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Auspex:
Ecosystemic Emergence as Generative Soundscape

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This paper presents an overview of *Auspex,* an agent-based artificial life ecosystem generating multichannel soundscapes from corpus-based concatenative synthesis techniques aligned with the acoustic niche hypothesis. Insights into its development are derived from the review of two prototypical systems; *BoidGran*, a boid-driven granular synthesizer, and *Swarmscape*, an audio-visual performance system that emphasizes the acoustic emergence of swarming bodies. Analysis includes conceptual approaches in the contextualization of the system's output.

Keywords: Soundscape composition, acoustic ecology, swarm dynamics, concatenative synthesis, artificial life, acoustic niche hypothesis, FluCoMa

Anyone who has heard the sounds of a natural habitat has spent a moment listening to it as music. Yet contrary to Western notions of musical creation, environmental music emerges with no composer, conductor, or leadership of any kind. The self-organisation of an ecosystem's acoustic behaviour is most clearly described by Bernie Krause's Acoustic Niche Hypothesis, whereby a species evolves to emit sounds in a niche not occupied by other species in the biome (Krause 1993). This spectral autopoiesis shares similarly emergent qualities to position-based behaviours like flocking and swarming. In Ancient Rome, an augur would interpret bird flocking as deterministic omens, referred to as "taking the auspices" or *Auspex.* Today, the proliferation of machine learning technologies has ushered in new possibilities for interpreting complex data. Within the realm of acoustics, sounds can be organised by spectral and timbral descriptors to assemble a latent data space known as the corpus. How then could a corpus space of acoustic information self-organise in accordance with acoustic and behavioural considerations, and could this emergent structuring be considered music? In recent years, Barry Truax, one of the pioneers of soundscape composition, has expanded the definition of soundscape by interchangeably entitling it *context-based composition,* whereby the context of a created sonic environment is served by the intention of its composition (Truax 2018). In our endeavour to creatively integrate these phenomena within an electroacoustic composition, we have developed a generative soundscape system, *Auspex*. What follows is a technical overview and a conceptual analysis which asks: what context has been created at the convergence of acoustic and behavioural emergence?

Acoustic and Behavioural Emergence

By definition, a non-centralized system cannot be studied in isolated parts. Instead, it is the self-organisation of its parts that creates the emergent phenomena that characterize its function. Perhaps most plainly, emergence is a macro-structural consequence of micro-interactions between agents, who may do so without awareness of the developing structure. Music can be considered the emergent phenomenon of organised sound. By extension, soundscape composition can be considered as recontextualizing 'the perception of sound as it pertains to a necessary epistemological shift in the human relationship to our physical environment' (Dunn 1998: 3).

A classic example of emergence in natural systems is swarming. A swarm is a meso/macro structure that forms cohesive patterns based on laws of attraction between agents. Swarming combines regular and chaotic properties of self-organisation to create a collective behaviour of entities which exhibits a singular identity. Typically, a swarm does not follow central coordination, yet it possesses behavioural abilities which can qualify as unified cognitive functioning. This "swarm intelligence" has been observed in nature and simulated in computational models for problem-solving in optimization tasks. In 1986, Craig Reynolds developed an algorithm for simulating emergent swarming/flocking behaviour which followed only three rules: cohesion, separation, and alignment of an agent's position in relation to the central mass of its neighbours (Reynolds, 1987). Granular synthesis exemplifies a phenomenon of acoustic emergence that could be classified under swarm dynamics. The sub-sectioning of a waveform into micro-sound (<50ms) grains and their subsequent stochastic rearrangement unlocks an interaction of the local waveforms with "meso-scale time patterns characterized by emergent properties, which are not present in either

global or local parameters" (Keller/ Truax 1998: 4; Truax 1994). Therefore, it is no coincidence that the implementation of self-organising principles in synthesis has proven especially effective at recreating naturally occurring stochastic sounds, like those made by a streaming river or a crackling fire.

Swarm simulations have seen extensive popularity in digital media applications, offering the ability to decouple low-dimensional parametric input from higher-dimensional target domains, with applications found in synthesis and sound spatialization systems (Schacher/ Bisig/ Kocher 2014). Tim Blackwell and Michael Young have made analogies between swarming bodies and an ensemble of musicians, where temporal structures may only be perceivable at a distance (Blackwell/ Young 2004). But where their *Swarm Music* uses the gesture of swarming behaviour, *Auspex* extends to characterize these agents and immerse the listener within their environment.

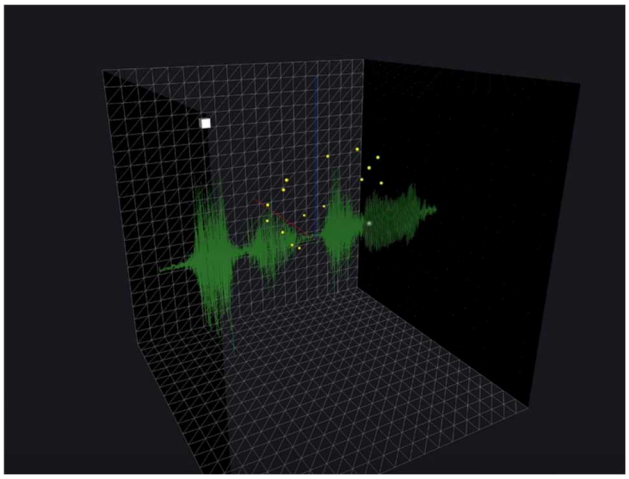

Figure 1. *BoidGran*, a 16-voice granular synthesizer controlled by the boid flocking algorithm

Sound 1. Excerpt of *BoidGran* performing a flocking gesture
Available to listen at www.keams.org/emille

Prototypes

BoidGran

What can now be considered the initial prototype of this work was not designed as a composition but as an instrument, a boid-driven granular synthesizer written in Max/MSP, *BoidGran.* 16 particles in a 3D-vector space were mapped to 16 voices of a granular synthesis engine. The traditional granular controls of grain play-position, rate, and duration, along with multichannel spatialization controls, were mapped to the positions of each particle. The particles' positions were governed by the boids algorithm to enable flocking behaviour. This instrument was capable of expressive and organic control over spectromorphological models of particle-based gestures, outputting ecologically informed particle synthesis similar in spirit to Keller-Truax's model of environmental granular synthesis, and other boid-controlled granular systems. (Smalley 1997; Keller/ Truax 1998; Blackwell/ Young 2004; Bisig/ Neukom/ Flury 2008)

Swarmscape

The original objective of the audio-visual composition *Swarmscape* was the implementation of *BoidGran* in a larger, compositional context. We set out to develop a system that could generate music without human intervention or leadership, mimicking the self-organising behaviours of a swarm in nature. Initial efforts involved stochastic conducting of parametric controls dictating compositional movements based on degrees of attraction, cohesion, and separation. This produced compelling sonic gestures, yet efforts to create more complex music were limited by the system's reliance on positional control for synthesis without any consideration of higher "state-based" parameters of individual boids within the swarm. To create a more nuanced compositional complexity, it became necessary to extend the behaviours of the boids to inhabit the cybernetic dynamics of an ecosystem. Rather than depending on absolute cartesian position as the basis for parameter modulation, an ecosystem provides an ecologically grounded model which emphasizes an agent's behavioural state as its primary dynamic force.

Establishing an ecosystem begins by introducing a variety of species, which sets in motion a complex web of interactions—attraction, avoidance, and competition for resources. These interactions drive the life cycles of birth, death, and reproduction, reflecting the population dynamics governed by the Lotka-Volterra equations that dictate the ecosystem's phase transitions. With the established intention of classifying 48 total agents within 3 species, an additional methodology was needed to distinguish these agents as both individuals and species from a synthesis perspective. The natural step was to assign each agent its own waveform, enabling dynamic buffer swapping. This is where the analysis of input source material could be augmented by machine learning and concatenative synthesis.

Concatenative Synthesis, also known as audio mosaicing, is a data-driven sound synthesis technique that assembles sound samples in series based on timbral analysis (Schwarz 2007; Zils/ Pachet 2001). The Fluid Corpus

Manipulation Toolkit (FluCoMa), created by the University of Huddersfield, provides an extensive assortment of data analysis processes packaged to enable real-time analysis of sound information. FluCoMa allows for the dynamic creation of a corpus of sound units that can be directly used for concatenative synthesis. The FluCoMa toolkit also includes packages for dimension reduction of parametric control, providing a linear control of the higher-dimensional parameters of the boids simulation. Finally, the state-based and procedural rendering needs of the system dictated the transition from Max/MSP to a combination of Supercollider for FluCoMa analysis and audio synthesis, and Unity 3D for ecosystem simulation. Bi-directional communication between applications was made using the Open Sound Control (OSC) network protocol.

Composition Example

Upon starting the simulation, a folder of audio source material is analysed and sliced into subsections based on novelty, then arranged as units in a 3-dimensional corpus space based on similarity in timbral qualities. Next, units are partitioned into K-Means clusters representing three distinct gene pools from which 3 unique species will derive their sonic genome. With data analysis complete, 3 sample units from each gene pool are randomly selected and set as source waveforms for 3 spawned agents.

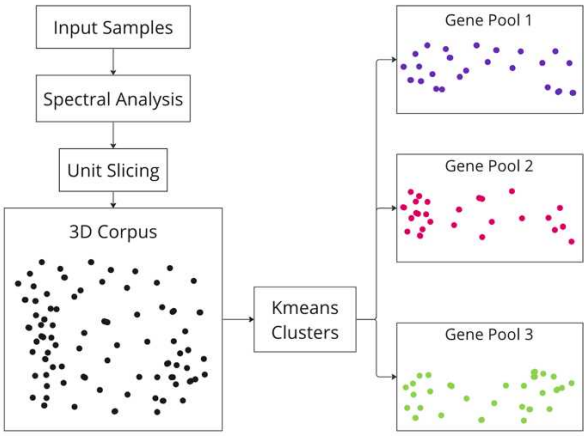

Figure 2. The analysis and arrangement of input samples into a corpus using the FluCoMa Toolkit

These agents now occupy and engage with the environment, each with a natural predator and prey which they respectively avoid and seek. Positioning near a predator decreases an agent's health, and positioning near prey increases it. If health surpasses a specified threshold, a new agent is born with a waveform loaded from its special cluster, and the mother agent's health is halved. The age of each unit increases in alignment with an in-world time system, and an agent dies if its health either reaches zero or its age surpasses a maximum limit. With the birth and death lifecycle of agents, a species can either reach a population limit of 16 or go extinct once the population reaches 0. Population increase across this spectrum contributes to increasingly coherent swarming behaviour amongst agents of a species, resulting in increasingly complex and gestural sonic content. Given the triangular predator-prey relationship between the 3 species, the extinction of one species creates a resource imbalance leading to the eventual collapse of the entire ecosystem.

