BIOKYBÉRNĒSIS: CASE STUDIES ON BIOMUSIC AND BIOAESTHETICS IN CONTEMPORARY SOUND PERFORMANCE

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ABSTRACT

This paper examines biomusic as a framework for Sound and Music Computing, focusing on the integration of physiological signals such as EEG, heart rate, ECG, EMG, breath, and GSR into interactive musical systems. It argues that biosignals should not be understood as direct representations of internal states or as simple control streams, but as mediated inputs shaped by signal conditioning, feature extraction, adaptive mapping, and rule-based or inferential processes. Drawing on cybernetics, neuroaesthetics, predictive processing, and embodied cognition, the paper conceptualises biomusic systems as real-time feedback ecologies in which performer, physiology, and computation co-produce musical behaviour. Through contemporary artistic case studies, it analyses how adaptive system design, instability, and physiological variability shape musical time, texture, and form. The paper contributes to SMC discourse by linking embodied interaction, biosignal processing, and aesthetic design, and by proposing biomusic as a model for understanding how musical form can emerge through continuous negotiation between human and computational agency.

1. INTRODUCTION

Contemporary biomusic integrates physiological sensing into musical systems in ways that increasingly align artistic inquiry with central concerns in Sound and Music Computing [1]. Works incorporating EEG, heart rate (HR), and galvanic skin response (GSR) extend established interactive music practices by introducing data streams that are simultaneously embodied and computational. These signals originate in measured physiology, but become musically operative through signal conditioning, feature extraction and algorithmic mediation [1,2]. Biomusic therefore tends to function as a coupled system: physiological state shapes system behaviour, and system output, in turn, acts back upon the performer over time.

This coupling is most explicit in real-time performance contexts [3]. Biosignal-driven instruments can be designed to track physiological variation continuously, enabling adaptive behaviours that redistribute agency between performer and machine. Such systems pose recurring design considerations, such as the stability and interpretability of data measurements within live conditions. They also prompt aesthetic questions about the form of interaction or abstraction being staged and how physiological processes cohere as musical material.

This paper proposes a framework to support interdisciplinary discussion of biomusic and neuroaesthetic concerns within an SMC context [4]. Rather than prescribing a single methodology, it offers a set of perspectives for describing biosignal integration, feedback-oriented interaction and embodiment as a design parameter.

The framework is grounded through short autoethnographic case studies by contemporary sound artists. Each study presents a situated account of a single work that employs biosignals or related biodata in performance or composition. The paper concludes by outlining implications for future research on the refinement of sensory-adaptive musical systems, biosignal-based interaction design and audience-performer studies.

2. ADAPTIVE MUSICAL SYSTEMS: INTERACTION, AUTONOMY AND REAL-TIME DECISION-MAKING

Adaptive and responsive musical systems occupy a central position in contemporary electroacoustic and interactive music practices. Such systems are defined by their ability to respond dynamically to incoming input—sonic, gestural, or physiological—and to operate with varying degrees of autonomy. Importantly, autonomy in musical systems does not imply independence from human agency, but rather the capacity to make context-sensitive decisions in real time within constraints defined by the composer or designer [5].

Real-time decision-making has been present in computer music since early algorithmic and rule-based systems. However, adaptive systems extend this paradigm by allowing behaviours to evolve during performance. Through probabilistic models, machine learning techniques, or adaptive mappings, these systems do not merely react, but adjust their internal parameters based on accumulated data or interaction history. As Jourdan and

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Caramiaux [6] note, such systems function less as predictive mechanisms and more as expressive mediators, shaping timing, timbre, and musical articulation through interaction rather than prescription. In this sense, adaptive musical systems foreground process over outcome. Musical form emerges through interaction, negotiation, and feedback, rather than being entirely pre-determined.

System behaviour during performance is not fixed but enacted. It arises from the interaction between compositional intent, performer input, and the technological characteristics of the system itself. While the composer defines structural parameters—such as mapping strategies, learning models, or decision thresholds—the actual behaviour of the system unfolds in real time, shaped by contingencies of performance.

