 DOI:10.3217/978-3-85125-378-8-8

Brain Painting Version 2 - evaluation with healthy end-users

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Abstract

Brain Painting is an application for a brain-computer-interface (BCI) that allows for painting using the brain activity generated by event related potentials (ERPs) in response to maintained attention on visual stimulations. Considering feedback from the extended use of Brain Painting V1 at home by two locked-in patients, we developed a new version of Brain Painting including auto-calibration, new painting features, and a tutorial video explaining its functions. This new version was tested with 10 healthy participants. Results ascertained that the tutorial video is sufficient for BCI Brain Painting novices to perform the subsequent Brain Painting session. Copy Painting was achieved with 94% accuracy and subjects used the application for on average 51 minutes in the free painting mode after termination of copy painting. Feedback from healthy subjects will help us to refine the application before bringing it to the two end-users in the locked-in state.

1 Introduction

The BCI application Brain Painting (Münßinger, et al., 2010) allows an end-user to paint on a virtual canvas using brain activity without the requirement of motor pathways. Brain Painting is controlled by a BCI with event-related potentials (ERP) as input signal.

Brain Painting allows the end-user to select basic shapes of different color, opacity and size on a virtual canvas displayed on a monitor, such that the user can combine them and compose pieces of art. This system was designed to match the requirements of paralyzed or "locked-in" end-users (Zickler, Halder, Kleih, Herbert, & Kübler, 2013). Formerly restricted to lab or demonstration purposes, the system has been adapted for home use by Holz and colleagues (Holz, Botrel, Kaufmann, & Kübler, under review) and was given to two locked-in patients so they could use Brain Painting on a regular basis for several months. Our first end-user reported to be highly satisfied with the system, and we could measure an improvement in the quality of life. The end-user expressed the wish to have more painting features and a signal validation tool that would ensure a correct setup prior to every use.

Following the user-centered design (Kübler, et al., Manuscript submitted for publication), Brain Painting Version (V) 2 has been developed to face the new challenges encountered in home use environment. Thus, Brain Painting V2 is not only an extension of Version 1, but has been newly programmed to incorporate additional painting features such as lines and text. An autocalibration was also implemented that can easily be performed prior to every session. With the following study, we aimed at evaluating the usability of the system with a sample of healthy users in the laboratory.

2 Software

The Brain Painting V2 application uses, Python 2.7, Qt, Pygame and BCI2000. It is composed of 3 independent but connected modules: (I) The graphical user interface (GUI), coded in Python and Qt, contains the painting canvas in the middle and a status bar on the left (see Figure 1) to display important information such as selected colors and brush size. The menu bar on the top allows to load or save paintings. Below the menu bar, there are play, pause and stop buttons that respectively allow to start, pause and stop a Brain Painting session. (II) Running in background, BCI2000 processes the EEG signal, classifies and sends stimulations to the speller. The GUI uses the Telnet protocol interface of BCI2000 to load parameters, start and stop signal processing. (III) The custom P300 speller matrix feedback uses Pygame. It displays the Brain Painting matrix such that one symbol represents one painting function on the canvas. Famous faces flashes are implemented for stimulation to increase the signal-to-noise ratio (Kaufmann, et al., 2013). Several matrices were created to include all requested painting functions, and can be reached from the main menu.

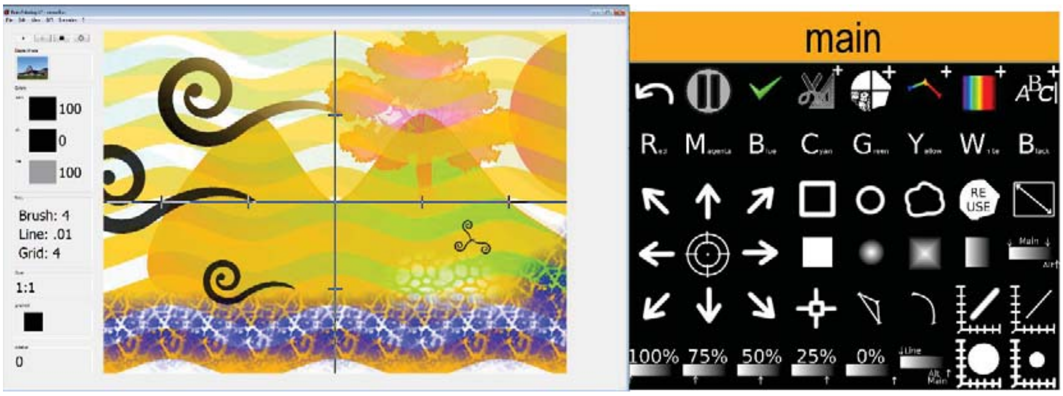

Figure 1: (left) Graphical User interface with the Canvas and the status bar, positioned on the side. The session control buttons are above the status bar. (right) 6x8 Speller matrix with symbols associated with Brain Painting functions positioned in front of the participant. The painting on the left was composed during a live demonstration in the 'Psychologie und Gehirn' conference in Würzburg (PuG 2013; http://tagung.dgpa.de/).

