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Unlocking Creativity: Using EEG Technology to Analyze Musical Activities

Music communicates with us emotionally through the systematic violation of expectation. These violations can occur in any domain — the domain of pitch, timbre, contour, rhythm, tempo, and so on — but occur they must [... music] has to involve some element of the unexpected or it is emotionally flat and robotic. (Levitin, 2006, pp. 168-169)

Introduction

Understanding the impact that music has on the brain is at the forefront of much cognitive research happening today (Sakai et al., 2021). As technology becomes both more accurate and affordable, music educators are able to bring new and relatively easy-to-use materials into their classrooms to better understand a question they have often asked, "What activities allow my music students to be more creative?"

The nervous system of the human body can be broadly understood as a large feedback circuit, with the sensory inputs connecting the world to the brain and the motor outputs connecting the brain to the world. Researchers can look at both branches of this loop to identify possible correlations with musical "surprise." The sensory input side can show a relationship between external stimuli (sensory input) and internal response (that is, brain activity measured by EEG devices). The motor output side can show a relationship between internal brain activity and external action (motor output). In this work, we focus more on the latter.

To demonstrate such a relationship, we needed to track brain activity somehow, that is, to identify a representation of the will to act. Various technologies exist to do so. Electroencephalography (EEG) offers excellent ability to determine the precise times when brain activity is occurring. While EEG also has somewhat poor ability to determine which specific brain areas are active, it excels in ease of use, cost, and safety. Thus, EEG was our choice.

We selected the temples as appropriate locations to measure brain waves. The temples are a very thin skull region and are near the frontal lobes where executive functions are nominally located.

While creativity is inherently subjective, the areas of the brain associated with artistic creation have been broadly understood and measured using EEG technology for decades. Numerous studies have been published exploring the positive impacts of how the brain is changed through musical exposure (Eck, 2024).

Deeper investigations into jazz improvisation and creativity have explored the brain activity of highly trained musicians in controlled environments (Berkowitz & Ansari, 2008, 2010). Further studies into EEG alpha power and creative ideation have shown that creativity is associated with increases of alpha waves in the frontal sites of the brain (Fink & Benedek, 2014).

Therefore, the purpose of this study was to discover if various musical tasks in school-aged musicians would result in elevated alpha wave production associated with creative decision making. Our research question was: Are there activities that are achievable by relatively young instrumentalists in concert/jazz/modern bands that will allow similar creative output to be measured?

Methods

This research was partially funded by a grant from the New York State School Music Association Action-Research Committee with additional funding from Portledge School. By first creating a permission slip to give to parents, we were able to both explain the scope of the action research project on our campus and also receive consent from those families interested in participating. After the Portledge School Institutional Review Board approved the work (prior to execution), we ordered the Biosensing EEG hardware from OpenBCI, which included the materials listed in Table 1.

Table 1
Study Materials

Material (Hardware and Software)	Use
1 Ganglion (with battery and charger)	Portable bio-sensing computer board with multiple inputs
1 Bluetooth Dongle	Connect wirelessly to a computer
1 EEG Headband Kit with 4 Ag-AgCl electrodes	Fitted headband with moveable EEG sensors
OpenBCI GUI [Graphical User Interface]	Computer program to interpret data signals into usable visual and numerical formats
Spectra 360 Premium Electrode Gel	Improve connectivity of sensors to skin
1.5 meter length cables	Connect EEG sensors to bio-sensing computer and provide isolation from body movement of subject

Additionally, upon receiving the hardware, we downloaded the corresponding software OpenBCI GUI [Graphical User Interface] to begin testing the materials. The set up began with first using the stock equipment provided before realizing that the project hardware would require modifications to achieve optimal results. This resulted in acquiring longer cables (1.5m) to reduce need for the bio-sensing computer to be attached to the subject (which interfered with accurate results due to body movement), and the use of Spectra 360 Premium Electrode Gel to improve connectivity.

Preliminary test results were inconsistent for both musical and technical reasons. Many trials were needed to determine which activities would consistently yield brain activity in the 7–12 Hz range, known as alpha wave activity (Fink & Benedek, 2014).

Our original tasks included both sight-reading and reading known material at various levels of rigor, but we removed these due to eye movement that resulted in large signals on the EEG equipment that were caused by muscle motion rather than brain activity. Also, electrode placement on the back of head (parietal region) proved impractical to do in a timely fashion with children.

A consistent and reliable model of testing was achieved by applying Spectra 360 Premium Electrode Gel on four Ag-AgCl electrodes and placing them on the temples (frontal lobe) while placing the Ganglion computer 1.5 meters away from the subject. Additionally, all non-essential electronics were removed from the subject (e.g., phone, smart watch) and most electronics in the room were shut off (lights, computers, etc.) as there was interference with the Ganglion resulting in elevated levels of activity at all frequencies.

While conducting test trials based on improvisation texts (e.g., Crook, 1991; Hall, 2009; Stevens, 2007), an interesting discovery helped shape the experiments that we used for our research findings. While working with a high-level pianist, we allowed him to play completely improvised material. Expecting to see a larger density of waves in the alpha region when fast and technical runs were performed, we were surprised to see these were often the lowest levels of alpha wave activity associated with creative ideation.

Our hypothesis is that these passages came from previously practiced material that was already memorized and simply sounded novel when, in reality, the material was simply being recalled. After weeks of preliminary trials, the three principal experiments included in this report involved students ages 9–18 playing:

1) Known material, scales, or fragments with added rhythm (student- or teacher-determined).
2) Improvisations with periods of pre-determined musical material.
3) Excerpts with transposition.