This behaviour often includes elements of unpredictability, which are not errors but integral aesthetic components. As embodied interaction studies suggest, performers engage with systems not only through control but through resistance, adaptation, and exploration [7]. The system listens, interprets, and responds according to algorithmic models that inevitably embed specific assumptions about movement, sound, or data. Consequently, behaviour reflects both human intentionality and machine-specific modes of perception.

In adaptive systems incorporating physiological or biometric data, behaviour becomes even more relational. Biological signals do not function as deterministic controls but as fluctuating indicators of embodied state, translated into sound through inference and interpretation. Here, the system's behaviour contributes to a feedback loop in which performer, body, and sound co-evolve over time, reinforcing the notion of distributed musical agency.

2.1. Neuroaesthetics, Predictive Mechanisms and Music Perception

Neuroaesthetics has profoundly reshaped how musical experience is conceptualised, moving beyond strictly formalist and semiotic accounts toward dynamic frameworks integrating perception, affect, prediction, and action. Within this perspective, music is no longer treated as a static acoustic object but as a temporally unfolding process that engages distributed neural systems associated with sensory processing, attention, memory, valuation, and reward [4]. Musical meaning emerges through the continuous interaction between incoming auditory information and the brain's predictive mechanisms.

Predictive processing models propose that the brain actively generates expectations about rhythmic, temporal, and spectral developments, continuously comparing predictions with sensory input. Deviations from expectation — prediction errors — are central to aesthetic engagement rather than peripheral disturbances [8]. The balance between predictability and uncertainty contributes to tension, surprise, and perceptual salience, shaping both cognitive and affective responses.

However, the application of predictive frameworks to contemporary musical practices remains theoretically underdeveloped. Much empirical research relies on musical materials characterised by relatively stable tonal or rhythmic regularities. In contrast, electroacoustic music, noise-based works, and texture-oriented compositions often foreground instability, spectral transformation, and reduced conventional syntax. In such contexts, predictive mechanisms may reorganise around alternative features, including energetic continuity, timbral evolution, or ecological patterns of change. Prediction, therefore, does not vanish; it shifts its coordinates.

2.2. Sonic Affect and Physiological Coupling

The relationship between sound and affect constitutes a central concern of neuroaesthetic research. Emotional engagement is understood not as a secondary by-product of musical perception but as intrinsic to it [4]. Music recruits neural systems implicated in emotional regulation, arousal, and valuation, including limbic and paralimbic networks. These neural processes are closely coupled with physiological dynamics, indicating that musical experience unfolds across brain–body systems.

Acoustic features such as intensity, rhythmic density, and timbral variation modulate arousal and affective interpretation. Rather than merely symbolising emotion, sonic structures influence autonomic responses and contribute to the emergence of felt states. Musical experience may thus be understood as a regulatory interplay between auditory perception, predictive evaluation, and physiological resonance. Sound, in this sense, does not simply communicate emotion; it participates in shaping the conditions under which emotion is experienced. There is also a more experiential dimension to this interaction. Sound moves through bodies as vibration, pressure, temporal flow—organising attention, modulating tension, anchoring perception and occasionally dissolving it. Affect arises within this relational field rather than residing exclusively in stimulus or listener. Biomusic systems introduce a significant conceptual shift in the role of physiological signals. Neural and autonomic activity are no longer treated exclusively as measurement outputs but as potential generative variables within musical processes. The concept of "music in the loop" [9] captures this reciprocity, describing closed-loop systems in which neural activity influences sonic parameters while sound simultaneously modulates neural dynamics. As Frigg [10] argues, models do not passively mirror reality but organise relations between observation and interpretation. Biomusic systems thus construct new perceptual and aesthetic conditions in which physiological variability becomes structurally meaningful.

