitive changes from wrist data or body movement. But does this data help people? It's a critical time to ask how users could be informed by wearable neurotechnology, in a way that would be relevant to their needs and serve their personal well-being. The aim of this SIG is to bring together the key HCI communities needed to address this: personal informatics, digital health and wellbeing, neuroergonomics, and neuroethics.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**; *Ubiquitous and mobile computing theory, concepts and paradigms.*

KEYWORDS

neurotechnology, personal informatics, digital health, wellbeing, work-life balance

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1 INTRODUCTION

Rapid progress in wearable neurotechnology and activity tracking means that our cognitive activity will soon be monitored, quantified, analyzed, and interpreted, similar to how wearables already cater to 'improving' our physical health. Currently, research that seeks to classify cognitive activity from both on-body [1] and off-body technology [8] is, arguably, as mature as physical activity tracking was in the 2000s [9]. Meanwhile, the average consumer can *already* buy dedicated "brain-monitoring" devices that claims to support cognitive well-being (e.g., meditation exercises[1], work focus[2]). Similarly, other wearable technology claims to estimate our stress by tracking our breathing [3], via wristbands that learn "to recognize your emotional patterns"[4] or watches that recommend physiological regulatory activities (e.g., rhythmic breathing exercises) for well-being [5], and devices that measure our sleep and estimate our mental readiness for the day ahead[6].

The Research Gap and Open HCI Questions. Being able to track cognitive activity does not mean that we understand what it means for personal cognitive informatics. What is the goal for tracking cognitive activity? Is it always to lower stress? Is it always to increase mental workload without overburdening our mental capacity? What is the ideal pattern of stress or mental workload that an individual ought to target every day? What will these devices show exactly, to appropriately communicate that we are exhibiting an unhealthy cognitive lifestyle? How will we reach better work/life balance by taking these measures about ourselves? What is a good amount of mental activity for a cognitively sedentary older adult? Can this kind of brain data as personal data tell us about education and learning?

[1] Muse Headband
[2] Neurosity Headset
[3] Spire Stone - discontinued in 2019
[4] Feel Wristband
[5] Apple Watch Breathing Exercises
[6] Oura Ring - readiness score

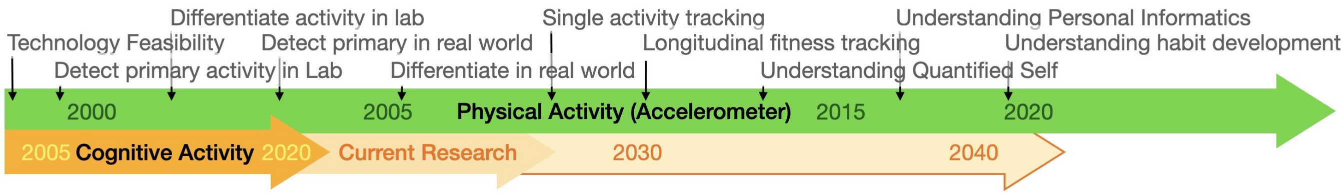

Figure 1: A proposed comparison of where cognitive activity tracking is compared to physical activity tracking

These are not questions about the classification accuracy of cognitive activity, which will move (as physical activity data did) towards being primarily a machine learning challenge. Instead, these questions are more about the interaction with and the design of these devices [16, 27], understanding the meaningful forms of personal data that will come from them, and understanding healthy life patterns in terms of the kind of brain data as personal data that we will soon have within our hands [16]. Quite separate to classifying state, we do not know what meaningful measure of activity will be useful for people, such as a 'step', and e.g. what the cognitive equivalent is of reaching 10,000 steps per day. How we come to define good patterns of cognitive activity will have far-reaching implications for implementation, in terms of how we would monitor, quantify, analyze, and interpret it. Beginning to address these open HCI questions requires the involvement of researchers beyond Brain-Computer Interfaces (BCIs), such as experts in neuroinformatics, the future of work, digital health and wellbeing, and ethics and trust.

The Right Time. A key challenge for HCI research is for individuals, society, and technology to be at the right stage to understand and answer research questions. While physiological computing has been maturing, the arrival of consumer neurotechnology creates both opportunity and a pressing demand to study how such technologies should be designed and how they will help people. Prior to the arrival of consumer neurotechnology, participants have only been able to speculate about what they think about the benefits [16, 27] and risks [15] associated with them. Now, we have the opportunity to study people that can experience neurotechnology in their own work and personal lives. Further, given a) that we do not know what benefits neurotechnology might bring, or indeed what the goals are, and b) that they are arriving before we have a clear understanding of privacy, trust, legal, and ethical concerns of how they may be [mis]used in the workplace or by 3rd parties that get access to the data, the arrival of such devices adds urgency to the study of the open questions.

2 RELATED FIELDS

Physiological I/O and Psychology. The community that is most familiar with this kind of technology is the one looking at how physiological data is being used for input and indeed output in physiological computing [13]. These involve studies that try to classify cognitive states from a range of physiological data [1, 8], and research that builds systems to either track and respond to physiological data [21], or indeed use them for direct input[7]. When applied to the brain, these are often based upon cognitive science assumptions, and involve researchers from psychology and neuroscience. These cognitive and neuroscience perspectives are critical for the discussion of personal cognitive informatics, because they ground what we understand happens in the brain, and what is practical or desirable to actually measure to make inferences.

