Position Paper: Brain Teasers – Toward Wearable Computing that Engages Our Mind

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Abstract
The emerging field of cognitive activity recognition – real life tracking of mental states – can give us new possibilities to enhance our minds.

In this paper, we outline the use of wearable computing to engage the user's mind. We argue that the more personal technology becomes the more it should also adopt to the user's long term goals improving mental fitness. We present a the concept of computing to engage our minds, discuss some enabling technologies as well as challenges and opportunities.

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Intelligence Amplification, Wearable Computing, Mind, Cognitive Activity Recognition

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
So far we are mostly augmenting our minds, externalizing it on documents, schedules, to-do lists, calendars etc. The speed this happens increased with the advent of the personal, pervasive and wearable computing.

Offloading appointments, birthdays, thoughts etc. gives us the ability to free our mind and to focus on other more abstract ideas. Yet, it also created an attention economy, in which it can be increasingly hard to focus and remember things without our analog or electronic tools.We get more and more dependent on technology. There are even some researchers arguing that we will lose the ability to remember and critical think [6].

Leveraging the advances in cognitive science, psychology and neuroscience we should be able to track attention, focus, engagement and other brain activities in realistic environments. We can use these cognitive logs to improve our cognitive skills while performing a task. In this paper, we discuss how it can be possible to design interactions with computing is such a way that it supports, yet also gives us a certain autonomy and challenge: Computing to engage our Minds.

We believe that tracking cognitive activities and assessing cognitive load, attention, fatigue etc. can help us build computing systems that on the one hand support us during everyday life on the other hand enhance our intellect.

In the following we describe the concept of "wearable computing that engages our minds", go into some details about the enabling technologies and finally discuss some challenges we see.

Concept

Instead of just focusing on ease of use and pro-active computing (e.g. inferring what the user wants without direct interaction), we could also incorporate concepts and tools for cognitive self-improvement. There are already ample of applications that try to improve your mental skills, the process is usually named "brain jogging". However, as studies show these games have limited effect to real world brain performance.

We propose that the user improves her cognitive skills actively while being supported by a pervasive computing system. The system in turn regulates the difficulty and task granularity based on the mental state of the user and her goals.

For example take Naomi, she wants to improve her spatial and navigation skills for a trip to the Amazon. She's currently in Zurich and wants to visit a friend using a navigation application on her wearable system. As she still has around 2 hours time before the meeting, the wearable navigation system could make her trip harder by giving her just visual landmarks to navigate by in turn training her navigation skills.

As another example take Jim, who has first stages of age related dementia. He has a hard time remembering what he did over last weeks. He's wearing a life logging system and his pervasive home system picks the most memorable pictures from the last weeks and displays them on the digital picture frames in the house at a time when his mental state suggests he's active and able to process the information.

As we understand learning better in real life environments, this can lead to a new way of teaching and change education as we know it. We believe that the concept of "Engaged Computing" is not only beneficial in educational setting but also for a lot of other tasks we perform during our life. Cognitive activity recognition promises to detect the current mental capacity of the user. Imagine, keeping a car driver or pilot healthily engaged with their vehicle so they can control it better in case of an emergency.

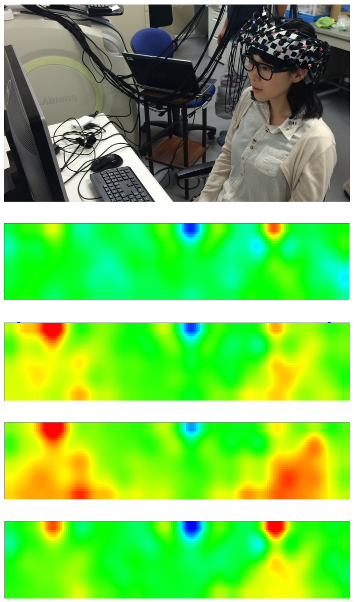

Figure 1: Experimental Setup of the LabNIRS device from Shimadzu and the brain activity of one participant for the n-back task with increasing difficulty. As seen from the heat maps, the last most difficult task shows less brain activation.

