Stress Beat: EMG-ECG Interface for Tempo and Microtiming

Noel Alben
Michael Verma
Rosa Westfall

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1 Introduction

Stress Beat is an interface that plays upon the user perception of micro-timing and groove in tandem with their physiological state. Tempo is set by the user tapping their finger to the beat of the desired tempo. A musical groove begins playing to the set tempo, and the user's real-time changes in the heart rate adjusts micro-timing of an individual component of a drum groove. If the heartbeat is actively increasing, the given component occurs behind the beat in relation to the rest of the groove/tempo grid, and vice versa.

The ability for the user to control the tempo through a motor rhythm of finger tapping creates a biofeedback loop where the user will become more aware of their tapping through the sound of the beat being played. Previous studies have shown how a persons tapping rate tends to increase as stressful stimuli are presented, and will continue to increase even after the stressful stimuli ceases - with the tapping possibly continuing the stress response even once the stimuli is gone [Murata et al., 1999]. *Stress Beat* attempts to counter this phenomenon by making the user aware of their tapping and the potential stress it could carry with it.

Changes in the heart rate is shown to have an inverse relationship with stress, as heart rate changes to a lower BPM a person is in a relaxed state [Yu et al., 2018]. This compliments how *Stress Beat* introduces more energy in the track through micro-timing offsets. The offset delays are controlled by the changes in the heart rate over a given window of time.

2 User Base

This interface is designed as a sandbox-style system for individual exploration of the tempo and micro-timing paradigm. The limitation of its application potential lies primarily in the sensitivity of the OpenBCI sensor hardware. The intended user base would be anyone who may want to be more aware of their tapping and/or heart rate. A fine tuned and ideal system can be helpful for:

- A meditator hoping to be aware of their changes in heart rate
- An office worker hoping to monitor their nervous tapping
- An athlete who goes through rhythmic motions wanting to be aware of the changes in their heart rate
- A tool for therapists for people with nervous tics to monitor them

3 Design

The user is provided with live audio feedback of the beat with micro-timing variability applied. In Max/MSP, the user interface also provides several modes of visual feedback of their biosignals and manual control. The tempo is displayed numerically, as well as with a visual pulse. The signal meter of the EMG input is displayed to provide the user with feedback that their tapping is being read by the system, and the cleanliness of their input signal. The playing beat is also displayed as a series of five blinking lights for the

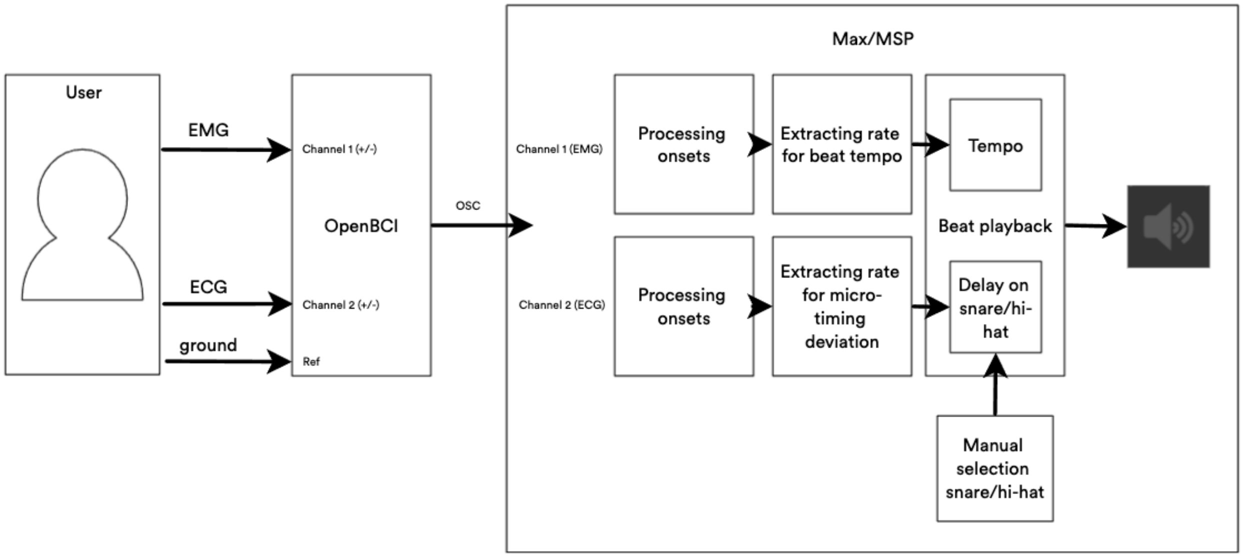

Figure 1: System diagram of *Stress Beat*.

