Outline of Proposed Research

Brain-computer interfaces (BCIs) use human brain signals to directly communicate with an external electrical device. The goal of the proposed project is to assess the potential of a music-based BCI that detects the contents of a participant's imagination using only the recorded electroencephalography (EEG) signal. BCIs have the potential to change the way humans interact with the world around them. Significant first steps have been made to create interfaces that give patients with severe motor deficits a simple method of communicating with the world. For example, researchers were able to successfully distinguish whether a vegetative patient was imagining playing tennis or imagining walking through their home[1] and the patient could use this technique to answer yes or no questions. This BCI used functional magnetic resonance imaging (fMRI), an expensive and cumbersome technique which can not be used at a patient's bedside. Electroencephalography (EEG), a more portable and inexpensive imaging technique, can be used at the bedside making it widely accessible and is a therefore a good candidate for future BCIs. EEG-based interfaces have been successfully used by individuals with severe motor deficits, enabling them to move a cursor on a screen by controlling their brain signals in the 8-12 Hz range[2]. Further work was able to reliably differentiate three different brain states when subjects purposefully modulated their own EEG signal[3]. However these techniques were only able to distinguish large scale changes in brain state, severely limiting the BCI's number of responses.

Recent advances in EEG signal processing have made it possible to distinguish increasingly subtle differences in brain activity. These advances enable many brain states to be differentiated, allowing a communication device to handle more than simple yes or no questions. Music is especially suited to an EEG-based BCI, as music unfolds over time and EEG has high temporal precision and can detect small changes over time. As noted in my thesis summary, my Master's research showed that heard pieces of music can be classified at a statistically significant level and I am working to achieve reliable accuracy rates during classification of imagined music.

I would like to continue this line of research in order to create a robust music-based BCI. The next step is to determine what characteristics of music allow for the most accurate classification. Characteristics such as the presence of lyrics or different rhythmic patterns may provide differentiable signatures in the EEG signal. Using musical rhythmic patterns as the basis for a BCI shows promise as *perceived*[4] rhythms can be classified from EEG. In a separate experiment participants were asked to *imagine* a single speech syllable in a particular rhythmic pattern and these rhythms were classified from the EEG signal[5]. However, imagining a meaningless pattern of sounds (such as syllables) may be difficult for participants to do accurately. A more meaningful stimulus may be necessary. Speech is something that is inherently rhythmic and words and phrases are likely easier for participants to imagine than single syllables. I propose that differentiating rhythmic patterns using meaningful phrases may provide a more robust BCI than my previous work done with differentiating music. To induce rhythmic patterns in a participant's EEG signal I will use short, rhythmic, repetitive phrases. If this proves to be a successful way to detect what a participant is imagining, then the next step will be to integrate other musical features (for example melody or pitch) to determine whether this increases our ability to robustly classify the contents of a participant's imagination. This will allow us to build a powerful music-based brain-computer interface.

1. Owen, A.M. et al. (2006). Science. doi:10.1126/science.1130197.
2. Wolpaw, J.R. et al. (1991). Electroen Clin Neuro. doi:10.1016/0013-4694(91)90040-B.
3. Kalcher, J. et al. (1996). Med Biol Eng Comput. doi:10.1007/BF02520010.
4. Stober S, Cameron DJ, Grahn JA. (2014). In: 28th NIPS proceedings.1449-1457.
5. Deng, S. et al. (2010). J Neural Eng. doi:10.1088/1741-2560/7/4/046006.