Brain-Computer Interfaces for HCI and Games

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CHI 2008, April 5 – 10, 2008, Florence, Italy.
ACM 978-1-60558-012-8/08/04.

Abstract
In this workshop we study the research themes and the state-of-the-art of brain-computer interaction. Brain-computer interface research has seen much progress in the medical domain, for example for prosthesis control or as biofeedback therapy for the treatment of neurological disorders. Here, however, we look at brain-computer interaction especially as it applies to research in Human-Computer Interaction (HCI). Through this workshop and continuing discussions, we aim to define research approaches and applications that apply to disabled and able-bodied users across a variety of real-world usage scenarios. Entertainment and game design is one of the application areas that will be considered.

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces (D.2.2, H.1.2, I.3.6).

Keywords
Brain-computer interfaces, multimodal interaction, affective computing, games

Introduction
Advances in cognitive neuroscience and brain imaging technologies provide us with the increasing ability to

interface directly with activity in the brain. Researchers have begun to use these technologies to build brain-computer interfaces. In these interfaces, humans intentionally manipulate their brain activity in order to directly control a computer or physical prostheses. The ability to communicate and control devices with thought alone has especially high impact for individuals with reduced capabilities for muscular response. In fact, applications for patients with severe motor disabilities have been the driving force of most brain-computer interface research.

The Potential of Brain-Computer Interfaces

Although removing the need for motor movements in computer interfaces is itself challenging and rewarding, we believe that the full potential of brain sensing technologies as an input mechanism lies in the extremely rich information it could provide about the state of the user [5,8]. Having access to this state information is valuable to human-computer interaction (HCI) researchers and opens up at least three distinct areas of research:

Controlling Computers with Thought Alone. Much of the current BCI work aims to improve the lives of patients with severe neuromuscular disorders in which many patients lose control of their bodies, including simple functions such as eye-gaze. However, many of these patients retain full control of their higher level cognitive abilities. These disorders cause extreme frustration or social isolation caused by having no way to communicate with the external world. Providing these patients with brain-computer interfaces that allow them to control computers directly with their brain signals could dramatically increase their quality of life. The complexity of this control ranges from simple binary decisions, to moving a cursor on the screen, to more ambitious control of mechanical prosthetic devices.

Nearly all current brain-computer interface research has been a logical extension of assistive methods in which one input modality is substituted for another (for detailed reviews of this work, see [2,5]). However, there now is the need to start thinking about brain-computer interface applications for users with no physical disabilities and where brain activity can be seen as one of many of the possible input modalities that can be used sequentially or parallel with other input modalities. Clearly, also able-bodied users can enter applications where they meet situational impairments. This includes applications in domains such as traditional communication and productivity tasks, as well as games and entertainment computing.

Evaluating Interfaces and Systems. The cognitive or affective state derived from brain imaging could be used as an evaluation metric for either the user or for computer systems. Since we can measure the intensity of cognitive activity as a user performs certain tasks, we could potentially use brain imaging to assess cognitive aptitude based on how hard someone has to work on a particular set of tasks. With proper task and cognitive models, we might use these results to generalize performance predictions in a much broader range of tasks and scenarios.

In addition to evaluating the human, we can understand how users and computers interact so that we can improve our computing systems. Thus far, we have been relatively successful in learning from performance metrics such as task completion times and error rates. We have also used behavioral and physiological measures to infer cognitive processes, such as mouse movement and eye gaze as a measure of attention. However, there remain many cognitive processes that are hard to measure externally. For example, it is still extremely difficult to ascertain cognitive workloads or particular cognitive strategies used, such as verbal versus spatial memory encoding.

Brain imaging can potentially provide measures that directly quantify the cognitive utility of our interfaces. This could potentially provide powerful measures that either corroborate external measures, or more interestingly, shed light on the interactions that we would have never derived from these measures alone.

Building Adaptive User Interfaces. If we tighten the iteration between measurement, evaluation, and redesign, we could design interfaces that automatically adapt depending on the cognitive state of the user. Interfaces that adapt themselves to available resources in order to provide pleasant and optimal user experiences are not a new concept. In fact, we have put quite a bit of thought into dynamically adapting interfaces to best utilize such things as display space, available input mechanisms, device processing capabilities, and even user task or context.

