Chapter 5
Brain-Computer Interfaces as an Emerging Assistive Technology (AT): The AT Professionals' Perspective

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5.1 Assistive Technology: A Professional Field of Intervention

BCI technology is a "new entry" in the world of technology-based assistive solutions for people with disabilities. But what does this world look like, who are its custodians, and what is important to them?

5.1.1 Assistive Technology Professionals

The aim of every Assistive Technology (AT) professional is to support people with disabilities by identifying appropriate technology-based solutions that will enhance their independence and participation. As a matter of fact, there are a wide range of high- and low-tech solutions that offer empowerment for people with functional limitations, but for many reasons, some of which will be discussed in this chapter, matching people with the right technological solution for them is not an easy task. Professional expertise is therefore essential and ever since assistive devices became more widely available, professionals with differing backgrounds, such as occupational therapists, physiotherapists, speech and language therapists, psychologists, special needs teachers, educators, rehabilitation engineers, information and communication technology (ICT) experts, and others, have started to specialize in Assistive Technology. Ideally all these professionals have had some basic preparation in AT on which to build in order to become an AT professional. In other

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words, AT professionals will typically have a disciplinary background in some domain of the health, education, or technology sectors and become AT experts through further formal and non-formal learning and work experience. According to the Guidelines for Lifelong Learning in Assistive Technology developed under the *Keeping Pace with Assistive Technology* project (Gresswell and Hoogerwerf 2007), levels of professional development in AT are determined by different factors, all related to performance requirements, such as the particular concerns of the professional, the depth of the knowledge demanded for the utilization of available solutions, deployment strategies and their implementation, and responsibilities in the process of selection and recommendation of solutions to people with disabilities. The latter process involves user-centered needs assessments, i.e. identifying solutions and implementation paths in collaboration with the user. This process might be actuated in a social, educational, or medical setting, but ideally it would take place in a context in which all these different domains are drawn upon.

Making sure that the user is at the center of this process is an important prerequisite for various reasons, including ethical ones. Ethical behavior in AT provision involves recognizing the importance of values such as self-determination, equal opportunities, and justice as the basis of the AT assessment and implementation process (Vanhove 2011).

Many AT professionals work in multidisciplinary teams, either in a context that provides general rehabilitation in which AT provision is one of the many considerations (Steel et al. 2011) or in specialized AT centers (Hoogerwerf et al. 2002), as it is their firm belief that successful outcomes are the result of the integration of different viewpoints.

Although AT professionals are important stakeholders and gatekeepers for the development of BCI applications for people with disabilities, their knowledge and understanding of BCI is often limited and vague. It is expected that studies involving users outside BCI research laboratories will increase this knowledge, especially when the added value of BCI applications compared to other AT solutions can be demonstrated.

5.1.2 Assistive Technology and Related Fields

The Association for the Advancement of Assistive Technology in Europe (AAATE) defines AT as an umbrella term that refers to "... any product or technology based service that enables people of all ages with activity limitations in their daily lives, work, education and leisure" (AAATE 2009). This definition is very broad and includes both mainstream technologies and special devices designed specifically for people with disabilities. It further includes services, often remotely delivered, that enable people in their environment, such as telecare services, translation services, or GPS and navigation systems and services. As a matter of fact, it could be said that many assistive technologies are enabling technologies

because they allow access to opportunities that are normally only available to people without disabilities.

It is important to highlight that assistive technologies are not just "compensating" for impairments by allowing access to opportunities that might be considered normal for people without disabilities. Just like any other technology it has the potential to empower people beyond its strictly intended function, thus creating other opportunities, sometimes even unexpected. The act of installing a lift does not just allow a person to leave the house. It might also remove a significant barrier to employment, education, or social life.

Nevertheless, enablement would be more successful if opportunities were inherently accessible. As people are not only disabled *in* their environment but also *by* their environment, an important area of concern for AT professionals is the accessibility of mainstream products, systems, and services. Products, systems, and services that are designed according to *Universal Design* (UD) principles are intended to be more accessible for people with disabilities than those that are not designed according to those principles. In recent years, UD principles have started to be successfully applied on a wider scale. UD is the process of designing environments, services, and products to be usable, as far as possible, by people with a wide range of disabilities without the need for special adaptation (Centre for Excellence in Universal Design 2013). UD leads to more opportunities for the inclusion of people with disabilities in society and makes the border between AT devices and mainstream technologies less clearly defined (Pullin 2011). When environments are designed not only to be accessible, but also to support people in their daily lives, we speak of *Ambient Assisted Living*.

