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Integrating Physiological Measures within a Music Therapy Research Course: Program Description and Initial Evaluation

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ARTICLE

Integrating Physiological Measures within a Music Therapy Research Course: Program Description

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Abstract

Applying research to practice is an essential competency for music therapists, and some educators have turned to course-based undergraduate research experiences (CUREs) to support students in developing these skills. This paper provides the pedagogical and clinical rationale for incorporating the use of biosensors such as electroencephalogram (EEG) headsets, heart rate variability (HRV) monitors, and galvanic skin response (GSR) sensors into music therapy courses, and outlines how the instructors acquired materials, software, and expertise to implement them in teaching. This preparation led to the development of lab manuals and to training an undergraduate research assistant to provide in-class support. We then provided a bounded CURE involving a research question involving data from three different biosensors. The research assistant shares her perspective of her role in this experience, including her deepened understanding of research concepts through data collection and preparation. We plan to refine our work and continue implementing CUREs with biosensors in future runs of the course. Furthermore, as class sizes grow, we aim to publish data from our projects, while also examining students' experiences.

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Introduction

Music therapists work in healthcare, education, and rehabilitation settings. Accordingly, they engage in evidence-based practices (EBP) to integrate the highest quality research available with professionals' expertise and clients' needs, values, and preferences (American Music Therapy Association [AMTA], 2015). Research is one of three legs in EBP, and yet surveys of music therapists found that practitioners experienced many barriers to reading and implementing research in their practice, including a lack of familiarity and confidence with interpreting data in research articles (Waldon, 2015; Waldon & Wheeler, 2017). To this end, the AMTA developed the Music Therapy Research Initiative 2025 (MTR2025) to build research capacity and increase high-quality research in the field. The initiative emphasizes the importance of clinicians accessing, using, and participating in research as clinician-scholars (AMTA, 2015).

Building this capacity begins in the undergraduate classroom and should include a wide range of data sources that music therapists may encounter in various settings, including hospital monitoring equipment. One other team has studied generalized research skill development in music therapy education; however, their studies focused on outcome measures of self-rating scales and did not include physiological measures (Dvorak & Hernandez-Ruiz, 2019; Hernandez-Ruiz et al., 2022). Most music therapy research courses do not introduce students to physiological measures such as heart rate, heart rate variability (HRV), galvanic skin response (GSR), or electroencephalogram (EEG); this is likely due to a lack of such equipment for educators, as well as a lack of developed teaching materials and instructor familiarity with these tools to develop lab experiences. However, as researchers within and outside the field continue to advance knowledge about how the human body responds to music-based interventions, technology in the field expands beyond hospital monitoring equipment to include smartwatches that measure HR and HRV and gaming headsets using EEG. Thus, music therapists can make explicit connections between their interventions and physiological outcomes. Furthermore, we can directly engage with state-of-the-art research concepts for our field, such as social neuroscience (Fachner, 2014; Tucek et al., 2022). However, to accomplish this, music therapists need a foundational understanding of how to design practical and clinically relevant questions, collect and interpret data using these measures, and communicate those findings to lay audiences.

Previous iterations of the Music Therapy Research Methods course at our institution included introductory research experiences with these measures but, until now, we had not documented using such resources for class-based projects, nor had we involved an undergraduate research assistant as part of those experiences. This paper presents how we implemented physiological sensors in our music therapy research course and shares the research assistant's experience supporting the course. Because of the small class size in this run we did not intend to collect publishable data; therefore, we do not discuss the research question and outcomes of our class project in this paper.

Throughout the rest of this paper, we refer to resources, hardware, and software we have used in the development and implementation of the CURE; in addition to photos and descriptions in the text, we describe each resource in the Appendix with links to websites where possible.

Process of Implementing Physiological Measures in Research Methods Course

Acquiring and Developing Materials and Resources

Developing the materials and background knowledge to undertake this task has been a years-long process. In 2018, our department provided funding to purchase an Emotiv EPOC+ headset and EmotivPRO software. These purchases allowed us to collect and export EEG signals. The department also supported purchasing a Polar H10 HRV monitor, which could be paired with a free mobile application to collect and analyze HRV. We used institutional subscriptions to MATLAB/EEGLAB and Kubios HRV Standard for analyses from both types of sensors.

Furthermore, we fostered collaborations with researchers in related disciplines to help us develop additional tools and resources we could use in our classes. First, a computational biologist and data science educator used the statistical package R to build a ShinyApp web-based application that could create Power Spectral Density maps for a given frequency range and calculate Frontal Alpha Asymmetry statistics for specific electrode pairs. We piloted this application in previous semesters of Psychology of Music and Music Therapy Research Methods, testing the user interface. At every opportunity, students successfully navigated the app and generated maps and statistical output for their projects. This application would still require data preprocessing before students could upload files into it; initially, the course instructor (first author on this paper) managed these tasks and validated the application's output by comparing it to output from EEGLAB. For the latest run of Music Therapy Research Methods, the course instructor trained a research assistant (described below) to conduct simple preprocessing of EEG data and validate the output in MATLAB.

Second, an associate professor of music technology at another institution had been collaborating with us on a project involving sensors linked to music streaming apps, IMAGS (https://imags.eamir.org/). As an initial effort, this professor and one of his students built a GSR sensor using an Arduino microcontroller that interfaced with an open-source application they developed using Max8. Though we had not initially planned to integrate GSR into the research course, we decided to test it on this project to get feedback on the application.