2.3. Embodied Listening and Neurofeedback

Embodiment plays a central role in contemporary theories of music perception. Research demonstrates that musical listening recruits motor-related neural networks even in the absence of overt movement [11], supporting accounts of perception grounded in sensorimotor simulation. Listening may therefore be conceptualised as an active

process involving covert anticipation, bodily alignment, and action-oriented prediction. Studies of improvisation further indicate that creative musical states involve dynamic reorganisation of neural systems associated with executive control and self-monitoring [12]. Creativity emerges through fluctuating balances between constraint and spontaneity, prediction and novelty. Auditory feedback plays a stabilising role within this sensorimotor loop, enabling continuous calibration between predicted and perceived sound [13]. Listening then is not disembodied cognition but an embodied negotiation with sound. Even in stillness, the body participates through micro-adjustments of attention, tension and expectation, and sound is perceived as movement across perceptual and somatic space.

2.4. Relationship to Affective and Embodied Cognition.

These developments extend beyond empirical findings into epistemological and ontological domains. Biomusic and neuroadaptive systems both reveal and participate in constructing experiential frameworks. Computational mediation shapes perceptual realities rather than merely representing them [10]. Haworth's [15] notion of ontological politics further highlights how technological and artistic systems co-produce modes of listening, embodiment, and experience. Art–science platforms, competitions, and residencies recognise artistic environments as fertile sites for exploring perceptual, affective, and embodied phenomena. While laboratory settings privilege experimental control and reproducibility, artistic contexts enable the study of temporally extended, ecologically complex and experientially rich interactions. When supported by appropriate sensing technologies and methodological rigour, artistic environments may reveal dimensions of cognition and affect that are difficult to isolate within tightly constrained experimental paradigms. Art, in this sense, operates as a complementary mode of experimental investigation—one that privileges lived complexity, situated perception and embodied engagement. Within this expanded framework, biomusic and embodied interaction systems emerge as hybrid research spaces linking neuroaesthetics, affective cognition and interactive musical practice. Music becomes a site where the brain, body and system continuously negotiate the conditions of experience.

3. Cybernetics: Feedback, Communication and Control

Cybernetics—derived from the Greek κυβερνήτης (*kybernētēs*), meaning a steersman or governor—concerns the control and communication in coupled biological and machine systems, treating feedback as the return of information about behaviour to guide subsequent action; analogous to the steering of a ship [16]. Feedback is readily illustrated by the microphone-loudspeaker loop, in which amplified output re-enters the microphone input and loop behaviour depends on recirculation. In physiological computing, real-time psychophysiology is used to communicate user state to an adaptive system, and this logic applies to musical computing when such measures are used as control data for sound synthesis and processing. These loops may employ negative control dynamics that reduce discrepancy or positive control dynamics that amplify it, tending toward stability or escalation[17].

3.1. Biomusic, Biocybernetic Loops and Performer Embeddedness

Biomusic can be defined as a physiology-mediated musical feedback system in which psychophysiological measures are inferred as aspects of the user's state and mapped to parameters of sound synthesis or processing. Sensing provides the measurement stream and mapping defines actuation rules for adaptive adjustment. Biomusic is distinguished from one-way sonification by reciprocal influence: system outputs are designed to alter the physiological conditions that will be sensed next, so sound operates as an intervention within a 'biocybernetic loop' linking user and apparatus [17].

This framing has precedent in early biofeedback art and music, where EEG and related bioelectrical signals were returned to the performer as control information, for example in David Rosenboom's *On Being Invisible* [18], which can be understood as a biocybernetic loop insofar as EEG channels generated control triggers for sound events [18]. It also aligns with EEG neurofeedback, which is described as operant learning insofar as feedback supports learned self-regulation, and is evidenced in music and sound art performance contexts. The performer is embedded in the system when playing and listening are internal to loop operation and are continuously adjusted in response to sonic return. Sound is produced through interaction with an instrument and is re-encountered through room acoustics and signal processing, conditioning subsequent technique and decisions [19]. Agency is therefore distributed across performer and apparatus because behaviour depends on mutual adjustment, complicating controller-instrument models [20]. This can be framed as a performance ecosystem in which performer-instrument coupling is situated within an environment and may include virtual processes. To recall a previously mentioned loop analogy, some feedback practices make the return path explicit through a microphone-loudspeaker chain, increasing sensitivity to room acoustics and loudspeaker gain and making the environment a variable within the operational circuit [21].

