

# **Epistemological and Phenomenological Issues in the use of Brain-Computer Interfaces**

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## **Extended Abstract**

Brain-computer interfaces (BCIs) are an emerging and converging technology that translates the brain activity of its user into command signals for external devices, ranging from motorized wheelchairs, robotic hands, environmental control systems, and computer applications. In this paper I functionally decompose BCI systems and categorize BCI applications with similar functional properties into three categories, those with (1) motor, (2) virtual, and (3) linguistic applications. I then analyse the relationship between these distinct BCI applications and their users from an epistemological and phenomenological perspective. Specifically, I analyse functional properties of BCIs in relation to the abilities (particularly motor behaviour and communication) of their human users, asking how they may or may not extend these abilities. This includes a phenomenological analysis of whether BCIs are experienced as transparent extensions. Contrary to some recent philosophical claims, I conclude that, although BCIs have the potential to become bodily as well as cognitive extensions for skilled users, at this stage they are not. And while the electrodes and signal processor may to a variable degree be transparent and incorporated, the BCI system as a whole is not. Contemporary BCIs are difficult to use. Most systems only work in highly controlled laboratory settings, require a high amount of training and concentration, have very limited control options, have low and variable information transfer rates, and effector motions are often slow, clumsy and sometimes unsuccessful. These drawbacks considerably limit their possibilities for transparency and incorporation into either the body schema or cognitive system which is essential for bodily and cognitive extension. Current BCIs can therefore only be seen as a weak or metaphorical extension of the human central nervous system. To increase their potential for cognitive extension, I give suggestions for improving the interface design of what I refer to as linguistic applications.

## **1. Introduction: Brain-Computer Interfaces**

BCIs are an emerging and converging technology that translates the brain activity of its user into command signals for external devices. Invasive or non-invasive electrode arrays detect an intentional change in neural activity, which is translated by a signal processor into command signals for applications such as wheelchairs, robotic hands, environmental control systems, and computer applications. In essence, BCI technology establishes a direct one-way communication pathway between the human brain and an external device, and can to some extent translate human intentions into technological actions without having to use the body's neuromuscular system. However, contemporary BCIs are difficult to use, the technology is still in its infancy and has barely passed the "proof of concept" stage. Most systems only work in highly controlled laboratory settings, require a high amount of training and concentration, have very limited control options, have low and variable information transfer rates, and effector motions are often slow, clumsy and sometimes unsuccessful.

## 2. Goals, Method and Structure

### 2.1. A Typology of BCIs

In this paper I explore the relationship between BCI technology and their human users from an epistemological and phenomenological perspective. My analysis has five parts. First, I present a preliminary conceptual analysis of BCIs in which BCI systems are functionally decomposed (Vermaas & Garbacz, 2009) and BCI applications with similar functional properties are grouped in categories. Based on this preliminary analysis, I distinguish between three categories: (1) *motor applications*, which restore motor functions for disabled subjects such as motorized wheelchairs or robotic hands; (2) *linguistic applications*, which allow a disabled subject to select characters on a screen, thereby restoring communicative abilities; and (3) *virtual applications*, which allow a subject to control elements (e.g. avatars) in a virtual environment.

### 2.2 The Current Debate on BCIs

Second, I briefly outline the current philosophical debate on BCIs. It has been claimed that a BCI-controlled robotic arm is a bodily extension fully integrated into the body schema of a macaque, thereby constituting a “new systemic whole” (Clark, 2007). It has also been claimed that functionally integrated BCIs are cognitive extensions, i.e., they extend cognitive processes of their users into the material environment (Fenton and Alpert, 2008; Kyselo, 2011). These philosophical claims are evaluated later on in this paper.

### 2.3 Human-Technology Relations

Third, I introduce some key concepts for better understanding human-technology relations. These key concepts are “body schema”, “incorporation”, “transparency” and “extended cognition”. A body schema is a non-conscious neural representation of the body’s position and its capabilities for action. We are able to incorporate artifacts such as hammers, screwdrivers, pencils, walking canes, cars, glasses, and hearing aids into our body schema, thereby enlarging our body schema (Brey, 2000). These artifacts are *embodied* and are not experienced as objects in the environment but as part of the human motor or perceptual system. When using embodied artifacts to act on the world such as hammers, pencils, and screwdrivers, a subject doesn’t first want an action on the artifact and then on the world. Rather, a subject merely wants an action on the world through the artifact and doesn’t consciously experience the artifact when doing so. The perceptual focal point is thus at the artifact-environment interface, rather than at the agent-artifact interface (Clark, 2007). In this sense, embodied artifacts are transparent (Ihde, 1990).

Cognitive artifacts such as calculators, computers, and navigation systems, can under certain conditions be incorporated in the human cognitive system in such a way that they can best be seen as literally part of that system. These devices, then, perform functions that are *complementary* to the human brain (Sutton, 2010). There is, furthermore, a two-way interaction when using such devices, and both the brain and the cognitive artifact have a causal role in the overall process, thereby forming a “coupled system”. In such coupled systems, the cognitive process is *distributed* across brain and artifact, and the artifact is seen as co-constitutive of the extended cognitive system. Remove the technological element from the equation and the overall system will drop in behavioural and cognitive competence. So there is a strong symbiosis and reciprocity in coupled systems. Moreover, what is essential when extending cognition is a high degree of trust in, reliance on, and accessibility of the cognitive artifact (Clark & Chalmers, 1998).

## 2.4 Human-BCI Relations

Fourth, I explore the relationship between motor, linguistic, and virtual applications and their human users in the light of the concepts just introduced. I analyse whether BCIs are incorporated into the body schema or cognitive system of their users, and analyse whether they are experienced as transparent extensions of the human body or cognitive system. I demonstrate that, although BCIs have the potential to become bodily as well as cognitive extensions for skilled users, at this stage they are not. And while the electrodes and signal processor may to a variable degree be transparent and incorporated, the BCI system as a whole is not. Contemporary BCIs are difficult to use. Most systems only work in highly controlled laboratory settings, require a high amount of training and concentration, have very limited control options, have low and variable information transfer rates, and effector motions are often slow, clumsy and sometimes unsuccessful. These drawbacks considerably limit their possibilities for transparency and incorporation into either the body schema or cognitive system which is essential for bodily and cognitive extension.

## 2.5 Distributed Cognition for improving BCIs

And fifth, I give suggestions to increase the potential for cognitive extension of linguistic applications. To do so, I draw from concepts of the distributed cognition framework. Jim Hollan, Ed Hutchins and David Kirsh (2000) argue that the nature of external representations is essential when effectively distributing cognition. Their notion of “history enriched digital objects” implies that often selected letters should be presented larger or brighter on the screen. Their notion of “zoomable multiscale interfaces” implies that for someone who is selecting letters on a screen, it might be more effective if the letter the person wants to select becomes larger when the cursor moves towards it. And their notion of “intelligent use of space” implies that for people who are not used to the QWERTY-style, it might be logical to present the most often selected letters in the middle and letters that are selected less often in the periphery of the screen.

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