The BioSynth—an affective biofeedback device grounded in feminist thought

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ABSTRACT

This paper presents the BioSynth, an affective biofeedback device for generating electronic music developed over a decade as part of a research-creation practice. The BioSynth has facilitated the research and creation of work involving performers from a variety of ages and professional experiences, enriching diversity of knowledge regarding emotional performance, production, and differences between perceived and felt emotion within biofeedback art, extending emotional quantification techniques to notions of emotional performance technique, emotional labor, and what feminist Alva Gotby calls emotional reproduction.

The design of the BioSynth privileges relational and real-world interactions as well as feminist thought. This feminist inquiry has led to the development of alternatives to traditional frameworks for biofeedback music that rely on metaphors of musical instrumentation.

This article is divided into three sections: hardware, software, and wetware. The hardware section describes the BioSynth through its design, which privileges ease-of-use for non-expert users. The software section describes mapping considerations based on feminist principles of measuring the emotional subject only against itself. Finally, in the wetware section I describe a feminist-inspired approach to emotional performance that embraces artificiality, irony, play, pleasure, and performance in biofeedback art, implying novel models for composer-instrument-performer relations.

Author Keywords

biofeedback music, affective computing, research-creation, feminism

CCS Concepts

• **Applied computing → Arts and humanities → Sound and music computing**; • Applied computing → Arts and humanities → Media arts; • Human-centered computing → *Human computer interaction (HCI)* → Interaction devices

1. INTRODUCTION: RESEARCH-CREATION AND LIVED EXPERIENCE

Scenario 1: On stage, the lights come up on the Hamilton Children's choir, seven children aged between seven and fourteen years old, each standing beside a box on a music stand with blinking lights and cables connected to their hands (Figure 1). The children stare ahead at the audience as undulating sine tones wash over the performance space: harmonic overtones fade in and out, punctuated by gentle staccato pulses. A soloist approaches a microphone and starts singing her personal story of immigrating to Canada a few years ago: she feels happiness, fear, excitement, anxiety, which she expresses in her own words. The young choir listens to her voice. The pulses we hear are the collective beating of their hearts: rhythmic frames for appreciating the sounds of their collective skin conductivity as moments of stress or emotional intensity ebb and flow through the palms of their skin, shaping the overall expression of a shared emotional voice through sound. The girl has finished. Quietly, slowly, she returns to her place in the choir. The conductor raises the baton to cue an entrance: the whole choir's skin conductance rises in anticipation. The sonic drones dance in a lively response, and the singers open their mouths, ready to sing their first entrance together.

Figure 1. *Song of Seven* (2016) Performed by members of the Hamilton Children's Choir.

Scenario 2: Actress Laurence Dauphinais is experiencing a regular morning routine during pandemic lockdown in the Summer of 2020. As she sits with her coffee to read the news, she suddenly realizes that she has once again fallen into grips of melancholy at the state of the world. Careful to not waste the moment, she gets up from her morning coffee to a chair near the TV where she has installed the device. She sits down, puts her palm into the hand rest, adjusts the oxygen tube under her nose, and sets her foot on the foot pedal. She switches the device and turns the knob until the words "SAD MODE" appear on the tiny blue screen. She pushes a button to begin recording her physiological state. Leaning into the feeling, within a few minutes she begins to cry. In this moment of intensity, she presses down on the foot pedal. A marker is set within the data to indicate that this is a special moment of intensity. After a few minutes the feeling passes: she selects "END RECORDING" and goes back to checking her email. Every day she contributes recordings of her happiness, sadness, fear, and anger as they arrive, slowly building up a dataset of her own emotional physiology within the rhythms of her own lived experience, one that will then be used to train a deep neural network to represent the range of emotions she feeds it.

The scenarios above describe first-person encounters with the BioSynth, a device for measurement of physiological markers of emotion through cardiac activity, respiration, and skin conductance that I have been developing as part of my research-creation in electroacoustic music composition and media art for at least ten years. Each creation has demanded different affordances of the device: for instance, while the first scenario

required that the device be suitable for real-time processing of emotional data, it also had to be easy enough for children to get in and out of the sensor devices when they got up to approach a microphone on stage, and also rugged enough that they wouldn't break the devices during inevitable horseplay and fidgeting that occurred during rehearsals. In the second scenario, the BioSynth is not a performance instrument, but a way of bringing a research environment to the everyday life of a collaborator slowly building her own "emotional database."

