Playing with Your Brain: Brain-Computer Interfaces and Games

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ABSTRACT
In this workshop we investigate a possible role of brain-computer interaction in computer games and entertainment computing. The assumption is that brain activity, whether it is consciously controlled and directed by the user or just recorded in order to obtain information about the user's affective state, should be modeled in order to provide appropriate feedback and a context where brain activity information is one of the multi-modal interaction modalities that is provided to the user.

Categories and Subject Descriptors
H5.2. [**Information interfaces and presentation**]: User Interfaces. I.2 [**Artificial Intelligence**]: Cognitive simulation, Philosophical foundations, Games, Analogies.

General Terms
Algorithms, Design, Economics, Human Factors.

Keywords
Games, Brain-Computer Interfacing, Affect, Multimodal Interaction.

1. INTRODUCTION
In this workshop we study the research themes and the state-of-the-art of brain-computer interaction in order to look at applications for games. Brain-computer interfacing 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) and games. Through this workshop and continuing discussions, we aim to define research approaches and applications that apply to able-bodied users across a variety of real-world usage scenarios. Entertainment and game design is the main application area that is considered here.

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 which patients with severe motor disabilities can communicate and control devices with thought alone. Although removing the need for motor movements in computer interfaces is 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. Having access to this state information is valuable to human-computer interaction (HCI) researchers and opens up at least three distinct areas of research: (1) Controlling computers with thought alone, (2) Evaluating interfaces and systems, and (3) Building adaptive user interfaces.

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2. 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 physical 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 mental 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 [1]. This makes sense because when these patients lose control of their physical movement, the physiological function they have the most and sometimes only control over is their brain activity.

3. 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.

4. 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.

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.

5. GAMES AND BRAIN ACTIVITY

Currently there is a development from traditional videogames using keyboard, mouse or joystick to games that use all kinds of sensors and algorithms that know about speech characteristics, about facial expressions, gestures, location and identity of the gamer and even physiological processes that can be used to adapt or control the game. The next step in game development is input obtained from the measurement of brain activity. User-controlled brain activity has been used in games that involve moving a cursor on the screen or guiding the movements of an avatar in a virtual environment by imagining these movements [5]. Relaxation games have been designed [4] and also games that adapt to the affective state of the user [2,3]]. BCI game research requires the integration of theoretical research on multimodal interaction, intention detection, affective state and visual attention monitoring, and on-line motion control, but it also requires the design of several prototypes of games. These may be games for amusement, but also (serious) games for educational, training and simulation purposes.

6. CHALLENGES OF BCI IN HCI AND GAME 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 gaming 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 availabe to us. A particular point of interest is how to fuse information coming from more traditional input modalities (e.g. touch, speech, gesture, etc.) with information obtained from brain activity.

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