The rapid development of ICT has not left the field of disability untouched. New opportunities, some of them previously unimagined, have become widely available and have led to a wealth of applications in the field of assistive technology.

However the way digital content is presented has also created new difficulties. E-accessibility is an important area of interest and research. Complementary to assistive technology it aims at solving problems of accessibility to digital content, so predominantly in relation to the mainstream digital environment.

BCI applications targeting people with disabilities have not, therefore, presented themselves in a vacuum, but in an environment where other solutions are available and where the thinking on AT is not only governed by what is technically possible, but also by what is desirable and by environmental, economic, political, and educational considerations.

5.1.3 Identifying Appropriate Solutions

The process of selecting and using a technology is a familiar one to most people. Studies of user acceptance of new technologies have highlighted the importance of expected benefits and perceived ease of use (Davis 1989). However, a wide variety of factors are involved in technology take-up. The most important, of course,

concern the needs or wishes of an individual. Why is the technology needed? In what kinds of activities does the person want to participate or enhance his/her independence? Is the technology needed to allow or facilitate communication, learning, mobility, social networking, etc.? The border between needs and wishes is not always clear, but in a citizenship model of disability, as opposed to the medical model where the person is merely considered a non-proactive patient, the wishes of a person are equally important. For example access to games or social networks might not be relevant needs from a strictly medical point of view but from a social or rights-based perspective they certainly are.

Then there are factors related to the health of the person, which ever since the adoption of the International Classification of Functioning, Disability and Health (ICF) by the World Health Organization (World Health Organization 2001) have been referred to as "body functions" and "body structures". Each person is unique and functional restrictions of various kinds can impact on their potential to use mainstream devices, especially when these are not designed according to universal design principles.

Other factors concern the environment in which the technology is to be used and the conditions in that environment, e.g. indoor or outdoor, quiet or noisy, standalone or connected to mainstream technologies. There are a wider range of such variables that impact on the choice of one solution over another or on the creation of a solution with the highest possible level of usability under different conditions.

An AT professional trying to support a client with disabilities in identifying an appropriate solution will have to take these all variables into consideration before recommending a choice of one solution over another. This also goes for BCI-based applications, which in certain cases have to prove that they are a better choice than other technologies.

In the case of BCI technology for people with disabilities we are still speaking about new and innovative technologies that are somewhere between the research & development stage and the demonstration stage. Deployment will follow when AT experts outside the immediate BCI research community, "early adopters" (Rogers 1962), start to design and develop highly personalized solutions for their clients.

At this stage in the knowledge translation process (Sudsawad 2007), collaboration between end users, AT experts (professional users), and BCI system developers is fundamental. All AT provision that includes BCI components will need to be implemented according to User-Centered Design principles (UCD; ISO 2010), as no standard solutions are available yet (Holtz et al. 2013).

5.1.4 Meeting the User's Needs: The Evaluation of Outcomes

A key question that AT experts face is the following: When can technology deployment be considered successful?

Knowing what constitutes a measure of AT success and factors related to a user's acceptance of a technology can help professionals involved in designing BCI-based applications to set clear objectives for their technology and, most importantly, learn a common language for communicating with AT professionals and users.

The term *outcome* identifies the effects of any intervention. In the specific case of AT interventions, outcomes refer to (Fuhrer et al. 2003):

> [...] the changes that are produced by AT in the lives of users and their environments. Those changes may range from improvements in delimited aspects of users' motor, sensory, and cognitive functioning to enhancement of their social participation, vocational productivity, and sense of control over their own lives. The cascade of outcomes may extend to individuals' environments as well and include, for example, a reduction in caregivers' assistance and decreased costs to insurers and social welfare agencies.

What is clear from this definition is that assessing the outcomes of an AT intervention means measuring the impact of any device not only in relation to the specific functions which are supposed to be replaced or compensated by the AT, but also, and equally importantly, on aspects related to psychosocial and environmental dimensions. Indeed, measuring AT-related outcomes is a complex process which goes far beyond the evaluation of the usability of an AT device. Once AT professionals and the user have together identified a possible AT solution that seems to match the user's needs, the technology (or set of technologies) involved have to be tried and tested, and often modified over an extended period of time, within the context of the user's everyday life. How long this will take cannot be predetermined as it should continue until the technology becomes an integral part of the user's life.

