D5.3 – Tests oft the BCI System with the robot

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Del 5.3	Executive Summary
This deliverable describes the results obtained for the BCI based control of the Robot during the different user tests.	

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2 Abstract

In work package 5 a brain computer interface (BCI) system is developed for the ALIAS robot. The BCI provides an additional interface for interacting with the ALIAS robot. During the field trial reported in deliverable 1.5 [1]and as well as in a final test, users were able to test the BCI for controlling the ALIAS robot. In deliverable 5.2 [2] these were described in detail. These tests mainly focused on interacting with the robot, talking, chatting via Skype with friends or selecting an audio book to listen to using a P300 based control paradigm as described in deliverable D5.2 [2] along with its integration within the dialog system and graphical user interface of the robot. Three users were testing this system and trying to interact with the ALIAS robot using the BCI. The results achieved by these users and the feedback received from them is reported within this deliverable along with the final improvements applied to the BCI system.

Keywords: brain computer interface, P300, XML interface, user test, BCI based control

3 Introduction

In work package 5 a brain computer interface (BCI) system is developed for the ALIAS robot. The BCI provides an additional interface for interacting with the ALIAS robot. The BCI allows the user to control the robot and the programs by his thoughts only. This is beneficial in case the user is not able to use the touch screen or the natural speech interface for example when suffering from severe stroke. During the period where the user can hardly move his arms and has difficulties to speak clearly enough to be understood by the robot, the BCI allows him to interact with the robot and stay in contact with relatives and friends. A detailed description of the first BCI system available within ALIAS can be found in deliverable 5.2. “BCI System” [2].

The BCI system was tested during the field trials, the outcome of which is reported in deliverables 1.5 “Analysis of pilot’s second test-run with qualitative advices on how to improve specific functions / usability of the robot “ [1] an in during a dedicated test session where 3 users were testing the possibility to interact with the robot using the P300 based BCI. In these thests The latest version of the BCI was used which is able to correct for erroneous commands selections using statistics based measures on the likely hood that it was made by the user thereby reducing the amount of active corrections to be made by the user.

The following section 4 provides a short description of the setup and the new implementations and improvements applied to the system described in deliverable D5.2. The remaining section 5 reports the results obtained during the user tests which are discussed in section 6. Section 6 further provides an outlook for the future developments and necessary improvements of the system.

4 Test setup

The BCI system uses different types of visual stimuli to trigger a response of the brain which can be detected from the EEG signals of the user. For the tests described in this deliverable the P300 based paradigm was used. The EEG signals are measured at 8 electrode positions mostly over occipital and parietal regions as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Basic details on the system and on how it operates are described in 5.2 “BCI System”.

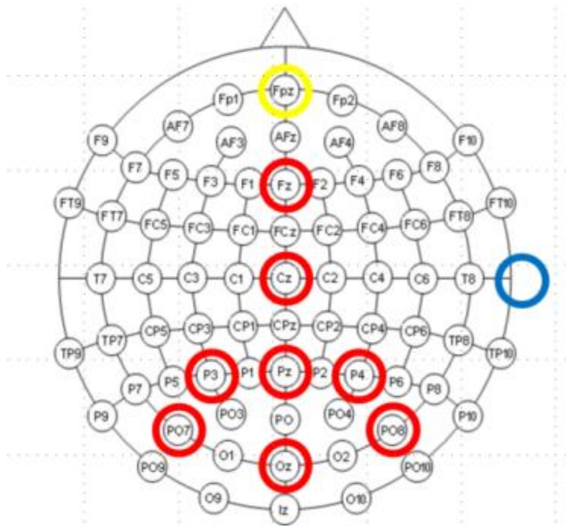
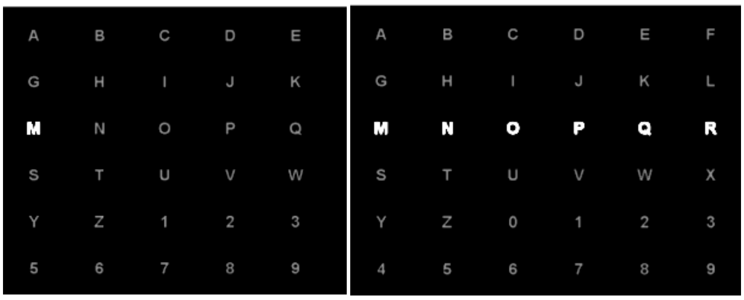


Figure 1: Common electrode setup for P300 spellers according to [1]. Eight EEG electrodes are placed at Fz, Cz, P3, Pz, P4, PO7, Oz and PO8. The ground electrode is mounted on the forehead at Fpz (yellow circle) and the reference electrode is attached to the right ear.