I develop the BioSynth from an interdisciplinary position at the intersection of music composition; emotional physiology; instrumentation; mapping; and feminist and queer theory emerging from musicology and performance art, through artworks that function discursively with one another in an interrelational process described by Springgay and Truman as thinking-doing-performing [1].

Each project has allowed me to fruitfully problematize my research, to develop specific technological affordances of the device, and to work with different publics. Because research-creation centers the personal experiences and reflections of the artist within the creation process through methods such as auto-ethnography [2], it is a natural ally to feminist methods that articulate lived and social experience within knowledge systems [3], [4].

The importance of developing awareness of and support for such work within the music technology community has been highlighted by Hayes and Marquez-Borbon as an antidote to "audio-technical" framing of research within narrow fields of inquiry [5], which Gurevich said could be addressed through increased attention and engagement with what he calls methodologies of creative practice research [6]. This being said, humanities researchers Chapman and Sawchuck note that quantitative methods within the research-creation framework still tend to be taken more seriously than qualitative methods within the academic community, so research-creation in itself cannot be credited as an "easy fix" to longstanding diversity issues in electronic music and instrument design [7], nor should quantitative methods be seen as antithetical to the goals of equity, diversity and inclusion embraced by many STEM researchers today.

1.1 Background Context

Significant research into emotional biofeedback music through non-invasive wearable sensors has been conducted by Winters & Wanderley [8]. Some of the earliest documented research into biofeedback conducted by composers David Rosenboom and Richard Teitelbaum could be considered as emotional in nature, such as Teitelbaum's use of biosensors in his 1969 piece *In Tune*, which amplified the brain signals of female performers as they reacted to the public broadcast of themselves moaning sexually and performing sexual acts with one another [9]. While what Teitelbaum described as a "psychosexual" experiment remains innovative in many ways, it also naively reproduced gender stereotypes by staging young women performers emoting at the service of male composers as a sexual spectacle for public consumption. It is conspicuous for example that these particular feminine (homo)sexual bodies are present in the official histories of biofeedback art, while the many biofeedback performance artworks of American composer Ruth Anderson (who happened to also be lesbian) are missing from biofeedback music history altogether [10], [11]. Renowned electroacoustic composer Barry Truax observed in 1993 that in his experience, sexuality was rarely addressed as an aesthetic topic in electroacoustic music, and moreover felt that the conspicuous avoidance of masculine sexuality (whether heterosexual or homosexual), could be attributed to the homogenously male social environment of electroacoustic music [12]. Reading Teitelbaum's only "psychosexual" artwork through the lens of Truax, the instrumentation of female bodies in this biofeedback work can be read as a strategic means represent "sex" while avoiding the representation of male sexuality altogether, thus staging female homosexuality for the tastes of heterosexual men.

The fact that emotion has been historically instrumentalized in biofeedback music both through contemporary metaphors of clinical scientific research, and through the instrumentalization of emotional, female, and sexual bodies in various points of biofeedback music history, is worthy of special mention in the context of this article because of how it unconsciously reproduces unjust hierarchical relationships in electronic music through binary tropes, namely the logical and disembodied masculinity that thinks in contrast to an emotional and sexualized femininity that performs [13].

2. HARDWARE

Ideally, low-cost, open-source devices would create a means for people from all walks of life to access and control affective and biological data. To support artistic work that creates narratives for biofeedback art beyond the scope of what Truax described in 2003 as a homogeneously straight male academic culture, we need a device that is accessible in the first place. Existing devices on the market suitable for affective biofeedback music include the BITalino, at $800USD [14], or the Emotibit, an open-source hardware system that costs $400USD [15]. In comparison, the BioSynth is a non-commercial open-source and DIY project that costs around $200USD in parts but requires assembly that is beyond the scope of non-experts.

