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Neuronal Dances
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Abstract

Neuronal Dances is a project inspired by Alain Destexhe and Luc Foubert’s music compositions of neuronal activity. Their songs were derived from electroencephalogram (EEG) recordings of human brainwave activity during wakefulness, non-rapid eye movement sleep (NREM), rapid-eye movement sleep (REM), and epileptic seizures. Their unique sounds were combined to provide the soundtrack for Neuronal Dances performance. The movement of the performance was inspired from brain activity research describing the types of brainwaves and neurons that inspired the sound. The goal of Neuronal Dance was to represent these processes through dance for concert performance. If this project were to be done again, live EEG recording and data processing could be incorporated to enhance the performance through influencing light components of the show.

Introduction

Mickey Hart, known for being the drummer of Grateful Dead, puts on more than a great rock performance. In his recent shows, he has donned an electrode cap. This cap measures and records the electrical impulses produced by his brain while performing for his audiences. These recordings are converted into light and set design, showing his different brainwaves in real time to enhance his performance (Henn, 2013).

The electrode cap Mickey used is known as an electroencephalogram (EEG). EEG’s and their potential have been adding to performances in unique ways. The Spikiss project is an example of unique application of EEG data. In the Spikiss Project, neuronal activity recorded on EEG’s have been transcribed into songs. These songs differ depending on what stage of consciousness the individual is in when the recordings take place. The Spikiss Project and its melodic interpretations of EEG recordings have inspired my Honors Thesis, Neuronal Dances.
The goal of Neuronal Dances is to represent the processes behind these EEG recordings, while dancing to them. The basic physiological processes of different brainwaves, Spikiss and its mechanism, other use of EEG in performance, and the process for Neuronal Dances will be discussed.

**Biological Processes**

Neuronal Dances aimed to represent some of the physiological functions occurring during neuronal firing. Firing activity is not constant and varies depending on what stage of consciousness an individual is in. There are three classes of consciousness: wakefulness, rapid eye movement (REM) sleep, and non-rapid eye movement (NREM) sleep. Each has varying brain activity as seen on electroencephalogram (EEG) recordings. Wakefulness is noted by beta waves, which are high in frequency and low in amplitude, but have variable form. Alpha waves are also seen in wakefulness, showing slower frequency and lower amplitude. Theta waves are seen in the first stages of NREM, which are slow in frequency. During this stage sleep spindle and complexes appear, forming spontaneous high frequency and amplitude bursts on EEGs. Delta waves are slower still and are found in the slow wave sleep (National Sleep Foundation, n.d.). REM sleep is known for when dreams occur. In REM sleep, brain activity becomes intense, so much so that it is similar to wakefulness (National Sleep Foundation, n.d.). In Neuronal Dances, the different stages and their unique characteristics inspired movement discussed later in the paper.

A unique aspect of the Spikiss project was the assignment of sound to specific types of neurons. Destexhe and Poubert utilized the EEG input and sound to differentiate different types of neurons. Regular spiking neurons can be separated from fast-spiking neurons based on their individual characteristic intrinsic firing properties (Peyrache et al., 2012). Regular-spiking
neurons are excitatory in firing activity while fast-spiking neurons are inhibitory. Both of these function in the brain for activating and inhibitory neurotransmitter release. The fast-spiking, inhibitory neurons showed long refractory periods, while the regular-spiking, excitatory neurons showed shorter refractory periods (Peyrache et al., 2012). In addition, results showed the firing of both neurons are correlated. These findings inspired flow in the dance, which will be discussed further on.

**Electroencephalogram to Sound Waves**

The Spikiss Project was not the first to convert brain wave activity to sound. Attempts to turn brainwaves into music date back to 1934 (Adrian & Matthews). In 1965, Alvin Lucier was an early experimenter with EEG-induced music production with physicist Dewan. They utilized alpha waves to create the sound from the recordings in their piece, “Music for the Solo Performer” (Rosenboom, 1976). The result was raw, unmanipulated music transduced from EEG recordings.