Meanwhile, the instructor dedicated time to learning how to use EEGLAB through free online tutorials (e.g., Mike X Cohen and Arnaud Delorme on YouTube) and interpreting HRV through the Elite HRV Academy (elitehrv.com/academy). Using this knowledge, she developed lab manuals describing step-by-step procedures for installing and configuring software, preparing for data collection, collecting data, managing data and preparing files for analysis, and guidelines for interpreting data. The lead author continually updated these manuals over six years for the Emotiv headset, and one year for the HRV and GSR sensors, piloting these procedures with students in course-based lab experiences.

The lead author first introduced these materials into a Psychology of Music course starting in 2018 to help illustrate the impact of various kinds of music experiences on human physiology, and to explore student-driven questions within the classroom in Research Methods in Music Therapy. Inspired by the work of Dvorak and Hernandez-Ruiz (2019), the lead author sought to integrate these experiences and lay the foundation for a publishable CURE in our program.

This next step required additional support given that our department does not have graduate research assistants. Accordingly, the lead author (also the course instructor) hired a work-study student (co-author) to provide research support. This person previously worked on a grant-funded research project for the program and demonstrated strong organizational and computer skills; they were willing to engage in additional training on the use of these resources and data analysis.

In this next section, we outline the rationale for integrating these specific measures into the Music Therapy Research Methods course, and then describe the sensors and materials in more detail.

Selection of, and Rationale for, Physiological Measures

Rationale for Using EEG in Research Methods

In a prerequisite course (Psychology of Music) students reviewed a growing body of work examining the role of Frontal Alpha Asymmetry (FAA) in elucidating emotional responses and/or arousal states in response to music interventions (Fachner et al., 2013; Fachner et al., 2019; Kang et al., 2022). Asymmetrical power in the alpha frequency in the frontal region of the brain appears to be an indicator of positive (approach) or negative (withdrawal) responses (Davidson et al., 1990). It is simple to calculate this statistic when using average power over the duration of a given experimental condition, thus with some preparation it is practical and accessible for music therapy students to understand.

Rationale for Using HRV in Research Methods

Music therapists often design interventions to reduce autonomic nervous system (ANS) arousal. One measure of ANS arousal is heart rate variability (HRV). HRV is a measure of the amount of variation between heartbeats (called R-R intervals), which can be averaged over a set period or measured on an ongoing basis. Fluctuations in this measure indicate sympathetic (SNS) and parasympathetic nervous system (PNS) arousal. In general, greater HRV indicates an ANS that can adjust according to situational demands to rest or be more active due to physical activity, alertness, stress, or even threat, whereas low HRV can indicate that ANS is not adjusting arousal according to a given situation, perhaps due to continuously elevated stress. As with EEG, there is a growing body of evidence showing ways music interventions affect HRV (Fuchs et al., 2018; Koelsch & Jäncke, 2015; Mojtabavi et al., 2020, Metzner et al., 2022) and HRV is becoming more accessible to laypersons through smartwatches and fitness trackers. With a greater understanding of how music-based interventions affect HRV, music therapists could design interventions for clients who need to modulate their ANS and use HRV monitoring to track changes.

Rationale for Using GSR in Research Methods

Galvanic Skin Response (GSR; also known as skin conductance, or electrodermal activity) is a measure of electrical resistance in the skin caused by sweat, and therefore is linked with ANS and emotional arousal. This measure has been used for over a century in psychophysiological research, was used in early music therapy studies (e.g., Borgeat, 1983; Taylor, 1973), and continues to be of interest to current researchers (Hernandez-Ruiz et al., 2020). Overall, research shows that GSR is linked to the degree of autonomic arousal, regardless of the valence of the arousal–in other words, GSR does not detect positive or negative emotions, but rather indicates how strong one's emotional or attentional focus is in the moment (Laine et al., 2009). Its temporal resolution allows us to see changes in response to specific musical features in a continuous recording.

