BCI and Creativity

Yee Chieh (Denise) Chew
Georgia Institute of Technology
85 Fifth St. NW
Atlanta, GA 30308
ychew@gatech.edu

Chip Mappus
Georgia Institute of Technology
85 Fifth St. NW
Atlanta, GA 30308
cmappus@gmail.com

Melody Moore Jackson
Georgia Institute of Technology
85 Fifth St. NW
Atlanta, GA 30308
melody@cc.gatech.edu

CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.

Abstract
In this paper we describe two studies in which Brain Computer Interfaces (BCI) can be used to achieve and evaluate creativity. The two studies use electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) as instruments for gathering brain data.

Keywords
Brain-computer interfaces, creativity

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation;

Introduction
There are three important features that must be considered when deciding on a brain computer interface: invasiveness, response time, and difficulty of use. here is often a trade-off between them. Traditional BCIs have mainly used EEGs and implanted electrodes, the latter being highly invasive and both requiring some expertise in handling though provide good response time. A newer technique for brain imaging is the use of functional near-infrared spectroscopy (fNIRS) which is easy to use and non-invasive. It is not as susceptible to noise as EEG but comes at a cost of response time, as there is a hemodynamic delay. It is this technique that we first explore in our study of the use of fNIRS for creative expression.

The second study, still in its initial pilot phase, is done in conjunction with the Music program at Georgia Tech, and utilizes EEG in an attempt to isolate brain areas that are involved with creativity. It will be described at the end of the paper.

Approach

Creativity in individuals is something that is easily achieved but difficult to measure. What constitutes "creative expression" is often something that is determined by the intent of the producer and not the observer. To deduce this intent, our first project combines fNIR and a post-hoc clustering algorithm in a freeform line drawing program. This was chosen because freeform line drawing is one application that directly facilitates creative expression. While it has been shown that brain-computer interfaces can control a cursor to land or arrive at a destination (i.e. a BCI can be used to "pull" a cursor as it automatically moves from one end of the screen to the other), we are interested in using a single channel of information for arbitrary two-dimensional movement. Specifically, we are interested in users' abilities to trace arbitrary paths in two dimensions. We constructed a line drawing interface that makes several assumptions and constrains line movement. The single channel of activity is used to control both the curvature and the rate at which the line draws. The drawing session always begins in the center of the window. The curvature value always starts with no curvature, and the line starts drawing downward.

We constructed representations of the 26 characters in the English alphabet. These serve as a "template" for users in each experimental trial and are shown as a grayed background image. We coarsely grouped characters according to the number and radii of component curves. From this grouping, we selected a final subset of letters for the experiment based on the relative curve complexity which resulted in the set: E,H,I,J,L,M,Q,R,Y. Users are instructed to trace the line using the BCI that follows the template letter in each trial. Being able to trace the letter representations successfully is evidence that subjects can draw arbitrary shapes using the control interface.

Experiment

Seven subjects participated in the experiment and received monetary compensation for participation. All participants had normal vision and hearing with no history of neurological or psychiatric illness. All subjects gave informed written consent, were compensated for their participation, and the study was given approval by the Georgia Institute of Technology Institutional Review Board. Participants were seated in a comfortable chair approximately 75cm away from a video display showing the drawing interface using a horizontal refresh rate of 70Hz. For each subject, the sensor array was placed over the left inferior frontal gyrus, approximately at F7 (Broca's area of the brain) in the 10-20 placement system. The sensor array was then calibrated to threshold light detection rates. The recording room was dark during calibration and experimental phases of the session.

A preliminary screening process was used to ensure participants were able to indicate intent using the BCI. After successful screening, the experimenter explained the goal of the experiment was to trace a total of 18 characters (9 unique) on a drawing pane. Participants were asked to perform activation tasks (e.g. subvocal singing, counting, spelling) in order to draw a straight line, and deactivation tasks (e.g. mental cube rotation) to draw a curved line. The interface provided visual feedback about the extent of activation to help guide participants in controlling the interface. The drawing line color indicated activation along the color spectrum: red indicated maximum activation; blue indicated minimum activation. The experiment paused after the first block, and participants were given the option to rest before the next block.

We recorded sample points as Cartesian coordinates of the rendered drawing, allowing us to compare template drawing points to trial performance. We also recorded the BOLD response data for each trial, allowing us to compare groups of trials.

