MusEEGk: A Brain Computer Musical Interface

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Abstract
We present a novel integration of a brain-computer interface (BCI) with a music step sequencer composition program. Previous BCIs that utilize EEG data to form music provide users little control over the final composition or do not provide enough feedback. Our interface allows a user to create and modify a melody in real time and provides continuous aural and visual feedback to the user, thus affording them a controllable means to achieve creative expression.

Keywords
Brain-Computer Interface, P300 Evoked Potential, Music composition

ACM Classification Keywords
H5.5. Information interfaces and presentation (e.g., HCI): Sound and Music Computing

General Terms
Design, Experimentation

Introduction
A brain-computer interface (BCI) is a tool that allows its user to communicate to an interface using only his or her brain signals. Research into this area has yielded a variety of applications that range from spelling via

evoked potentials [1] to driving a wheelchair by attending to a specific flashing pattern [5]. There has also been some research into using BCI for creative expression, such as using BCIs for painting images [6] or drawing shapes [3]. Following in that vein of creativity, we designed and implemented a BCI that can be used for musical composition and performance.

There have been a few attempts to use biological signals for music composition. The most common method is by using electroencephalography (EEG). EEG measures electric fields produced by neurons through the use of electrodes that are placed on the scalp. Though this method produces very good temporal resolution compared to other brain imaging techniques, it is subject to artifactual noise. Despite this, EEG remains a viable method for monitoring brain signal in real time.

Creating a reliable musical BCI will be an important step, not only for the community of musicians, but also for the realm of assistive technology. Though there have been some studies looking at brainwaves as generative sources for music, none of the experiments have resulted in a device that could be used by people with disabilities. We believe that succeeding in building such a device would provide these patients with a much needed creative outlet.

In order to create a BCI for musical composition (BCMI), two things are needed: a reliable and robust brain signal that is detectable by a machine, and a method to interpret these signals and translate them into music in real time. There has been some work done to address these issues, though there are still many challenges ahead. In this study, we attempt to address the various challenges raised by previous research and create a BCI that not only allows a user to create music with thought, but to do so reliably.

Background and Related Work

There are several methods that researchers can employ to control a BCI. One such method is the P300 response. The P300 is an event-related potential (ERP) – a brain signal that occurs in response to an external stimuli. Often called the "oddball paradigm," the P300 occurs approximately 300ms after a particularly salient or infrequent stimulus. Perhaps its most well known use is for selecting letters from a matrix to spell out words [1]. However this is not its only potential use. In a pilot study, a researcher at Goldsmiths College attempted to create a BCMI by using the P300 response to choose notes from a matrix. Five participants were asked to select the notes of the C major scale in ascending order. The notes were displayed on a 6 x 6 grid. After seven trials, four of the five participants were able to recreate the scale with a 75% success rate [2]. Affording the user discrete selection of individual notes is a concrete step toward building a flexible BCMI, but can be cumbersome if an individual has to compose a song by only selecting one letter at a time and stringing them all together. Additionally, audio feedback in this experiment was given when a note was selected and at the end of the experiment. The individual would not know the melody of the song (unless keeping track in their head) until after the composition was over.

In their 2005 paper, Miranda et al [4] produced a neural music composition program. Their work combines EEG with Hjorth analysis, an EEG analysis method that examines the activity, mobility, and complexity of a given EEG signal, to look for specific

EEG patterns and assign them to a musical type. The result of this experiment is a system that is able to derive a musical piece by using a subject's brainwaves. The problem with this study is that it attempts to "guess" at a musical piece in which the subject has little control over the final piece that is produced.

P300 Based Music Composition

Our aim is to design an interface that allows for freeform composition that provides constant feedback to the user. Figure 1 shows the display that our participants see. The left matrix is used for note selection and the right matrix displays and plays the selected notes. A user will attend to the left matrix as rows and columns flash, focusing on the cell that contains the desired note and mentally counting the number of flashes.

We used BCI2000, a common program used by BCI researchers, to gather EEG data and run the classification algorithm [7]. BCI2000's P300 Speller Application forwards note selections via UDP to a local Clojure image which activates the selected note on a step sequencer rendered by the Processing visualization library. An audio event loop cycles through the matrix from left-to-right, playing all active notes in a column at the same time step.