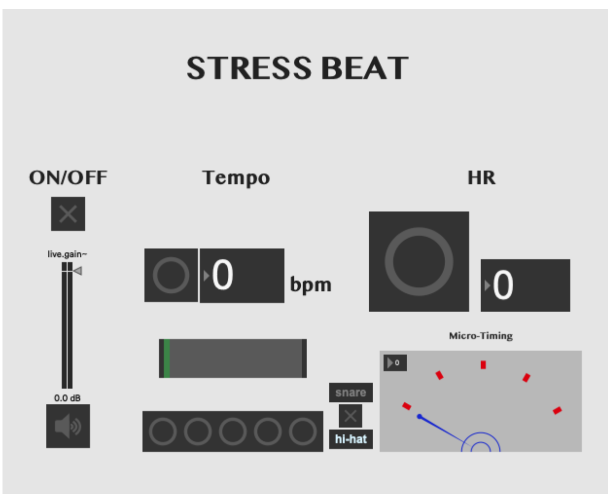

Figure 2: User interface for *Stress Beat*.

onset of musical events. The live heart rate is displayed in real-time, along with another pulse signifying the changes in heart rate that reflect the microtiming within the groove.

4 Methods

The interface utilizes 5 foam solid gel electrodes, two of which are placed on opposite sides of the chest for ECG measurements, and two of which are placed on a section of the Extensor Digitorum muscle near the elbow either for EMG muscle activation measurements. The fifth electrode is placed on the bottom rib as a common ground for both ECG and EMG signals. The electrodes are connected to a Ganglion OpenBCI unit, which is transmitted to the OpenBCI GUI via low energy Bluetooth. The OpenBCI signal is then transmitted via OSC networking into Max/MSP, where the data is processed, smoothed, mapped, and displayed in the UI.

In order to extract HR from the incoming ECG data, the magnitude value (numerical) is converted to a momentary and binary pulse. The time intervals of each pulse is extracted in milliseconds. For every sixteen (16) time interval values, the highest four (4) and lowest four (4) values are removed from the data set, and the remaining 8 are averaged to output the user's heart rate. A separate list records every five (5) time interval values, omits the highest two (2) and lowest two (2), and outputs the median value of the more recent data. The difference in these two data sets is used as the change in heart rate for that particular window of time. This change is then scaled to the delay amount of the selected instrument (snare or hi-hat). The applied delay/lead is mapped by 80 ms in either temporal direction for a heart rate difference of 10 and -10 bpm.

Figure 3: Deviation of tempo read by the *Stress Beat* when tapping with a metronome.

A similar process is used to extract the onsets and time intervals of the incoming EMG data, and average the intervals from the user's taps in order to generate the beat tempo. Due to the prolonged window of the periodic input signal, the system processes the tap input as half-notes of a 4/4 time signature in order to raise the maximum tempo. In other words, the beat detection from the user input is doubled to output the tempo. The input stream for EMG and ECG is live and continuous, allowing the user to change the tempo at any time.

5 Results

In order to test the accuracy of our beat detection method with the EMG data stream, we had a subject tap the half-note to a metronome at various tempi. Live bpm was recorded for each of seven (7) tempi for roughly eight (8) bars for us to observe the deviation. This does not take into account the margin of human error, however all seven tempos were performed by the same individual. The study was informal, but supported our hypothesis that the beat detection accuracy would drop significantly at higher tempi, due to the system's inability to distinguish the separate events.

6 Discussion

Although we had limitations with the technology used in our system, the interface functions as intended, with few bugs. In order to improve the system for use in a particular context (as referred to in Section, more research should be done about the relationship between HR, HR variability, and motor skills. True heart rate variability (as opposed to the *change* in heart rate) could be utilized for an application with a more specific objective. It would also be beneficial in fine-tuning the system to be able to test the accuracy of the HR measurement, as we had the most trouble with ECG input due to noise and other artifacts that were easily mistaken for beat onsets. Additionally, running trials on multiple subjects would allow several improvements. Not only would the user interface be properly tested, but the variability of individual physiological responses was not taken into account during programming.

References

[Murata et al., 1999] Murata, J., Matsukawa, K., Shimizu, J.-i., Matsumoto, M., Wada, T., and Ninomiya, I. (1999). Effects of mental stress on cardiac and motor rhythms. *Journal of the Autonomic Nervous System*, 75(1):32–37.

[Yu et al., 2018] Yu, B., Funk, M., Hu, J., Wang, Q., and Feijs, L. (2018). Biofeedback for Everyday Stress Management: A Systematic Review. *Frontiers in ICT*, 5:23.