During this phase in the AT provision process, the role of the AT professionals is to collaborate with the user in order to find answers to the following questions:

(a) What is considered as successful use of AT by the particular user?
(b) What factors (individual characteristics of the user, family environment, training opportunities) influence outcomes and to what extent?
(c) Is the aid becoming an integral part of the person's life?

In order to answer these questions and avoid the non-use or abandonment of AT devices, AT professionals have started to develop instruments based on evidence for measuring the effects of AT solutions on factors related to the user's experience which seem to affect the user's acceptability of an AT device (Federici et al. 2012). In particular, the user's attitudes and user satisfaction are important factors that should be taken into account in any outcomes evaluation process. In this section, we briefly review two commonly used evidence-based instruments which can be used by BCI researchers and AT professionals together to explore the opinions of the end users over specific potential use motives and barriers, and to investigate their general satisfaction and level of intention to use any new AT device in order to develop solutions which will fit the ever-changing user needs.

First, Matching Person and Technology (MPT; Scherer 1998) is a model which offers a wide range of tools both for clinical and research purposes. MPT is the most widely validated client-centered approach to AT provision. Central to the model is

the idea that both the use and the non-use of any AT solution is mainly influenced by three interrelated factors: (i) the *milieu*/environment(s) in which the user interacts with the technology; (ii) personal factors unique to any user, like preferences, predisposition to use the AT solution, and his/her needs; and (iii) the characteristics of the technology. In particular, the *Assistive Technology Device Predisposition Assessment* (ATD PA) scale of the MPT set of tools represents a thorough instrument for measuring the user's attitudes towards specific AT solutions, taking into account all the factors that could affect the user's attitudes towards the technology. The ATD PA asks users about their subjective satisfaction in several functional areas (nine items), asks them to prioritize the aspects of their lives they consider most important to improve (12 items), and profiles their psychosocial characteristics (33 items). The last worksheet of the ATD PA asks the users to rate 12 aspects which can affect the use of a particular type of AT solution and could be used by researchers to collect specific information about users' attitudes towards a particular AT device.

User satisfaction with an AT solution represents another important dimension which should be measured during the outcomes assessment process. A definition of user satisfaction with any AT solution is provided by Demers and colleagues (2002) and refers to a person's critical evaluation of several aspects of a device and may be influenced by expectations, perceptions, attitudes, and personal values. These authors developed a widely employed instrument for measuring user satisfaction with an AT device named *Quebec User Evaluation of Satisfaction with Assistive Technology* (QUEST 2.0; Demers et al. 2002). The questionnaire consists of 12 items divided in two scales. In the first scale, eight items focus on dimensions related to the device (comfort, dimensions, simplicity of use, effectiveness, durability, adjustments, safety, and weight); while in the second scale, four items focus on the quality of service (professional service, follow-up services, repairs/servicing, and service delivery). The study conducted by Zickler and colleagues (2011) provides an example of how QUEST 2.0 can be employed for the usability evaluation of BCI-based AT.

5.2 BCI Technology: The AT Professional's Perspective

This section, written by AT professionals, draws upon the experience of our AT team in working on a major European BCI research project and on its experience of testing the non-invasive BCI applications for communication, control, and leisure developed in the project with a variety of end users in different conditions.

5.2.1 *Just Another New Assistive Technology?*

The AT ICT sector has developed greatly in the last 30 years and, in many ways, can now be considered to have reached maturity. The contexts in which AT ICT technology can be employed are well defined and there is general agreement on their classification. Among the most important fields of application are access to ICT devices with interfaces adapted to the various needs of users, access to digital content (e-accessibility), augmentative and alternative communication (AAC), environmental control, and smart homes/domotics.

As far as AT devices are concerned, a mature market now offers a wide range of solutions at differing prices covering many of the operational needs of users.

Over the years, alongside the development of technological solutions, protocols and methods of use have also been developed, as well as modes of assessment involving multidisciplinary teams and methodologies for the assessment of outcomes. In this scenario, when a new technological solution is made available, whether by the market or as a result of a process of research and development, it is evaluated by AT professionals, ideally at a specialist AT center. Given the level of sophistication that has been reached in the sector, most new solutions take the form of modest improvements to existing products. In other cases, however, a product may extend AT functionality to a whole new class of ICT solutions: This is true, for example, of the special input modality recently proposed for smartphones and tablets. In all these cases, evaluation by AT experts involves a variety of activities, including a technical and functional assessment of the new product, in comparison with the existing solutions covering similar end user needs, as well as field trials, possibly in collaboration with expert final users in real-life situations.