The Spikiss project started off with simpler assignments of musical notes to brainwave activity. The initial recordings were called Neuronal Melodies. In Neuronal Melodies, woodblock was assigned to excitatory neuron spikes while xylophone tone was assigned to inhibitory spikes. The ‘Wake’, ‘Sleeping’, ‘Dreaming’, and ‘Epileptic Melodies’ produced allowed for audible visualization of firing distribution of the two types of neurons during these different states of consciousness (Destexhe & Foubert, 2016). EEG to sound conversion resulted in the recognition that REM activity of inhibitory and excitatory neurons had similar firing qualities of the wakefulness state.

The Spikiss project used 80-100 neuron recordings to produce the each song. To convert the EEG data in Spikiss, the researchers used a methodical approach for assigning musical notes.
Electrical impulses from the brain can be recorded as spikes via electrodes. The data plot from these recordings normally show vertical deflections in addition to points, both representing a single electron firing in that moment in time. The graph is made simpler by only displaying the points; this graph is known as a raster (Destexhe & Foubert, 2016). The raster on different lines show the activities of different neurons and their activity, all recorded by separate electrodes. The relative space between each point is correlated to an amount of time that went by. Destexhe and Foubert assigned individual instrumental notes to each neuron so when that neuron fired, its assigned musical note would be played. This was done with multiple neurons all displayed on the raster plot. When the raster is read like sheet music, a sort of song is played. The methods described in Destexhe and Foubert are called parameter mapping. Parameter mapping allows for the relative time scale to be applied to EEG recordings similarly to how they are used in music, the most popular method for converting brainwaves to music (Rosenboom, 1976). This aids in the artistic processes due to the typical rapid firing nature of neurons. The EEG recordings do not produce audible song-like sounds, rather low frequency mumbles (Wu, 2018). The artistic assignment of tone creates Spikiss’s unique sound.

The Spikiss Project was different than the original Neuronal Melodies. Destexhe and Foubert took creative freedoms in altering the recordings to produce more interesting music composition (2016). Things like altering the speed in which the spikes were “heard”, the assignment of noise for specific neurons, and looping parts of the raster to repeat neuronal impulse patterns in the score, added intricacy to the music. While respect to neuronal firing may not have been upheld, all of the composition was taken in some way from the rasters of brain activity (Destexhe & Foubert, 2016).
Music composition for Neuronal Dances came from different clips of the Spikiss Project. These recordings reflected neuronal activity recorded in wakefulness state of conscientiousness, NREM, and REM. These three individual clips from the Spikiss Project (2016), “Wake Beats”, “Slow Waves”, and “REMiniscence”, were edited together in this order for Neuronal Dances. These three segments inspired the stages of the dance.

**EEG Entertainment and Dance**

The novel idea of turning brainwaves into sound has long been appreciated and astounded audiences. Before Mickey Hart, Alvin Lucier was able to display his own neural activity in performance through EEG recording linked to percussion instruments. It was highly variable and inconsistent, but was happening live in real time (Wildermuth, 2018). Another group, EIEIO, stands for ‘Electroencephalogram In, Electronic Instrument Out’. EIEIO Modulation created a touring stage performance that showcased live transduction of EEG data into sounds (n.d.). This particular performance also included light features demonstrating the state of conscientious one of the performers was in, determined by the type of waves observed on her EEG, similar to Mickey’s utilization.

Other physiological phenomena influence and inspire live performance. In Regenerative Music, engineers recorded brain waves among other various vital signs such as respiration rate and heart rate (2003). This experience utilized 48 participants, whose bodily functions (brainwaves, heart rate, respiration rate, etc.) were recorded and analyzed. This data was taken and used to influence the way an instrument played, typically to match the mood of its participants. When the physiological response of the participants changes in response to the music, the music shifts again. This mutual response interaction resulted in an artistic feedback loop.
On the dance development side, Carlson, Maranan, Subyen, & Schiphorst utilized EffortDetect, a wearable apparatus that incorporated a single accelerometer to measure movement quality (2013). The software is able to track and differentiate into eight distinct movement types: press, glide, punch, dab, wring, float, slash, and flick. These qualities were classified based on their specific combinational uses of time, weight, and space detected through the apparatus’s accelerometer software. The EffortDetect apparatus was used in live performance to gauge and identify the performer’s actions. Astral Converted performers were able to use this wearable kinetic software to direct the stage lighting based on the type of movements made during performance (Trisha Brown Dance Company, 1991).