3.2. Sound as Mediation and System-Based Musical Practice

In a physiology-mediated musical system, sound functions as a mediating signal because it carries the system's intervention to the user and modifies the physiological conditions that will be measured on the next iteration. In Fairclough's [17] description of the biocybernetic loop, adaptation is implemented through

interventions intended to influence user state in relation to explicit goals, so system output is part of the control pathway and should be designed as such. Depending on how feedback contingencies are specified, sonic mediation can support discrepancy reduction or intensification. Contemporary research demonstrates that music can operate as a constituent of biofeedback: when musical parameters were algorithmically modulated by heart rate data, participants learned to increase and decrease arousal more successfully than during music listening, with performance comparable to sonification biofeedback, controlling for respiration rate [22]. Likewise, contingent auditory feedback—whereby sound is presented as a reinforcing stimulus in response to specific physiological or behavioural events—is reported as an observation within the neurofeedback process for musicians, including applause sounds delivered when target criteria were achieved [19].

System-based musical practice treats the work as behaviour generated by an interactive system specified through mappings and constraints, including adaptive rules. Composition and instrument design converge with performance because musical structure is enacted through system responsiveness and the performer guides it [23]. This can be described as "feedback musicianship", where feedback becomes "the instrument listening to itself" and resistance is treated as a musical parameter [24]. This contemporary shift continues from earlier cybernetic arts discourse, wherein a core historical precedent exists in the form of the *Cybernetic Serendipity* exhibition in London (2 August–20 October 1968). Here, the curated works exemplified how control and feedback could be treated as compositional methods that specify conditions under which unfolding system behaviour becomes a discrete aesthetic form. The exhibition and its catalogue framed computer-based art and music as experimentation with cybernetic devices and emphasised links between artists' use of random systems and the operation and design of those devices [25].

4. Case Studies on Contemporary Artistic Practices

In contemporary practice, biometric signals (HR, ECG, EEG, EMG, breath, GSR) are increasingly treated not as auxiliary controls but as aesthetic forces shaping musical time, texture, and form. This shift foregrounds instability, mediation, and error as meaningful compositional conditions. The term "error" operates in two registers here: the prediction error of perceptual processing, in which mismatch drives aesthetic engagement, and the postdigital sense of failure reclaimed as compositional material [33]. The latter is treated as the condition through which the former is made audible. Glitch, in this context, emerges from the interaction between biological signals and technological systems. Irregularities such as noise, drift, latency, and threshold ambiguity do not disrupt performance but reveal it as a continuous negotiation between body, sensor, and algorithm. Parameters like smoothing and scaling thus operate as aesthetic decisions. Biofeedback practices can therefore be understood as postdigital objects, where biological, digital, and cultural processes are entangled [26], aligning with Stengers' notion of situated knowledge [27]. Sound's temporal and embodied nature enables dynamic coupling between physiology and computation, reframing immersion as attunement. This is anticipated in Machover's hyperinstrument [28] and Donnarumma's biophysical performance systems, where agency is distributed across body, interface, and algorithm [29].

4.1 Emerging Practice-Based Systems

Recent artistic and research-driven systems increasingly emphasise adaptive mappings, rule-based inference, and performer–system co-agency. Instead of simplistic one-to-one correspondences (e.g., "alpha ↑ = reverb ↑"), contemporary approaches develop multilayer architectures in which interpretation, abstraction, and emergence are central to form [10, 30]. Reviews of brain–computer musical practice document this shift toward hybrid models combining signal processing, statistical or rule-based inference, and interaction design—treating physiological streams as dynamic contributors within evolving performative ecologies [31]. In HR- and ECG-based works, musical time often shifts from a stable grid toward an elastic field. Cardiac micro-irregularity introduces a kind of living rubato: accelerations and decelerations operate as dramaturgical pressures, while small fluctuations resist full quantisation. Courtney Askey's *Heart Throb* makes this explicit through a chain of translations (see Fig. 1)—ECG printouts, manual darkening and tracing, alignment with staff paper via makeshift lightbox procedures, conversion of peaks and troughs into notation, and finally the realisation and re-filtering of the resulting score in different performance contexts. The work's subsequent iterations extend the initial transcription procedure into distinct modes of realisation. The first score was rendered digitally and realised through pipe-organ sonority, fixing the manually derived ECG notation in a conventional score format.

