

Can Brain Computer Interfaces Become Personal Health Devices?

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Introduction

Assistive technology (AT) may be employed to facilitate the personalized health paradigm. AT can comprise home tele-health systems for measuring heart rate, blood pressure, weight, blood oxygen saturation [1]; and wearable technology that may facilitate wellness (see [2]), by providing motivational feedback. The latter may utilize accelerometers, gyroscopes, pedometers etc, to assess movement and global positioning system (GPS) technology to provide location. For emergency personal health, much research has been done on sensing and interpretation of the electrocardiogram (ECG), with a view to predicting adverse cardiology events, so that emergencies may be detected or early intervention may be scheduled [3,4]. Much less work has been done with the ongoing assessment of brain activity, known as the electroencephalogram (EEG), even though Stroke is the third biggest cause of death in the UK and the largest single cause of severe disability. Each year more than 110,000 people in England will suffer from a stroke which costs the NHS over £2.8 billion [5]. Science fiction has speculated for many years about a time when brain activity will merge with computers [6]. Technology now exists that demonstrates that noninvasively recorded brain signals can be used to control a prosthetic arm, or 'smart' devices to interact with the environment or to control a cursor on a computer [7], in order to interact with cyberspace. Already electrodes may be implanted inside the brain to allow direct control from neural signals, bypassing limbs immobilized by amyotrophic lateral sclerosis or stroke [8]. In the next few years, we expect to see significant progress in the brain computer interface (BCI) [9]. But just how far can BCIs develop? Can they become personalised health devices? And if so, what will be the time frame? We believe that the overall picture is optimistic. In the last two years, The European Union has provided significant funding for a number of e-inclusion projects: BRAIN [10], TOBI[11], BRAINABLE [12] to address the scientific and technical obstacles. Leading BCI laboratories throughout the world have similar funding mechanisms. Here, we describe the 'state of the art' in BCIs, discuss the major challenges that are currently being addressed, comment on progress and speculate somewhat on a future where wearable personalized technologies could include 'getting your thinking cap on' for communication and rehabilitation.

Materials and Methods

There are two major types of BCI. The first is a 'true' BCI. The subject uses imagined movement or other complex tasks (e.g. mental arithmetic) to self stimulate a portion of their motor cortex, and this activity is detected and used to make decisions by actuators or computers. At least two brain states must be detectable, but preferably more to optimise interaction. This 'intended' movement paradigm is called event-related de-synchronisation/ event related synchronisation (ERD/ERDS). The second category uses external stimuli to modulate or influence brain activity. There are two paradigms, which have shown promise. The first uses flickering light stimulation to evoke activity in the visual cortex, at the occipital region of the cortex. This activity is called the steady state visual evoked potential (SSVEP). The second approach capitalises upon recording the brain's response to an unexpected stimulus, which manifests as positive electrical activity approximately 300 msec after the onset of the unexpected or 'rare' stimulus, known as the P300. For this paradigm, a number (16 or more) of individual EEG responses are normally averaged. For all the paradigms significant signal processing is required to detect the desired signal from the ongoing electrical activity known as the EEG.

Results

In the BRAIN project, we have made advances in the following areas:

Recording has been improved with the introduction of a smaller amplifier (TMSi Porti [13]), which can use fibre optic cable or Bluetooth to transmit signals to the computer. The SSVEP paradigm has been extended to higher frequencies, above 30Hz stimulation rates. These rates are more comfortable to the user, but are associated with a lower signal to noise ratio. Hence signal processing has been used to extract the features associated with High Frequency-SSVEP. Acceptable Receiver Operating Characteristic (ROC) rates of >80% have been achieved [14]. Progress has been made with

personalizing BCI, by the use of sophisticated calibration using a ‘wizard’. An intelligent Graphical User Interface (IGUI) has been developed to map features extracted from the EEG to a versatile menu structure. A Universal Application Interface has been developed using standard wired and wireless protocols to control smart home devices. Integration of all the above components has been demonstrated at three independent sites.

Discussion

Progress with BCI has continued in specialist neuroscience laboratories. There is now evidence that BCI has application in smart homes [15]. BCI is also attracting considerable attention for gaming applications [16]. However current BCI paradigms suffers from the acceptance that ‘one size does not fit all’. Some people are more susceptible to one of the main paradigms: ERD/ERS, P300, or SSVEP. Within each paradigm, parameters must also be tuned or optimised, and an optimised wizard is required. BCI requires sophisticated signal processing and computing procedures, but such is the computing power on even mobile devices, we can conceive that a functional, portable solution to equipment is possible. Obstacles of user interface and application development are also being addressed with good success. The recording equipment has advanced, and data can be communicated wirelessly. With volume production cost can also be considerably reduced, particularly if gaming applications become a reality. We expect significant progress in the next two years on these fronts. So what obstacles remain? Significant progress must be achieved with the electrode/cap interface for BCI to become practical outside the laboratory, with minimal assistance for attachment and removal. This is particularly important where the user may have impairments, e.g. as a result of Stroke, and requires assistance from an ‘non-expert’ carer. Surface, water based or dry electrodes would provide a significant step forward. However, recorded signals are less well characterised and currently suffer a poorer signal to noise ratio than conventional gel based electrodes. New electrodes will require further progress from signal processing, feature extraction and personalisation. The time frame for this is more difficult to assess. Although BCI systems can still emerge from the laboratory, will users accept them in sufficient numbers? Also more aesthetically pleasing caps are required to facilitate secure reliable connection, and of-course user acceptance.

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