4.1 P300 Paradigm

Whenever an unlikely event which is awaited by the user occurs randomly between other events a so called P300 evoked potential is elicited. It manifests itself in a positive deflection in the amplitude of the EEG signal around 300 ms after a visual stimulus onset.

For a P300 spelling device commonly a 6x6 matrix of different characters and symbols is presented on a computer screen [4]. In single-character mode all characters are flashed in a random order but only one character after each other as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**a. In row-column mode a whole row or a whole column flashes at a time as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**b. The subject has to concentrate on a specific letter he or she wants to write. The flashing of exactly this character or the corresponding row or column is a relative unlikely event which induces a P300 component in the EEG signal reaching its maximum amplitude around 300 ms after the onset of the flash. For all other characters, rows or columns no such P300 component is elicited because they are not relevant to the subject currently.



(a) (b)

Figure 2: Screen layout of a 36 character speller. Either a single character is highlighted (a) at a certain time or a whole row or column (b).

To measure the P300 component acquisition of EEG signals from 8 electrode positions mostly over occipital and parietal regions is sufficient (see **Fehler! Verweisquelle konnte nicht gefunden werden.**) [1]. To train the BCI system an arbitrary word like LUCAS is announced to the system to be aware of which characters the subject is supposed to concentrate on (targets) and which not (non-targets). Each of these letters respectively each row and column flashes several times e.g. for 100 ms per flash. The subject focuses on each of these letters, one after the other and increments a mentally running count whenever the letter flashes the subject is currently concentrating on. EEG data of a specific time interval around each flash is then sent to a LDA classifier to learn to distinguish the typical EEG signal form of the target characters from the typical signal form of all other non-targets.

The EEG data were recorded with a g.MOBIlab+ biosignal amplification unit (g.tec medical engineering GmbH, Austria) at 256 Hz sample rate and transferred to the computer wirelessly via Bluetooth. A notch filter (50 Hz or 60 Hz) and a band pass filter were applied to the signals in order to eliminate possible artifacts before they were down-sampled to 64 Hz. Data from 100 ms before each flash onset to 700ms afterwards were filtered and down-sampled again to get 12 feature values (i.e. samples) per channel and flash. These data chunks were sent to the LDA to determine if a target character flashed or not. A MATLAB/Simulink model controls the interface masks, processes the received data via a specific device driver and dispatches the targeted commands via the described

UDP XML message passing interface. The subjects were sitting in front of a computer screen and were instructed to relax as much as possible.

4.2 Robot Interface Integration

The integration of the BCI system is achieved by embedding it within the Graphical User Interface (GUI) of the robot. For this, a dedicated Screen Overlay Control Interface (SOCI) library 5 was developed. This library manages the display of all P300 stimuli as well as the feedback about the selected symbol to the user. It uses a UDP message based protocol to communicate with the BCI system. The SOCI library allows to annotate buttons and other GUI elements with BCI controls or to transparently replace them (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). This has the advantage that no additional screen is needed which simplifies the BCI based control of the robot and allows the user to interact with ALIAS in comparable fashion as he would when using speech or the touch screen.

The BCI system itself uses standardized protocol for Application ConTrol and Online Reconfiguration (ACTOR) 6. The ACTOR protocol was further extended to interact with the DialogManager component of the ALIAS robot and to adjust the symbols and actions which can be selected by the user online. Within alias, this extension of the ACTOR protocol is used to adapt the BCI masks to the active status of the robot and to allow the user to navigate through the application menus equal to using the touch screen or the speech input modality.

Whenever the user selects a command or a menu entry using the BCI, the ACTOR protocol is used to transmit a corresponding message string to the DialogManager component of the robot, for further interpretation and execution. The ACTOR protocol is described in more detail in deliverable D5.2 and in 6.

By combining the BCI system with the network based SOCI library and the ACTOR protocol a loose coupling between the other components of the ALIAS could be achieved. Therefore the BCI software can be run on the Apple Mini built into ALIAS or on an external windows PC. In the latter case, a dedicated wireless LAN connection is used by ALIAS and the external BCI system to transmit the commands and to control the display of the BCI masks and Stimuli.