Audio events are handled by a SuperCollider synthesis server which we control via the open source Overtone music toolkit. Overtone provides abstractions for creating instruments, generating notes, scales, and sequences, altering musical styles and modes, and timing audio events. We render the step sequencer via a wrapper around the Processing visualization library.

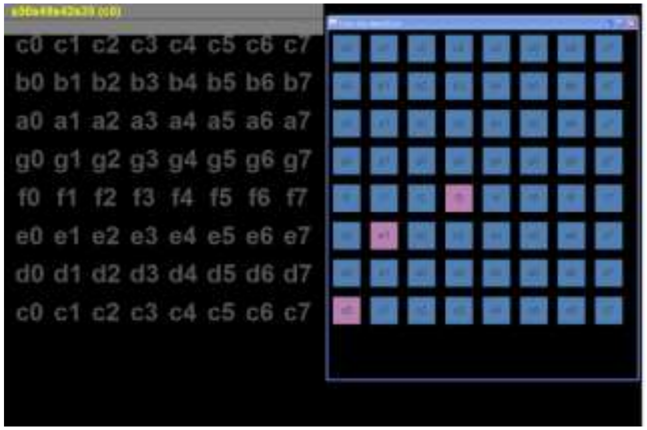

figure 1. The left matrix (BCI2000) is used for selection of notes while the right matrix (Clojure) displays notes selected.

Experimental Design

We performed an experiment to assess the effectiveness of a P300 based Brain Computer Interface combined with a traditional musical step sequencer. The main aim is to determine whether or not this interface would be a viable music composition program that would allow a user to achieve creative expression. Eleven participants (1 female, average age = 25.60) took part in this study. All participants were staff or students at the Georgia Institute of Technology and this study was given approval by the institute's IRB Review Board. They were not compensated for their participation.

Each participant gave written informed consent before taking part in this study. Participants were introduced to the equipment and allowed to familiarize themselves with the musical step sequencer while being fitted with the electrodes and the electrode cap. We used a g.tec gUSBamp that supports 16 channels. Electrodes were placed according to the international 10-20 system. The ground electrode was placed on the right mastoid and the reference electrode was placed on the forehead. An example of the P300 note grid was displayed and run using a signal generator included with BCI2000 software so the participant would know what to expect. The experiment consisted of three parts: a training portion, a freeform composition portion, and a post-experiment paper questionnaire. The overall experiment lasted approximately one hour.

During the training portion, participants were asked to select four notes in three blocks - for a total of twelve notes - by counting the number of flashes of the specified note. The first two blocks contained the notes of an ascending scale. The first note block consisted of c0 (lower left hand of the matrix), d1, e2, and f3. The second note block consisted of g4, a5, b6, and c7 (upper right corner). The third note block had the participants starting from the top left corner going diagonally down, skipping every other column, which results in the notes c0, a2, f4, and d6. Each row and column containing the target note was flashed 15 times in random order. After a note is selected, the corresponding note in the sequencer is played. The recorded data is analyzed offline using a linear classifier algorithm called Stepwise Linear Discriminant Analysis (SWLDA) that comes with BCI2000 software to create an EEG classifier. This analysis only takes a couple of minutes.

The freeform composition portion occurs after the classifier has been created. Participants are once again shown the P300 note matrix next to the step sequencer. They are told that they have six minutes to create whatever they want and are reminded that notes can be selected and deselected. The procedure follows that of the training, with a few exceptions. The number of flashes is shortened from 15 per row and column to 8 times. We have also included a pause of 9 seconds after each selection. We chose to do this to allow participants to listen to what they have selected and to give them an opportunity to plan which note they want to select next. Additionally subjects were asked to verbalize their intended target after each selection so that we could measure the accuracy of the interface.

After the allotted composition time expired and data saved, participants were asked to fill out a post-experiment questionnaire. The questionnaire, using a 1-7 Likert scale, asked questions about the degree of difficulty of the task, enjoyment of the task, and enjoyment of the composed piece. Space was included at the bottom of the sheet for any additional comments regarding the task or the interface.

Results

Eleven participants were involved in this experiment, but one subject could not complete the study due to time constraints. We have not included his data in these results.