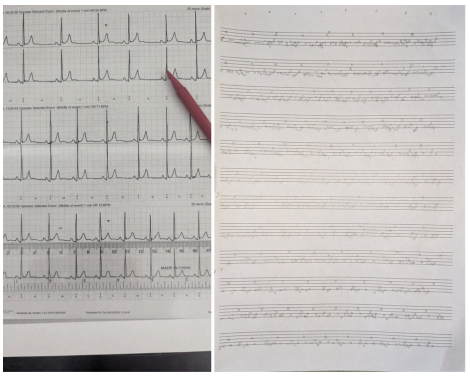


Figure 1. The captured ECG readings and the score manually traced from them for *Heart Throb.*

Later versions shifted the emphasis toward re-performance and re-inscription: heartbeat sound was recorded by contact microphone and combined with live vocal humming, while *Heart Strings* re-drew the ECG by

eye, randomly reordered score segments and translated them for cello. These later forms retain the source logic while foregrounding the practical contingencies of execution, especially where unstable spacing, absent time signatures and instrument-specific limits require performer negotiation. Here, form is manufactured through translation, where scale inconsistencies, tracing imperfections, and bodily fatigue become part of the aesthetic object. Importantly, "error" is not treated as a defect but as an index of mediation and labour—precisely the condition through which the work becomes meaningful. Data aesthetics becomes semantic, as the score does not merely derive from data; it speaks to the limits and affordances constitutive of the data's form. EMG-based practices complicate this paradigm further because they foreground the boundary between disciplined gesture and continuous flow.

4.2 JENNIFER - Lou Barnell



Figure 2. Performance using JENNIFER. Credit: Accidental Theatre , Belfast 2024.

Lou Barnell's wearable vocal processing unit and sculpture JENNIFER (see Fig. 2) translates muscle flex data into granular synthesis and looping behaviours worn on the chest. The system's aesthetic cannot be separated from an ethics of embodied musicking and access: Barnell's neurodivergent perspective motivates the choice of voice and muscle flex as inputs, where voice provides an immediate point of musical entry and muscle gestures offer a pathway through effects that can reduce barriers associated with motor coordination. The most revealing dimension, however, is using EMG to stage a design decision between thresholded events and continuous signal behaviour. Barnell's prototyping with Myoware (binary flex detection) and VoxEMG (continuous EMG) demonstrates how continuous signals resist clean thresholding and thereby push the work toward a different aesthetic logic: one in which constant data "upends" human-led augmentation and favours a data-led collaboration with unexpected representational behaviour (Reed et al., 2024). However, the final design favoured the Myoware prototype. A decision based on 'human-led' design and thresholding allowed for access and motor processing requirements (e.g. '5 muscle flexes turns on record function'). Code was written in Max/MSP, allowing for thresholds and flex numbers to be adjusted as well as aesthetic decisions, such as grain size, loop length and density. A 'panic button' which generated responses if no data was detected for three minutes was included. This responded to the real -time performance environment when electrodes occasionally became detached due to heat and a heavy costume / collar encasement. This led to considerations on how human-led design is still dependent upon complex entanglements between humans and non-humans. Similarly to data-led design, this is precisely where glitch becomes conceptually productive: the system's refusal to behave neatly becomes an aesthetic generator rather than a technical failure.

