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# UTRECHT NEUROPROSTHESIS SYSTEM: NEW FEATURES TO ACCOMMODATE USER NEEDS

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ABSTRACT: Individuals with locked-in syndrome can benefit from Brain-Computer Interfaces (BCIs) as an alternative assistive technology for communication. The Utrecht NeuroProsthesis (UNP) is a fully implanted ECoG based BCI that provides the user with independent control of a computer using intentional brain signals. In order to avoid technology abandonment and to stimulate home use, a user-centered approach to design and development of the system is essential. Here we show accommodation of several of the needs expressed by users of the UNP system, including new features that provide the user with control over the system during the night and which increase training efficacy.

## INTRODUCTION

The Utrecht NeuroProsthesis (UNP; [www.neuroprosthesis.eu](http://www.neuroprosthesis.eu)) has been recently presented as an augmentative and alternative communication system for individuals with severe paralysis and communication problems [1]. This system is fully implanted and is specifically designed for autonomous home use. It makes use of two electrocorticography (ECoG) strips, one placed over the hand area of the sensorimotor cortex and the other placed over the dorsolateral pre-frontal cortex (DLPFC). The selection of these locations is based on previous work showing that neuroelectrical activity can be generated by patients with quadriplegia by attempting hand movements [2], and on work showing the feasibility of accurate BCI control by modulation of gamma-power of the DLPFC in epilepsy patients [3]. The activity of the sensorimotor area is used for home use by both users as it yields the most consistent BCI control [1]. By attempting to move the hand, the user generates a decodable brain signal and can control the UNP with the resulting 'brain click', which selects the currently highlighted item on the screen, analogous to a mouse click.

We have previously reported on the signal processing pipeline and presented the graphical user interface [4]. In short, the signal is processed by six consecutive filters that smooth and normalize the signal and convert it to a brain click. Simultaneously, the user can activate an 'escape sequence', which results in a specific screen being shown immediately, with the option to alert a caregiver [5]. The brain clicks and escape sequences are produced by attempting to move the hand with different durations: short and long respectively.

To avoid technology abandonment and to improve home-use, the system needs to be usable in an easy and intuitive manner. To this end software was developed within a quality system for medical software that provides the user with a personalized user menu, training applications, a spelling application, possibility to alert a caregiver with sound, and stand-by functions.

Here, we give an update on the development of the UNP software and describe the novel features of the system that have been employed in two users implanted with the UNP.

## MATERIALS AND METHODS

The UNP was implanted in two locked-in individuals, one suffering from late-stage Amyotrophic Lateral Sclerosis (ALS), referred to as UNP1 here, and another individual who suffered a brainstem stroke, referred to as UNP4. Subdural ECoG strips with 4 electrodes each (Resume II®, Medtronic, 4 mm electrode diameter, 1 cm inter-electrode distance, off-label use) were placed over the sensorimotor hand region and over the DLPFC. Electrode strips are connected subcutaneously to an amplifier and transmitter device (Activa® PC+S, Medtronic, off-label use), subcutaneously placed under the left clavicula. This device amplifies and digitalizes the signals, both in the power and time domain, from pre-selected bipolar electrode pairs. Signals from sensorimotor and DLPFC strips can be used to control the UNP menu.

User requirements have led to the development of new features in the UNP system. In this paper we address two new features: the *Sleep Mode,* and the *Continuous Click Task* (CCT). The Sleep Mode was developed on the request by one of the UNP users. It allows the user to autonomously wake the system up during the night and alert the caregiver. In this way the user can get help when needed during the night. The CCT was developed to allow users to more efficiently practice generating brain clicks.

The Sleep Mode can be accessed from the menu by both the user and caretaker, by means of a brain click or tap on the screen, respectively. When the Sleep Mode is activated, the screen turns black and the

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brightness is decreased to not disturb sleep. A grey lock symbol indicates the system is in standby. The caretaker can exit the Sleepmode by tapping the screen, which brings up the main menu. The user can wake the system by activating an escape sequence, which requires a longer duration of attempted movement than the regular escape setting used during the day. This prolonged duration is used to prevent unintended waking of the system due to spontaneous brain activity occurring during sleep. When the user awakes the system, an auditory notification is played, which informs the caretaker that assistance is required. This notification continues to play until the caretaker taps the screen, after which three options are displayed: to return to the Sleep Mode, go to the main menu, or start the spelling application (Tobii Dynavox Communicator 5, referred to as 'Typer' in the menu), which allows the user to spell words on the screen. Based on the judgment of the caretaker an option is selected, allowing the user to either return to sleep, give further instructions through the spelling application, or access the main menu for any other desired actions. As a safety measure, in case the caregiver forgets to click one of the three options, the user can still activate the night mode escape, which will again sound the auditory notification, until a caregiver taps the screen. This flow of activity is depicted in Figure 1.

