THE BERLIN BRAIN-COMPUTER INTERFACE PRESENTS THE NOVEL MENTAL TYPEWRITER HEX-O-SPELL

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SUMMARY: We present a novel typewriter application 'Hex-o-Spell' that is specifically tailored to the characteristics of direct brain-to-computer interaction. The high bandwidth at which a user may perceive information from the display is used in an appealing visualization based on hexagons. On the other hand the control of the application is possible at low bandwidth using only two control commands (mental states) and is relatively stable against delays and the like. The effectiveness and robustness of the interface was demonstrated at the CeBIT 2006 (world's largest IT fair) where two subjects operated the mental typewriter at a speed of up to 7.6 char/min. It was developed within the Berlin Brain-Computer Interface project in cooperation with specialists for Human Computer Interaction.

INTRODUCTION

Brain-Computer Interfaces (BCIs) translate the intent of a subject measured from brain signals directly into control commands, e.g. for a computer application or a neuroprosthesis ([3]). Although the proof-of-concept of BCI systems was given decades ago, several major challenges are still to be faced. One of those challenges is to develop BCI applications which take the specific characteristics of BCI communication into account. Apart from being prone to error and having a rather uncontrolled variability in timing, its bandwidth is heavily unbalanced: BCI users can perceive a high rate of information transfer from the display, but have a low-bandwidth communication in their control actions.

The Berlin Brain-Computer Interface (BBCI) is an EEG-based BCI system which operates on the spatio-spectral changes during different kinds of motor imagery. It uses machine learning techniques to adapt to the specific brain signatures of each user, thereby achieving high quality feedback already in the first session ([1]). The mental typewriter presented here incorporates state-of-the-art knowledge from Human Computer Interaction (HCI) and report results of a public performance with two subjects.

METHODOLOGY

The challenge in designing a mental typewriter is to map a small number of BCI control states (typically two) to the high number of symbols (26 letters plus punctuation marks) while accounting for the low signal to noise ratio in the control signal. The more fluid interaction in the BBCI system was made possible by introducing an approach which combined probabilistic data and dynamic systems theory based on our earlier work ([2]) on mobile interfaces.

Here we take the example that the typewriter is controlled by the two mental states *imagined right hand movement* and *imagined right foot movement*. The initial configuration is shown in the leftmost plot of Fig. 1. Six hexagonal fields are surrounding a circle. In each of them five letters or other symbols (including '<' for backspace) are arranged. For the selection of a symbol there is an arrow in the center of the circle. By imagining a right hand movement the arrow turns clockwise. An imagined foot movement stops the rotation and the arrow starts extending. If this imagination is performed in a longer period the arrow touches the hexagon and thereby selects it. Then all other hexagons are cleared and the five symbols of the selected hexagon are moved to individual hexagons as shown in Fig. 1. The arrow is reset to its minimal length. Now the same procedure (rotation if desired and extension of the arrow) is repeated to select one symbol.

A language model determines the order of the symbols in one hexagon depending on the context, but this and many more important details go beyond the scope of this note.

RESULTS

On two days in the course of the CeBIT fair 2006 in Hannover, Germany, live demonstrations were given with two subjects simultaneously using the BBCI system. These demonstrations turned out to be BBCI robustness tests *par excellence*. All over the
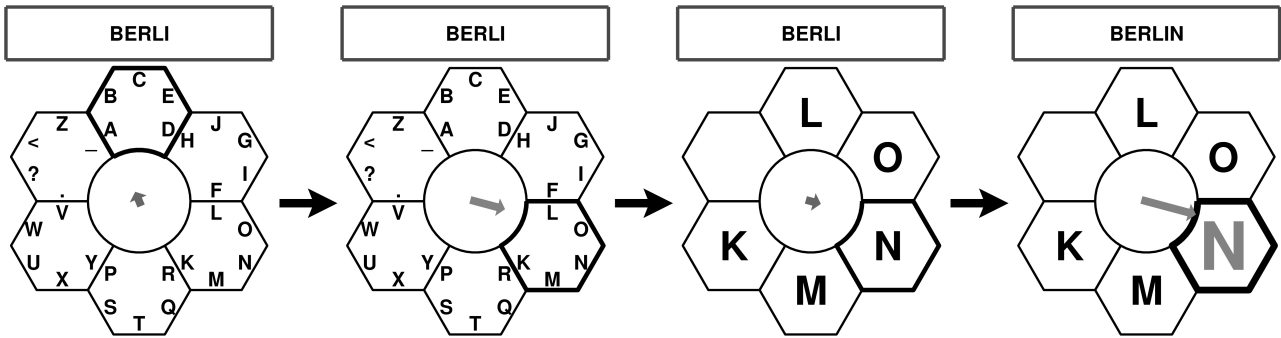
Figure 1: The mental typewriter 'Hex-o-Spell'. The two states classified by the BBCI system control the turning and growing of the gray arrow respectively (see also text). Letters can thus be chosen in a two step procedure.

fair pavilion, noise sources of different kinds (electric, acoustic,...) were potentially jeopardizing the performance. A low air humidity made the EEG electrode gel dry out and last but not least the subjects were under psychological pressure to perform well for instance in front of several running TV cameras or in the presence of the German minister of research. The preparation of the experiments started at 9:15 a.m. and the live performance at 11 a.m. The two subjects were either playing 'Brain-Pong' against each other or writing sentences with the typewriter Hex-o-Spell. Except for short breaks and a longer lunch break, the subjects continued until 5 p.m. without degradation of performance over time which is a demonstration of great stability. The typing speed was between 2.3 and 5 char/min for one subject and between 4.6 and 7.6 char/min for the other subject. This speed was measured for error-free, completed phrases, i.e. all typing errors that have been committed had to be corrected by using the backspace of the mental typewriter. The total number of characters spelled in error-free phrases was up to 560 per subject per day.

For a BCI driven typewriter not operating on evoked potentials this is a world class spelling speed, especially taking into account the environment and the fact that the subjects did not train the usage of the BBCI typewriter interface: the subjects used the typewriter application only twice before.

DISCUSSION

The prospective value of BCI research for rehabilitation is well known. In light of the work presented here we would advocate a further point. BCI provides stimulation to HCI researchers as an extreme example of the sort of interaction which is becoming more common: interaction with 'unconventional' computers in mobile phones, or with devices embedded in the environment. These have a number of shared attributes: high-dimensional, noisy inputs, which describe intrinsically low-dimensional content; data with content at multiple time-scales;

and a significant uncontrolled variability. The mismatch in the bandwidth between the display and control channels (as explained in the introduction) and the slow, frustrating error correction motivate a more 'negotiated' style of interaction, where commitments are withheld until appropriate levels of evidence have been accumulated (i.e. the entropy of the beliefs inferred from the behavior of the joint human-computer system should change smoothly, limited by the maximum input bandwidth). The dynamics of a cursor, given such noisy inputs, should be stabilized by controllers which infer potential actions, as well as the structure of the variability in the sensed data. Hex-o-Spell demonstrates the potential of such intelligent stabilising dynamics in a noisy, but richly-sensed medium. The results suggest that the approach is a fruitful one, and one which leaving open the potential for incorporating sophisticated models without *ad hoc* modifications.

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