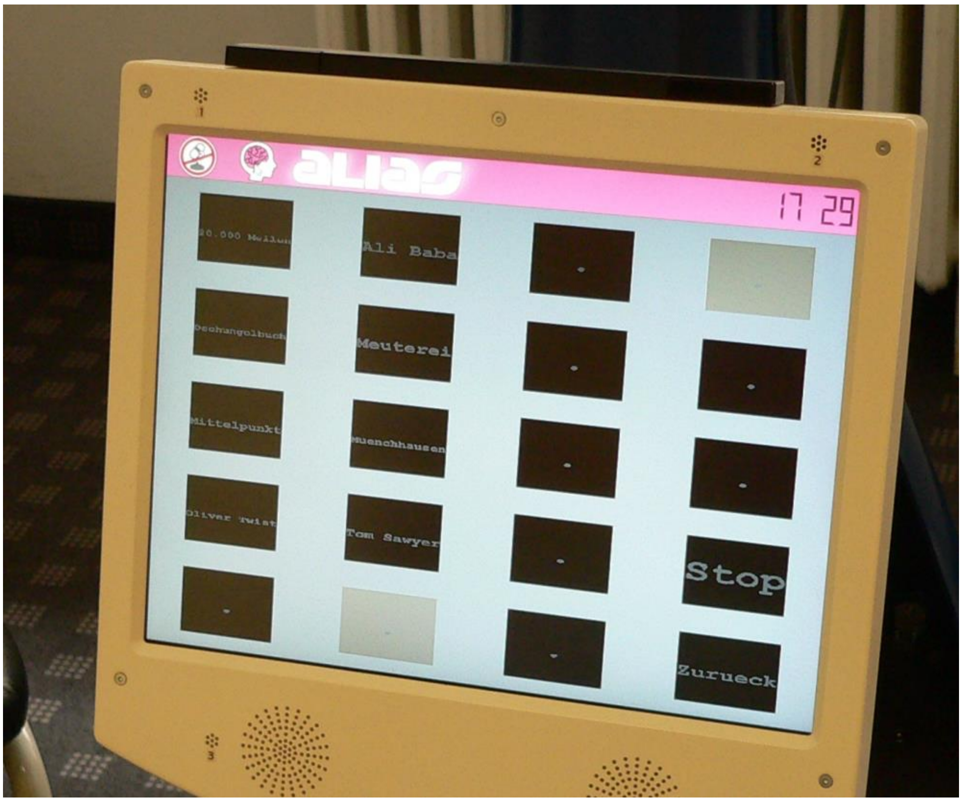


Figure 3: P300 Stimuli are displayed instead of the ALIAS GUI for example to select an audio book to be played to the user.

5 User tests

The final user test took place end of June 2013 at the Technical University Munich in the premises of the ALIAS partner TUM-MMK. Three male subjects (M1, M2, M3) of age 27, 37 and 70 respective volunteered to test the BCI and to use it to control the applications and services provided by ALIAS. For each subject one hour was planned including the mounting of the cap, the training of the classifier and for using the BCI to control the robot.

For training the classifier the standard P300 spelling matrix was flashed on the screen of the robot. From the 36 available characters (6x6) the BCI system picked 5 random characters which were flashed 15 times. After training the subjects, the BCI connection to the robot was activated and the users were asked to use the BCI to freely navigate through the user interface (UI) of ALIAS and test different applications.

For example, the user shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** decided to listen to an audio book. For this, he opened the entertainment menu and choose the audio books library. First he decided to listen to the German version of “Ali Baba and the forty robbers” and later on changed his mind to listen to “Meuterei auf der Bounty“. Finally he stopped the playback of the audio books and returned back to the main menu where he tried to enter the communication menu and start Skype to chat with a friend.