Each agent granulates its loaded waveform, with the parameters of this granular engine dictated by the agent's behavioural state. Each species has its own octave range which the granular play-rate can cycle within, ensuring that its output occupies its distinct spectral niche. As an agent moves closer to its prey, its health rises, increasing its movement velocity while narrowing the durational window of granulation, further stabilizing timbral character and fundamental frequency. As the age of an agent increases, the maximum amplitude of an agent's output correspondingly diminishes, and the starting play-point of granulation moves through the waveform. Agents also ensure that their synthesis output is enveloped at a trigger rate and phase dependent on position to other agents of their species, so that agents closer together fire more rapidly and more synchronously to one another, recalling the phase-coupled oscillations of fireflies and other insect species (Ermentrout 1991). As the agent moves around its environmental space, its cartesian coordinates are used to spatially diffuse its audio output when performed in (real world) environments with multichannel speaker arrays.

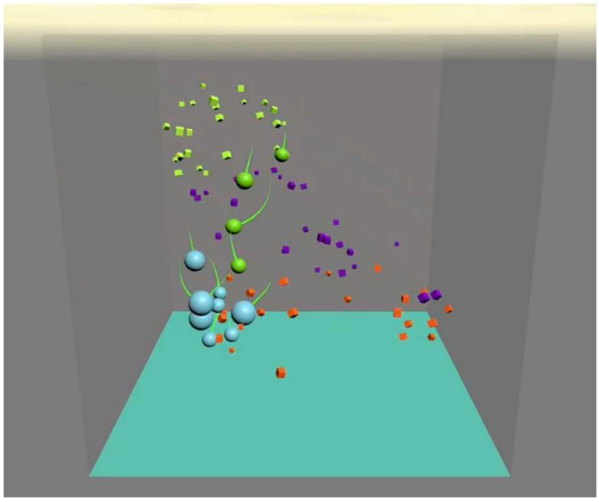

Figure 3. The environmental display of *Auspex*, shown with 2 species and 3 gene pool clusters

Sound 2. Except of an *Auspex* performance. Here, a monkey species dies, leaving an empty acoustic niche eventually filled by birdsong

Over time, an imbalance in the ecosystem's population across the species will lead to a corresponding imbalance in the composition. What starts as the harmonious interplay of three spectral species eventually erodes into a dominance of a single frequency bandwidth, the Darwinian victor at the finale of the *Auspex*. During the performance, newly recorded source material can be continuously analysed and added to the gene pools of a species to ensure an endlessly evolving timbre of eco-composition.

Taking Auguries

> There is meaning in space before the meaning that signifies. Taking auguries is believing in a world without men; inaugurating is paying homage to the real as such. (Serres 1995)

Ecological psychologist James Gibson (1979) defines environmental affordance as relating to 'the complementarity of the animal and the environment' (p. 119). Considering environmental sound as music frames the subsequent music as a human affordance of the environment, a provision towards relational listening. Furthermore, soundscape composition, as the human interpretation of the soundscape, creates new affordances from an acoustic environment. Thus, establishing environmental sound as music relies not only on the observance of emergent structures but must include the sensorial and subjective experience of the soundscape. When compared to the prototypical systems described above, *Auspex* prioritizes auditory perception and phenomenological interpretation of the soundscape, moving away from system creation to explore the deeper hermeneutic processes that underlie the meaning of the composition.

As Jon Appleton (1996) notes, electroacoustic composers tend to be more interested in 'logical construction than by intuition' (p. 70), a troubling notion that has forced us to consider the intuitive experience of the emergent behaviours of our digital ecosystem. To emphasize a phenomenology of listening, the decision was made to remove the visual components that we felt had dominated the aural experience of *Swarmscape*. We began to listen to the piece with our eyes closed, asking if the experience was comparable without its visual aid. Though the behaviour of *Swarmscape* is *observable,* assisting its audience in contextualizing the composition, the inclusion of visual components deemphasizes deep listening initiatives central to the pedagogical approaches of acoustic ecology. The reliance on visual media for analysis, including the complex visual displays of virtual instruments, is central to electroacoustic practices that emphasize the physical properties of sound objects as arbitrary signals. However, the source material of the soundscape composition relies on a contextual relationship to its semantic content for the very recognition of the composition as soundscape. Therefore, by removing visual components *Auspex* deliberately shifts from what Barry Truax (2022) calls the 'signal transfer model' (p. 14) to emphasize in situ listening or listening in context.

Figure 4. The Augury at the founding of Rome (Fontana 1573)

Michel Serres (1995) deems the augur the 'inaugural logician' (p. 77). History suggests that auspex played an important role in the foundation of Ancient Rome, though the use of bird diviners to translate the will of the gods purportedly predates Rome by at least a millennium. The augur begins their ritual by using their wand to outline *templa* in the sky; vector spaces where the auspices might be observed. With the removal of visual media, the *templa* of *Auspex* is determined in physical space by a scalable multichannel speaker array. This *templa* is populated with a corpus of sonic species, inviting the listener to take the auspices. *Auspex* uniquely pairs an agent-based artificial life ecosystem with corpus-based mapping, thereby offering a meta-contextual relationship to the acoustic niche hypothesis from a behavioural perspective. The ecosystem does not rely on environmental recordings as source material to generate ecological context, relying instead upon the eco-assembly of sound objects by frequency to establish its various species and agents. In this way, the resultant soundscape composition maintains a meta-contextual relationship to the natural soundscape from a primarily behavioural perspective.

It may be important to distinguish this output from what is commonly considered music. As David Dunn (1998) writes, rather than integrating all sonic phenomena in our cultural understanding of music, sonic art can expand human engagement with sonic phenomena beyond music

'as a prime integrating factor in the understanding of our place within the biosphere's fabric of mind' (p. 3). From this perspective, environmental sounds as additive aspects of human music are anthropomorphized into the human experience. Instead, soundscape and soundscape composition can be considered as recontextualizing sound to (re)connect humans with their greater environment. Thus, it is important to acknowledge the legitimacy of natural behavioural complexity as gesture, regardless of its status as music.

Conclusion

Auspex is best described as a living process. Our ongoing research into the mechanisms of behaviour have expanded our understanding of what constitutes creativity, control, and composition. We hope that by unifying naturally organised structures with naturally organised sounds, we can uncover and re-engage with patterns fundamental to the problems we face as a species at odds with our world. Ultimately, while the work involves the principles of competition applied by game theorists, it is cooperation that is its defining feature. Decentralization has not only become a dominant theme of the work, but an important aspect of our artistic collaboration. We have failed when attempting to gain control over the system or each other and have been rewarded by allowing this sometimes violent and obscene environment to thrive. Its best performances were in private, as though it did not want our role in its existence to be apotheosized. Thus, acknowledging *Auspex* as art or music is less important than acknowledging it as a living thing, just as perceiving the agency of individual agents is less important than acknowledging the collective consciousness of the swarming species. *Auspex* is an ecosystem of interdependent parts whose sentience includes not only so-called 'living' organisms but also their 'abiotic' environment, factors of which are necessary for the survival of life.

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[Abstract in Korean | 국문 요약]

오스펙스Auspex: 생성하는 소리풍경로서 생태계적 출현

마이크 캐시디/ 크리스찬 노스

이 글은 음향 틈새 가설에 맞추어 구축된 코퍼스(말뭉치) 기반 연결 합성 기술을 통해 다중 채널 사운드스케이프(소리풍경)를 생성하는 에이전트(행위자) 기반 인공 생명 생태계인 오스펙스(복점관)에 대하여 개괄적으로 보여준다. 이것을 개발하게 된 것은 두 가지 프로토타입 시스템을 검토함으로써 파악하게 되었다; 보이드 구동boid-driven(한 단위별로 작동케 하여 큰 무리를 이루는) 그래뉼러 신디사이저인 보이드그란BoidGran과 떼지어 움직이는 생명체를 음향적으로 표현하는 데 주안점을 둔 시청각 퍼포먼스 시스템, 스웜스케이프(떼풍경)Swarmscape가 그 둘이다. 이들을 분석하는데 시스템의 결과를 맥락화하는 개념적인 접근 방식이 포함되었다.

주제어: 사운드스케이프 작곡, 음향 생태학, 스웜 역학, 연결 합성, 인공 생명체, 음향 틈새 가설, 플루코마

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Modes of Acting: mismatches and collective intention during improvisation

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Processes of auditory-motor co-representation in musical consciousness are described in relation to the neurological processes of Mismatch Negativity (MMN) and mirror neurons (MN). MMN has been detected as a part of auditory perception that discriminates for musical variants based on previous experience and will be used as a basis to suggest how unconventional sounds in electro-acoustic music are systematized. Mirror neurons in the motor cortex are shown empirically to simulate the goal-directed actions of others using tools, or in this case musical objects. Due to mirroring effects, in conjunction with ideomotor theory, intentions of individual improvisers in an electro-acoustic ensemble can break free from their unitary coherence and form into larger complexes, known as a collective intention. Bridging from the well researched concept of listening modes, acting modes will be proposed here and used to describe interpersonal dynamics during improvisation.

Keywords: Rhythm, Time, Acousmatic, Composition, J. Adams, J. Alvarez, M.V. Avantaggiato, F. Bayle, F. Donatoni,

Recent empirical studies connect human listening to neurological responses in the mind. A mapping of the mind starts to emerge where biological regularities become explanatory factors for musical practices and their differentiation. During neuroimaging experiments, sequences of sounds are designed to elicit certain kinds of responses in the auditory cortex, such as signals that indicate surprises. Other experiments record images of the motor cortex to locate motor activation that mirrors the actions of action-related sounds. Self-produced sounds along with sounds produced by others lead to mismatches (surprises) and mirroring effects in the mind, that during the course of improvisation promote trajectories of music synthesizing interpersonal objectives. The varieties of action and perception as a concurrent and mutually augmenting duality, will first be described in terms of listening modes (Schaeffer 1966) and then a new formulation of *acting modes*. These two modes in conjunction with neuroimaging evidence of two contemporary experimental subfields: auditory mismatch negativity (MMN) and mirror neurons (MN), will be used to argue for and investigate the interpersonally mixed nature of ideation and intention during improvisation. Moreover, these capacities for acting and listening, along with collective action during electro-acoustic improvisation, show how novel and abstract sounds are systematized and brought into a commons of aesthetic understanding.