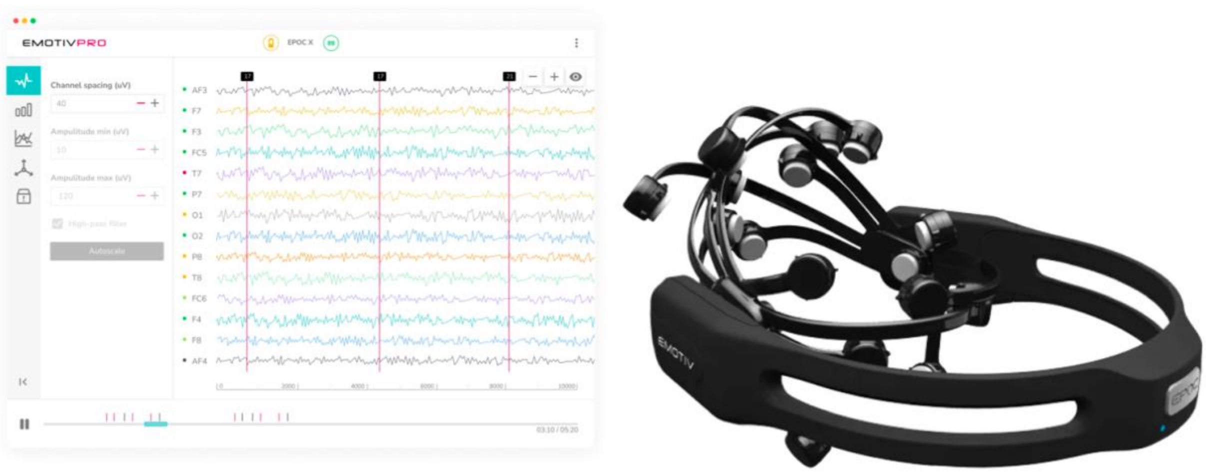
Physiological Sensors and Resources

EEG materials: We used the Emotiv EPOC+ headset, a commercially available product (emotiv.com), along with EmotivPRO (v. 3.5.2.471) acquisition software (Figure 1 and Appendix). The device was originally developed for video gaming but has been increasingly used in research because of its affordability and ease of use. A user can simply slide the headset onto the head and adjust the 14 electrodes which are attached to flexible arms; the headset transmits its signal to a computer or mobile device via Bluetooth. The electrodes maintain contact with the scalp using saline solution, rather than gels or other substances often used in clinical EEG systems. The EmotivPRO software guides users through the setup process, including headset placement and checking for good electrode connectivity and signal quality.

HRV materials: Upon recommendation from HRV researchers, we purchased the commercially available Polar H10 HRV monitor (http://polar.com; Figure 2). The device is most often used by high-level athletes who want a very accurate measure of HRV. The sensor is a flat oval disc about two inches by one inch, which snaps onto an elastic band fitted around the user's torso, with the sensor centered on the sternum. Like the EPOC+, the H10 transmits its data via Bluetooth. Several mobile apps are compatible with the H10, and we used the PolarFlow application (http://flow.polar.com; Figure 2) which synchronizes with a web-based user account and can export data collection sessions.

Figure 1.

A screenshot of EmotivPRO Software (from emotiv.com) (A) and Emotiv Epoc+ Headset (B)



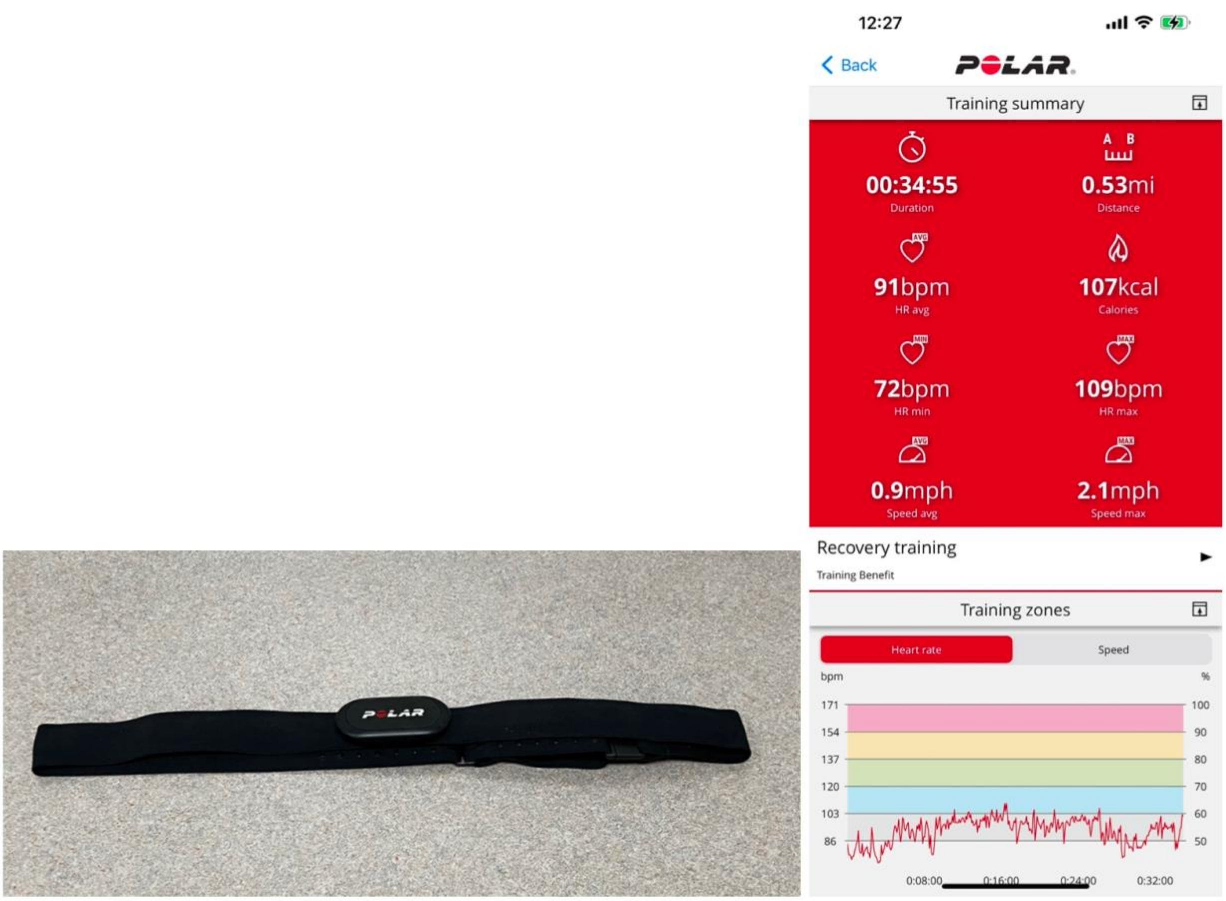
A B

GSR Materials

Prior to teaching at her present institution, the instructor used a commercially available Galvanic Skin Response sensor (eSense, by Mindfield; https://mindfield-esense.com/) in her teaching. While this device sufficed for teaching purposes, the instructor ultimately wanted to integrate GSR into a research project using a mobile application for pain management via music listening. Thus, we needed to be able to work with the source code directly rather than the proprietary application tied to the eSense. Our music technology collaborator, V.J. Manzo, and his student, Ava Mattimore, built an Arduino GSR sensor and wrote code to capture GSR data using the Max8 application. This application captures and saves data as a comma separated variable (.csv) file that can be opened in Microsoft Excel. From there, users can plot the data in graph form for reports.