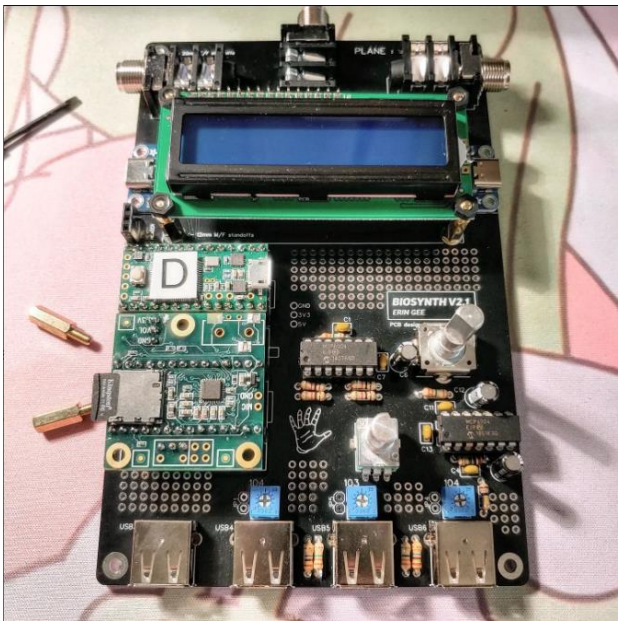

Figure 2. Interior view of BioSynth Device

2.1 Design Considerations

To privilege the investigation of social connections between multiple users, the hardware of the BioSynth (Figure 2) is centered on affordability, material robustness, and a user-interface that makes collaboration between artists and non-expert users easier. Hardware and software alike are detailed at the BioSynth's GitHub page [16].

While the use of an idiosyncratic or fragile device is permissible within research environments that allow for one-on-one contact with expert users, this approach demands constant expert presence. For example, the expert user must be present to install the sensors on the bodies of users, to initialize start-up or

shutdown routines, to monitor their use, and particularly to repair the devices should they become damaged. While these constraints are acceptable in research environments, this approach is unsustainable when devices are called to withstand non-expert use in a loosely supervised art gallery, or when many users need to be hooked up to electronic devices within a relatively short period of time, such as a sound check or rehearsal.

During the development of *Song of Seven* (2016/2022), one of the pieces that I described in the opening of this article, I realized that the aesthetics of the device itself had the power to affect the openness that the children had to working with the devices, which largely affected their attitudes to performing with them in rehearsal. For example, one child asked me if the sensors could hurt her and seemed hesitant to touch the sensors when they were first turned on. Another mentioned that the box looked like a toy and started to mash the buttons excitedly, making sounds like lasers being fired. Yet another complained that her Velcro strap kept on falling off, growing increasingly exasperated each time I had to take her sensor to a back room and perform a quick repair.

I based my design decisions around these comments from non-expert users (musicians, singers, actors, children, art gallery visitors). Many comments revealed that first-time users were nervous about being witnessed in public using the technological devices incorrectly, and therefore being judged by their peers: they also often expressed anxiety about inadvertently damaging a fragile DIY device. The anxiety that a DIY device might malfunction or harm them might have been increased due to the intimate, wearable nature of biosensors. According to a literature review conducted by industrial design scholars Fayazi and Frankel, attention and knowledge of social and emotional relationships in regards to the design of wearable devices is still lacking, and these design elements can have a wide range of social impacts [17]. In developing several artistic works, I have found that improving the aesthetics of the device to make it more comfortable, friendly, and durable in nature were not merely cosmetic choices, but made collaborations smoother, as the materiality of the device can make a user feel more at ease and receptive to new human computer interfaces.

To maximize familiar elements, the BioSynth features cables that would be familiar to non-expert users (USB-A and USB-C). While the USB-C cables for powering and programming the device via serial port are compatible with industry USB standards [18], I also use USB-A cables in non-standard ways by reappropriating them for use with custom sensors. Although it is generally less desirable to use USB cables in non-standard ways, USB-A cables are great for the biosensor designs because they are lightweight, unintimidating to non experts, and are easy to detach in case a user accidentally walks away from the device while wired. Additionally, many USB cables are shielded, an essential feature for delicate electrical signals obtained from the body.

2.2 Implementation and Features

The BioSynth features three non-invasive wearable sensors:

1. The heart rate and amplitude sensor
2. Two skin conductance sensors
3. Respiration sensor

The heart rate and amplitude sensor is an affordable and commercially available and open-source photoplethysmograph device called a *Pulse Sensor* [19]. It has a small form-factor, ease of use, and effectiveness at capturing the heart signal in meaningful ways. The heart sensor is recessed into a 3D printed hand-rest to shield its light-based function from noisy light sources like spotlights or flashing projection screens, and to protect the device itself.

The skin conductance sensor (Figure 3) consists of two aluminum electrodes buffered through an op amp**.** All processing on this signal is performed in software. Skin conductance probes are aluminum greenhouse screws, slightly raised off the surface of the 3D print, providing extra reassurance to users that their fingers are in the right spot. This sensor has been tested in a scientific study regarding the conductive properties of experimental polymer materials [20].