Listening Modes and *Acting Modes*

Perceiving musical sounds informs the motor production of actions. These actions then cause sounds to emanate from an instrument. Action and perception have a continuous and mutually augmenting connection due to the fact that motor actions change what is heard. Due to the close coupling mentioned, listening modes might be said to have conjugate modes involving the motor system, as acting modes. These modes of thought, as listening and acting, have a concurrent duality during improvisation, where listening informs acting and visa versa. A list of selected listening modes will be presented below in Table 1, followed by naming and defining the new concept of acting modes.

Perceiving	Schaeffer (1966)	The electro-chemical dynamics of the body responding to the stimuli.
Hearing	Schaeffer (1966)	Engaging conscious awareness to focus on a particular sound or set of sounds in the environment.
Listening	Schaeffer (1966)	Engaging conscious awareness to focus on a particular sound or set of sounds in the environment.
Comprehending	Schaeffer (1966)	Involving semiotic mental processes to place the sound heard into relation with others previously experienced by the listener.
Everyday	Gaver (1993)	Focus shifts to the entirety of the event rather than the individual sounds that constitute it.
Musical	Gaver (1993)	Focus shifts to the many characteristics of timbre, envelope, fundamental and intensity, to name a few. A single sound object as it processes through time can be listened to as a function of focal attention as many different traces of characteristic
Connotative	Huron (2002)	Inferring physical properties of the sound source. This implies that the index is thought to be identified and goes further to say that the sizes of objects, their orientations, material properties, and velocities are understood as well.

Associative	Huron (2002)	Learning to expect certain associations of sounds either as concurrent or as predecessor/ successor relations. It is important to note that this applies not only to, for instance, certain dyads in melodies but also to any feasible kind of sound.
Critical	Huron (2002)	Sussing out the intention of a sound if the sound is produced by an agent.

Table 1. Selected Listening Modes.

Now categories of acting modes will be proposed. These modes include: *mirror, source, epistemic, focused, musical, indexical, kinetic, consistent, contextual, default and critical*. Acting Modes share characteristics with the Listening Modes presented in the table above and correspond to actions that may co-occur with listening during improvisation.

Similar to the listening mode of perceiving, raw unconscious dynamics related to mirroring actions of others or preparing novel actions are evoked in the motor systems. Unless learning to play a new instrument or perform a novel technique on familiar instrument, most of the productive dynamics of preparing the gestural and haptic aspects of the actions are done unconsciously. In an experienced musician, the effect of an action, as the intended musical sound, is the most likely thought to occupy representational space in consciousness before performing the action. Only the aim of the action and not the mechanics of arranging fingers is consciously experienced.

From here we can assert two acting modes, one is *mirror acting*. This is the mirroring of a goal-directed action of another person. Here the intention originates from the body of another musician. Since the production, ownership and carrying out of an intention are separable processes (James, 1980), the musician performing the action could take ownership of the intention originating from another person. The second mode is *source acting*, where the intention is also goal directed, however it was produced in the body of the person carrying out the musical action. These two modes share a feature of pragmatism. The intention superseding the action has a distinct goal that satisfies the parameters of a musical idea in a direct or pragmatic way; for instance, the closing of phrases to create openings, the supportive contrast of drones and staccatos, or the production of interferences to extend or divert musical passages.

Pragmatic actions can be distinguished from those of epistemic value (Kirsh/ Maglio 1994). The former functions well under the auspices of certainty and clarity of musical context, while the latter occurs under the influence of uncertainty as an action to reveal information about the context and to locate terminal points of stability. With this we have a mode of action called *epistemic acting.* Actions that reveal information about musical context can (but don't always) exist below the threshold of conscious experience in a preparatory phase. Action-related events occur in the mind that are not specifically observable in the bodily production of the performer, however have some effect on what is seen.

Continuing toward the conscious level of acting, *focused acting* involves being consciously aware of action. Such as, being aware of mirroring someone's action on an instrument. If using a different instrument from an interlocutor, then this action might take on a translational quality, recruiting the resources of conscious attention to reproduce this action as a mapping to your instrument. It could also involve hybrids of mirroring by selecting actions to mirror multiple people and constructing a musical gesture therein by switching, interpolating or some other means of hybridization. Focused acting also can oversee the source mode and be used to augment the passage of an action to suit the momentary changes in the musical environment.

Some overlap exists between musical listening and Schaeffer's listening mode of hearing. The same is true with focused acting and *musical acting*. A distinction here could be made about the granularity of focus. Here musical acting is a mode of musicianship where actions are directed toward moments and developments of unique articulations of the sound. The actions focus on individual musical qualities, such as dynamics, timbres, frequencies or timings, via common or extended techniques. These of kinds of actions can highlight, delimit and create space in a musical environment.

With electronic instruments that make use of highly recurrent feedback paths, coupling techniques between sources or stochastic processes, actions on the control surface of the instrument do not always produce results that are predictable or reproducible by the performer. In this case, there is a disassociation of the action and effect. *Indexical acting* questions the necessity of the predictability of an action given the state of the electronic instrument. At one end of the spectrum, actions can produce effects that are to a certain degree predictable, while on the other, there is an inability to identify the effect as having something to do with the action. Something called *kinetic acting* can be used in a situation like this to ground uncertainty. This refers to action on the basis of the sensation of the material properties of the instrument. Moreover, material properties are sensed through interoceptive cues to inform a course of action,

as the movement, contact and articulation of finger digits. Musical listening with focus on the timing of musical features also aids in indexically ambiguous sound-action relationships. Kinetic actions are timed to intervene in non-linear processes at salient moments to co-create the temporality of events with the electronic process. Kinetic acting is also important during improvisations that make use raw materials not associated with conventional musical instruments. These materials contain the impetus for sequences of action informed by the sonic potentiality of the materials.

Sonic actions and their results are brought into commons of aesthetic practice due in part to associative abilities. *Contextual acting* involves the comprehension of actions as the association to other related actions for performing instruments. These mental associations can be semiotic relations about the meaning of gestures and have a fluidity. *Consistent acting*, then may work in conjunction with the contextual mode, disregarding the moments of short term goal-orientations, the focus is on larger scale events, made of up of contextually merged blocks of actions; a series of actions that are constitutive of an event. A musical inquiry about the patterns and successions of daily activity, that mirror and augment the experience of being embodied from the level of affects to politics. In one way it is a performative mode that deploys compositions of action that reflect and extend political dispositions.

Default acting involves the notion that over time certain regularities develop in the our successions of action. This mode is one of letting the default mode take precedence and exploring the tertiary. A way to interrupt the default, could be the critical, or *critical acting.* This could be an intention to break with the default activity and do something irregular. It is action with a specific focus on intention, to match an intention, promote an intention with an alteration by taking a different means to that end, or to respond to an intention with a different intention.

Now that listening modes have been described and some new acting modes have been defined, the focus shifts to contemporary experiments in neuroscience. Two subfields regarding auditory mismatch negativity (MMN) and mirror neurons (MN) are described. MMN an MN are selected because these well studied phenomena are both unconscious processes that have a large effect on resulting conscious episodes. These two phenomena also functionally integrate on a neural level. Listening and acting modes are brought into dialog with MMN and MN scientific experiments to extend and at times complicate the conditionality of these experiments, but also to locate consistences that reveal information about the mysterious conscious experience of electro-acoustic improvisation. As MMN and MN both include descriptions of observed unconscious dynamics, these findings help disambiguate the underlying processes of the first person phenomenological experience of fully formed musical ideas appearing in consciousness, without deliberation, during improvisation. Another related enigma to be investigated involves how the collective organization of musical materials during improvisation generates its own context with structural, dynamic and associative regularities all in real-time. Moving forward, the experimental music can be projected on to the experimental science, where the neuro-experimentation stands in for the performance of experimental music.

Auditory Mismatches, a default activity in the mind

Mismatch Negativity was a signal first experimentally detected within the auditory cortex in 1978 (Näätänen/ Altenmüller/ Jäncke 1978). The MMN signal occurs in the preconscious interval of time of a person's auditory perception as a response to deviant environmental patterns. What is considered deviant is an experimentally situated variable introduced to the subject as a cue. Experimental recording protocols of real-time brain activity from ideally relaxed subjects look for windowed concurrences of the sonic cue and a particular feature of brain activity, the MMN. The window of observation is based on the temporal gap between events in the world and the conscious perception of those events. Because the MMN occurs within this gap of time, musicians are said to discriminate for musical variants before conscious attention as an automatic reaction.

An early technique for eliciting MMN used the so called ‘oddball paradigm ’(Schröger 1998). The method prepares a sequence of repeating tones with one event in the sequence that deviates in greatly in pitch. The monotony of enveloped sine tones of equal frequency is interrupted randomly with a variant. The MMN signal is typically observed to occur within 100 to 250ms after the onset of the deviant event. MMN is a specific characteristic of event related potentials (ERPs) which are a series of pulses that are measured by electroencephalogram (EEG) in response to sonic events in the world. A chain of ERPs recorded from the mind is called a memory trace and (are thought of empirically to) reflect an encoding of immanent sensory events. Each event contained within a memory trace is further contained within a sliding window of temporal integration, with a duration of about 160ms (Yabe/ Tervaniemi/ Sinkkonen/ Huotilainen/ Ilmoniemi/ Näätänen 1998). Eliciting an MMN by interfering with the temporal window is possible by either compound stimulus

or stimulus omission. In the former, the onsets of two sonic events occur within 160ms of one another (Van Wassenhove/ Grant/ Poeppel 2007). In the latter, the intensity of a droning sound is dropped to silence for an duration of less than 160ms (Yabe et al. 1998).

Moreover, MMN is neurally generated and modality specific. This carries the implication, backed by observations of (Giard/ Lavikahen/ Reinikainen/ Perrin/ Bertrand/ Pernier/ Näätänen 1995) that the dimension that deviates in the sound as either frequency, amplitude or intensity, elicits a response from different locations or neural generators in the right superior temporal gyrus. The signal that can then be considered a reflection of features of significance, where a mind tracks the stability of events by simulating traces of its component features. Here a neural picture of musical listening starts to emerge as neural generators of feature representations form cascades. At this stage of neural timing, the sound in the mind is at the level Shaeffer's perceiving. Only the subconscious dynamics of preparing the sound, scrutinizing its structure, and passing what needs attention to the conscious mind. The explanatory framework of this process, its discursive moves, easily fit into a Darwinian theory of natural selection and brain development. The brain develops as a threat detector or else. We are predisposed to focus on certain features in the mode of musical listening, rather than always and willfully choosing those features. These mismatches augment our actions, increasing the precision of acting by increasing the overall certainty of the musical context. In the case of free electroacoustic improvisation this context is not generally agreed upon explicitly beforehand. The experience of a mismatch or a surprise aids in the negotiation of an implicit and fluid context.