Personal Informatics and Digital Health. The major change, as we move on from classification accuracy of various states, is to focus on personal informatics [12, 22]. Personal informatics "is a class of tools that help people collect personally relevant information for the purpose of self-reflection and self-monitoring"[8]. Research into personal informatics has developed considerably in the last 10 years to focus on lived informatics [4, 23] and habit formation [25]. As with examples of prior work on e.g. menstrual tracking [3], a key challenge for the future of personal cognitive informatics is bringing in this expertise and prior knowledge at its early stages. In terms of actual improvements on digital health and wellbeing, work has shown that understanding how all these different forms of personal informatics relate to each other, across our devices, is critial [11], and the importance of using such health data to stay active in contrast to how we work [18] was only exaggerated during the covid-19 panedemic.

Neuroergonomics and The Future of Work. Most forms of work are moving towards more cognitive, rather than physical, effort [24] due to increased use of automation, and a key expectation is that managing a more cognitive future of work means better understanding of our daily mental workload and better strategies for managing stress [17]. Some core work in HCI has looked at how people's stress, for example, varies from day to day according to their work tasks [14]. Fleck et al. also showed how the integration of work devices in the home needs to be managed for a good work-life balance [7]. We consider this understanding of healthy lifestyles, and good work/life balance, to be a critical view on the future of personal cognitive informatics, and needs to be better informed by our understanding of healthy cognitive activity. Epstein, for example, showed the value of taking regular breaks in work to increase productivity [2]. As a companion to these HCI studies of work and health, Neuroergonomics is a field focused on understanding the cognitive factors of work, including safety critical work[20], and neuroadaptive technologies [19]. Fairclough and Lotte present three grand challenges for neuroergonomics [5], where the second is the user experience with neurotechnologies at work and at home, and the third is a whole-systems approach to understanding the role that neurotechnologies will play at work and in society, including legal and ethical issues.

[7] A real brain-computer interface mod for Skyrim VR!

[8] Personal Informatics

NeuroEthics and Trust. The neuroethics field concerns the ethical, legal, and social challenges that emerge through developments in neuroscience [6]. It is imperative to consider the ethical dimensions that accompany the development of the neurotechnology market as it grows in quality, quantity and investment [10]. There is a fairly substantial neuroethics community (including the IEEE Brain NeuroEthics committee) that few SIGCHI members have engaged with, but who producing guidance on the ethical considerations of neurotechnology. Research in this area has focused on aspects of privacy, trust in the data validity, and self identity [10, 26]. Further, the market remains largely unregulated outside of medical neurotechnology used in research or medical settings [9]. We believe its a critical development for this area, that HCI researchers interested in trust, law, and ethics get involved with neuroethics, and hope that this SIG and associated emerging community is a way to foster this engagement with the broader neuroethics community.

3 AIMS OF THE SIG

The aim of this SIG is start a new community, bringing together the right groups of researchers to be able to address the problem in the right way. In doing so, we hope to build on the adhoc conversations of well meaning ideas, towards a serious push towards understanding and addressing the open research questions. Together, we hope to understand the size of the group that are interested in these questions, and to set out a initial view for how we should move forward. In summary, the aims are: 1) to identify the size of this new community, 2) to collectively identify explicate the RQs/Topics, 3) to establish a research agenda and 4) to plan upcoming events and other actions.

To achieve these aims, the SIG will identify interested members of the community prior to the conference, allowing the main session at the conference to focus on community building and planning. We aim to set an agenda that is well informed by different communities, and a follow-up plan that promotes ways of bringing this group back together, including future workshops and special issues focusing on the topic.

4 ABOUT THE ORGANISERS

Max L. Wilson. is an associate professor in the MRL at Nottingham, focused on evaluating the mental workload involved in completing work tasks and created by differences in user interfaces, using fNIRS. Max has also worked on brain-controlled movies that have toured around the world, using consumer brain devices. Max is also a member of the IEEE Brain NeuroEthics Committee.

Serena Midha. is a final year PhD student, focused on the measurement of brain data in everyday work and everyday life. Serena has a background in Psychology and Neuroimaging, and uses mixed methods in HCI to evaluate physiological data associated with work tasks, and qualitative data about people's everyday experiences of mental workload.

Horia A. Maior. is an assistant professor in HCI with the School of Computer Science and the Horizon Digital Economy Institute at the University of Nottingham, with a focus on Mental Workload as Personal data, and the wider use of brain and physiological data in trustworthy autonomous systems, manufacturing, and other industry environments.

Anna Cox. is a professor of HCI in UCL Interaction Centre, in the Division of Psychology and Language Sciences. Anna's research focuses on understanding the relationships between the design of information and communications technologies (ICTs) and behavioural outcomes, and leveraging these relationships in the design of novel interfaces and systems to support people in work.

Lewis Chuang. is a professor for "Humans & Technology" at TU Chemnitz. He holds a doctorate in behavioral neuroscience and employs task analyses, physiological monitoring, psychophysics, and applied computational modelling to understand how we interact with digital technologies and automation.

Lachlan Urquhart. is a lecturer in Technology Law at the University of Edinburgh. He is an interdisciplinary researcher with an LL.B/LL.M in law, and a PhD in computer science. He works on the boundaries of law, computing, and ethics, focusing extensively on the technical, sociological, and interactional implications of living with interactive computing.

[9] IBC neurotechnology report

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