The appearance of a completely new class of solutions happens comparatively rarely nowadays, and their development makes sense if they promise potential improvements on existing solutions, are able to meet the needs of users who have not been able to benefit from existing solutions, or can offer novel modes of use. An important sector in which there is still room for new developments, and where breakthroughs are needed, is that of human–machine interfaces, understood in the broadest sense of the term, relating not just to technology but also to methods of use and the modes of interaction available to users. One of the most significant cases of recent years has been that of gaze-controlled technology, which has made it possible to interact with technology using a part of the body, the eye, whose primary function is that of receiving information as opposed to controlling technological devices. It is worth noting that, while gaze-controlled technology has been used successfully for some considerable time, the range of users was largely limited to people with relatively little involuntary ocular or physical movement. A significant change occurred comparatively recently when systems and software were developed that were able to accommodate involuntary physical and ocular movement (e.g. due to nystagmus). These changes have meant that many disabled people can now control technology using their eye movement who were unable to before,

including some people with significant involuntary physical movement due to, for example, athetoid cerebral palsy, or people with involuntary eye movement following a stroke.

Nonetheless, the interaction provided by gaze-controlled systems is still linked to a relatively well-controlled eye movement and so there remains the problem of how to interact with technological solutions without any kind of controlled muscular activity or any physical movement at all. For this reason, and also because of the particularities linked to the possibility of interpreting at least some aspects related to the mental states of the users, BCI is now considered to be an extremely interesting field of research by many AT experts, potentially filling or reducing the gap still left by gaze control and other assistive technology control devices. For example, Donegan et al. (2011) emphasize the need for BCI to be investigated as a viable alternative to gaze control, particularly for those who are in a completely locked-in state where gaze control might not be an option but where, for example, the user might use a BCI to make selections from a range of auditory prompts.

5.2.2 Discovering the BCI Together with End Users

When the team became involved in the project on BCI, it brought with it know-how accumulated through 30 years of experience in the field of AT. Within the project the team has been involved, among other things, in the definition of experimental protocols and in the testing of solutions with end users.

The following objectives have been pursued:

- Considering BCI applications no differently to any other AT solution
- Highlighting the similarities and specificities of BCI technologies and existing AT
- Involving AT experts and skilled AT users in a user-centered design process based on the evaluation of the new technology in real-life environments
- Evaluating not only the functioning of the prototypes, but also broader aspects related to human–machine interaction such as user acceptability

These objectives have guided the definition of the project's test procedures and protocols.

Regarding the selection of the potential end users of these new technologies, the team has decided to move away, at this stage of development of the prototypes, from those groups that are typically considered potential BCI beneficiaries, for example people with locked-in syndrome and ALS patients for whom the BCI could provide the only possible means of communication. Although it is a long-term aim to provide these groups with functional solutions, it was felt that for many reasons of an *ethical*, *political*, and *practical* nature it would be better to engage experienced AT users with severe motor disabilities but at least one other communication channel (body signal) in more stable physical conditions (Hoogerwerf et al. 2010).

The *ethical reasons* here concern the management of expectations and frustration, including the emotional stress that could arise from the product not being immediately available even in the case of positive results, as well as other considerations such as lack of choice and lack of balance in the relationship of power between the researcher and the user.

The *political reasons* concern the difficulty of creating the conditions for an early and full involvement of these groups in all phases and aspects of the project. Such involvement is necessary in order to make the design process as user-driven as possible and requires users who are fully aware and able to choose, consent, agree, or disagree.

The *practical reasons* involved concern the need to reduce disturbance arising from those non-BCI-related factors that often characterize hospitals or other institutional care settings (noise, the presence of non-relevant people, prevalence of a medical approach, shortage of time, life support equipment, etc.).

5.2.3 New Interfaces for New Forms of Interaction

One of the aspects that most differentiates BCI from other AT technologies is the nature of the interaction between the system and the user, which takes on completely new characteristics that can only partly be related to the experience of other AT solutions.

From the point of view of AT experts, BCI may not represent a unique class of solutions, but they will have to turn to various types of BCI as points of reference rather than to their previous experience of AT solutions. For example the interaction with BCI applications based on a paradigm of evoked potentials, for example by a flashing cursor highlighting icons represented on the screen, is completely different from the interaction with a BCI application based on the motor imagery paradigm, where a signal is retrieved by the person imagining for example the movement of a hand. Also the training to develop the necessary control skills requires a different approach.