In this interface, each selection is a choice between 64 potential targets. Subjects were able to select 13 notes during the time allotted and the average accuracy level was 86%. Three participants achieved 100% accuracy and 6 of 10 participants scored above 90%. Previous work on assessing the speed of a P300 interface calculates the number of selections per minute as a measure of success. Our system, when using this as the criteria, would be considered slow, with about 3 selections a minute with 86% accuracy versus 4.8

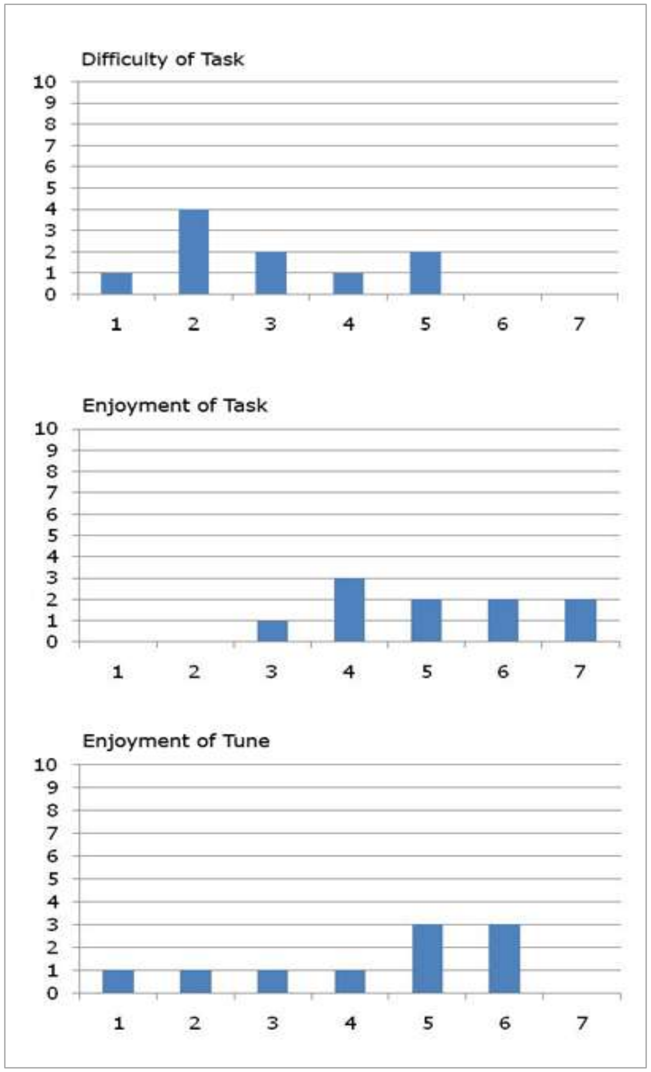

figure 2. Rating distribution of post-experiment questionnaire. The x-axis denotes the responses for each question and the y-axis denotes the number of participants who responded.

selections per minute and a 90% level of accuracy [1]. However, using this as a rubric for our system would not take into consideration the pause we included between selections. This pause was necessary because unlike the traditional speller matrix, where a subject plans selections at the word level and thus does not need much time between letters to know which one to choose next, subjects using our interface must plan note by note.

Figure 2 shows the distribution of scores we received from the questionnaire. On average, subjects rated the difficulty of the task at 2.9 (with 1 being "not at all" difficult) and their enjoyment of the task at 5.1 (with 7 being "very enjoyable"). The average score for how well they liked their composition was a 4.3 (with 7 being "like a lot").

Discussion

The data above provide a promising step toward creating a viable Brain Computer Musical Interface for real time music composition. Qualitative data indicate that the interface is not difficult to use and allows its user to create a unique melody that can constantly be updated or modified. Additionally, though the program has a high level of accuracy, selection errors may not interfere with enjoyment of the composition process. One participant in particular commented that "The slight errors in composing actually added some stoicastic [sic] process, which adds variety to the experiment."

In order to create a richer composition environment, there are several areas for future modifications to this interface. Integrating the music engine with the selection matrix would allow for a more seamless transition and possibly a wider variety of notes. Additionally, implementing a “stop” button can allow the composer to take more time to plan the next note or to indicate when they are satisfied with what they have created. Lastly, allowing for a selection of different types of scales or different synthesized sounds can help the interface provide a more full-bodied sound.

This experiment demonstrates that the P300 paradigm can be extended into the creative domain, enabling its user interaction in a meaningful, predictive way. Future work on improving the performance of this interface will be useful in expanding the ways that this application may be used.

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