Figure 2.

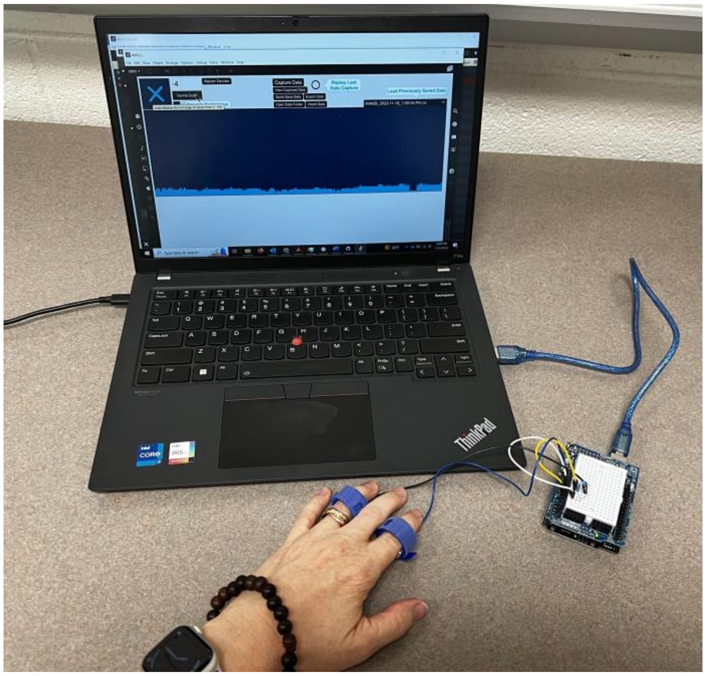
Polar H-10 HRV Sensor (A) and Screenshot of PolarFlow App (B)



A B

Figure 3.

Custom-built Arduino GSR Sensor in Use with Custom Software in Max8



Integration of Physiological Measures into the Research Methods Course

Generating the Research Question and Project Methodology

The task of developing a question to investigate began in a course immediately preceding Music Therapy Research Methods. During the previous semester, the instructor taught Psychology of Music and as previously mentioned, introduced students to the sensors along with their clinical and research potential. The instructor also introduced the students to literature searching and extracting information from research articles by focusing on a bounded topic, emotional responses to music. At the end of the semester, students presented their own questions and potential means of investigating them using the sensors.

Most of these students took Music Therapy Research Methods the following semester. At the beginning of this course, the instructor collated the previous semester's final proposals and led the students in a discussion regarding their interests and preferences as a group based on these proposals. The group came to a consensus on a topic and question, and then identified the variables and keywords related to this question. The instructor and class divided up the tasks for the project, assigning student leaders for each stage, with each student having one leadership role (sometimes working in pairs): 1) literature review and synthesis leading to the final research question; 2) Data collection procedures; and 3) Data analysis and results reporting. The entire class contributed to each stage, and the student leaders of each stage were responsible for collecting and organizing the group's contributions.

Our curriculum is hybrid-online, therefore we scheduled tasks and deadlines around the face-to-face meetings scheduled once per month over the semester along with scaffolded asynchronous work due each week. Therefore, at each face-to-face meeting, we covered these topics and tasks:

- First meeting: finalized the research topic and assigned roles for the rest of the semester.
- Second meeting: finalized the background literature and research question and collaborated on the design and data collection procedures.
- Third meeting: collected data.
- Fourth meeting: shared the results and discussed their implications.

In the following section, we describe how, after finalizing the research question and methodology in the second face-to-face meeting, we proceeded with the third meeting to collect data.

Data Collection Procedures

Students prepared materials ahead of time, including recordings of music for different experimental conditions as well as rating scales and open-ended questions for the participants to complete. The instructor and the research assistant set up the hardware and software while the students prepared the audio setup for music delivery. Once we tested all the equipment, we began data collection.

EEG Data Collection Procedure. The instructor assisted students in placing the headset on each participant and ensuring good connectivity and EEG signal quality, according to the EmotivPRO software's interface. The instructor then recorded separate files for each experimental condition and took notes of any environmental or situational factors during data collection that may have influenced signal quality or participant response. We then exported the recordings as universal text files for EEG (.edf) and saved them for preprocessing.

HRV Data Collection Procedure. Each student-participant wore the Polar HRV monitor during data collection; another student paired the monitor with the PolarFlow mobile app. We collected continuous data for all experimental conditions in a single recording. The student researchers took notes of the time counter on the app for the start and end of each condition. At the end of the session, we uploaded the data to the

PolarFlow website, where we could export a comma-separated value (.csv) file to Kubios HRVStandard software (v. 3.5.0) for analysis.

GSR Data Collection Procedure. The research assistant connected the Arduino unit to a PC laptop via a lightning cable, then launched the application in Max8. She then connected the participant to the Arduino using two wires with Velcro straps to two of the participant's fingers. Once the experiment began, the research assistant recorded separate files for each experimental condition then exported .csv files and saved them in a location where the instructor and students could access them.

