Transcript of “Muse Within” Voiceover by Susie Green.

Intro
What might our brainwave spectrum sound like?
And, how might that sound change while we are listening to it?
What does it sound like & how does it change when we start to actively interact with it by improvising musically?

And pushed a bit further, how could we map our brain activity to effect what the improvisation sounds like while we are playing along with our *Muse Within.*

Muse Within System
These are some of the questions that came up during the 2020 pandemic lockdown the catalyst for exploration that resulted in creating a bespoke prototype brain-computer musical interface (Or BCMI). There’s decades of projects and research that have used various combinations of equipment and mapping of BCI to make music and art. I highly suggest the book “Brain Art” which includes a collection of chapters on the history and applications of BCI, edited together by Anton Nijholt.

This system is made up of consumer grade equipment and software like:

- The MUSE brain-sensing band,
- Mind Monitor IOS Application and website,
- Ableton & Max4Live

Brainwaves
The musician wears a MUSE band that detects their brainwaves through a flex circuit with worn across the forehead. There are 2 forehead sensors and two conductive sensors that hook behind the ears. Brainwaves are a spectrum of frequencies that are occurring simultaneously. They are divided into 5 frequency ranges:

- Delta spans 1-4Hz.
- Theta 4-8Hz.
- Alpha 7.5-13Hz
- Beta 13-30Hz.
- Gamma 30-44Hz.

Now, when you about a certain “brain states” what’s really happening is that a specific frequency range is more dominant at a higher amplitude as compared to the rest of the frequency ranges.

For instance, a dominance in the Beta frequency range has been found when the mind is really busy. As opposed to a higher amplitude of Theta which might indicate a transition from a “Delta state” or deep sleep to “Alpha state” or meditative lucidity.

System Flow
All of this data is sent through Bluetooth to an IOS application called Mind Monitor. The 4 main sensors used for this project were found to be the most stable data streams, specifically for real-time use and mapping.

Each sensor picks up on the full spectrum of ranges and the Mind Monitor application runs this data to average out the individual frequency ranges and parse out the mappable data in the form of Bels or decibels which it sends over wifi to a Max4Live OSC Monitor called “Tekh Map Master” in Ableton. Now that the data is being received by Ableton it is easily sent to another M4L device called “Tekh Map Dial” where the brain frequency range data can be trained, smoothed and mapped to two device chains created to make brainwaves audible.

Mapping
The first device is an instrument chain called “Muse Within” which processes the tonal & timbral representation of the data.

1) “Muse Within” is made up of 5 pairs of customized Operator and Spectral Resonator devices per brain frequency range.

In order to hear the waves they need to be placed within the human audible spectrum. Since this was a prototype to test the tech flow, usability and data extraction of the system, multiplying each range by 100 was a simple way to boost them into the middle range of human hearing. The frequency and decibel tuners of each operator was mapped through Ableton’s MIDI mode both in consideration of the listeners hearing protection and to emulate the mechanics of the experience of sound. For instance, as the frequency range was driven higher, the volume of that frequency was lowered. As the frequency range was lowered the volume was raised. These dials were assigned to a labeled macro controlled by the incoming data in the form of Bels which lent itself well too be mapped to potentiometers. Each operator fed into a dedicated spectral resonator device that was set to a simple multiple of the upper level of the actual frequency range by 10 respectively. The ranges of each were set as follows:

Delta- Operator range 100 - 400Hz , Resonant frequency 40.0Hz
Theta- Operator range 400 - 800Hz / Resonant frequency 80.0 Hz
Alpha- Operator range 750-1300Hz / Resonant frequency 130 Hz
Beta- Operator 1300 - 3000Hz / Resonant frequency 300 Hz
Gamma- Operator range 3000- 4400Hz / Resonant frequency 440Hz

2) The second device was named “Drum Spectral Time” and uses Ableton’s Spectral Resonance as a dynamic feedback device. It is driven by 4 of the 5 brain frequency ranges:

-Beta waves were mapped to drive the Decay rate due to their correlation with a busy and active mind. It was assumed that the player’s beta levels would be fairly engaged with the feedback of effects on their instrument as they improvised.

-Delta values were mapped to the Low Frequency Dampening dial while Gamma was mapped to High Frequency Dampening dial. These assignments were based on their respective ranges to make use of the extreme ends of the brain activity spectrum.