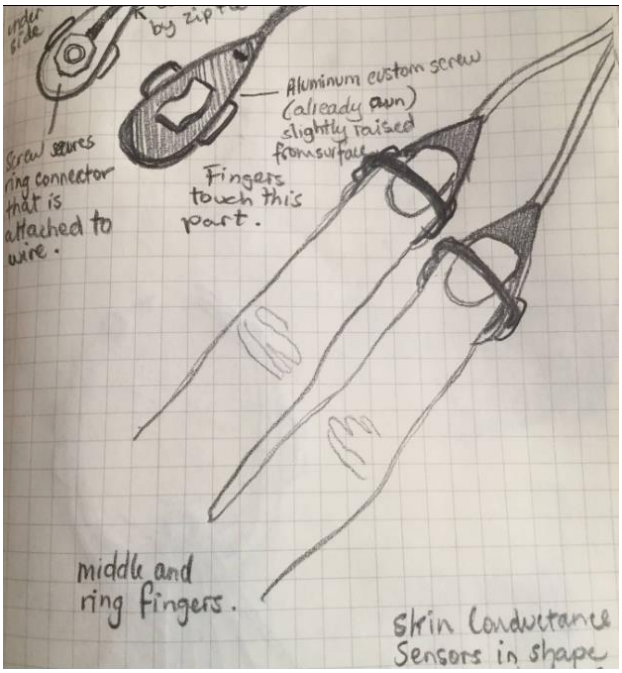

Figure 3. Sketches for design of 3D-printed skin conductance enclosures

A 3D printed hand-rest brings the heart and skin conductance sensors together and mitigates the kinds of cable twisting that destroys a DIY device over time. The hand rest is intuitive: one simply rests their hand on the device. There is no cheap feeling Velcro band, nor a fabric glove of dubious cleanliness to tolerate. The entire device can be sterilized with wipes, ideal for a contagion-conscious context.

The respiration sensor (worn on a performer's face in Figure 5) has gone through several designs, including masks and belts worn around the chest. I settled on a thermistor nestled into a modified oxygen tube for several reasons. Oxygen tubing is lightweight and comfortable on the skin, and I rarely encounter someone who doesn't intuitively know how to put the tube onto their own face. Masks and bands can rarely accommodate every possible body that might encounter the device, and making an interface that you trust the user to adjust themselves is a dicey proposition at best. A thermistor is cheap, and although its signal obtained is still a compromise compared to other methods, it works surprisingly well. Finally, the tube can be safely and thoroughly sterilized by non-expert users with sterile pads.

2.3 Visual Sensor Feedback, Text-screen Interface

Graphic cut outs on the device are backlit by colored LEDs used to confirm signal fidelity: the brightness of each led is directly mapped to each sensors' normalized signals (Figure 4). For example, if the red heart icon does not flash the recognizable

rhythms of a heartbeat, it might signal a problem with the sensor hardware, a problem with finger placement, or calibration.

Small trimpots are located below the icons and can be accessed with a screwdriver to calibrate the sensors to individual users, using the illumination of the LED icons as a visual reference. This option is immediate and efficient in a performance situation where multiple users might need to be calibrated on the fly.

The LCD text screen can display an alphanumeric identifier upon start up, or direct the user to scroll to a specific mapping strategy during a performance via the rotary selector. This bottom-up approach to show control entrusts humans to learn a few cues rather than relying on automation, which also makes for more flexible rehearsals.

Figure 4. Several BioSynth devices connected in a modular fashion to share their power supply.

2.4 Wired, serial communication and audio outputs

While the advantages of wireless communication are many, there are compelling reasons to stay plugged in.

When working with many devices, it is desirable to eliminate elements that can malfunction during setup. To facilitate an independent, "computer-free" experience, I chose the Teensy microcontroller for its capability to sonify the data directly through its onboard digital-analog converter [21], making the devices truly "plug and play."

In music presentation contexts, one might have as little as a one hour "soundcheck" to verify sound, lighting, and electronics: if something malfunctions, the show must go on. Furthermore, when working with professional choirs or musicians who are paid by the hour and have limited availability, one cannot afford to delay a rehearsal to hunch over a laptop configuring the system for the venue's router. Finally, if you want to give one of these devices to a collaborator to work with at home, wireless setup can pose an additional barrier if the wireless setup and configuration ever fails, not to mention that one will still need to go an extra length to configure a router.