Data Preparation and Analysis Procedures

The instructor and research assistant took the next week to organize and prepare the data from the sensors.

EEG Data Preparation and Analysis. Prior to data collection, the research assistant received training from the instructor on using EEGLAB to preprocess EEG data, including visual removal of eyeblinks and other signal artifacts. Once we had collected the data, the research assistant prepared each raw .edf file from EmotivPRO and exported them again so students in the course could use them in the ShinyApp application.

Following the step-by-step lab guide created by the instructor, students took these preprocessed .edf files and uploaded them into a web browser-based application (ShinyApp) using the R statistical software package and eegUtils (https://craddm.github.io/eegUtils/) to generate power spectral density maps at the alpha frequency and to conduct FAA comparisons for three electrode pairs (F3-F4, AF3-AF4, F7-F8; Figure 4).

HRV Data Analysis Procedure. The instructor prepared the .csv file for analysis in Kubios by calculating the R-R values for each datapoint in the file, then pasted the R-R values into a text-based file for use in Kubios. This software allows users to compare analysis “windows” from the same sample, looking at different segments of time within the same recording. Thus, following instructions in the lab manual, the students created analysis windows for each experimental condition within Kubios and then ran a report. Kubios creates a PDF document that shows the SNS and PNS indices, as well as minimum and maximum heart rate values for each window. The instructor provided guidance in the lab manual and also met with students to assist in their interpretation of the comparisons, looking at changes in SNS and PNS indices and heart rate within and across conditions, and within and across participants (Figure 5).

GSR Data Analysis. The instructor worked with students to convert the .csv files into graphs using Excel. The students then visually analyzed the graphs for changes in GSR values over the time span of each participant’s file; higher GSR values indicate a higher arousal state. Finally, students compared the baseline readings with each experimental condition within and across participants.

Figure 4.

Screenshot of ShinyApp "EEG in the Classroom" Application Displaying FAA calculations, Power Spectral Density, and Alpha Power Topographic Plot

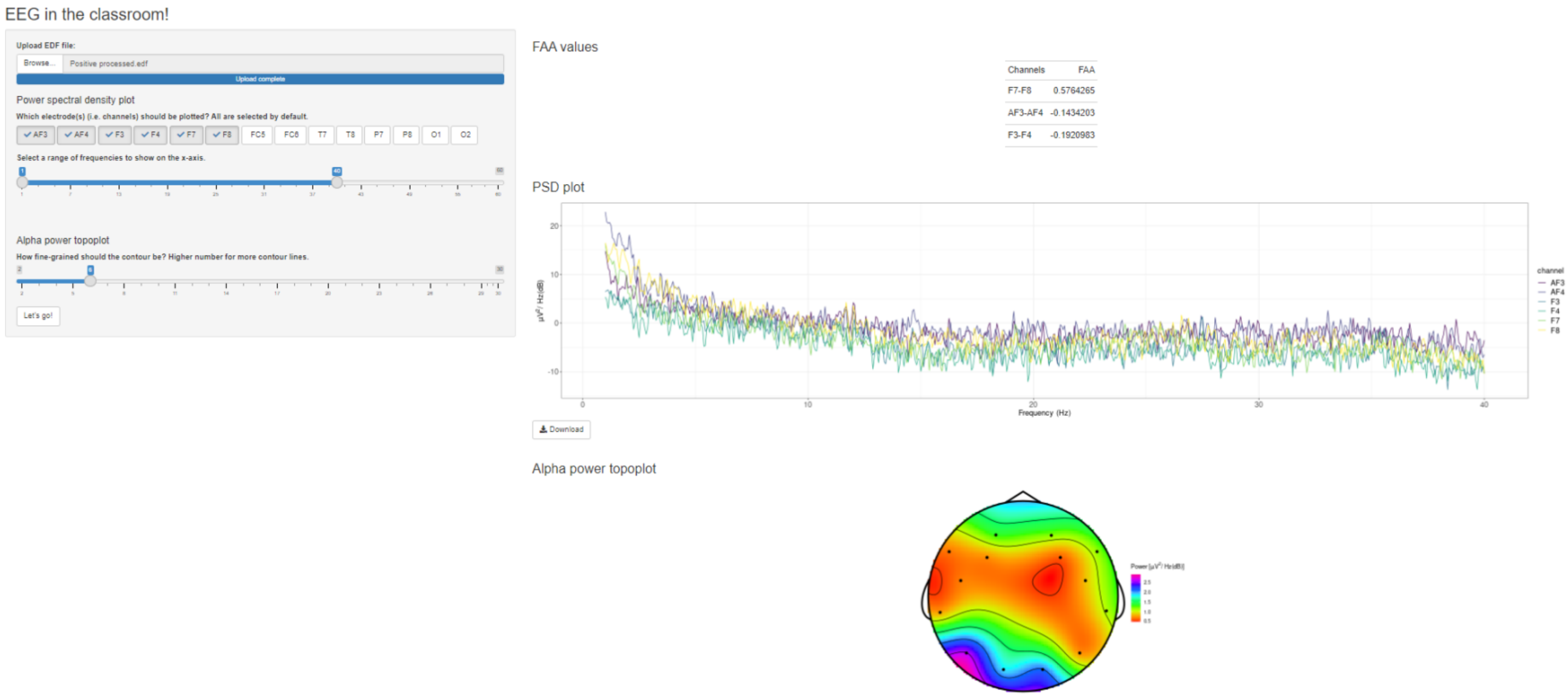
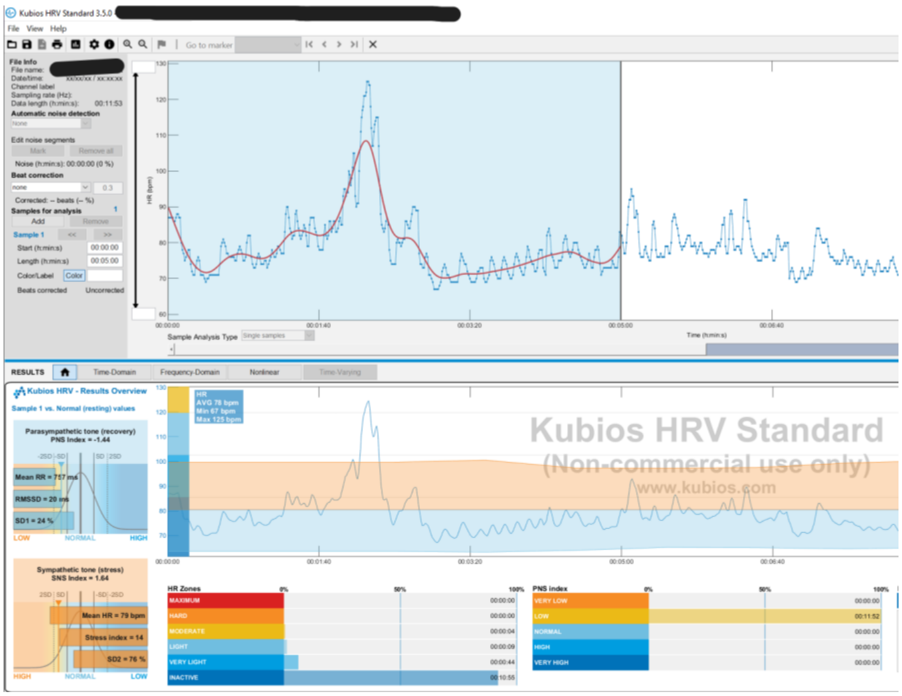