The CCT is a modification of the previously reported click task [1] and was implemented with three options, aiming to make practicing more efficient using different approaches. In the 'basic' mode, the user can practice his or her timing of creating brain clicks. In the 'help' mode, the system can aid the user with creating clicks during initial training, and in the 'dynamic' mode, the system can optimize the parameters of the task in real time. In all modi the interface is the same, to provide the user with a consistent view.

Through this interface the user is shown a row of eight molehills, with a mole sitting on top of one. Aim of the task is to select the molehill with the mole on top. To this end a selection box highlights the molehills

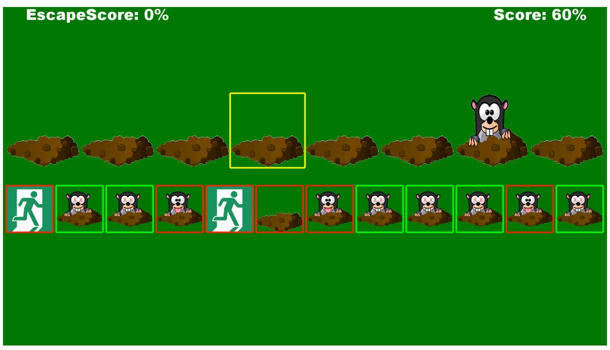


Figure 2: Interface of the CCT, showing the row of eight molehills. In this screenshot the mole sits on the seventh molehill and the selection box highlights the fourth molehill. Below this the feedback icons are shown. The scores for escape sequences and brain clicks are shown in the top corners.

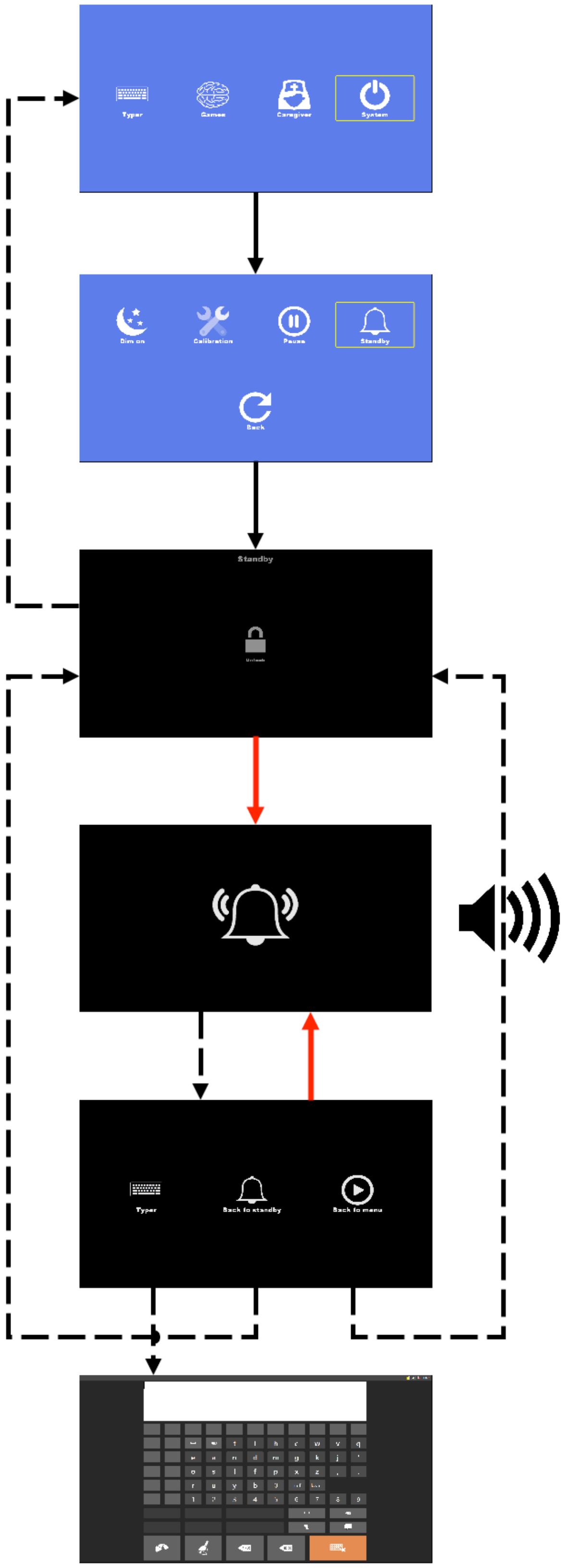


Figure 1: Schematic overview of the Sleep Mode. Solid black lines depict transitions between screens that both the user or caretaker can perform, red solid lines are transitions that only the user can perform, and dashed lines depict transitions only the caretaker can perform.