Enabling Technologies

Cognitive Activity Recognition

If we can quantify attention, focus, engagement, concentration and similar mental states, we can track cognitive progress/decline and build systems that can improve our mental abilities. Therefore, cognitive activity recognition is crucial [3, 4].

For example, near-infrared spectroscopy (NIRS) can measure the blood hemoglobin concentrations and give information about brain activity. We use the device to get the ground truth for the cognitive load of the user coupled with other sensing modalities (e.g. head motion, eye tracking).

In Figure 1, we see the experimental setup, a user wearing a near-infrared spectroscopy (NIRS) device (42 channels). We depict also the brain activity in the prefrontal cortex of a participant doing a memory game (dual n-back) with an increasing difficulty. As seen from Figure 1, the brain activity increases steadily from easy to hard. Yet, for the last, hardest case we have a drop in brain activity (dual n-back, n=4). The user is overexerted in this case and cannot cope with the problem anymore, leading to a reduced oxygen level in the brain.

Therefore, a system trying to improve the user's memory should adjust the difficulty to n=3 to engage the user's mind optimally.

As brain imaging techniques, eye trackers and other cognitive task tracking devices are still expensive. We need to focus on alternative technologies that are already commercially available or can be easily integrated into consumer devices, to enable cognitive task tracking. One way to approach this problem, is to provide affordable commodity devices. Head-mounted display computers, most prominently Google Glass, seem a perfect tool for cognitive task analysis, as they are already worn on the head (close to the brain) enabling easy sensor integration. A very simple sensor (infrared distance sensor from Google Glass) can for example measure eye blinks. Astonishingly, blinking frequency alone is already able to distinguish a couple of cognitive tasks (e.g. Reading versus Talking to a person [1]). And we see also new devices that focus on cognitive activity recognition, for example J!NS MEME (see Figure 2, smart glasses that use Electrooculography to detect eye movements recognizing fatigue).

Life Logging as Memory Enhancement

Most life-logging technologies focus on capture and access scenarios to index and retrieve information at a later point in time. However, We can also use this technology in combination with cognitive activity recognition to boost our brain (see Jim's Scenario).

There is already research by Isola et al. analyzing what makes images memorable [2]. If we build on this work and combine it with life-logging and measures for user's attentiveness and the cognitive load while looking at the picture, we can build systems that make it easier to remember situations, people and places. Here again cognitive load estimation is important, especially while the user sees the picture. With this feedback the system can decide when to show the picture again.

Discussion and Challenges

Miniaturization – as seen from one of our current experimental setups (Fig. 1), a lot of the brain imaging devices are still too large and cumbersome to be worn during everyday life. Yet, current research efforts already focus on making them useable during everyday life [5].

Exploration of Sensing Modalities – Initial research shows

Figure 2: User wearing smart glasses able to track fatigue and other mental states related to eye movement.

that especially eye tracking but also other pervasive sensing modalities can give insights into cognitive activities. Using brain imaging techniques for ground truth we should explore other sensors.

Cognitive Computing in the large – As our brains are very versatile, there is large variability between users. Therefore, we need large scale, well-designed user studies to better understand the relations between cognitive load, task and applicable sensing. As with wearable computing in general, large representative datasets are required.

Stress Versus Engagement – This challenge is again more related to the work-load measurements: Can we distinguish between healthy engagement of and stressful, unhealthy straining of our mind? Challenging the user too often creates the danger of stress and might lead eventually to burn-out. We will need a new level of quality for the detection algorithms and maybe a novel decision making process for systems tracking cognitive tasks, as simply an accuracy of 90% (ok for most physical activity recognition tasks) is not be good enough to prevent these problems.

Mind Improvement?– As we still struggle with cognitive sensing, quantifying cognitive tasks in everyday life, it's hard to tackle the question about effective interventions to improve our mind. We should begin analyzing the impact cognitive activity tracking of usability, human computer interaction and design.

Interaction Design – For learning tasks and memory games, the interaction design for "engaged computing" seems straight forward: As long as the user seems mentally fit and brain activity increases, make the task more difficult. Yet, this might be dangerous for a lot of real world activities (maintenance, transportation etc.). How can we introduce the concept of computing that engages our mind without risking the safety of people and without frustrating the user?

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