In other words, users (and this also goes for most AT professionals) are not used to the new forms of interaction possible with BCI. During testing, traditional interfaces for access to ICT, which distinguish sharply between output channels and input channels, proved to be ill suited to the forms of interaction possible with BCI. And this situation can therefore easily give rise to problems of usability.

In addition to problems related to usability, another problem to address is that of acceptability. This is a very important issue for interfaces which are so new, and it is also a more invasive issue than others. For these reasons it is evident that interface and interaction paradigms are something that cannot be forced on users and must be designed with their input.

5.2.4 Objective: At the User's Home

The ultimate objective of the experimentation was to test the prototypes in real situations and in the context of the daily lives of the users. The project provided for the testing of application prototypes at different stages of their development. This allowed the team to plan its testing activities over time and in different settings. Preliminary prototypes were tested at an AT center in order to benefit from a more protected environment in which tools were readily available for the solution of any potential technical problems that might arise.

In order to maximize user contribution, it was also decided to carry out these tests with the help of more experienced AT users, also because users of this kind would be more aware of the limitations of preliminary prototypes (this is an important factor with a view to avoiding disappointment in the event of negative results due to technical problems). In later stages, when the prototypes were more developed and reliable with greater functionality and human–machine interfaces (HMI) developed within the UCD process (ISO 2010), testing was extended to less experienced technology users and those with more severe disabilities and in their home environments.

5.2.5 Results and Conclusions

The very fact of having BCI applications for everyday activities with prototypes being tested in the context of everyday life is a big step forward and finally makes it possible to compare BCI with alternative AT solutions in similar contexts.

As with many other technologies, the success of AT solutions is often related not so much, and not only, to the main functions, but to a multiplicity of details regarding both hardware and software. The most important are those relating to the human–machine interface for the end user and for the operator and the procedures for use and assembly, dismantling, and activation.

The criteria proposed by Batavia and Hammer for AT device evaluation, reflecting a very pragmatic approach and probably therefore still useable, can serve as a framework of reference for AT experts to make a comparison between different assistive technologies (Batavia and Hammer 1990). However, the comparison between advanced BCI prototypes and products currently available on the AT market is only possible for some aspects. There is not much sense, in this stage of development of BCI applications, to evaluate factors such as affordability, consumer and supplier reparability, durability, ease of maintenance, flexibility, and securability.

Regarding other criteria such as compatibility, dependability, ease of assembly, effectiveness, learnability, operability, physical comfort and security, personal acceptability, and portability, it has nevertheless been possible to evaluate the advanced prototypes developed in the project.

As the prototypes have been able to successfully perform the functions for which they were designed and developed, the BCI can definitely be considered a new AT. The possibility to use them without any muscle movement has also been ascertained; an element that substantially differentiates the BCI-driven AT applications from all other AT solutions.

From the point of view of compatibility, the tested prototypes were based on standard ICT hardware and software solutions, while the hybrid BCI approach developed in the project successfully allowed the BCI to be interfaced with other AT solutions, both hardware (for example special input devices) and software (for example on-screen keyboard or integrated software environments).

The non-invasive BCIs tested confirmed to be input interfaces with low bit rates. Like other AT with similar characteristics, such as those based on a scan approach, they require, in order to improve the productivity performance, dedicated software modules like word prediction software and interfaces optimized for better access to frequently used functions. The prototypes were complex machines, composed of numerous hardware and software modules, and accordingly were quite complex to assemble. However future products developed for the AT market might be based on simpler, more integrated architectures, with a complexity similar to the ones of other AT solutions, such as eye trackers.

Caps and the electrodes are still critical elements in BCI technology. The development of caps which are comfortable and aesthetically pleasing and of electrodes which are comfortable and dry has to be pursued with determination. The setup procedures that operators and assistants have to perform in order to allow the end user access to BCI solutions is still a complicating factor. It is very important that these setup and configuration operations are simplified, and trouble-shooting should be included in the setup software. The world of neural signals is often completely unknown to end users and their carers. Therefore, where possible the extraction of suitable features from the signals, the identification of classifiers, the management of training sessions, and the management of problems should be dealt with directly by the operating systems.

The end goal is that well-functioning BCI solutions respond to the needs of specific groups of end users, probably including those with complex disabilities, and are reliable, well supported, and competitively priced compared to other solutions. If there is market potential, industry will invest and solutions will become widely available. This will also lower the costs. It is envisaged that AT professionals will play a key role in further fine-tuning the systems and in fully realizing their potential. Nevertheless they won't be able to do this alone. More basic research is still necessary to better explore and cope with BCI's intrinsic limitations.

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