4.3 Dromos/Autos - Matt Rogerson

In EEG-driven works, the compositional problem frequently shifts from rhythm to state, texture, and behaviour. Because EEG does not map cleanly onto discrete musical units, contemporary practice often avoids naïve one-to-one mappings and instead builds behavioural ecologies: features are extracted, stabilised, scaled, and interpreted into regimes that activate transformations of density, recursion, spectral morphology, and temporal diffusion. Matt Rogerson's *Dromos/Autos* (see Fig. 3) exemplifies this approach by situating EEG inside a cybernetic performance assemblage designed to provoke neurocognitive shutdown–or "sensory overload"–as a means of advocating that a system can render one's ontology incongruous with it. EEG data is streamed, parsed, smoothed, and adaptively scaled; the resulting control structures modulate feedback synthesis and spectral processes, while audiovisual elements remain mutually reactive. The work's aesthetic is not EEG as a direct representation of cognition, but EEG as an imperfect mediator inside a recursive and volatile ecology that stages cognition under pressure. In postdigital terms, anomaly and noise become a critical lens: instability is not concealed but used to "open" the black box of computation, revealing constraints that would otherwise disappear under seamless operation [33, 34] .



Figure 3. Performance of *Dromos/Autos* at the Phoenix Cinema and Art Centre, Leicester, 2023. Image credit: James Andean.

At the centre of the system is a neurofeedback loop facilitated by an OpenBCI Brain-Computer Interface. An eight-channel Ultracortex IV EEG headset, paired with the Cyton biosensing board (later substituted for a modular eight-channel EEG headband), measures scalp voltage differentials and streams data to the open-source OpenBCI GUI running on a dedicated "BCI" laptop. Band-limited activity is derived from each channel and summed into five frequency bands (delta-theta-alpha-beta-gamma), then routed to a second

"performance" laptop over OSC. A Max/MSP translation layer (see Fig. 4) parses the five data streams, applies configurable logarithmic smoothing and performs adaptive scaling by buffering recent values to update input bounds, ensuring stable mapping into fixed control ranges. These preprocessed signals modulate synthesis and rendering parameters, forming a closed loop in which physiological responses to the output reshape subsequent system behaviour.

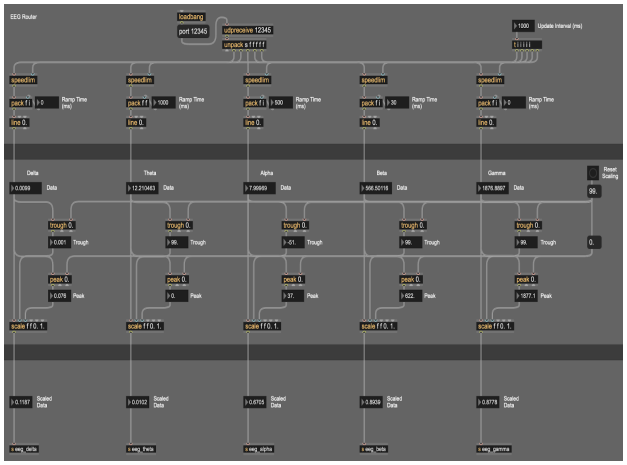


Figure 4. The EEG Router in Max/MSP used for feature extraction (average band power), adaptive smoothing/scaling and routing.

4.3.1 Architecture of Dromos/Autos

Using Max/MSP, sound is generated and transformed in real-time using a hybrid computational-acoustic feedback system and spectral processing. An electroacoustic feedback loop (microphones and loudspeakers in a closed acoustic circuit) is treated with FFT-based processing, including variable-window pitch shifting and a custom spectral convolution operation used to produce non-linear transformations. These techniques are consolidated as Compressed Feedback Synthesis [35] , which implements microphone-loudspeaker feedback to function as a controllable acoustic carrier signal for a computationally recursive FM Feedback module, allowing feedback behaviour to be shaped by EEG-driven frequency and modulation depth parameters. The Fluid Corpus Manipulation Toolkit (FluCoMa) [36] extends this ecology, implementing spectral interpolation of the FM Feedback and Compressed Feedback Synthesis via an Optimal Transport algorithm; in addition to audio slicing based on novel spectral descriptors, spatial organisation of slices based on their self-similarity in spectral power (MFCC's) and the concatenative playback of slices distributed through multichannel layering. A complementary scheduling layer governs the temporal organisation of the system through a global stochastic trigger stream. Onset and outset states activate or suspend this process, while alpha-band EEG shapes the interval range of a random-walk generator, whose continuously updated durations are distributed across the patch to determine corpus coordinate selection and time-based playback processes such as pitch-modulation, slice duration and the attack envelope of the multichannel playback.

