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Brain-Computer-Interface-based screen numeric keyboard

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Abstract: The article presents research on EEG-based screen numeric keyboard and performance measurement

Key Words: Brain-computer Interface, Neural, Brain activity detection

1. INTRODUCTION

The paper presents research focused on designing of an Brain-Computer-Interface-based (BCI) numeric keyboard interface for entering PIN numbers. Tests were performed to reveal the quality of the acquisition system. Additionally, subjective user feedback on system utilization was collected. UI of the application was created in Unity Engine. Data collecting device utilized in the work: NextMind allows for the acquisition of information about brain electrical activity and converts the data to easily interpretable control signals.

2. PROJECT ASSUMPTIONS

To perform tests on user-device interaction, certain assumptions were made: all tests were completed on the same hardware and software. In addition, all performed scenarios were identical between each subject.

3. DATA ACQUISITION

Electroencephalography (EEG) is typically a non-invasive method for detecting brain activity based on voltage fluctuations, primarily resulting from the orientation and distance to the source of the activity. The observable frequencies are in the range of 1 to 30 Hz [1].

A wide range of effects related to brain activity can be used to enable effective control of various processes, including [4] slow cortical potentials (SCP), stimulus-related synchronizations and desynchronizations, steady-state evoked potentials (SSEP), P300 wave.

From the point of view of Brain-Computer interfaces, steady-state evoked potentials (SSEP) are especially interesting. SSEPs are electrophysiological responses caused by exposure to stimuli of a specific frequency, resulting in the appearance of a component of a corresponding frequency in specific areas of the cerebral cortex. Depending on the nature of the interacting stimulus, the following steady-state evoked potentials are distinguished: auditory (steady-state auditory evoked potentials, SSAEP), visual (steady-state visual evoked potentials, SSVEP), and sensory (steady-state somatosensory evoked potentials, SSSEP). An important advantage of the SSEP effect is the short reaction time to the appearance of a stimulus, which ensures a high bandwidth of the brain-computer interface [5].

Such BCI interfaces are particularly interesting in supporting people with disabilities for rehabilitation and even communication purposes (e.g. BCI keyboards) [2] [3]

The Next Mind interface was chosen because of its ease of use, compact design, and available SDK, allowing seamless integration with the Unity Engine. The application of this device allowed to put the focus on the rapid prototyping of the UI of the on-screen keyboard application as well as simplified the process of data collection.

For the purpose of this research, the SSVEP effect was exploited [6]. An on-screen numeric keyboard was presented, and each button was assigned a different type of NextMind active asset (related to various texture patterns and texture blinking frequency). When the user gazes at a specific button in the occipital area of the brain, patterns in EEG signals emerge related to the specific active asset configuration. Thus, there is a way to determine the button on which the user is looking at so the selection of the proper button-related value.

4. USER INTERFACE

A unified interface was created in the Unity Engine. The user was able to select numbers by looking at the buttons. The goal of the user was to enter a four-digit passcode (which was displayed in the top right corner of the screen). After the passcode was provided, the user had to accept the entered passcode by selecting the ENTER on-screen button. The time of entering a passcode was limited to 30 seconds. The information on what button the test subject was looking at was, as mentioned previously, obtained by an EEG sensor mounted to the back of the participant's scalp. The UI of the application is presented in Fig. 1 - 5.

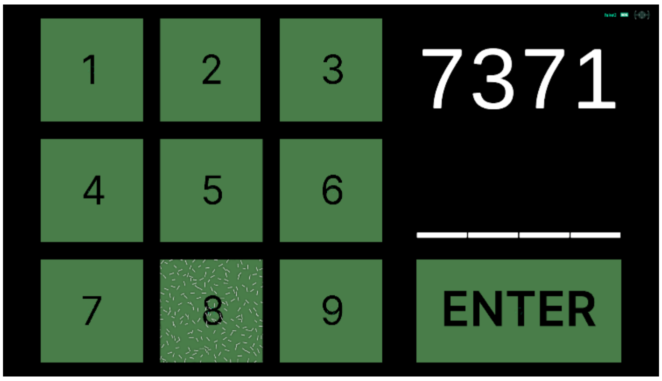

Figure 1: Before typing has started.

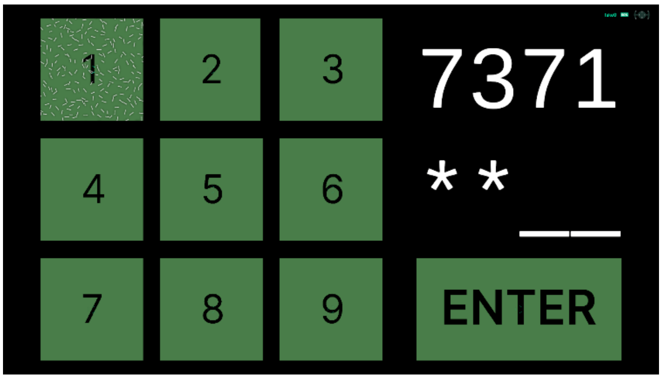

Figure 2: While typing.