Scientific analytical devices have drawn inspiration for performance and often were included in the performance itself. To the best of my knowledge, a piece combining movement inspired by the EEG activity and the sound from brainwaves has not taken place. Neuronal Dance’s aim was to explore the processes in brain impulse activity, EEG brainwaves in different states of consciousness, and differentiating characteristics between fast-spiking and regular-spiking neurons, through movement for entertainment and appreciative purposes.

**Neuronal Dances Process**

Neuronal Dances was divided in 3 parts, one for each of the three states of conscience represented in the music. The initial plan was to choreograph in phases to represent only the processes that occurred during that stage. The introduction was going to be an action potential, the physiological process behind the electrical impulses that stimulated each sound heard in the music. This would be to introduce the topic to the audience. The first phase going into wakefulness was to show the characteristics of this stage in the EEG, like beta and alpha waves.
The second phase was NREM sleep and its qualities, and the final phase was the REM sleep and its qualities, emphasizing the similarities in quality to wakefulness phase.

To inspire movement in general, the eight basic movements (press, glide, punch, dab, wring, float, slash, and flick) from Carlson, Maranan, Subyen, & Schiphorst served as a jumping off point. In particular, punching and flicking were used for fast-spiking neurons, while glide and float served characterized the movements of the regular spiking neurons. These moves gave dancers a direction or quality of movement to start out as and would branch from there.

Most of the choreography was assigning intention of qualities I wished to convey, such as the characteristics of each type of neuron. The direction in addition to the quality of movement was specified using the eight basic movements. Initially I started by choreographing specific movements for almost everything, with some creative liberties to improvise in parts to make their own. The dancers almost always ended up being more comfortable with the movements they improvised. I observed this earlier on and was able to change my style of choreographing to giving a general direction rather than specific movements for everything.

The direction of the dance changed slightly. The dance first started out with the action potential, demonstrating its all-or-none threshold potential (Appendix A). The wakefulness stage demonstrated the quality of brainwaves that occur in that state, and also explored the two types of neurons inspiring the different sounds in the music. Inspired by Peyrache et al.’s findings, dancers were split into two groups during the wakefulness state of consciousness to represent the two types of neurons. The two groups moved at the same time, to show their correlation, with one dancer in the middle acting as a region being affected by both inputs. The regular spiking had more continuous movement, representing the shorter refractory periods between impulses, while the ‘fast spiking’ had long periods of stillness between peaks of movement. To contrast the
bursting period with the stillness more, ‘fast-spiking’ dancers were encouraged to move with jerking movements when prompted to move. In this section, I wanted to depict the timing of the neuronal firing and its non-unanimous nature (Appendix B). I had the dancers in groups do parts together and parts not.

   The next phase of the music that represents NREM sleep captured some elements of the delta waves and their qualities: slow, but still high in amplitude waves. Movements were slower, more controlled, less random. To echo the high amplitude, certain moves were added to enhance the peaking of the wave. One move in particular was the handstand-like rocking initiated by the dancers’ legs kicking into the air (Appendix C). The movement was carried across the stage by each dancer to represent the waves going by on the EEG. This phase was completed with a series of lifts representing a neurons transmission and reuptake of neurotransmitters, done in series to show the repetitive process for it.

   The last phase of REM kept the energy that was intended, which was to be similar to wakefulness phase. I took a different direction and had the dancers split off in pairs to represent different lobes of the brain. I did this to avoid repetitiveness; REM phase kept the spontaneous, irregular actions, but the dancers did not represent the neurons or their firing characteristics. The spacing was supposed to represent where the different lobes were relatively on stage, with frontal lobe being downstage (Appendix D). Not all lobes were represented but the movements were inspired from the functions of the different lobes. For example, the temporal lobe houses the primary auditory cortex and plays some role in memory consolidation. The ear led the dancers, the rest of them following the movement it carried out. After completing a small combination of choreography, they were told to repeat the movement in reverse to represent a sort of an act of memory.
Reflection

Neuronal Dances had barely been completed before the onset of the COVID-19 pandemic. While the music was filled, the dance was not done in terms of editing. The editing process had begun just before the break. My mentor, Darryl Clark, was especially helpful in this process. As it was a performance piece for entertainment purposes, he prompted questions that would lead to enhancing the choreography from a performance standpoint. For example, shortening the series of lifts was considered. I had four identical ones in series, which to an audience member loses the element of surprise and could get boring. Had I the opportunity, I would have played with changing the way the dancers interacted with each lift, played with direction, and ultimately shortened it to two or three lifts in series.