Visuals are generated in a Jitter rendering context, and are both bio-reactive and audio-reactive. EEG and audio signals drive the contrast and stroboscopic behaviours, and visual matrices are also converted into envelope control signals for the FM Feedback–producing cascading interdependencies between the sonic, visual and biofeedback modalities. The development process is iterative and practice-led: assemblages are prototyped, configured and reconfigured into human-machine feedback loops, predicated on a recursive process of neurofeedback and systemic feedback output as data-sonification/visualisation. The motivation behind this is to evocatively present the quotidian, socio-structural discourses that bracket my autistic ontology, and to reveal the alienating and disabling effect of these discourses by embedding said ontology as an affective component within them; an act of self-advocacy through the presentation of one's ontological incongruity with the structures they inhabit.

4.1 *Rhoē* - Penelope Bekiari

Within this landscape, *Rhoē* extends the bioaesthetic paradigm by integrating EEG, heart rate (HR), within a piano and live electronics framework. Rather than employing physiological streams as continuous modulators, the system operates through state-based mediation, where patterns of neural and autonomic fluctuation activate transformations in texture, granulation, and temporal diffusion. In this sense, the work does not sonify biometric data as representation but stages physiology as a generative condition of musical form, aligning with postdigital aesthetics in which variability, instability, and emergence are structurally embedded [26, 33].

4.4.1 Architecture of the Hyponoia System

Rhoē is established upon a custom performance framework developed by the artist titled Hyponoia, which strengthens its aforementioned aesthetic position through a rule-based inferential layer that mediates between physiological activity and musical behaviour. In this system, electroencephalographic activity is analysed in real time and organised into oscillatory patterns and transient microstates derived from spectral band activity and cross-frequency relationships. Rather than mapping these signals directly to sound parameters, Hyponoia translates them into symbolic neuro-affective regimes that activate compositional processes such as granular processing, recursive structures, and spatial reverberant diffusion. Technically, the system operates as a distributed performance architecture linking EEG acquisition, signal conditioning, and musical control layers. Neural signals are streamed through a Lab Streaming Layer (LSL) pipeline, which enables synchronised data transmission between sensing devices and processing environments. Incoming EEG data are segmented into short analytical windows—typically two-second intervals—within which spectral bandpower

dynamics and cross-frequency relations are calculated. These windowed measurements allow the system to detect transient oscillatory configurations and stabilised microstate-like patterns, which are subsequently interpreted through a rule-based model (see Fig. 5).

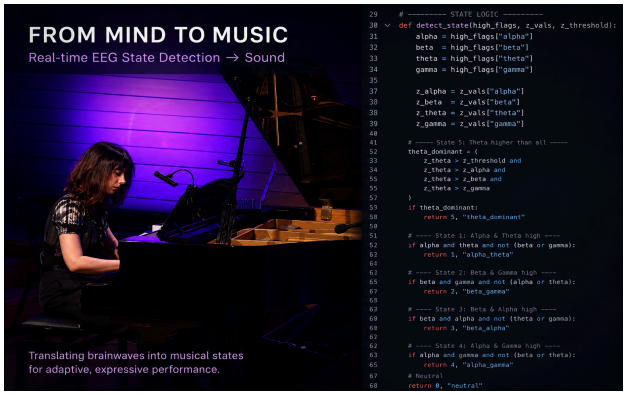


Figure 5. From Mind to Music: Python-Based EEG State Detection and Rule-Based Musical State Inference in Hyponoia.

These interpreted states define behavioural regimes that structure the evolution of sound processes over time. The extracted states are transmitted via OSC to a performance environment implemented in Max/MSP, where they modulate synthesis engines, temporal density, spatialisation, and textural evolution. Because the analysis operates on overlapping windows, the system produces a continuously updating representation of neural activity, enabling smooth transitions between sonic states rather than abrupt parameter switching. Here, sonification forms a layered interpretive process in which data analysis, symbolic inference, and musical design jointly shape the unfolding sonic behaviour.