-Alpha waves controlled the Frequency dial which was set to a range of 8.20 - 50Hz. This spans the Alpha, Beta and Gamma frequency ranges. Alpha brainwaves have been found to “tune” brainwave activity and is dominant during meditation and centered flow states. This characteristic of modulating task-irrelevant information was the reason for mapping it to dial in the center of the harmonic spectrum on the device. Theta wasn’t part of the mapping strategy for the second device because during preliminary testing it was were nearly identical to Alpha activity.

ERP/Instructions
The experiment consisted of three phases during which brain wave data was recorded in Mind Monitor while sound and automation of dials was recorded in Ableton Live. Richard Hargett is a seasoned professional drummer and trained jazz improvisor who agreed to test the system while playing a small Bebop kit. Very little information was disclosed to the musician. All that they knew was that they would be improvising with a “track” while wearing a MUSE band & earbud monitors.

In addition to running the system, brainwave data was recorded for later review for any evidence of Event Related Potential or ERP. ERP is categorized by the latency between stimulus and voltage spikes in brain activity. For instance, ERP belonging to the P300 paradigm was of special interest since it is known to be within a reaction time of about 200-300 milliseconds and easily elicited through an “oddball” or infrequent stimulus. Prior to playing, the musician was given these instructions to establish an expectation of stimuli for them to respond to:

1) Sit still and silently for a bit at the start of the session.
2) Listen for the volume of the “track” to be raised as a cue to begin playing.

3) Listen for an abrupt dip & restoration of volume of the track as an indication that we are at the halfway point of the session.

4) Listen for a slow lowering of volume signaling the end of the improv session as a cue to close out the recording with a final phrase.

3 Phases
The three parts that made up the experiment were broken down like this:

Phase one - Listening. The musician sat in silence a while brain data drove the “Muse Within” instrument chain. This provided baseline data, automation of the instrument and the audio it produced (referred to as “the track”) and was recorded by Mind Monitor and Ableton Live respectively. At about the 1.5 minute mark volume was slowly raised in the monitor.

Phase two - Improvisation. At the around two minute mark the musician began to improvise with the track. This is where the first invisible feedback layer was introduced. Their brain activity picked up significantly while playing since they are in a more active listening and responsive state. This in turn changes the what they the track and becomes a simulated multi-agent scenario. Composer and BCMI pioneer David Rosenboom, in his contribution to “Brain Art” wrote: “BCI in the arts was seen as a manifestation of interconnectivity, a broadening of self-reference to encompass multiple selves.”

Phase 3 - (re)Iteration. Just before the 4 minute mark the volume dropped abruptly and came right back in. In addition to the track, another feedback layer is introduced as the volume of the “Drum Spectral Time" device is slowly raised in the musicians monitors allowing them to hear the effects return of what they were playing.

This feedback layer is significant because it creates a naturally changing sound world for the musician to respond to in real-time. Furthermore, as the music evolves over time through bio-feedback created by their own interaction more complexity is added to the experience.

And, finally, at around the 6 minute mark, the volume of the dynamic effect was lowered completely, while the musician continued to play. And, just before the 7 minute mark the track volume was lowered and the musician then closed out the session.

Results
Upon reflection of the data a sonic data-story was unveiled through harnessing bio-data to enhance creative practice. This form of research, practice AS research, is also a means to understand the subject-adjacent sciences while building practical and creative applications for human-computer interaction.

The three phases and feedback loops engaged deeper mindful listening and performative interaction by the musician and can be heard as the session progresses. Mapping brain activity as Passive or unconscious[1] control to generate music in phase 1, prompted attempts for active control in phase 2 and as more complex spectral audio images were introduced as each phase progressed.

Data in graphical form showed evidence of ERP spikes in the Delta range after “oddball” target auditory stimuli was executed in each phase of the experiment. The dominant level of Delta active during playing was unexpected since a dominance of Delta is usually present during deep sleep. However, considering Richard Hargetts’ over 20 year Samhadi meditation practice makes sense. Perhaps this accounts for the high levels of Delta. For closer look at the technical findings and more references on the subject of BCI please check out the paper that accompany’s this experiment.

Sound wise, this Delta dominance accounts for the dominance of lower end frequencies produced in the track as well as the effects processing once active play ensued. It would be interesting to test this system with a variety of musicians with different neuro-types and backgrounds to hear the differences in brainwave activity.

Conclusion

Ultimately, the successful assembly of this bespoke working BCMI prototype system, using consumer level resources has provided a way to test and create a nested mapping strategy for a closed interaction loop. Moving forward, the use of real-time brain-data will be folded into current development of creative multi-modal inclusive interactive systems with the addition of visual content to be used by people with diverse ranges of abilities in performance and interactive art installation.