Figure 2: Timeline of the study

3 Methods

Ten healthy participants (mean age 25 SD=2,8, all students) were included. Each participant was seated in a comfortable chair for the duration of the study (see Figure 2) with a speller stimulation monitor 0.5 to 1 meter distance in front. The second monitor, placed aside, displayed the Brain Painting canvas. A custom 14 electrodes EEG cap (Debener, Minow, Emkes, Gandras, & Vos, 2012) was used for EEG recording. The cap is a low-budget combination of a customer grade EEG amplifier with passive EEG electrodes commonly used in lab experiments.

Teaching someone how to use the Brain Painting is the first step for its use. Bearing in mind independent home use of Brain Painting, we created a tutorial video that would ensure a complete understanding of Brain PaintingV2 without the experimenter being present. The tutorial video lasted 29 min and presented all Brain PaintingV2 functions available in the matrix, by displaying their effect on the painting Canvas (see Figure 1). A female speaker uses a mouse cursor to navigate in the matrices and select available functions while commenting every action. Brain PaintingV2 features were summarized in 12 different categories such as "colors", "lines" or "text" and presented point per point.

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Calibration trials comprised 15 stimulations of each rows and columns. Stimulated symbols were overlaid during 62.5ms with a picture of Einstein. The inter stimulus interval was set to 125ms. The user was instructed to focus on one symbol and count how many times the overlaying Einstein face was visible. After 10 trials, classifier weights were adjusted using a stepwise-linear discriminant analysis for 800 ms post-stimulus. The calibration process returned the minimum number of sequences required to reach 100% spelling accuracy. To ensure high accuracy the number of sequences returned was increased by 2; and maintained throughout copy and free painting.

During the "Copy Painting" task participants were asked to select target indicated on the matrix. Each and every selection had an effect on the canvas. If a wrong selection was made, the feedback instructed the user to revert the error using the "undo" function within the matrix. Accuracy was retrieved during this Copy Painting task, and reported the number of correct selections divided by the number of total selections.

In the Free Painting mode, participants were given 15 to 60 minutes to compose two paintings of their own with the new Brain PaintingV2. The experimenter did not provide any hint or help concerning the painting interface during the Free Painting task nor in the Copy Painting task. Time spent on Free Painting was recorded

Participants were given visual analogue scales (VAS) at three different time points during the session: after the tutorial (t1), the Copy Painting task (t2) and the Free Painting task (t3). They were asked to rate, on a scale from 0 to 10, how well they understood each of the 13 Brain Painting features we distinguished.

After the Free Painting task, users were asked to answer on a VAS from 0 to 10, how satisfied and how frustrated they were during the Free Painting session. Participants also filled in the NASA-TLX to indicate the workload of the Brain Painting V2 (0 for no workload to 100 for maximum workload).

Subject	Nb. Seq.	Accuracy	Work load	Satisfac-tion	Frustra-tion	Free Painting duration	Selection / minute	Evalua-tion (t3)
A	4	.97	19	7.7	.9	32	3.3	9.9
B	4	.95	66	5.1	6.5	23	3.6	8.6
C	5	.95	75	3.7	4	68	2.9	6.8
D	5	1	54	9.6	0	60	2.8	9.2
E	5	1	n/a	9.4	1.2	60	2.9	1
F	5	.91	59	6.2	4.5	51	2.9	6.7
G	6	.90	40	7.1	2.5	58	2.5	8.4
H	4	.87	74	4.7	8.1	53	3.3	8.5
I	5	.97	20	5.8	4.8	52	2.9	8.7
J	5	.84	60	7	.8	55	2.8	7.9
Mean	4.8	.94	52	6.6	3.3	51	3	8.5
SD	.63	.05	21	1.9	2.7	12	.31	1.1

Table 1: Individual results indicating parameters, performance and evaluation results. Mean and standard deviation are mentioned at the bottom of the table. "Nb. Seq." states for number of sequences.

4 Results

Participants achieved mean accuracy of 94% (see Table 1 for results of all participants) during the Copy Painting task. Participants spelled with an average of 4.8 sequences which allowed an average of

3 selections per minute. According to the VAS participants understood well the Brain Painting features with an average rating of 9 after the tutorial video (t1), 9 after the Copy Painting task (t2) and 8.5 after the Free Painting task (t3). During the Free Painting task, participants painted during on average 51 minutes. In the VAS applied after Free Painting, participants reported being satisfied with their Free Painting session (M=6.6) and reported low to average frustration (M=3.3). The total workload according to the NASA TLX was M= 52.

5 Discussion

Firstly, our results indicate that the auto-calibration worked fine for all subjects. Further, the tutorial video was very effective because participants reported good understanding of the Brain Painting features. Accuracy was high during Copy Painting corroborating the functionality of Brain Painting V2. After more than 1 hour of sustained use, participants reported average to high satisfaction and low frustration for a medium workload. That indicated good efficiency and high overall satisfaction (Kübler, et al., Manuscript submitted for publication). They spent on average 51 minutes with Free Painting although the experimenter only asked for at least 15 minutes, meaning that participants truly enjoyed Brain Painting. The low-budget EEG cap renders the system even more applicable. It is now safe to provide our locked-in patients with the Brain Painting V2, and investigate whether they will benefit from the practical outcomes of the enhancements of Brain PaintingV2.

Acknowlegments

The study was funded by the European Community for research, technological development and demonstration activities under the Seventh Framework Programme (FP7, 2007-13), project grant agreement number 288566 (BackHome). This paper reflects only the authors views and funding agencies are not liable for any use that may be made of the information contained herein.

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