Figure 5.

Screenshot of Kubios HRV Output



Subjective Ratings and Qualitative Data Collection. Interpreting physiological measures requires contextualizing them with participants' subjective experiences such as mood, energy level, and reactions to the experimental situation. Therefore, the students developed a survey with Likert scales for participants to rate subjective states (e.g., degree of stress, degree of relaxation) pre- and post-each condition. Surveys also included open-ended questions where participants could provide more context for their experiences during each condition, e.g., reactions to the music conditions. During the week that the instructor and research assistant were preparing the sensor data for analysis by the students, the students collated the Likert scale ratings and transcribed the qualitative responses.

Interpreting, Integrating, and Reporting Data

The students compared outcomes from each sensor's measure across conditions separately, then integrated these with participants' subjective ratings and open-ended reports of the music experience during data collection. As a group, the students sought to understand whether and how the physiological responses could be related to each other and line up with participants' experiences. This was a challenging and enlightening process, as it highlighted how data interpretation requires openness to unexpected outcomes and contextualization. This process began immediately after data collection, where the entire group shared immediate reactions to the data collection session, and then continued through email and Zoom dialogues between students who were interpreting the data and the course instructor. These students shared their tables, graphs, and reports in the ongoing Google Doc outline that documented our group project, and other members of the class posed questions and insights in response. When the class and instructor reached a consensus on the meaning of the results, assigned students related the results to our initial literature search, formulated conclusions, and generated future research questions.

Proposed Benefits of Integrating Physiological Measures for Music Therapy Education

The AMTA Professional Competencies (AMTA, 2013) do not require music therapists to conduct research, however, they do require skills in collecting, analyzing, and reporting clinical data, e.g. C.11.2 and C.11.4: relating to assessment data; C14.:1 relating to design of measuring and evaluating client response to therapy; C15.1-3 and C15.6: relating to gathering, documenting, and reporting clinical data and outcomes.

Furthermore, engaging in a hands-on project based on students' interests and questions has, in our experience, helped students understand and solidify research concepts. For example, for competency C20.3, "Perform a data-based literature search" students work collaboratively to search databases for research studies on their topics, and with assistance from the instructor learn how to refine their search terms, filter articles by reviewing abstracts, and then extract information relevant to the topic. The entire process of defining the research question based on that information, defining the experimental conditions and outcome measures, then collecting and interpreting the data helps students relate to these stages of a research project as described in the articles they read for classes. Thus, they are better prepared for competency C20.1, "Interpret information in the professional research literature" and understand the need for critical interpretation based upon the specific contexts of that study, according to competency C20.4, "Integrate the best available research, music therapists' expertise, and the needs, values, and preferences of the individual(s) served."

Furthermore, the AMTA symposium MTR2025 (AMTA, 2015) produced several recommendations for policy and infrastructure changes to promote the advancement of clinical research. Among these is the recommendation for increased numbers of doctoral-level research-active scholars leading to increased research capacity. Therefore, we need to spark interest in research among undergraduates so that they are motivated to pursue graduate studies.