During improvisation, the lack of writing can lead to forms of risk and its active mitigation. Risk increases with uncertainty about the context, opening potentialities to the active production of musical events which function to collapse ambiguity into a mutually understandable musical ideas between improvisers. Musical acting is a mode where techniques performed produce something heard as an emphasis on features. In these cases of uncertainty, features are bound up with a break down of default acting as expected and automatic relations change course. Motivations to stabilize and reduce uncertainty can give way to intentional modes of acting as assertions about what the context might be, as a communication of possible ways to find a mutual stability. A sonic negotiation arises about the premises of this event. Who is currently authoring? Or are we somewhere inbetween authors in a tangle of agencies, defining in real-time new consistencies of acting?

Certain brain regions in the auditory cortex show similarities in functionality to the segmentation of mathematical features of sounds. These distinct areas specified by (Kropotov/ Alho/ Näätänen/ Ponomarev/ Kropotova/ Anichkov/ Nechaev 2000) show Area 41, known as the primary auditory cortex, responsible for the analysis of frequency and construction of stimulus features. These features are passed to Area 42, known as the secondary auditory cortex, which is particularly responsive to the speed of the stimulus, and has the function encoding and forming short-term memory traces out of frequency-based features. Comparison with the memory trace in area 42 occurs in the neighboring region area 22, also a portion of Wernicke's area responsible for processing the syntactical elements of musical sound. Area 22 existing on the surface tissue of the brain can be measured with EEG techniques and is the location where MMN originates.

Before moving on to experiments in mirror neurons. A brief interlude describes the role of the instrument in this tangle of musical agencies. This interlude will be further developed in the last section of the paper because it leads to insights about how novel actions and sounds are brought into a commons of aesthetic understanding. Furthermore, questions arise about the structural and theoretical basis of music that does not include a score and can be especially pointed in the case of electro-acoustic improvisations. However, electronic sounds and extended techniques can exist independently of current writing and conceptual systems. MMN and MN are neurological processes that make phenomenological distinctions and aid in joint activities, respectively. With this, new collections of phenomenology are systematized into meanings that can be written, are embodied or can only be embodied through collective coordinations.

MMN and acting with instruments

The set of sonic qualities that lead to the detection of a MMN signal, are found to be more nuanced in the case of musicians than non-practitioners (Münte/ Altenmüller/ Jäncke 2002). This leads to the idea that the mismatch signal is a reflection of the physical or bodily things a person needs to do to acquire a musical skill. With these bodily processes there is the interpretive process that correlates the particularities of haptic moments to those of the sounds produced. The interpretive process is further constrained to the initial haptic moments of apprehending this relation of action to sound. Kinetic and musical acting have a close relation in this context. Interoceptive cues map to the physical excitation of sonic qualities and characterize the articulation of expressions bound up with a musical context or intended genres.

Different kinds of sensation of haptic moments become familiar to a practitioner, showing distinctions of embodied experience dependent on the genre.

Acquiring a musical skill also can be seen as a distinct use of the hand itself and its negotiation of equilibrium dynamics. In terms of haptic moments, the somatosensory system plays a critical role in understanding the internal state of the body as a mechanical representation influenced by contacts with outside things and beings (Hayward 2018). The hand as one aspect, takes signal from the load-bearing constituents as the tendons (which connect muscle to bone) and the ligaments (which connect bones together) to infer physical properties from the world. The internal state of the body in relation to positions in the world is concurrently sensed by mechanoreceptors that cover the surface of muscles. Agonist-antagonist relations of muscles activate in different groups toward states of quasi-equilibrium. The hand has an internal tendency by accord of its own structuring to tend toward states of balance during the variety grasps necessary to articulate sounds from musical objects. The variety of grasps can be thought of as successive activities of initialization in relation to a musical object.

For the sequence of initializations, it can be said that the mind creates a representation that is an idea about, say, the specific placement of fingers on an object. If there is a mismatch between the representation (an idea) and where fingers are seen to be, then the fingers are moved until matching the representation; the representation in the mind is not changed. Once the match is made the next representation in the mind is presented as a goal for the process to continue. The mind doesn't change to match the motion, the motion changes to match the mind. In terms of consistent acting, larger motor activities can be planned because the time until the match and the selection of which path to the match are variables to the improviser. Acting contextually can locate associations between musical gestures or indexical actions. Then larger complexes of associations can be concatenated, operationalized and extended through consistent acting.

The body is responsible for initializing the sound and the instrument is responsible for carrying the envelope of the sound through time. In considering this secondary role of the instrument as an image, a processor and an amplifier, it has latent properties as suggested by (Magnuson 2009), relating to the interaction of the mechanical sound wave and the instrument body that interrupt the interpretation of action to sound causation. Here the importance of the spectrum of indexical acting starts to emerge. The earlier example of electronic instruments, showed the extreme pole where the effect of dislocates from the indexical action. Here the latent properties in the acoustic instrument can produce and reproduce indexical ambiguities, however in subtle ways such as the rolloff in the decay of a note or the transients at the attack of the note. Larger than a mere physical disposition, instruments also contain embeddings of psychological codes that effect the production of sound. The instrument could then be said to suggest modes of engagement, subsuming acting modes of a musician.

As in the case of the keyboard, the instrument itself holds psychological dispositions and mirrors the dimensions of the body (Moseley 2015), meaning that it carries more than a certain mechanical responsibility to bodily actions. The psychological part, borrowed from Freud, includes the physical activities shaping, ordering and repeating, having the mental effect of translating anxiety into a sense of security. The mirroring relation is based on a conditionality that for a person to physically operate the instrument, the instrument is typically an object that is some inversion of a figure created by bodily positioning, posture and transitivity.

Empirical evidence of the MMN signal in the auditory cortex shows a plasticity of systemizing sounds based on subjective experience as either a listener or a practitioner, however it is important to note that research shows primacies in perception that are difficult to reverse even with experience. The high voice superiority effect (Trainor/ Marie/ Bruce/ Bidelman 2014) suggests a perceptual bias to process the highest pitched sound in a group of sounds. Musicians who have years of experience playing instruments in the bass register showed a reduction to the superiority of the high voice, but not a reversal. ERPs that represent a sequence of high frequency events form more robust memory traces that overshadow the responses other of simultaneous events. This is inferred from the fact that MMNs related to higher voices are higher in amplitude and lower in latency. Filtering in the middle ear may account for the physical differences in memory traces for high-frequency sounds.

Default acting and associative listening might be bound up with primacies, such that our perception of detail of sounds is overshadowed by certain cognitive and physical constraints. Myriad primacies and known auditory illusions exist that complicate the idea of a human intention being the source of observable musical actions. Intentions arise by calling on sensory evidence. What is in the world and what is perceived as salient are related, however differ as perception becomes regarded as a predictive hallucination or a kind of theatre of the mind. The body as a part of the environment, embodies physical quantities, such that expected relations of successive actions are based not only on experience but the body itself. Intentions then have a universal embodied

component as distinct from, yet entangled with individual intentionality by way of plasticity.

Motor mirroring and Co-representation

The concept of auditory-motor co-representation describes the fact that sounds produced by actions create the environmental conditions to detect activity in the motor regions of the brain of a listener. Mutual plasticity, or in this case the changing of neuron connections within the auditory cortex and motor cortex, alters underlying physiology, preparing the brain to respond to future sonic occurrences with effective motor responses. Scientists (Hauk/ Shtyrov/ Pulvermüller 2006) tested prerecorded sounds of a similar characteristic created by different body parts. It was found that listening to recorded sounds such as finger snaps elicit brain activity in the region of the dominate hand, while tongue clicks go on to a region mostly likely associated with the mirroring of the mouth. The brain creates mappings, so to speak, from perceived sounds to the potential cause of the action. To emphasize, vision is not required in this process after perceiving the sound-action relation at some other time.

The brain is thought to, using scientific parlance, discriminate, for patterns that deviate from known experience in the case of action-related sounds and then pass these sorted signals to motor regions for emulation as a preparatory activity. In terms of coding the index of a sound and what might be the intention behind the sound, it again appears much of that activity occurs in the preconscious interval of a person's perception. The study (Hauk et al. 2006) reports that an MMN discrimination phase happens automatically. Discrimination is followed immediately by a synchronization phase that is able to properly place the memory traces of sound in a listener's motor regions that correspond to the inferred cause of the sound. Since the event was a future condition that was unknown, the activity in the premotor cortex occurs *after* the events in the world. At this subconscious stage, the brain integrates sensory events to direct the mind toward important contents in the external world. The conscious awareness of events occurs when a listener has a linguistically grounded experience of naming, attempting to name or senses the possibility to name, in this case, an aural or action related content.

In terms of understanding action in a linguistically grounded manner, it might be better to ask not what is in the mind, but what the mind is in. Say in one place finger snaps are a rude way to get the attention of a waiter, and in another it was a polite way to show appreciation for a beat poet. There wouldn't have been a waiter at certain venues for beat poetry, so the intention of the action as a gesture would not be confused. The kind of environment the mind is in delimits much of the requisite reasoning necessary for managing the significance of actions and the details of these actions are socially mediated by codes of conduct with corresponding rules of engagement (Moseley 2015). It might be that the brain acutely responds to the fact that it is situated in a specific itinerant context by having different interpretive modes available, which is supported by ideomotor theory (James 1890) and also robotics specialists working in the field of situational awareness. The situation is a scaffold for the interpretive modes available.

A study (D'Ausilio/ Altenmüller/ Olivetti/ Belardinelli/ Lotze 2006) measures the relation of mutual plasticity between the auditory and motor cortex as the intensity of excitability in the motor region when under the influence of magnetic stimulation, after a session of focused learning. For the experiment, piano players were selected that had upwards of 8 years of experience reading and performing music from traditional scores. Musician subjects learned to play the left-hand part of J.S. Bach's *Prelude no. 20 in A minor*. During the experiment, subjects were placed in a reclining chair and administered magnetic stimulation to an 'optimal position 'in the right motor cortex while listening to a MIDI rendition of the music without playing. This kind of experimental condition, listening without playing, is known as passive listening. The reason only the left hand part was learned and listened to during the experiment was due the discomfort experienced by subjects under the magnetic stimulation. Both sides of the motor cortex could not be tested at once. Increased motor excitability under stimulation was found in the motor cortex to the previously learned Bach piece. While relatively less motor excitability was observed during control Bach piece that was not learned beforehand. This leads to the conclusion that passive listening to a learned piece of music creates higher activation in the motor cortex. The statistical metric of spatially averaged excitability in this brain region is thought to signify a brain region that has learned or done something specific recently. From this one might infer that events during improvisation and previous improvisations leave plastic impressions in the cortex of musicians. Especially for musicians that rehearse and perform on a regular basis over the years, a co-representation of potential modes of actions exists in the minds of the group. Another important dynamic observed was synchronization between the auditory and motor regions. Under these experimental conditions and similar to (Hauk et al. 2006), synchronization signifies a functional bi-directional link between these regions, activated only if the indexical action of sound being

heard during the passive listening condition, had been learned at a previous time.