Students performed the listed tasks and we video recorded the GUI screen during all sessions to synchronize musical output with brain activity upon analysis.

We excluded students playing percussion from the study due to extreme vibration, even at low volumes. All participants were asked to sit as still as possible with their eyes closed to capture only musical outputs and were filmed (361 sessions totaling 836 minutes, roughly 14 hours) to synchronize the brain waves observed with the musical performance.

Results

Our results strongly suggest that asking students to play (1) known material with added rhythm, (2) improvisations with periods of predetermined motives, and (3) excerpts with transposition may help music educators interested in unlocking the creative potential of their students.

We observed standard baseline brain activity during preliminary tasks such as playing known scales or fragments, whereas adding predetermined rhythms to these resulted in increased brain activity in the alpha region.

Figure 1 illustrates EEG measured intensity by color. The most significant difference occurred when students used self-directed improvisatory rhythms on known material (scales/fragments) yielding the most difference from the rudimentary musical tasks (see Figure 2).

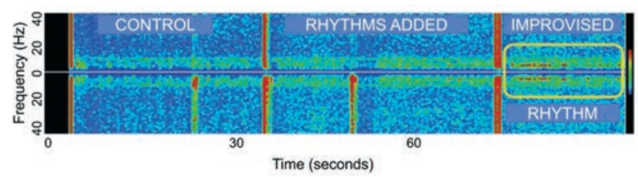

Figure 1. Linear spectrogram color and EEG measured intensity.

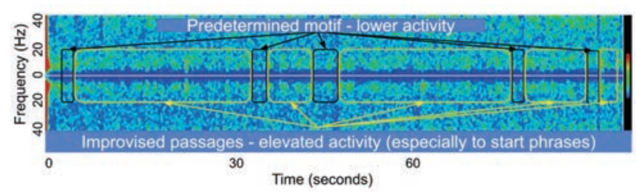

Figure 2. Control major scales vs. added rhythm vs. improvised rhythm on piano.

When students were given a predetermined short motif to remember and then were allowed to freely improvise, the result did not yield as much alpha wave intensity as when allowing them to add rhythm; however, something interesting happened. While students musically "wandered" around their instrument then came back to a predetermined musical motif, the moments of predetermined material served as a creative release for the students (see Figure 3) and allowed for higher results in terms of alpha wave activity when improvisatory passages recommenced.

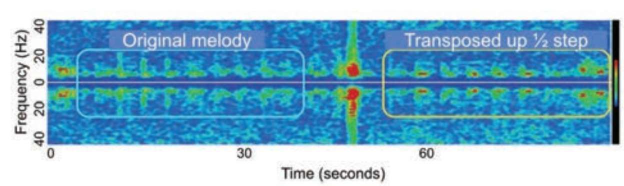

Figure 3. Structured improvisation with motivic interlude on tenor saxophone.

Having students transpose material (see Figure 4) yielded intense activity of alpha waves, however, this task was challenging to replicate across grade levels as younger students were less familiar with all fingerings and were inexperienced with ear training.

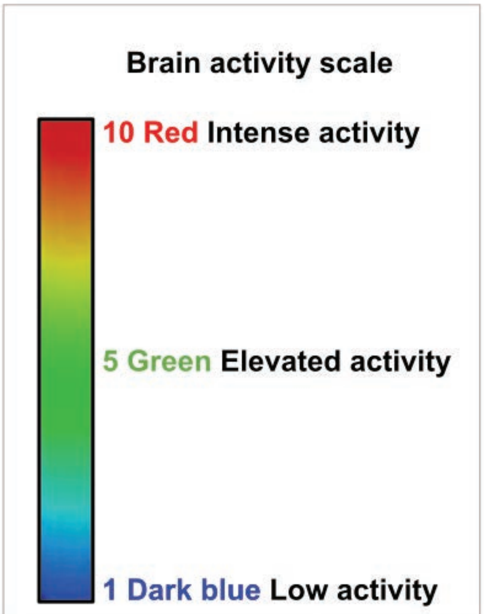

Figure 4. *Autumn Leaves* in original key vs. transposed key on trumpet.

Discussion

While the tasks students performed clearly supported our hypothesis (using known material in novel ways would yield elevated alpha wave outputs in comparison to basic scales and fragments), three interesting and unexpected phenomena presented themselves.

The first being that creativity was not a prolonged state, but rather it was a brief moment of creative decision making. Furthermore, those creative moments *preceded* the novel musical event and did not necessarily occur during the musical motor outputs.

Secondly, elevated levels of alpha waves were clearly observed during notes that were contextually wrong (such as playing an Ab in a C major scale). This is likely due to the brain/ear hearing a discrepancy and needing to figure out how to fix it quickly. Lastly, moments of free improvisation did not yield elevated alpha wave activity, and it was using controlled elements (such as rhythm or pitch) within a musical decision that yielded the highest alpha wave activity.

Conclusion

Students in grades 4–12 who participated in the study expressed enjoyment with these activities and gained insight into their cognitive processes, observing their brain activity in real time. This approach demonstrates creative stimulation can arise from structured tasks that balance familiarity with opportunities for exploration. Allowing students to work with familiar material (e.g., scales, warm-ups, excerpts) while incorporating rhythmic variations, transposition, and structured improvisation may be an effective way for music educators to spark creativity and engagement. Our results highlight the value of combining known material with controlled improvisation techniques to foster both musical growth and creative thinking, providing educators with actionable strategies to enhance teaching practices.

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