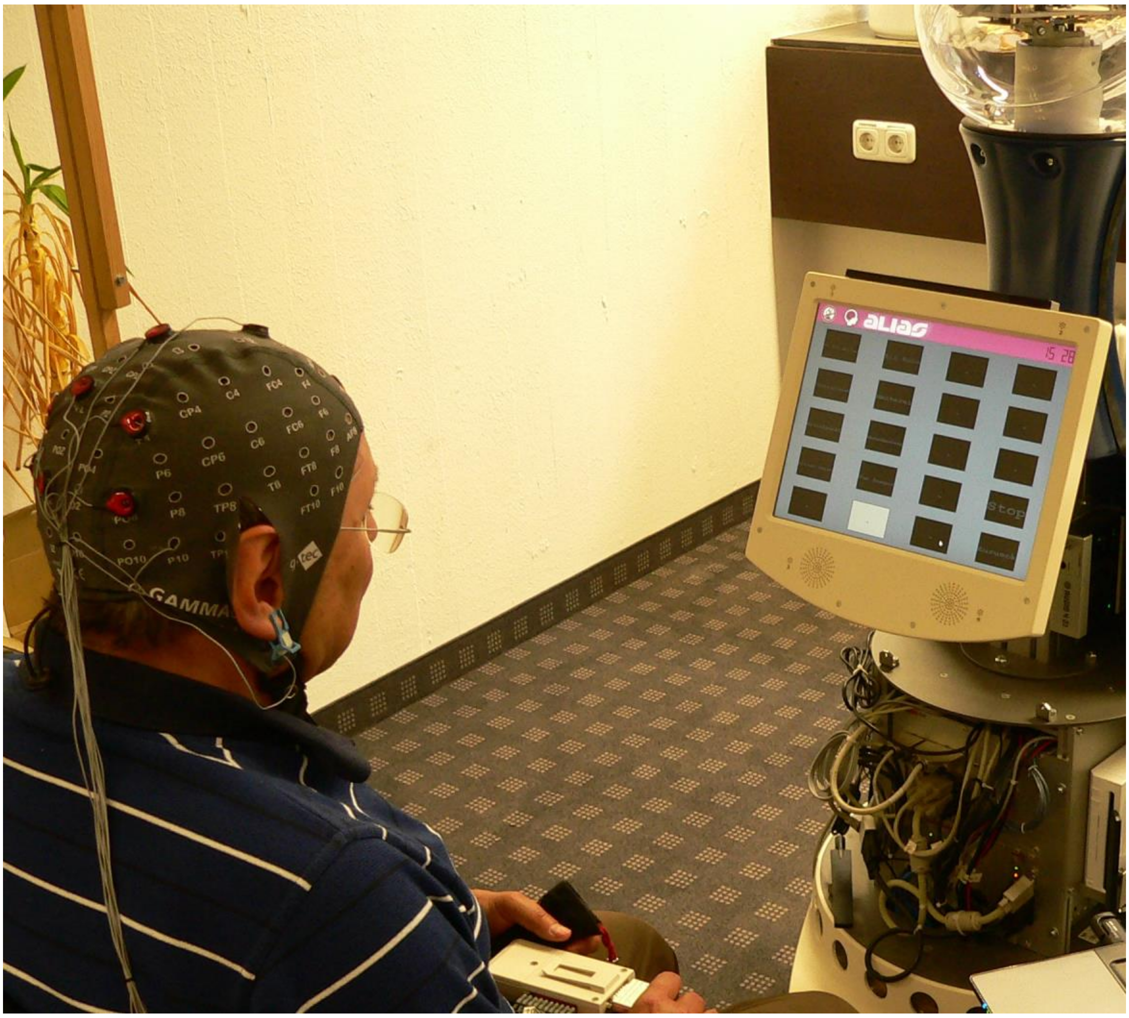


Figure 4: Senior selecting …. Audiobook for playback using the P300 BCI installed on the robot.

In order to achieve this, Subject M1 needed 37 attempts to navigate to the audio books, select his two favorite ones and return again to the main menu. This resulted in an effective selection rate of only 30%, even though the subject reached an average accuracy of 50 %. The subject reported that several retries were necessary to read the text on the icons and to locate the correct ones. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows that subject M1 needed on average 4 flashes and 11 seconds to take a Selection.

Table 1: Accuracies and selection rates achieved by the subject. Further the mean time required for a successful selection time and the number of flashes required are shown.

Subject	1	2	3
Accuracy	50%	20%	80%
Selection rate	30%	0%	80%
Mean # Flashes	4	9	4
Mean time / Selection [s]	11	20	14

Subject M2 had some difficulties in taking any selection. Amongst others it had like the first subject problems to read and identify the icons, in addition to the poor overall accuracy was able to achieve. To take one single selection, it needed about 20 seconds and on average 9 flashes each.

Subject M3 decided to go to the communication menu and open the web-browser (**Fehler! Verweisquelle konnte nicht gefunden werden.**), which currently has to be controlled via touch screen. After closing the browser by using the touch screen and returning to the BCI control it navigated back to the main menu and decided to listen to an audio book. This subject had already participated in earlier tests conducted during the second field trials in September 2012. Being already familiar with the different BCI masks and the BCI system, it had fewer difficulties to locate the different icons. Therefore it was able to achieve an accuracy of about 80%.

Figure 5: User started browser which displays ALIAS homepage as its start page.

6 Summary and conclusions

In this final test it could be shown that users are able to control the ALIAS robot using the BCI system. Thereby the new ACTOR protocol allows for changing the actions and selections presented to the user and adopt and extend the system dependent on the software installed on the robot. The instructions and predefined texts are transmitted to the dialog manager utilizing the UDP network protocol when selected by the user of the BCI. The SOCI interface allows for displaying the BCI controls on the same screen as the graphical user interface used to navigate the robot.

During the test, some of the users had problems to locate the appropriate icons they wanted to select and concentrate on them. According to their feedback they had difficulties to read the text displayed on the icons. The main reasons mentioned were the small font size used to fit the text inside the icon and the poor contrast between the icon and the background color of the GUI window. Another suggestion was to reduce the number of unused icons which may distract the user and move the icons closer together. It was also reported by one user that the position and angle of the monitor was not optimal for reading all the icons.

Despite the need to improve the display of the icons, for example by using larger letters, improving the contrast or allowing to adjust the position and angle of the screen to the users' needs, the achieved tight integration within the dialog manger and the GUI of the ALIAS robot enables users to control the robot.

7 References

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