The previous study does not consider when the specific schema of activation occurs in relation to the music being heard. Due to its methodology of impinging on real-time brain activity, representations of interdigital maps could not be observed in the motor regions. In passive listening to a learned piece of music (Haueisen/ Knosche 2001) found that the act of listening to music triggers predictive hand movement mirroring the act of operating an actual piano. Subjects are set up to expect a recurrence of a sequence of events and that is what happens, allowing involuntary motor articulation to run without defect. The window of observation was focused on the interval of minus 300 to 0 milliseconds, that is, the time 300 milliseconds before the onset of notes. This read-out was achieved with an FMRI scan, which produces an imagivistic representation of activity, reporting motor cortex vectors to have simulated movement of the pinky and the thumb with a physical separation of 8mm. The motor cortex appears to have spatially distributed regions, that are constant enough in physical location that real-time imaging reveals a one to one correspondence to finger digit actions of the hand itself. The premotor system extends to an entire body schema that simulates or rather mirrors our own previous actions as indistinct from the actions of others that match previous experiences. The kinds of preparatory action or potential captured in the study (Haueisen et al. 2001) do not show forms of epistemic acting, where the participant may be acting in a source mode that attempts to reveal information about the musical context. Rather the potential actions are in the variety of mirror acting of a known intentional state.

The fact that these neurons are seen to emulate future actions when the future is known, supports theories of mirror neurons in the brain. This subset of neurons have important implications for fields such as social cognition because these respond to not just any kind of action but to goal-directed actions (D'Ausilio et al. 2006). For mirror neurons to activate as goal-directed simulations, the perceived action must incorporate an object the observer has handled before, such as a musical object.

With improvisation, the future is unknown by its participants on the scale that a pre-rehearsed score provides. On what level of granularity are terminable directives heard in context, understood and collectively emulated during improvisation? Especially in the common case of musicians using different kinds of instruments where one musician has no direct motor experience with the other musician's instrument, the specific physical skills necessary might not be mentally emulated. However, musical listening gives the distinction that the qualities of sounds as raw phenomena are to a certain extent common to all instruments, where different instruments delimit and proportion those universal qualities. The observation of the effect of an action can be separated from the action itself and refigured to the familiar actions of the known instrument; an instance of musical acting, where the more general properties of the indexical gesture such as the energy, timing and spatial direction are emulated as invariants that constitute the objective. These general observed properties from another musician could also be an emulation on the kinetic level of action. Velocities and other forces observed, either visually or aurally, transmit information about gestural activity and its excitatory impact on the instrument. For instance, electronic instruments structured with non-linear dynamics, the mix of forces might be observed aurally without a visual experience of Indexical Acting. An acoustic musician in dialog might then act indexically to emulate the implied kinetics that are imagined to be constitutive of the aural phenomena.

The use of epistemic acting occurs in improvisational contexts and is not present in the performance of classically scored material. When these actions are heard and mirrored within a group, codes of the context are revealed and amassed at a faster pace than an individual inquiry. If the effect of motor mirroring, also known as motor resonance, is considered in conjunction with the intentions of individual musicians, it appears that the unitary coherence of intentions is subject to interference from the intentions of other performers, creating a collective intention. James 'ideomotor theory states that executing certain codes for action requires a cooperation with environmental context such that the action intended leads to desirable results. The agent must understand the context enough to properly select the retained action that satisfies the goal. The actions that do so are retained in long-term memory for reuse. For a goal to be a goal, it must be preceded by an intention. This is a mental process of imagining possible futures and then selecting one. The act of imagining a course of action, as a plan and sequence, involves the involuntary activation of parts of the brain responsible for motor coordination. This refers to the mental generation of an action before deciding or not to perform the action.

Granted recent empirical findings that mental generation of actions mirrors the actions of others that are directed toward an understandable end, the intention that precedes this moment of generation is subject to outside influences. If the unitary coherence of the intention depends on remoteness from other intentional beings, then interaction with the acting of other musicians during improvisation complicates the production of the motor

plan, so that the production of an intention takes into account the intentions of others. This transforms the intention into something that is mutually coherent and starts to explain the basis on which the collective arrangement of musical direction occurs during improvisation. The ends are immanent, not arrived at later, and are exchanged and interpreted leading to the effectuation of an improvisation via the interpersonal dynamics of co-representation.

No matter the system of musical expression, whether a tonal system, or a system of electro-acoustic materials, experience and neural plasticity function to form acute perceptions of salient details and operationalize those details into sequences of signification. The collective organization of sequences and layers of sounds in the course of improvisation is accelerated by processes of dialogical emulation of other musician's actions who know the context. Acting and listening modes mediate the dialogical process of improvisation forming the varieties of collective intention. These modes, scaffolded in the musical context, and as capacities for musicking facilitate the joint organization that operationalizes the new. It should also be considered that as much as a musician is playing their own instrument, they are also extending through the network of other musician's instruments and playing through those during improvisation. This extension is one mechanism in which the new and even the 'new new, 'gain significations and become part of an aesthetic commons.

An aesthetic commons functions as a basis for the potential varieties of collective intention. This commons of aesthetic understanding, or in cognitive terms, the default mode, is generated by the extensive nature of collective effects that are mediated by acting and listening modes. The coextension of listening and acting during collective action reveals hidden topologies and homeomorphisms between all modes. Compositions of acting and listening modes, such as, musical listening and musical acting, associative listening and default acting, or contextual acting and consistent acting are cognitive tools that organize the familiar and unfamiliar. Composing one acting and one listening mode from the modes presented here gives 99 unique pairs. Creating compositions of 3 modes from any of the 20 presented here gives 1,140 possible combinations. This set of embodied cognitive tools, that can grow exponentially through compositions, provide a number of strategies to create an aesthetic commons for improvisation, and 'security 'within that commons. Improvisation is a negotiation with the more liminal aspects of experience, gliding between coextensions of consciousness and unconsciousness, the self and the other, the familiar and the unfamiliar, and acting and listening.

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[Abstract in Korean | 국문 요약]

연주행위의 양식: 즉흥연주 시 불일치와 집단의도

데이빗 드필리포

음악을 뇌에서 의식화할 때 청각과 행위의 공통 표현 과정은 불일치 부정성Mismatch Negativity(MMN)과 거울 뉴런Mirror Neurons(MN)의 신경학적 과정과 관련하여 설명된다. 불일치 부정성은 이전의 경험을 바탕으로 다양한 음악적 변형 형태를 구별해내는 청각적 인식의 한 부분으로 파악될 수 있어서, 전자음향 음악을 행할 때 기존의 관습과 다른 새로운 소리들이 어떻게 체계화되는지 제시하는 근거로 활용될 것이다. 운동 피질 내 거울 뉴런은 도구(혹은 이 경우 음악적 개체)를 사용하는 사람들의 목표 지향적 행동을 경험적으로 시뮬레이션하며 나타난다. 관념운동 이론과 함께 미러링 효과로 인해 전자음향 앙상블에서 각 개인 즉흥연주자의 의도는 통일된 일관성에서 벗어날 수 있고, 집단의도라 불리는 더 큰 복합체를 형성할 수도 있다. 잘 연구된 청취 양식의 개념을 바탕으로 연주행위의 양식을 이 글에서 제시하고 이를 즉흥 연주 중 대인 관계 역학을 설명하는 데 사용할 것이다.

주제어: 음악적 의식화, 연주행위 양식, 즉흥연주, 불일치, 거울뉴런, 집단의도, 전자음향 앙상블.

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Cleaning Sounds: Analyzing Oram's Tumblewash

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This paper examines the composition *Tumblewash* by Daphne Oram and how the composer's ideas about sound are incorporated into the work. Frequency and spectrogram analyses show the relationship between recorded acoustic sounds and synthesized sounds created by the Oramics machine.

Keywords: *Tumblewash,* Daphne Oram, Analysis of tape music, Spectrogram, Oramics.

In her book *An Individual Note*, British composer and inventor Daphne Oram writes about how her electronic music tries to reflect a certain humanistic approach to musical expression that was not common in works by her contemporaries. She is explicit about her disdain for synthesized sounds that replicate musical formulas originally for acoustic instruments. She writes:

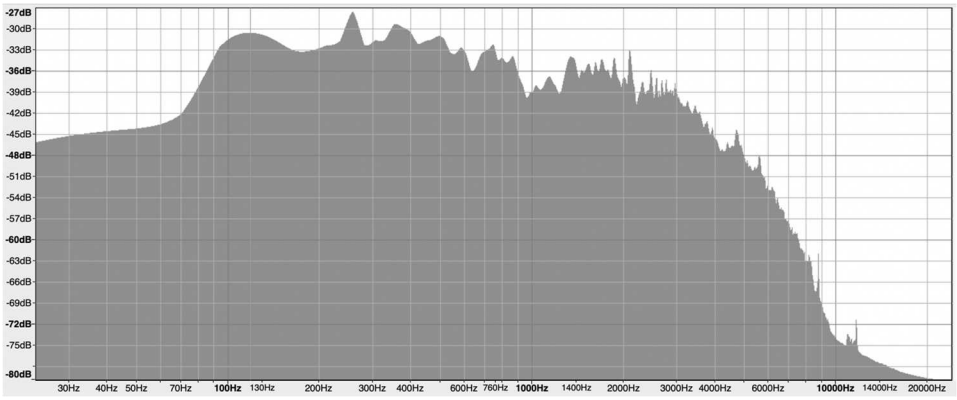
> My interest is in making new sounds which are musical. But I find that the adding of sine waves together in these 'classical recipes' gives a very 'electronic', inhuman sound with a clinical quality, lacking the possibility of subtlety and nuance (Oram 1972: 26).

Moreover, a major theme of the book is her desire to view electronic music as equally informative to our human perception as any acoustic sound. For Oram, balancing complexity with accessibility is key for achieving a holistic idiom within sound production. Many works composed using the Oramics machine were informed by these principles and their application can be traced through different musical parameters such as timbre, volume, and density. These parameters were precisely controlled by the composer to experiment with different ways of presenting her ideas to listeners. Through analysis of *Tumblewash*, a short washing machine advertisement composed with Oramics, this paper examines the multiple approaches Oram used to support her notions of balancing pure electronic-made sounds with recorded ones. Spectrograms of *Tumblewash* provide visual representations of what the Oramics tape would have looked like and its sonic interaction with recorded voice and water sounds.