To this end, after this implementation of our CURE, we sought to learn if students in this research course experienced any of these benefits by participating in the experiences described above. The cohort was unusually small (N = 4), so we piloted a survey utilizing a modified version of Undergraduate Research Student Self-Assessment (URSSA; Weston & Laursen, 2015) relevant to our CURE to gather preliminary data and assess the utility and feasibility of the survey. Overall, the results indicated that students found benefits in the CURE, and that the modified URSSA items were relevant. However, the sample size is too small to report results from this survey. We will make minor revisions to the survey items and implement it with a larger sample in the next run of the course.

Research Assistant's Experience as a Research Assistant

In participating as a research assistant in this study, I have gained some valuable knowledge on the process of conducting research. In conjunction, I learned new ways of analyzing the human mind with equipment specialized in tracking physiological and neurological changes (such as the EEG and the GSR sensor). This was my first experience participating in research like this since doing the music therapy research methods course, where we were required to do a group research project. I feel as though initially, I did not have enough experience with the process of research before my first course, and still was interested in learning more after it. Taking the time to participate and do hands-on work with this project has helped me gain a better understanding and perspective on the procedures taken to collect, analyze, and finalize data for research.

When being trained to look at brain waves through EEGLAB, I was fascinated with all the detail taken between milliseconds of brain activity between each participant. I learned the specific labeling of each electrode and where each of them, placed on the scalp with the EEG, is located. Even going through the setup process for each file with

EEGLAB was something educational for me as it was one of the most tedious yet informative parts of the data intake. I had help with the Emotiv/EEGLAB lab manual which had a step-by-step guide for setting up the data channels and applying the plotted brain waves into the program. Once it was set up, I could take a further look into the patterns of each electrode and see the activity of the brain. I learned about certain things such as spikes in the electrodes that are at the bottom of the head (nearing the visual cortex), which can indicate eye blinks due to suppression of the visual cortex, switching off when one blinks. These details, and many more, have helped me to understand how to do my assigned task in the research study when cleaning up artifacts after the data collection.

When it came to doing the actual data collection, I was assigned to record and time the GSR concurrently with the test being recorded by one of the other research assistants and students. I think this was a very good and collective experience as it was fun and interactive to engage in data collection with others and discuss some of the data results collected by the class members and myself. In turn, getting some feedback from the participants was a big help too as it gave us some general understanding of their experience and if there were any significant changes in mood that the data collectors needed to know for analyzing and interpreting the data. For me, it helped to know exactly where to look when cleaning up the data and the possibilities of artifacts, which indeed did show up in both participants' EEG signals when I was preprocessing the data. This was also an interesting process because looking at both participants, I noticed that they both had different experiences with their conditions which could be seen further after the interpretation of the clean data. For example, when comparing both participants' GSR during data collection, the levels were notably different as one of the participant's levels was consistently higher and the other one was consistently lower. This showcases the differences between each participant's levels of skin conduction while also taking into consideration everyone's stress level variability. Though one of the participants had shown consistently low levels in the GSR, indicative of low levels of physical stress or arousal, there were a lot of artifacts needing to be removed from the EEG signal during the same condition. This means that there were significant amounts of blinking or moving their face and body. I thought this was interesting because the contrast between these measures shows that not all measures will consistently reflect each other. When this happens, we should look further into each participant's music experience and try to explain the contrast between measures. The participants' different experiences can affect their bodies differently and thus could be the cause of their varied measures.

Overall, I think my time in this research has given me more insight into the effects of music on the human brain, the physiology of the human body, and how rapidly the activity of these processes can change. The skew in levels of each response could be from anything other than the music as well such as environmental distraction that caused the participant to drift away attentionally from the condition they were receiving. Other factors could have played a role in it as well, such as the music eliciting memories or recollections. I think that it is important for me to keep up with this sort of research to discover and investigate some of the unanswered questions I come up with after the experiment. I could do this by doing a research project of my own, or at a work setting in the future. If I decide to go to grad school, I could also involve myself in other research projects with musical experiments and study the effects of music on the brain there. There are many possibilities for furthering my studies as a researcher of music and the mind.

Implications and Future Directions

We are currently validating our ShinyApp application to ensure that the statistical and graphic output of FAA and power density maps are accurate. Once validated, we plan to publish the code and share this browser-based application with other instructors to test in their classroom labs. We are also collaborating with the developers of the Arduino GSR sensor to improve the user interface and graphical output in Max8; as this is part of the larger IMAGS project to incorporate the sensor with a mobile application, we want to create as user-friendly a system as possible. We also plan to collaborate with experts trained in psychophysiological data to review our interpretation of these datasets. Concurrently we will continue updating our lab manuals for all three sensors and work toward sharing those with music therapy educators.

In addition, as enrollment in the Music Therapy Research increases, with more students sharing the workload, we plan to implement a full CURE using one or more of these sensors, perhaps leading to publishable data. We would also like to survey students about their experiences to determine if outcomes with a larger class would match our preliminary results as well as those of Dvorak and Hernandez-Ruiz (2019) and Hernandez-Ruiz et al. (2022) while also continuing to develop the role of an undergraduate research assistant. With additional data about the benefits of CUREs in music therapy education, we hope to spur the development of CUREs in other programs. including programs that do not have graduate assistants to provide support.