2.5 Modular/Scalable

The hardware and software of the BioSynth are scalable and modular, facilitating easier setup and programming for multiple users. Using conventional 3A / 5V USB power adapters, four BioSynth units can be daisy-chained from either side of the device and share a single power source, enhancing flexibility during setup (Figure 4).

3. SOFTWARE

3.1 Methods inspired by feminist thought

While some may approach biofeedback music as a means to "instrumentalize" the (unconscious) body into specific emotional states in the service of electronic music, I argue that the metaphor of musical instrumentation is only one of many structural possibilities for emotional biofeedback, and perhaps one that is frustratingly self-contradictory when one considers the challenge of both "being" a body and also "controlling" the body.

Regarding emotional physiology, this approach might also be incorrect or impossible from the outset. Based on a broad literature review, scientist Sylvia Kreibig observed that although there is clearly a relationship between autonomic nervous system activity and emotional experience, that no strict rules about emotional valence had been determined based on a broad public in a wide variety of environmental settings [22]. Even if relationships between physiological expression and emotional experience have become increasingly clear in recent years, models remain contested. Those wishing to instrumentalize emotion through the development of musical instrument benefit from isolating convenient scientific metaphors and models that are clear-cut, such as Russell's circumplex model of affect from 1980 [23]. There are several shortcomings to this approach: namely that older models such as Russell's do not account for difference (such as gender). Furthermore, clear-cut models of emotion are the ones most likely to be exclusionary, relying on narrow definitions that limit cultural references, and as psychologists Nielsen et al. argued in 2017, are built upon small samples of experience confined to homogenous groups of Western, educated, industrially-rich and democratic populations [24].

The use of clear-cut models suits the needs of musical instrumentation, which demand predictable outputs from given inputs, and the ability to master the instrument. This artistic vulgarization of affective physiology risks "settling" the topic of emotion in misleading ways: first by appropriating science's voice of authority, secondly by using the emotive power of music itself to confirm the success of the instrument through emotionally leading/manipulative mapping. Feminist musicologist Susan McClary notes that music is political because it gives emotion to us as though it were already our own [25]. Whose emotion is it, that can be mapped easily between four poles on a circular grid in Max/MSP, and is being proclaimed as universal?

Scientist Elizabeth Feldman-Barrett (whose doctoral research was supervised by aforementioned scientist J. A. Russell) notes that emotion is highly contextual and subjective, and indeed that what one might consider to be the phenomenological *feeling* of a specific emotion might not only change from situation to situation, but that it might also change over time during the course of one's life [26]. Following Barrett, if emotional categories are based contingently on broad linguistic concepts and mental projections that co-construct one's phenomenological experience (psychophysiological sensation), it is difficult to treat emotion within the body as something akin to a musical instrument, even with expert use.

What this means is that even if one found a performer who was able to cry on cue, this wouldn't guarantee that the physiological data obtained from this emotional outburst would correspond to a universal set of rules that could be instrumentalized.

Given this situation, artists, musicians, and composers need not despair: we don't need to give up affective biofeedback, but rather, develop interesting ways to create music *beyond* the metaphor of musical instrumentation. For example, we could

explore what sociologist Benjamin Haber described as a queer algorithmic sorting, an algorithm that would continually adapt and change its methods, learning and re-learning arbitrarily with the goal of always drawing new conclusions about the subject, resulting in a forever unstable categorization [27]. This approach contradicts the use of algorithms trained on large-scale "emotional databases" that amalgamate large groups of users to create a fictional algorithmic subject that every user is measured against. This normative process in the service of musical instrumentation repeats what was one of the original complaints of feminist philosopher Simone de Beauvoir against the field of phenomenology as based upon an imagined universal category [28]. For this reason, I do very little interpretation of the emotional data beyond measuring the intensities of physiological signals against the subject themselves.

Reflecting the need to "read" emotional experience only through the individual and their body, I have found computationally frugal combinations of adaptive high and low-pass filters enacted through exponential moving average algorithms to be useful. Although these processes are very simple, they satisfy my intellectual curiosity to voice emotion through feminist principles of only measuring bodies against themselves, and not measuring them against universal standards or norms for emotional experience or performance. Rather than providing absolute values, such as the heart rate's BPM, my BioData library uses low-pass filtering and min-max scaling to provide standardized values between 0.0 and 1.0. While simple, this approach can represent a subject's physiological markers of emotions in a way that is expressive and subjective rather than normative and objective.