Historical Background

After World War II, there were competing circles in Europe arguing about what aesthetics should be propagated through electronic music. One of these groups was the Radiophonic Workshop, established by the British Broadcasting Corporation (BBC) with the specific aim of creating sound effects for their radio productions. Daphne Oram was one of the first Workshop staff members when it opened in the spring of 1958 (Holmes 2012: 83). While she was able to compose a landmark work, *Amplitryon*, while employed at the BBC, Oram was restricted by the artistic direction of the Workshop which had been set up to complement the burgeoning television and radio industries. Without access to adequate support or funds to work towards her personal goals, she resigned from the Radiophonic Workshop by the end of its first year in operation and independently developed a machine to create sound through optic means which she called Oramics. Unlike other forms of electronic composition used in Europe at the time, this new device developed out of a desire to create a correlation between audio stimuli and a direct visual representation. With each set of instructions for musical parameters in the Oramics machine, there are ten 35mm film strips painted with ink patterns to generate charges that determine amplitude, timbre, frequency, and duration. In many ways, this new approach to electronic composition is reflective of Oram's philosophy of sound as part of our daily sphere, incorporating other senses into the compositional process including visual, tactile, and aural, which she could not achieve with the technology available at the Radiophonic Workshop in 1958.

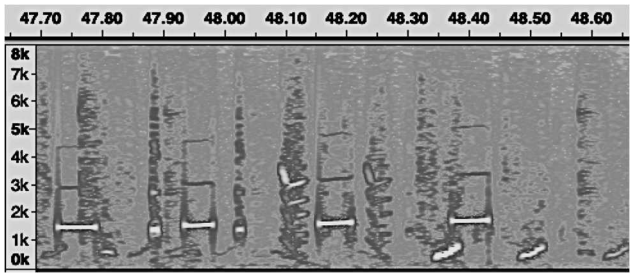
Tumblewash is one of Oram's works that uses Oramics in combination with recorded sounds. Like most of her musical works, there are few records about how the piece was created since the machine it was composed on kept being modified each year by the inventor. There is no record of the specific year this recording was created although it must have been composed sometime before 1968 when the English Electric Company, manufacturer of the Liberator Tumblewash machine being advertised, merged with General Electric (*The Times* 1968: 1). Not many recordings exist for other works by Oram from this period, but ones that do, show that the composer had a distinct interest in the intersection between electronic music and images of daily life along with more experimental idioms. Works similar to *Tumblewash* include *Lego Builds It*, *Food Preservation,* and *Nestea*. While not all of these recordings are commercial in nature, they share a sense of programmatic vision that contextualizes the electronically produced tones with concepts familiar to listeners of the time. Moreover, they achieve continuity through common techniques in electronic music, like splicing and looping, which Oram learned from her experiences working for the BBC Radiophonic Workshop and during an earlier visit to Pierre Schaefer's *musique concrète* studio in Paris.



Example 1. Frequency Analysis of *Tumblewash.*

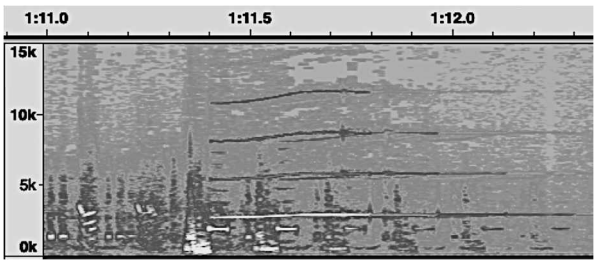
Frequency Spectrum

From a frequency perspective, *Tumblewash* features sonic events that can be divided into those that were recorded from an acoustic source and those purely produced by electronic means. The former includes the recorded voice advertising the washing machine and every swishing sound while the latter includes the Oramics-produced electronic treble and bass melodies. A frequency analysis of the piece reveals a large range of frequencies contained and their distribution, shown in Example 1. Such a range indicates that colored noise, possibly Brownian, is a factor in the sound spectrum of the work. This concept is not farfetched considering that Oram's looped sample recording is probably taken from a water source which would create a decreasing slope in Example 1. In each iteration of this "swishing" sound, there are frequencies as high as 20 kHz that drop in amplitude (dB) as the frequency increases similar to a low-pass filter.



Example 2. Spectrogram of Oramics Chriping Melody (0:47.7-0:48.65).

By creating spectrograms of different sections of *Tumblewash,* it is possible to take a snapshot of what the Oramics tape that controlled pitch specifically may have looked like. In Example 2, several seconds are taken from the middle part of the piece where an ascending "chirping" melody clearly cuts through the water noise loop. Considering the horizontal axis represents duration, what immediately becomes apparent are the white lines that stretch across at certain pitch levels because they are timbrally distinct from the surrounding sound. Furthermore, these lines tend to stay within the same range as the colored noise spectrum which is represented with dark, vertical streaks that line up with the melodic patterns. While the main audible pitches are centered within a certain range, around 1 to 2 kHz in Example 2, higher pitches can be heard in partial or overtone-like sequence above it that affect its timbre. These higher pitches appear as horizontal, parallel lines above the white lines that denote distinct electronic pitches. At 0:47.7, for example, the white line is at about 1.5 kHz while fainter lines appear at 3 kHz and 4.5 kHz.



Example 3. Spectrogram of Oramics with Partials (1:11.0-1:12.3).

Timbrally, Oram explores the interaction between distinct timbral qualities that are related by frequency spectra. Example 2 shows this relationship as the chirping melody does not float over the washing sounds but rather gets enveloped by it. The chirp at 0:47.9, for example, is surrounded by horizontal lines representing washing sounds at 0:47.8 and 0:48.0. Instead of focusing on its pitch content, which is microtonally inflected, Oram blurs the line between what sounds were produced in a studio and which ones come from acoustic sources through colored noise. Melodic contour is more important with these short blips of Oramics sounds, especially considering how slight alterations to the frequency in the form of glissandi make it difficult to always trace a determined pitch. Additionally, there are points where the timbral shifts mark significant places within the form. At the end of the second section of the work, there is a moment where the generated sound splits in amplitude with partials in higher registers

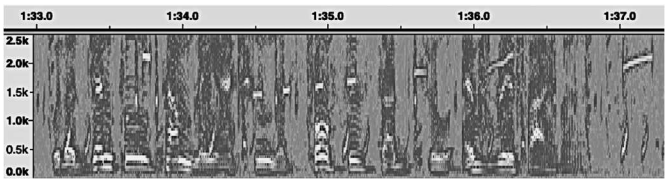
becoming much clearer than before. Example 3 has four nearly parallel lines at 1:11.4 which drop out over the span of a second one by one to create a tapering effect with the note's timbre. Moments like these show how complex tones play an important role in Oram's music even when the topic of the composition – a washing machine advertisement – seems mundane and a bit whimsical.

Oramics Connection to Spoken Voice

About halfway through *Tumblewash* (1:13), a recorded voice can be heard stating the following:

> Do you wash the new way, the Tumblewash way? The Liberator Tumblewash costs only 75 guineas and look what it does for you. It washes, it rinses, and it spins. All in one tub. Turn one dial to keep the water as hot as you want. Turn another dial to wash with a gentle tumbling action that forces suds through every fiber. One lever rinses till the water is crystal clear. Another lever spins. You never touch the clothes yourself until they are spun and sparkling clean. Wonderful Tumblewash. The only 75-guinea, one-tub washing machine. Made by English Electric. Made to last.

This text provides context for the piece of music: specifically to advertise for the eponymous washing machine. However, the text also provides a metacommentary about the Oramics machine itself and Oram's desire to present it as a novel invention worth investing in for music making. In particular, the notion of controlled parameters is important in relating the Tumblewash machine with the Oramics machine. The voice speaks about different dials that control the temperature and speed of a washing cycle similar to how Oram use film strips to control the musical parameters of Oramics. Thus, the advertisement tries to convince the listener that Tumblewash and Oramics provide a convenient solution to the operational limits of handwashing and acoustic instrument respectively.

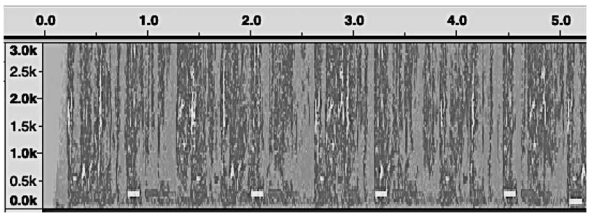


Example 4. Spectrogram of Spoken Voice with Oramics (1:33-1:37.5).

Spectrogram analysis of the vocal lines overlaid with chirping sounds shows an interwoven texture that supports the connection between the Oramics and Tumblewash machines. In Example 4, the speaker says "with a gentle tumbling action that forces suds through every fiber." The vocal line has a complex frequency profile, shown in bright lines under 1 kHz, and shifting intonation with each spoken word. This contrasts with the glissandi-like effects in the Oramics line which hover in a comparitavely smaller, frequency range of 1.5 to 2 kHz in Example 4. The clearest point of this effect in between 1:34.5 and 1:35.5. The chirping sounds conjure images of dripping water, representing suds passing through the fibers of the voice's sound, while an ostinato figure reminds listeners of a "gentle tumbling action."

Treatment of Time and Form

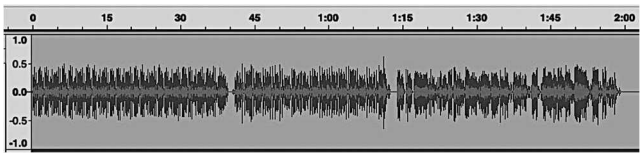
Regarding rhythm, density, and texture in *Tumblewash*, there is a clear sense of movement and proportion despite the use of looping. Oram wants the listener to hear a rhythmic pulse while simultaneously allowing the wash of looped aquatic noises to sound unordered and spontaneous. Since we do not have the Oramics graphs for this piece, looking at a spectrogram of a larger segment of music allows us to trace some of the patterns in rhythmic structure. Example 5 shows the first five seconds of *Tumblewash* with a bass line marked with bright shade similar to Examples 2 and 3. The straight line indicates that this is a sound produced through the Oramics machine. Comparing the rhythm of the bass note with the swishing water theme shows that there are in an equal 4:1 ratio, similar to the equal beat of a washing machine at work. Moreover, this ratio is nested since each phrase of the melody is four groupings in length as shown by the change that after the fourth bass note of the pattern in the 0:05 marker in Example 5.



Example 5. Bass Melody Opening (0:00.0-0:05.5).