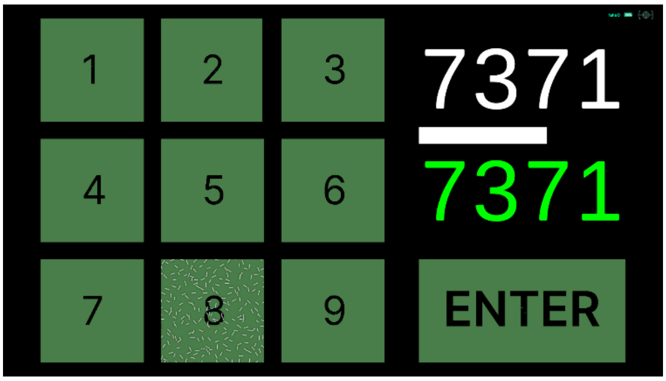

Figure 3: When written code matches the provided one.

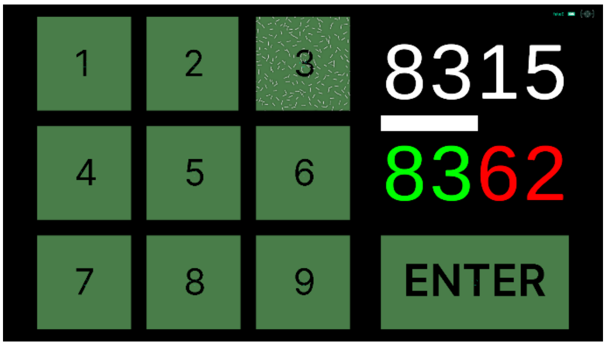

Figure 4: When written code does not match the provided one.

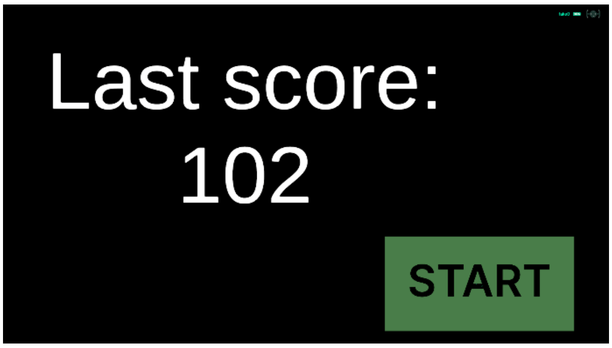

Figure 5: Display of total score after all tests has been completed.

The total score obtained by the user is calculated using the following formula:

$$Score = \frac{\sum_{i=1}^{n}(3 * 10^4 - t_i) * \frac{p_i}{c}}{100 * n}$$

where n is equal to the total number of tests, t is the time the test has taken, p is the amount of numbers being correct, and c is the total amount of numbers.

5. PERFORMANCE METRIC

To test whether a device/system, that the user is interacting with, is applicable in the real world or not, one cannot only judge based on the pure mathematical coefficients, but rather should observe the interaction of the device/system with the user, leading to a decent understanding of usefulness of such device. This is the reason why, while the tests were performed, two metrics were taken into account. The first one was the total score, which gives a good understanding of how well the test subject was able to cooperate with the test device. Second was the test subject itself and their own personal opinion after using the device.

6. TESTS

Tests were performed using NextMind’s EEG and developed application. Before the test, volunteers went through the process of NextMind calibration. During test execution, the subjects were asked to enter the correct code ten times. When the test was over, the program calculated the Score using the provided formula, and participants were asked to rate their experience with the device. For every test to be replicable, they were performed in the same room, on the same hardware and software, with dim light, occluded windows, and complete silence.

7. RESULTS

Results seen in the experiment were not as prominent as expected (tab. 1), with an average total score of 69 points and an average personal opinion of 4/5. The biggest issue in the tests was the inconsistency of results, with a high of 165 and a low of -7 points that, despite the rather high score of 69 points on average, makes the conclusion of whether the technology is or is not suited for wider use, extremally hard to make. But, besides that, there was still a lot to conclude from. The most interesting measure turned out to be the paradoxically very high personal opinion mark that every test subject was to give after using the EEG sensor. The lowest observable score was 3/5, even though the total score of that test of -7 points was lacking significantly, and the highest personal score of 5/5, which was given twice, could be seen next to both 165 and 42 total score points. It is obvious that in order to draw any sensible conclusion, more tests need to be performed, the total score is too random for being a scientific data source, and the personal opinion score needs to be redesigned as it seems to have no linkage with the calculated scores.

Table 1. The performed tests on which results were formed.

Score, defined by the formula	User rating
165	4/5
42	5/5
76	4/5
-7	3/5

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