Thus far, my mapping strategies have also been very simple. I make the audio signals as transparent as possible, sometimes using layering or masking for aural clarity. While explicit one-to-one mappings are not particularly sophisticated, complexity emerges through a group's psychological and social relationship to their body in conversation with other bodies. My avoidance of more virtuosic mapping (ideal for a solo performer) recalls technological historian Arnold Pacey's critiques of "virtuosity values", where engineers develop cutting-edge improvements for technology out of their own joy and thrill of engineering, perhaps overlooking approaches that would demand more mundane but practical solutions in response to material needs of the everyday world [29].

4. WETWARE

4.1 Performance and Composition Methods

A feminist approach to biofeedback technology uses performance and composition to interrogate metaphors of musical instrumentation that serve to treat emotion as a resource that is extracted as data from a user's body. This feminist critique can provide meaningful social and political expansions of musical experience. For example, feminist musicologist Suzanne Cusick has critiqued the division of mind and body in Western musical tradition, whereupon composers are traditionally considered as the "minds" in dominant power relationships to the "bodies" of the performers, who are subservient to the composer's creative vision [30]. In a different paper, Cusick explains that these power relationships exist at the intersection of pleasure, intimacy and power in music, and that music's emotional power seduces the listener into hetero-normative power binaries such as mind over matter, reason over emotion, conscious over unconscious mind in their unconscious experience of music itself. By reinterpreting these metaphors of instrumentation of the body in order to instrumentalize emotion itself through reason and technology, I consider the articulation of performance technique and emotional wetware as crucial to a feminist model for biofeedback music, one that moves towards what Cusick might call a lesbian experience of music based on queer mind-body relationships [31].

Following these principles of thought, I have moved away from treating the physiological signals of the emotional body as sets of data that can be "instrumentalized" in a strict sense. What if instead of demonstrating emotion as a universal and transparent concept bound to a singular conscious and sovereign subject, I could make music that demonstrates affect through its elements that are socially constructed as "non-dominating", "non-power" and to construct musical experiences that allow people experience music and emotion as 'a flow of power in both directions'[31]? Instead of instrumentalizing emotion as a subjective experience that is bound to an individual's body, how does one use music to illustrate emotion as an amorphous substance experienced between multiple unruly and sometimes contradictory users?

Returning to the ideas of McClary, the link between music and emotion can be seen as something that is falsely naturalized, that music has the power to artificially heighten or invokes emotion "as though it were already our own" [25]. McClary's observations echo those of scientist Elizabeth Feldman-Barrett: that emotion is not a naïve, natural, nor universal unconscious reaction to emotional stimuli that can be easily mapped or instrumentalized from subject to subject: furthermore, emotions might indeed not even be "our own." The idea that one might be deceptive in their emotions themselves was explored very early on in emotion detection technology, as it was found that physiological markers of deception are very poor—as the "lie detector" polygraph test, which uses many physiological markers, has poor reproducibility [32]. Eschewing emotional performance via instrumentation, one could work from emotional performance via feminist notions of emotional manipulation (see Jennifer Doyle's defense of the artist as prostitute or femme fatale) [33], emotional reproduction linked to pink-collar labor [34], clinical methods for psychosomatic emotional induction [35], or even following the work of humanities researcher Daniel Pettmann who considers emotion itself as a technology [36]. An important aspect of my practice is to apply these concepts to wetware, or the body itself, introducing performance techniques as a more explicit part of the interface, to compose the physiological markers of emotion in an intentionally non-naturalistic way. The consideration of this wetware introduces novel structural possibilities for composition and performance, including but not limited to strategies of *Instrumentalization*, *Empathetic resonance*, and *Psychosomatic Body Hacking.*

4.1.1 Instrumentalization

As explored in my earliest works for affective biosensors, one might instrumentalize the body like any instrumentalist would: manipulating emotional sentiment in timed intervals to achieve variance in emotional data. In 2013 I worked with method actors to explore these possibilities while developing the robotic installation *Swarming Emotional Pianos* [37]. I learned that even in a group of expert performers, the physiological activation of specific emotion without external cues is difficult or sometimes impossible, and indeed this emotional activation is a specialized technical skill. Furthermore, the emotional data obtained by each performer was not only inconsistent from subject to subject, but sometimes even inconsistent with the subject themselves from session to session, reflective of how perceived and felt emotion might differ based on environmental factors such as heat, humidity, or time of day.