As composer Lyn Goeringer notes in her 2016 article "The Recordist as Enunciator; Looping in the work of Delia Derbyshire and Daphne Oram," which looks at *Tumblewash* through its implied meanings, the piece is structured formally to represent human progress towards the space age. Goeringer writes the "looped water sound implies mechanical motion, while the electronic tones sounding above imply the future, where our laundry is automatic [and] timely" (Goeringer 2016). Looking at the form of the entire piece shows that the nested patterns found in Example 4 are found on the scale of the entire piece, which directly support Goeringer's argument that the implies organized motion towards a future goal. Example 6 looks at the waveform graph for the entire piece and reveals that one-second moments of silence break up the three parts of the composition almost equally. The use of silence

creates a sudden sonic shift akin to a mechanical lever or switch which reinforces Goeringer's observations of mechincal motions in the work.



Example 6. *Tumblewash* Waveform (0:00-2:00).

Using the short pauses as section breaks, *Tumblewash* can be divided into three large units, which are labeled Part 1, Part 2 and Part 3 in Example 7. The first one focuses on a bass melody, the second one focuses on a treble melody, and the last one features the spoken voice which contextualizes the first two. The voice in Part 3 is accompanied by musical material introduced in Part 1 and Part 2. However, the proportions are not equally divided in Part 3, with the full, 32 seconds of Part 2 being included but only 6 seconds of Part 1. This reflects Oram's spontaneity in her approach to form, imbuing the mechincal sounds with a improvisatory turn in dialogue with the vocal recitation. By the end of Part 3, Oram's vision of combining acoustic and electronic sound becomes evident rhythmically since recitation recitation speed becomes entangled with metric groupings established by the water loop and electronically produced tones.

Conclusion

In Daphne Oram's view, "indeterminacy has its place in our machines… it adds richness, it confirms individuality" (Oram 1972: 101). While *Tumblewash* shares many techniques with electronic music from the 1950s and 1960s, notably loops and sampling from *musique concrète* and other tape music styles, it takes into consideration the Oramics philosophy of thinking beyond the common scope of standard electronic music perception at the time. By creating an almost improvisatory feel through short, melodic blips and a free flowing recitation within a consistent metric pattern in loops and nested rhythms, the composer crafts a unique style that fits the philosophical ideas she advocated to younger generations. Though her Oramics machine did not catch on within the mainstream of electronic music in the 20th century, Oram's blend of organized sound control and free flowing spontaneity provides an important historical approach to electronic music, cleaning sounds of their "classical recipes" for greater musical expressiveness.

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Part 1 0:00-0:40 (40")	Silence (1")	**Part 2** 0:41-1:13 (32")	Silence (1")	**Part 3** 1:14-2:00 (46")		
• Splashing water loop • Oramics bass melody		• Popping bubble loop • Oramics treble melody		1:14-1:22 (8") • Spoken voice alone	1:22-1:28 (6") • Voice + Part 1 Music	1:28-2:00 (32") • Voice + Part 2 Music

Example 7. Graph of Formal Analysis of *Tumblewash.*

[Abstract in Korean | 국문 요약]
청소하는 소리: 오람의 텀블워시 분석하기

에릭 델가도

본 논문에서는 다프네 오람 Daphne Oram 의 작품 텀블워시 Tumblewash 를 살펴보고 사운드에 대한 작곡가의 생각이 어떻게 작품에 반영되었는지를 조사한다. 주파수 및 스펙트로그램 분석은 녹음된 음향 사운드와 오라믹스 Oramics 기기로 만들어진 합성 사운드 간의 관계를 보여준다.

주제어: 텀블워시, 다프네 오람, 테잎음악 분석, 스펙트로그램, 오라믹스.

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Music from Second Sound: How Advanced Physics Inspired Der Rufer for percussion quartet

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This report will discuss how principles from the advanced physics of cryogenics influenced my composition Der Rufer for percussion quartet. In this paper I explain how I translated information and concepts from superfluid helium (He II) to music composition. Achieved using different methods ranging from purely intuitive to quasi-quantitative, I transferred the following eight principles from ultra-cold physics into organized sound, including: anisotropy, isotrophy, vortices, vortex rotation, bifurcations, mutual friction, turbulence past an obstacle, and second sound. Written for Professor Olaf Tzschoppe, director of the Bremen Percussion Quartet, this work is the first result of a planned long-term collaboration with J.G. Weisend II, a Deputy Head of Accelerator Projects at the European Spallation Source (E.S.S.).

Keywords: European Spallation Source (E.S.S.), Superfluid turbulence, Music composition, Art-science collaboration, percussion instruments.

Der Rufer is a composition I wrote for the Bremer Schlagzeugensemble directed by Professor Olaf Tzschoppe and premiered in Theater Wrede (Oldenburg, Germany) in Sept 2021. This composition is the first result of a planned, long-term collaboration between Lund University/Malmö Academy of Music and the European Spallation Source (E.S.S.). The E.S.S. is a multi-disciplinary research facility based on the world's most powerful neutron source, whose goal is to enable scientific breakthroughs in research related to materials, energy, health and the environment, while addressing some of the most important societal challenges of our time. In the first step of this cooperation, I collaborated with J.G. Weisend II, a Deputy Head of Accelerator Projects at E.S.S. looking at the issues surrounding Superfluid Turbulence. Specifically focused on a property of cryogenics, known as superfluid helium (He II), we investigated ways to transmit processes used in cooling superconducting magnets used for MRI machines and particle accelerators, to organized sound by loosely modeling phenomena found in He II.

What is Superfluid helium (He II)?

He II is a phenomenon from quantum mechanics (the branch of physics that deals with the behaviour of matter and light on a subatomic level) which may be modeled as the flow of fluids that is independent of one another. For example, in figure one we see a normal fluid flowing to the right, while a superfluid stream flowing to the left (see figure 1).

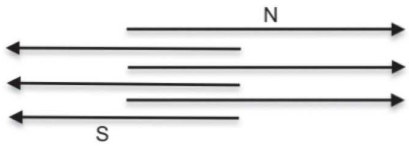

Figure 1. Independent flow in Second Sound.

In He II, the fluid component consists of fluctuations in the density of particle-like thermal (temperature) excitations. These fluctuations occur in regions in which the density of particles are densely to sparsely packed (see Figure 2). However, since it has no viscosity, superfluid flows are unaffected by fluctuations in particle density of normal fluid flows. With He II the propagation of temperature waves is known as second sound.

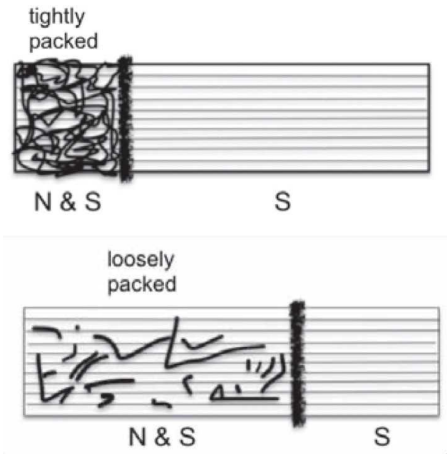

Figure 2. He II may present fluctuations of particle density, from tightly to loosely packed.

Second Sound

Second sound in He II can be understood by considering sounds in our everyday experience. Whether in the office or playing in the park, the sounds we hear involve changes in the density of air, water or even helium. These changes in density are caused by pressure changes, so that molecules packed at higher densities produce regions of higher pressure, while those molecules that are less densely packed produce lower pressures.

In He II we have two types of flows: the normal fluid flow and the superfluid flow. Even though considered to be different flows, the total density in He II is the sum of these two components. Since superfluid flows have no viscosity (energy), those regions dominated by superfluid component will be cooler than those regions rich with normal fluid flow. When regions are dominated by either normal or superfluid components, the overall effect they carry will be of temperature change. These temperature variations are known as second sound.

To compare, first sound is created when pressure changes the density of normal flow, while second sound is created by the alternation of heat pulses or oscillations between hotter and cooler regions in He II. The speed of second sound in He II is roughly 20 m/s which can be compared to the speed of first sound in He II ~ 200 m/s.

Influences of second sound and other properties of He II

In 2020, second sound came full circle.

> Inspired by sound, conceived within physics and then returned to music in *Der Rufer*, second sound became a central influence in this first cooperation of a planned, long-term exchange between Lund University and the European Spallation Source (ESS).

In *Der Rufer,* eight principles from ultra-cold physics influenced the composition, including:

(1) ANISOTROPY, which is the property of substances to exhibit variations in physical properties along different molecular axes, or in other words, looks different from different perspectives(Donelly 1988) (see fig. 3).

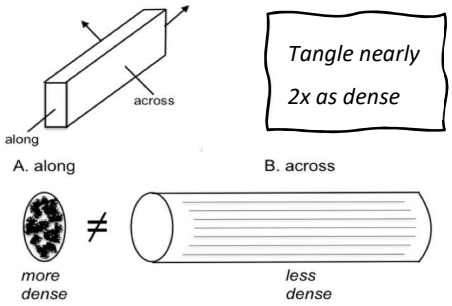

Figure 3. anisotropy

(2) ISOTROPY, which is the property of substances to exhibit uniformity in all orientations(Misner 1968) (see fig. 4).

Figure 4. isotropy

(3) VORTEX, which is the property of fluids to form a spiral. In fluid, a vortex revolves around an axis line, which may be straight or curved. Vortices may be seen in a cup of coffee, or while draining a bathtub. Vortices can move, stretch, twist and interact in complicated ways and are important in turbulence. The velocity within a vortex is greatest next to its core and decreases with distance from its center(Wikipedia) (see fig. 5).

Figure 5. vortex

(4) VORTICES, BEND AND TWIST, which Feynman proposed that superfluids rotate in more complicated ways than normal fluid(Feynman 1955) (see fig. 6).

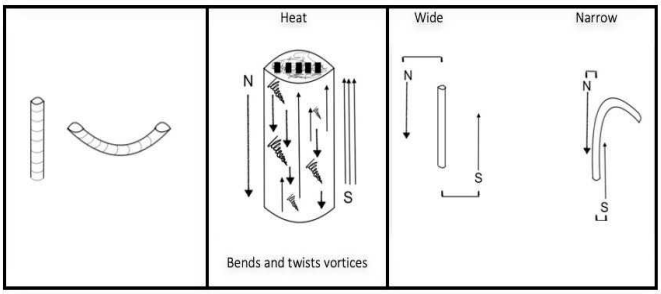

Figure 6. vortices bend and twist

(5) BIFURCATION (quantum leap), in quantum mechanics, an atom must occupy only one energy level. As the atom moves about, it can only acquire energy in set amounts. In order to move to a higher energy state, only a relatively high energy disturbance may drive the atom into a higher state(Williams 2020) (see fig. 7).