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sequentially, starting from the left and moving to the right. After the rightmost hill is highlighted, the selection box returns to the leftmost hill and the process repeats. The user can at any time create a brain click to select the currently highlighted molehill. If this molehill has the mole on top, one point is awarded and the accuracy is displayed at the top-right corner of the screen. Below the row of molehills a green-boxed icon (a mole with X's in his eyes) indicating a 'hit' (true positive) is added to a row of feedback icons. Conversely, if the highlighted molehill with the mole on top is not selected by the user, a 'miss' (false negative) is registered, adding a red-boxed icon of a mole sticking its tongue out to the feedback icons. To facilitate efficient practice, the mole changes position after a hit or miss. If a molehill is selected that does not have the mole on top, a red-boxed icon (an empty molehill), indicating a false positive, is added to the feedback icons. Escape sequences can also be trained using this task: in this case an icon of an escape sign is displayed above the row with molehills, cueing the user to produce an escape sequence. Based on whether an escape sequence is successfully produced, points are awarded and an escape sign is added to the feedback icons, with the colour of the border indicating whether the escape sequence was successfully created: green for successful and red for unsuccessful. These points are kept separately from the points awarded for hits with moles. Moles and escape cues can be presented within the same task run, or only moles or only escape cues can be presented. This process is depicted in Figure 2.

In the basic modus the CCT works as described above. In the help modus the CCT can provide additional help to the user: in case of a false positive or negative the system can instead assign the input as a true positive or true negative and give feedback accordingly. The amount of help can be varied: from adjusting a high percentage of false classes to a few, and eventually to no help. Rationale here is to gradually increase the control the user has, allowing the user to gradually adapt and train to create brain clicks, an approach that has been used successfully in other BCI systems [6]. In addition, this approach helps in keeping the user motivated during training, in order to further facilitate efficient training.

The dynamic mode allows for online optimisation of the parameters underlying user performance. These parameters pertain to either the feedback given to the user, such as the speed with which the molehills are highlighted (scan rate), or to the construction of a brain click, such as how long the movement should be attempted to create a brain click, or to the calibration of the signal, such as the z-scoring performed on the signal (cf. [4]). Based on the feedback (e.g. false positives or negatives) these parameters are continuously optimised online, converging to settings that allow the user to produce correct brain clicks and escape sequences as efficiently as possible. This modus can be used to make training more efficient by both reducing the time needed to optimise parameters required for optimal training, as well as allowing users to improve their performance by training with parameters that continuously alter towards increasingly effective performance. In addition, this modus allows us to monitor optimal parameter settings over time to see if (temporary) changes are useful, for example when the user experiences a period of time in which he or she is feeling more tired than usual, or is experiencing other temporary conditions that can alter the signal. To facilitate this, the CCT can be started by the user at home and the resulting optimal parameters are stored to be reviewed by the research team, allowing changes to be made to the standard parameters if necessary.

## RESULTS

The Sleep Mode requires different settings with respect to the duration the control signal has to exceed the threshold, and with respect to the value of the threshold during sleep, compared to the wake situation. We are currently in the process of optimising the parameters to the characteristics of the brain signal during sleep to accommodate use of the Sleep Mode without spurious alerting of the caretaker.

The CCT has been used by both users for 73 runs in total, with UNP1 using an average run time of 80 seconds and UNP4 an average time of 150 seconds. Of these runs, the basic mode has been used by both users, for a total of 46 runs, in order to practice timing. The help mode has been used 11 times by UNP4 and is perceived as more fun. Based on this feedback, the CCT was used during specific sessions to make training more rewarding. The dynamic mode has been used 16 times in total, by both users. With UNP1 we used this mode with the aim of reducing the scan rate. This resulted in a decrease of the used scan rate from 2.4s to 1.8s over the course of 7 training runs. UNP1 now uses the resulting 1.8s scan rate for home use and reports being pleased with the task and the resulting optimised scan rate.

## DISCUSSION & CONCLUSION

User input and specifications are crucial for the development of home use assistive technology. In the last two years we have designed and developed new features of the UNP system based on the request and feedback provided by the users implanted with this BCI. We have reported on two new features, which provide the user with control of the system during the night and improve the accuracy of BCI control. These features are especially important for users in a nearly complete locked-in state, likely providing the only reliable communication channel once no volitional residual movement is left.

Preliminary results are promising: users report finding the CCT pleasant, and based on the use of the dynamic mode of the CCT, one user now uses a faster scan rate for spelling, allowing for faster communication. For the Sleep Mode no results are yet available.

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The UNP system is continuously being updated to integrate user requests. There are a number of features that are expected to be implemented in the future, allowing, for example, faster menu navigation, and increased speed of spelling, both of which are features that users of BCI's have reported to be desirable [7].

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