# 1 Publishable Summary

TOBI will develop practical technology for brain-computer interaction; i.e., non-invasive BCI prototypes combined with other assistive technologies (AT) that will have a real impact in improving the quality of life of disabled people. These non-invasive BCI are based on electroencephalogram (EEG) signals. TOBI seeks to develop BCI assistive technology endowed with adaptive capabilities that augment those other AT they are combined with. In such a hybrid approach users can fuse brain interaction and muscle-based interaction or can switch between different channels naturally (based on monitoring of physiological parameters or mental states).

In TOBI we have identified 4 application areas where BCI assistive technology can effectively support people with motor disabilities, namely *Communication & Control*, *Motor Substitution*, *Entertainment*, and *Motor Recovery*.

For each of these application areas the project has developed a number of BCI prototypes. At the beginning of the third year of the project we have finished testing the first versions of our prototypes with end users. Based on the collected results and feedback from end users, we have kept the following prototypes for further development and testing:

- Hybrid P300 Text Entry (Communication & Control),
- Hybrid MI Text Entry (Communication & Control),
- FES Orthosis (Motor Substitution),
- Telepresence Robot (Motor Substitution),
- Connect-4 (Entertainment),
- Photobrowser (Entertainment),
- Music Player (Entertainment), and
- Motor Rehabilitation (Motor Recovery).

Importantly, new versions of all these prototypes are now compliant with the common implementation platform of our hybrid BCI architecture and implement the different interfaces developed in TOBI. Furthermore, following the user-centered approached adopted in the project, first versions of the prototypes were thoroughly redesigned or fine tuned as a result of the evaluation with and by end users. The final versions of the prototypes have started to be tested with end users, a work that will the focus of our scientific activities during the fourth year of the project. Initial results are quite positive.

During the third year of the TOBI project the main objective has been to demonstrate the degree of robustness of our work and prototypes to all our target audiences. To do so, we have invested a large amount of resources in giving a number of live demos of our prototypes in different settings —twelve live demos in this third year. As a highlight, we can mention that we participated in the opening of the *European Future Technologies Conference and Exhibition (FET11)* in Budapest on 4-6 May 2011, where TOBI's brain-controlled telepresence robot brought to the Commission Vice-President Ms. Neelie Kroes a red push button for her to press and officially open the FET11 conference (see Figure 1). Members of the TOBI team also demonstrated this and several other brain-controlled devices during the 3 days of the exhibition.




Figure 1: TOBI's brain-controlled telepresence robot brought to the Commissioner a red push button for her to press and officially open the FET11 conference.

These demonstrations is a continuation of our effort initiated in year 2, in particular the live demos our TOBI exhibit presented of six prototypes during the *ICT Exhibition 2010* held in Brussels on September 27-29, 2010. Visitors were also allowed to interact with the demos. In the first three demos, people controlled software for communication (text entry and web browser) and two physical devices for motor substitution (FES neuroprosthesis and assistive telepresence robot) by using their spontaneous brain activity. The next two prototypes exploited natural brain responses to items appearing in the computer for entertainment (photo browser and brain painting). The last demo was a new commercial wireless helmet made of dry electrodes that visitors could wear to visualise immediately their brain state. Figure 2 gives a snapshot of our ICT stand while two demos were running in the presence of media and public (the BCI subjects are occluded by visitors).




Figure 2: Snapshot of our ICT stand while two demos were running in the presence of media and public (the BCI subjects are occluded by visitors).

Live demos have attracted large media coverage and attention, and are contributing also to reinforce the scientific visibility of TOBI and its members. Two indicators proving so are the large number of peer-reviewed papers published during the third year of the project (41 journal papers, 31 conference papers, and 13 posters) and, perhaps more im-

pressively, 19 keynote/invited talks given by TOBI members at different meetings (mainly international and not only in Europe). Furthermore, research conducted in the framework of TOBI has been covered by the journal *Science* three times, two on occasion of the participation at *AAAS'11* (a live chat, http://www.tobi-project.org/2011/02/22/live-aaas-olaf-blanke-and-jose-del-r-millan-robotics, and a podcast, http://www.tobi-project.org/2011/02/23/podcast-using-thoughts-control-robots) and a third time after the publication of the first results of the test of our telepresence robot with end-users (http://www.tobi-project.org/2011/09/06/science-magazine-disabled-patients-mind-meld-robots).

Apart from demonstrating the robustness and maturity of the BCI technology developed in TOBI through extension live demonstrations of our prototypes, which is also a direct evidence of the progress in the state of the art achieved in the project, another scientific objective for this year concerned the further development of the hybrid BCI (hBCI) architecture and its components in order to come up with fully integrated prototypes. All prototypes are now compliant with the common implementation platform of our hybrid BCI architecture and implement the different interfaces developed in the project[1]. Open-source reference implementations of all before mentioned interfaces are available on http://sourceforge.net/p/tools4bci/home/ (reachable also from the TOBI website at http://www.tobi-project.org/download). A complete BCI system can thus now be embedded in generic interfaces.

We have also accelerated the integration of other components developed in the research WPs in the different prototypes according to their needs. In particular, a few prototypes are using hybrid signals —a combination of EEG and EMG, or several EEG components—, namely 'Hybrid P300 Text Entry', 'Hybrid MI Text Entry', 'FES Orthosis', 'Connect-4', and 'Motor Rehabilitation'. Shared control principles are incorporated in the prototypes 'Hybrid MI Text Entry', 'Telepresence Robot', and 'Music Player'. Finally, some adaptation principles are already integrated in prototypes 'Hybrid MI Text Entry', 'FES Orthosis', 'Telepresence Robot', and 'Music Player'.

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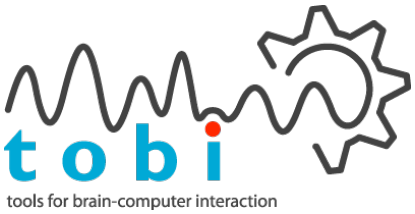


[1]Furthermore, various EEG processing platforms (EEGLab, OpenVIBE, FieldTrip, xBCI) have already agreed on using the tools implemented by TOBI or have expressed their interest. We have also continue our contacts with companies willing to make their data transmission compatible with our standards. Also, our common implementation platform will be used by two new EC funded projects, ABC and BackHome.