Artists can critically engage with instrumental approaches by creating work that highlights their unreliable nature: for example, through my emotional-control interface in VR work *Project H.E.A.R.T. (Holographic Empathy Attack Robotics*

Team) with Alex M. Lee in 2018 [38], users are challenged to create spikes of non-specific emotional arousal as a means of moving forward in a satirical war simulator. The absurdity of the narrative highlights the unreliability of emotional measurement, emotional control, violence and labor in a VR "militainment" context. The work is also a comment on the contradictory shift of VR technologies from their use to train soldiers for war, towards claims that VR might "amplify" the voices afflicted by war during the late 2010s [39].

4.1.2 Empathetic resonance

In my choral work *Song of Seven* (2016) I used the BioSynth to sonify the emotional data of singers as they improvise sung memories of their childhood where they felt strong emotions. This strategy makes use of narrative to inspire empathy in other performers wearing BioSynths through psychological projection, and also the ability of music to increase feelings of social bonding and empathy [40]. The use of empathetic resonance to structure affective physiology in biofeedback music need not be limited to in-person interaction, as it might involve empathetic resonance with narratives of those not present, either due to distance or time, or the use of a fictional account to invoke emotion, such as those in films or a spoken narrative, which might extend empathy to non-human subjects. Key to my approach is to reject attempts at emotional purity and to embrace inevitable affective contamination "beyond the score" due to performance jitters, annoyance at a coughing audience member, or how collective emotion speaks among bodies in social ways when physiological mapping is transparent.

Figure 5. Performance of *Affect Flow* (2022), ISEA 2022

4.1.3 Psychosomatic Body-Hacking

Recently I have developed work for biosensors around method acting techniques, guided meditation and hypnosis-inspired scripts to structure and invoke affective response, profiting from vocal delivery and sonic treatment techniques that manufacture intimacy and haptics. Many of these methods are derived from the social media-driven practice of Autonomous Sensory Meridian Response (ASMR), which has been linked reliably to physiological markers of emotion through scientific study [41]. I have taken advantage of performance methods known as "triggers" to structure physiological behavior in biofeedback music work both in the networked biofeedback performance *Presence* (2020, with Jen Kutler) and more recently in my large-scale solo work for vocalist, fixed electroacoustic part and biofeedback performers *Affect Flow* (2022) (Figure 5). A complete description of these techniques would be beyond the scope of this paper, but the importance of this approach is in how it consciously articulates *emotion* as a *technique* rather than as a natural resource to be extracted and instrumentalized by technology. Think of the emotional techniques developed through the lived experience of pink-collar workers, feminized family members who have refined methods for what Alva Gotby calls emotional reproduction—manufacturing positive feeling [34]. Humanities researcher Sarah Ahmad says emotions are political because of how they stabilize and support normative flows of political power in frictionless ways [42]. By denaturalizing emotion and pointing to affect as a technological practice (merely confirmed by the measurement processes of biofeedback devices), we might free ourselves from tired binaries of masculine logic/thought and feminine intuition/emotion. An affective biofeedback informed by feminist and queer thought leans into how lines between logic, emotion, nature, culture, masculinity and femininity can be productively and pleasurably blurred.

5. CONCLUSION

The BioSynth is a research tool for enacting new relationships between composer-performer-music that embraces play, performance, and co-constructed phenomenological experience in an affordable and frugal manner. Biofeedback music is still a relatively undeveloped field which has yet to fully benefit from the embodied knowledge systems of feminist and queer thought. Opening the accessibility of emotional monitoring technology also necessitates the opening of conceptual assumptions within the field. By focusing on unconscious sensory processing, human-centric, psychosomatic, and social aspects of biofeedback music, concepts such as emotion can be denaturalized and interrogated in novel ways through research-creation and performance.

6. ETHICAL STANDARDS

The BioSynth was developed during several research residencies, in particular the Algorithms that Matter Residency at IEM Graz (2018) and the Locus Sonus residency at ESSAIX/Université de Marseilles (2019). At various stages of the research of this instrument, my work has been supported by the Social Sciences and Humanities Research Council of Canada, Canada Council for the Arts and the Conseil des Arts de Montreal. This research has ethics approval *2022-2178: CERAH-2022-032-D*

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