Within performance, the system forms a closed feedback loop between performer, physiology, and sound environment. As the performer listens and improvises, musical gestures influence cognitive and affective states that in turn alter the neural patterns captured by the system. These fluctuations activate different sonic regimes, producing a continuously evolving ecology of interaction. Musical form, therefore, is not pre-given but enacted through the dynamic negotiation between bodily processes, algorithmic interpretation, and instrumental performance. This strategy aligns with modelling approaches in which computational systems function as epistemic and aesthetic constructs rather than transparent representations of internal mental states [10, 30]. Hyponoia therefore treats physiological data as mediating variables through which embodied performance, computational inference, and sonic form co-evolve in real time.

Hyponoia is a real-time neuro-performative system developed in Python and Max/MSP that translates EEG activity into evolving musical behaviours rather than into simple one-to-one control mappings. EEG data from a Muse 2 headset are streamed through Lab Streaming Layer (LSL) at 256 Hz and analysed in two-second sliding windows, with the AF7 channel selected for its relation to internal attention and mental imagery. Within each window, power spectral density is calculated using Welch's method across the theta, alpha, beta, and gamma bands, and these values are then normalised as z-scores against a rolling 60-second baseline, allowing the system to adapt to the performer's own fluctuating physiological profile rather than relying on fixed thresholds. A Python rule-based inference layer then detects cross-frequency co-activations and classifies them into symbolic neuro-affective states such as *alpha-gamma, beta- alpha, alpha–theta*, *beta–gamma*, or *theta-dominant*. These states are sent via OSC to Max/MSP, where they activate distinct compositional processes. For example, alpha–theta triggers sustained pitch-recognised accompaniment; beta–gamma activates live granulation; beta–alpha produces reverse delay; alpha–gamma recalls and loops the previous phrase and theta-dominant generates downward time-stretched reverberant behaviour. In this way, Hyponoia is built as a model of performative cognition in which neural fluctuation, adaptive normalisation, symbolic inference, and sonic behaviour together shape musical time, texture, and form in performance.

5. Discussion: Performance as Observation and the Preservation of Emergence

When glitch theory is extended to biointeractive performance, physiological noise—such as motion artefacts, electrode instability, ambiguous thresholds, misclassification, or signal saturation—can no longer be treated merely as technical interference but instead becomes compositional material. Artistically, this material is retained because it makes perceptible the unstable negotiation between the performing body and its computational interpretation, rather than presenting biofeedback as a seamless or transparent translation of physiology into sound. In this context, "error" acquires semantic value, marking the friction between embodied processes and computational capture, as well as the contingency inherent in performance. This does not imply a surrender to randomness; rather, unpredictability is deliberately composed to preserve tension between recognisability and collapse, allowing musical form to expose the fragility of the body–system relationship [33, 34]. This perspective aligns with postdigital theory and the New Aesthetic, where glitch, lag, and breakdown expose the limits of seamless digital mediation [37, 38]. Within biointeractive systems, it translates into a bioaesthetic emphasis on making processes such as thresholding, smoothing, inference, and latency audible as part of the aesthetic experience. At the same time, neuroaesthetic and predictive processing frameworks suggest that perception operates through continuous prediction and error correction [39, 40], rendering physiological variability perceptually significant as moments of cognitive reorganisation. Thus, glitch and biometric fluctuation converge as generative mechanisms: their artistic function is not simply to produce sonic variation, but to reveal the changing

relationship between embodied intention, computational interpretation, and perceived musical consequence [41, 42]. Within such systems, performance becomes a site of observation in which meaning and musical form emerge relationally through feedback between neural activity, physiological rhythms, computational inference, and sonic output, positioning biomusic as a feedback-based ecology where deviation, instability, and mediation actively participate in the real-time production of form.

This observational stance carries a design tension the case studies resolve differently: *JENNIFER* trades continuous EMG for thresholded, human-led control to protect access and reliability; *Dromos/Autos* invites instability where *Rhoē* constrains it, and *Heart Throb* moves the mediation offline into manual transcription. The problem is one of calibrating performer agency against aesthetic control, which points beyond observation toward dedicated performer–audience studies.

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