Another issue I had not anticipated running into was the timing of choreography for the dancers. Given that this music had no steady beat to count in time, I was challenged to create ways for the dancers to be in sync on stage when they were not improvising their movement. Some shifts in choreography were easier to set to the music, especially if there was a distinct, unique sound that would initiate the start of a new phrase. Other shifts were harder to time. I was reminded of previous experience I had with dancing myself. While nearly all of my previous experience involved counts and a right and wrong time to move, it was especially important to be adaptable in the piece. If someone else was off, went a count early, were off center from their position, it was everyone else’s job to be aware and adjust to not distract from the performance. This idea of having to rely on each other and adapt was used to get the dancers in sync. Dancers used sight and sound and vibration in the floor to gauge timing. Some dancers were given the role to initiate the movement, and others had to be aware of them while dancing to know when to go. I really enjoyed this aspect of the dance because it made the dancers dependent on each other.
to communicate on timing. This mutual awareness/reception allowed them to better move together as a group. I thought this echoed the idea of this piece due to the random, natural processes that inspired it.

While this piece was not performed this semester, there are plans to show it in the fall concert put on by Southern Illinois Dance Company. My mentor and the non-graduating dancers plan to edit and recast the piece. I look forward to seeing the piece come together. If I were to do this piece again, I would look into influencing the lights with EEG recording like Mickey Hart, or using the EffortDetect technology used in Trisha Brown’s *Astral Converted*. I think it could have added a unique enhancement to the performance.

**Conclusion**

Neuronal Dances is a piece meant to explore EEG display of neuronal patterns and biological processes. Its goal was to take inspiration from the biological processes and the quality of music that is produced from the activity in the brain. Through research of biological processes behind the song, the movement can be inspired with some degree of scientific foundation. The piece took inspiration from specific neuron types and their unique quality and frequency of firing. The inspired movements and the artistic renditions of recorded brainwaves they were set to resulted in performance art. The interpretation of the choreographer, individual dancers, and audience mold it into a unique entertainment experience.
References


https://trishabrowncompany.org/repertory/astral-converted.html

https://sapienlabs.org/brainwaves_eeg_sound/.

Appendix A

This picture is during wakefulness stage rehearsal. This was the artistic interpretation of an action potential firing and includes the full cast from Neuronal Dances. From Left to Right: Grace Brown, Paige Daly, Mackenzie Kinkade, Alexis Powers, Monika Fudala, Bella Stephenson, Lillian McIntyre, Emily Perez, and Olivia Vincent.

Appendix B

Both of these pictures are from wakefulness stage rehearsal. This is during the sporadic movement portion.
Both of these pictures are from NREM rehearsal. The moments captured are the handstand-like rocking and shows the movement of it and other movements.

Appendix D

Both of these pictures are from rehearsal of REM stage. The first pic is reflective of frontal lobe, the second picture has frontal (downstage) temporal and parietal.
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I am extremely grateful for my professor, Dr. Patrylo, for introducing me to Neuronal Melodies and sparking a curiosity into this field. I am thankful for the Honor’s Program and Elizabeth Donoghue for encouraging me to step outside of my academic comfort zone to pursue this research. I am very grateful for Darryl Clark. As an advisor and mentor on this, I was inspired and in awe of his expertise and knowledge into areas of dance I didn’t even know existed. I am also grateful for SIDC for allowing me to be a member and leader for my time at SIU. I am extremely grateful to Alexis, MacKenzie, Bella, Lillian, Monika, Grace, Paige, Emily, and Olivia who were open to experiment and play with movement. It is a shame that it didn’t come completely to fruition, but I am so appreciative to have had the capacity to explore this idea and field.

Biographical Note

Olivia Balsley Saltus was a Physiology Major from Geneva, Illinois. She was on a Pre-Medicine track with minors in Chemistry and American Sign Language. Her passion for dancing began at the age of three years old and has led her to many great experiences while on her pursuit for a career in medicine. She is very grateful to have this opportunity to combine her passions of physiology and dance in this exploratory performance piece.