Our students may have benefitted from these hands-on experiences using sensors, yet we are aware that not all music therapy educators will have the background knowledge and resources to set up similar experiences in their classrooms. We do not advocate that all music therapy students should take part in such experiences. However, we hope that by sharing our work we can support those who have the interest and ability to include such experiences in their research courses, while encouraging music therapy educators to consider developing new CUREs involving other measures or assessment tools that are accessible for their programs. As Dvorak and Hernandez-Ruiz (2019) propose, educators could collaborate on developing a national CURE model that could be adapted to individual programs' strengths and faculty expertise. Should additional data on the outcomes of these CUREs continue to show their effectiveness in promoting students' interest in reading, applying, and doing research, then our programs are doing their part to grow research capacity in our field per the AMTA MTR2025 priorities (AMTA, 2015).

Conclusions

Integrating physiological sensors in music therapy CUREs provides students with valuable opportunities to develop research skills and understanding of physiological responses to music interventions. Anecdotal reports from our students mirrored responses in Hernandez-Ruiz et al. (2022) indicating that "hands-on" experiences helped improve their research competence in both reading and doing research. They also shared that they gained skills in critically applying research to their future clinical work. In addition, the Research Assistant reported a deepening of these experiences that built upon her previous work in the same course.

We hope that our approaches will be helpful to other music therapy educators who desire to implement CUREs in their programs, particularly those housed in institutions primarily focused on teaching rather than research. Though our undergraduate program has limited research resources, we worked with available options such as hiring a work-study student to provide valuable support to the course. This provided an additional benefit to this student, who gained a deeper understanding and appreciation of research skills. We intend to gather additional data to continue developing resources and practices for CUREs involving biosensors and look to collaborate with educators to expand CUREs to include a variety of research questions, outcomes, and approaches.

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Appendix

Training Resources

EEG and Time Series Analysis Concepts by Mike X Cohen

- Mike X Cohen is a scientific mathematician and statistician with an in-depth YouTube library explaining concepts of EEG and time-series signal analysis. The tutorials help users understand what electrical signals are, how we visualize and make sense of them, and how we analyze them.

EEGLAB Tutorials by Arnaud Delorme

- Arnaud Delorme is a neuroscientist who developed the EEGLAB add-on for MATLAB and whose comprehensive YouTube tutorials explain EEGLAB functions and their purpose.

Sarraf, N. (2022). *Neural oscillations (brainwaves) analysis: A step-by-step guide to collecting and analyzing EEG data with Emotiv EPOC neuroheadset series & EEGLAB MATLAB.* Author.

- Nilo Sarraf is a research scientist who has used the Emotiv EPOC+ headset in her work and self-published a practical e-book providing step-by-step instructions on acquiring and preparing EEG signals for research purposes using the Emotiv EPOC headsets with MATLAB and EEGLAB.

Elite HRV Academy

- This online course provides the conceptual and practical foundation for understanding and interpreting HRV as a measure of the body's stress responsiveness. Though it is geared toward physical fitness and athletic performance, the information can be adapted to medical contexts.

Hardware

Emotiv EPOC X headset

- This is the current version of the 14-channel EEG headset made by Emotiv that can export signal for analysis in software applications such as EEGLAB.

Polar H10 HRV monitor

- This is used for athletic training as well as research on Heart Rate Variability. Users use it in conjunction with the PolarFlow mobile application which can also export data for analysis in other software applications.

Custom-built Arduino GSR Sensor for IMAGS

- Visit the IMAGS website and scroll to “Our Open-Source Tools and Resources” for information on our GSR sensor and data capture software built and developed by Dr. V.J. Manzo and student Ava Mattimore from Worcester Polytechnic Institute.

eSense GSR Sensor by Mindfield

- This commercially available biosensor can be connected to a smartphone or tablet and used in conjunction with a free app to view the sensor’s output. Data can be exported to a connected email account in comma-separated variable (.csv) format for manipulation in Excel or another spreadsheet application.

Software and Apps

EmotivPRO

- This software is required to acquire, record, and export EEG signals from Emotiv headsets such as the EPOC+/X. The software walks users through each step of the setup and calibration process, then allows for recording and analysis of overall brain activity through proprietary algorithms (excitement, focus, etc.). Users can save and export files in a universal file format (such as .edf) for analysis in EEGLAB or other applications.

MATLAB

- MATLAB is a programming and computing application used by scientists and engineers to analyze data and perform other computing tasks, and is the host application for the EEGLAB toolbox. Most universities have an institutional subscription to MATLAB for its faculty and students.

EEGLAB

- EEGLAB is an open-source toolbox for MATLAB that allows users to import, visualize, preprocess, and analyze EEG datasets. The website includes download information, written tutorials, and installation instructions; for video tutorials, use the EEGLAB YouTube channel (linked above).

eegUtils

- eegUtils is an open-source coding package used within the statistical application R for the processing, manipulation, and plotting of EEG signal. We collaborated with Dr. Stephanie Spielman, a computational biologist and data science educator, who integrated this package in ShinyApps to create our web-based analysis application for preprocessed EEG data.

PolarFlow App

- This free web application works in conjunction with the mobile app to acquire HRV data from the Polar H10 sensor; because it is web-based, it may be easier to gather data for processing than to use the Elite HRV application (described below). However, you will need to manually calculate R-R values with the exported data before conducting your analysis. After collecting data using the mobile app, follow the steps in this YouTube tutorial to export the data from PolarFlow, calculate the R-R values in Excel, and set up your file for analysis in the Kubios application.

Elite HRV App

- This free mobile application is compatible with the Polar H-10 monitor and automatically calculates R-R values.

Kubios HRV Standard

- This version of Kubios is free for non-commercial and personal use; your institution may have a subscription to a more advanced version for research purposes. This tutorial introduces users to different sensors and apps that are compatible with this version of the software.