Results and Analysis

We measured the error between the points representing the template and the points generated in each trial using the BCI control as a means of comparing participants' ability to reproduce the templates of each letter. Table 1 shows the root mean squared error (RMSE) for each letter. In this case, an increase in RMSE is correlated with the relative difficulty of each letter; as the number of curves increases or the radii of the curves decreases in each letter, the RMSE increases. As a coarse measure of success, the RMSE measure indicates that participants were unable to accurately control the interface to reproduce many of the character subset. For letters H,J, M,Q, and Y RMSE decreases from the first block to the second; evidence that performance improves with practice using the interface.

letter	first block	second block	total
E	269.12	322.50	349.51
H	319.64	305.74	297.28
I	310.92	326.21	108.80
J	300.48	234.27	205.05
L	332.16	364.10	371.24
M	351.75	341.46	352.31
Q	355.20	346.94	386.05
R	334.88	334.88	327.85
Y	309.89	299.17	358.07

Table 1: RMSE for each letter type for the first block, second block, and all blocks

In a post-hoc analysis, we explored the possibility for differentiating trials such that we can recognize the intended letters. We clustered the time series of BOLD response data of each trial using a Euclidean distance measure. In this way, we compare the relative distances between the time courses.

The cluster information reveals some interesting details about the time courses of the activation patterns for each letter. In general, letters whose beginning activation sequences are similar were clustered together. Qualitatively, letters H and R possess many of the same curve characteristics. However, a clustering approach groups them separately.

Discussion

As a means of creative expression, the drawing interface is difficult to control. Both the RMSE and visual renderings of the trial data show participants were not able to reproduce the template characters accurately. In part this may be due to the latent onset of the BOLD response. Additionally, we noted in many trials that activation patterns would tend to oscillate from maximum to minimum. One explanation of this is that participants were overcompensating activation once a deviation from the template began.

In spite of this, the clustering information provided evidence that the intended representation of the letters is differentiable, even when the visual representation of the activation pattern does not correlate well with the template. These intended representations, while not recreating the template letters themselves may be differentiated and therefore could be used as a set of gestures for indicating intent. In the context of using a fNIRS for control we feel the result has some significance. If we are able to differentiate intent using a relatively temporally short segment of the BOLD response, an fNIRS based interface may be better used to indicate discrete selections.

EEG and musical creativity

Our second study aims to understand the brain regions involved in musical improvisation and thus gain a better understanding of musical creativity. Thus far, there are only two neuroimaging studies that have looked directly at music improvisation. Both studies used fMRI to look at improvisation, one studying piano [1] and the other studying jazz [2]. This study will be the first to use EEG to study musical creativity. What is problematic about the first two studies lies in the difficulty in differentiating between music generation and music playback. That is, neither study adequately controlled for the mental demand that is required when attempting to remember what was improvised, which may have confounded that brain regions that were found active in the studies. This study seeks to address that problem.

The study will recruit twenty master musicians to play short improvised pieces on a keyboard while wearing an EEG cap. There are three conditions in the study: improvise, reproduce, and rest. Each task will last for 40 seconds. There will be 12 “blocks” of these three conditions where participants will improvise twelve different segments. During the reproduce portion of the task, subjects will be provided with a transcription of their improvised work, lessening the memory load required to reproduce it. It is our hope that this study will help us gain new insight to the nature of creativity.

Biography

Yee Chieh (Denise) Chew is a second year Human-Centered Computing PhD student at the Georgia Institute of Technology. She is a member of the Brain Lab under the direction of Prof. Melody Moore Jackson, and her research focuses primarily on exploring ways that Brain Computer Interfaces can be used to achieve and evaluate creative expression. She has worked on various projects involving different instruments (namely, EEG and fNIR) in her studies.

Acknowledgements

We thank our advisor and our labmates for all their encouragement and support.

Bibliography

[1] S.L. Bengtsson, M. Csíkszentmihályi, and F. Ullén, “Cortical Regions Involved in the Generation of Musical Structures during Improvisation in Pianists,” *Journal of Cognitive Neuroscience*, vol. 19, May. 2007, pp. 830-842.

[2] C.J. Limb and A.R. Braun, “Neural Substrates of Spontaneous Musical Performance: An fMRI Study of Jazz Improvisation,” *PLoS ONE*, vol. 3.