We assert that adapting to users' limited cognitive resources is at least as important as adapting to specific computing affordances. One simple way in which interfaces may adapt based on cognitive state is to adjust information flow. For example, using brain imaging, the system knows approximately how the user's attentional and cognitive resources are allocated, and could tailor information presentation to attain the largest communication bandwidth possible. For example, if the user is verbally overloaded, additional information could be transformed and presented in a spatial modality, and vice versa. Clearly, more global workload monitoring is important as well. Errors in task performance turn up in the EEG, such as the ERN or P300 activity.

Another way interfaces might adapt is to manage interruptions based on the user's cognitive state. For example, if a user is in deep thought, the system could detect this and manage pending interruptions such as e-mail alerts and phone calls accordingly. This is true even if the user is staring blankly at the wall and there are no external cues that allow the system to easily differentiate between deep thought and no thought.

Finally, if we can sense higher level cognitive events like confusion and frustration or satisfaction and realization (the "aha" moment), we could tailor interfaces that provide feedback or guidance on task focus and strategy usage in training scenarios. This could lead to interfaces that drastically increase information understanding and retention.

Challenges of BCI in HCI Research

There are many challenges unique to BCI applications in HCI. One example is the inevitable presence of artifacts traditionally deemed to be "noise" in traditional BCI explorations. In our applications, we cannot typically control the environment as tightly as in many medical applications (e.g. we do not typically want to be working in a faraday cage) nor are we usually willing to restrict the actions of the user (e.g. tie them down so they don't move). Hence, we have to devise techniques that either sidestep these issues, or better yet, that leverage the additional information we have available to us.

A particular point of interest from a HCI point of view is how to fuse information coming from more traditional input modalities (e.g. touch, speech, gesture, etc.) with information obtained from brain activity. We will also consider the potential of output modalities (i.e. input into the brain), such as transcranial magnetic stimulation techniques [6]. From the point of view of HCI and applications it is interesting to look at task classification (e.g., [5] and the design of applications for the able-bodied user, e.g., the design of games where brain activity is exploited to adapt the game to the affective state of the user or to provide direct input from controlled brain activity to play the game [1,3,4,7].

Participants will be expected to address and present new viewpoints and techniques, especially as they apply to BCI applications in HCI research, both for disabled as well as able-bodied users. Specifically, this workshop aims to identify and discuss:

- brain-computer interface applications for users with permanent and situational physical disabilities, as well as for able-bodied users; this includes applications in domains such as traditional communication and productivity tasks, as well as games and entertainment computing;
- sensing technologies and data processing techniques that apply well to the suite of applications in which HCI researchers are interested;
- techniques for integrating brain activity, whether induced by thought or by performing a task, in the palette of input modalities for (multimodal) human-computer interaction;
- interesting problems that need more work, especially in areas that are unique to HCI applications

References

[1] Bersak, D., McDarby, G., N. Augenblick, N., McDarby, D., McDonnell, D., McDonald, B., and Karkun, R. Intelligent Biofeedback using an Immersive Competitive Environment. *Proc. Ubicomp 2001*, 2001.

[2] Coyle, S., Ward, T. and Markham, C. Brain-computer interfaces: A review. *Interdisciplinary Science Reviews, 28(2)*, 112-118.

[3] Hjelm, S.I., and Browall, C. Brainball – Using brain activity for cool competition. *Proc. NordiCHI 2001*, 2001.

[4] Lalor, E.C., Kelly, S.P., Finucane, C., et al. Steady-State VEP-Based Brain-Computer Interface Control in an Immersive 3D Gaming Environment. *EURASIP Journal on Applied Signal Processing* 2005, 3156-3164.

[5] Lee, J.C., and & Tan, D.S. Using a Low-Cost Electroencephalograph for Task Classification in HCI Research. *Proc. ACM Symposium on User Interface Software and Technology* (2006), 81-90.

[6] Merton, P.A., and Morton, H.B. Stimulation of the cerebral cortex in the intact human subject. *Nature, 285* (1980), 227-228.

[7] Nijholt, A. and Tan, D.S. Playing with Your Brain: Brain-Computer Interfaces and Games. *Proc. International ACM Conference on Advances in Computer Entertainment Technology (ACE 2007)* (2007), 305-306.

[8] Tan, D.S. Brain-Computer Interfaces: applying our minds to human-computer interaction. *Proc. What is the Next Generation of Human-Computer Interaction?,* Workshop at CHI 2006.