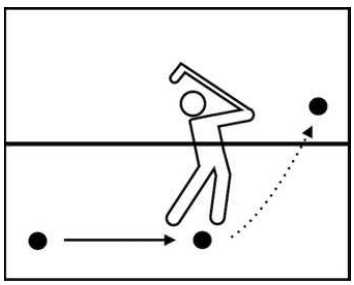

Figure 7. bifurcation

(6) MUTUAL FRICTION, occurs when normal fluid and superfluid are coupled, where velocity and temperature are higher[6]. As friction expands beyond normal fluid to affect superfluid flow, the superfluid begins to extract energy from normal fluid and grow in amplitude(Putterman/ Rudnick 1971) (see fig. 8).

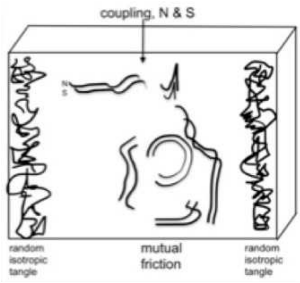

Figure 8. Mutual friction

(7) TURBULENCE, PAST AN OBSTACLE. In normal fluid, turbulence often occurs past an obstacle, like large boulders in a rapids, in the manner of eddies, whirlpools and all manner of vortices. Turbulence decays downstream of the obstacle (see fig. 9).

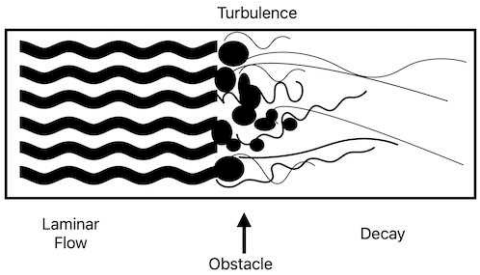

Figure 9. turbulence

(8) SECOND SOUND, is a quantum mechanical phenomenon which propagates through superfluid helium as a temperature wave rather than as a dispersal of energy. It is known as second sound because the wave motion of heat is similar to the wave motion of sound, which consist of fluctuations in the density or pressure of molecules in air. Similarly, second sound consists of fluctuations in the density of particle-like thermal excitations in superfluid.

Another important property of second sound is that superfluid helium consists of two fluid elements that can flow independently of one another. Normal fluid and supersound flow in opposite directions and thus “flow through each other”.

At low temperatures, viscosity disappears in superfluid, contrary to normal fluid where viscosity increases as temperature decreases. Some of the interesting effects from superfluid helium include a fountain that may flow forever due to thermomechanical properties of superfluid with no viscosity; that superfluid helium may climb up the sides of a bucket, and; that in a two-fluid experiment, that normal helium can be trapped by a plate with micro-holes while when cooled to a superfluid, helium can pass through the micro-holes.

Even though the regions of high and low density of normal fluid and superfluid change over time, the overall density remains the same(Balibar; Univ. of Innsbruck; Donnelly 2009; Pellam)(see fig. 10).

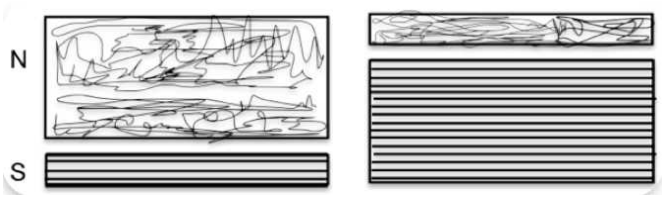

Figure 10. second sound

How was He II represented in music?

In *Der Rufer* I loosely modelled these eight principles in the following ways.

1. ANISOTROPY. That a property will look different from a different perspective, was seen in *Der Rufer,* when a single rhythmic series served as the object viewed from different perspectives. One perspective involved a contradiction; in which active, expressive gestures played over large physical distances on marimba and vibraphone, are muted to lessen the sense of pitch almost completely. The instruments decouple slightly from the monophonic rhythmic series, mirroring entropic processes, which at the end of this first section appears in retrograde (see fig. 11 and sound 1).

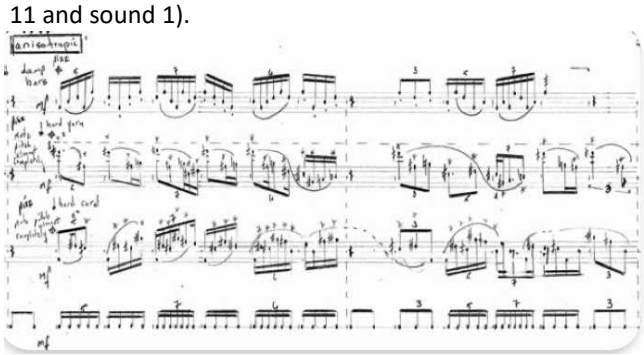

Figure 11. anisotropy

Sound 1. Edgerton. Der Rufer, *anisotropy*
Available to listen at www.keams.org/emille

2. ISOTROPY. Exhibiting uniformity in all orientations I developed material where the performers are asked to perform sustained tones by rubbing a handheld cymbal with drumstick. Referencing orchestral string performance practice, the percussionists are asked to exactly synchronize rubbing patterns similar to synchronized bowing by orchestral string sections, changing up- or down-bow simultaneously. As well, the players are asked to uniformly produce timbral changes on the cymbals that include playing pure tones, increase/decrease of roughness, vary pressure and scrape, changing direction of rub, etc. (see fig. 12 and sound 2).

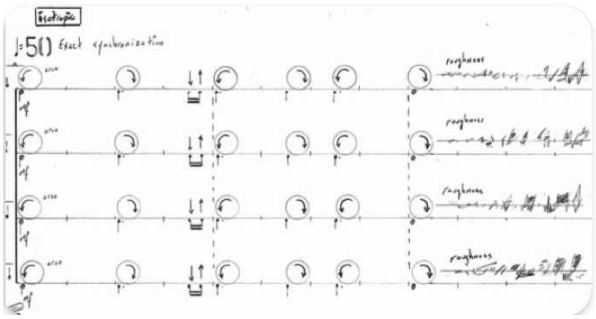

Figure 12. isotropy

Sound 2. Edgerton. Der Rufer, *isotropy*

3. VORTEX. The idea of a fluid forming a spiral was assisted by an evolving cone-like phenomena seen in whirlpools and tornados, etc. (see fig. 13).

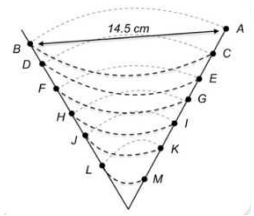

Figure 13. nodes on vortex

Scored for vibraphone and marimba, each with supplemental metal or wood sticks, these vortices produced the most complicated pitch and rhythmic structures in the entire piece (see fig. 14 and sound 3).

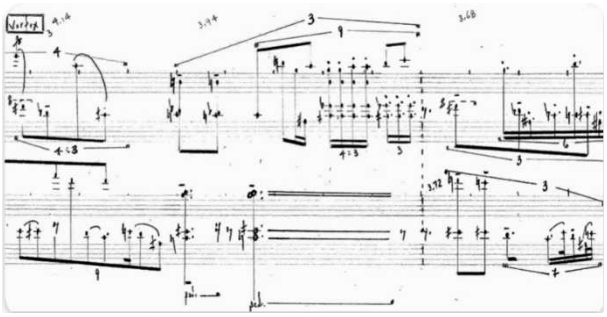

Figure 14. vortex in marimba and vibraphone

Sound 3. Edgerton. Der Rufer, *vortex*

Table 1 shows a nonserial matrix of integers used to generate non-determinative rhythms. These numbers were derived from the physical distance between nodes of a vortex. The measurements were taken at a descending series of nodes, for example the distance between point A and point B equaled 14.5 cm; while the distance between point B and point C equaled 13.8 cm, etc. In total there were 17 points, producing 16 lengths (see fig 15). In order to build in variation and develop scaling that would allow for intuitive control, I transposed this initial integer series downward, so that there were 21 integer series in total.

1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9
14.5	13.18	11.15	9.66	8.5	7.63	6.9	6.3	5.8	5.37	5	4.67	4.39	4.14	3.91	3.7	3.5	3.37	3.22	3.08	2.95
13.8	12.54	10.61	9.2	8.11	7.26	6.57	6	5.52	5.11	4.75	4.45	4.18	3.94	3.72	3.53	3.36	3.2	3.06	2.93	2.81
12.9	11.72	9.92	8.6	7.58	6.78	6.14	5.6	5.16	4.77	4.44	4.16	3.9	3.68	3.48	3.3	3.14	3	2.86	2.74	2.63
11.85	10.77	9.11	7.9	6.97	6.23	5.64	5.15	4.74	4.38	4.08	3.82	3.59	3.38	3.2	3.03	2.89	2.75	2.63	2.52	2.41
10.7	9.72	8.23	7.13	6.29	5.63	5.09	4.65	4.28	3.96	3.68	3.45	3.24	3.05	2.89	2.74	2.6	2.48	2.37	2.27	2.18
9.52	8.65	7.32	6.34	5.6	5.01	4.53	4.13	3.8	3.52	3.28	3.07	2.88	2.72	2.57	2.44	2.32	2.21	2.11	2.02	1.94
8.35	7.59	6.42	5.56	4.91	4.39	3.97	3.63	3.34	3.09	2.87	2.69	2.53	2.38	2.25	2.14	2.03	1.94	1.85	1.77	1.7
7.23	6.57	5.56	4.82	4.25	3.8	3.44	3.14	2.89	2.67	2.49	2.33	2.19	2.06	1.95	1.85	1.76	1.68	1.6	1.53	1.47
6.18	5.61	4.75	4.12	3.63	3.25	2.94	2.68	2.47	2.28	2.13	1.99	1.87	1.76	1.67	1.58	1.5	1.43	1.37	1.31	1.26
5.23	4.75	4.02	3.48	3.07	2.75	2.49	2.27	2.09	1.93	1.8	1.68	1.58	1.49	1.41	1.34	1.27	1.21	1.16	1.11	1.06
4.38	3.98	3.36	2.92	2.57	2.3	2.08	1.9	1.75	1.62	1.51	1.41	1.32	1.25	1.18	1.12	1.06	1.01	0.97	0.93	0.89
3.63	3.3	2.79	2.42	2.13	1.91	1.72	1.57	1.45	1.34	1.25	1.17	1.1	1.03	0.98	0.93	0.88	0.84	0.80	0.77	0.74
2.99	2.71	2.3	1.99	1.75	1.57	1.42	1.3	1.19	1.1	1.03	0.96	0.9	0.85	0.8	0.76	0.72	0.69	0.66	0.63	0.61
2.44	2.21	1.87	1.62	1.43	1.28	1.16	1.06	0.97	0.9	0.84	0.78	0.73	0.69	0.65	0.62	0.59	0.56	0.54	0.51	0.49
1.98	1.8	1.52	1.32	1.16	1.04	0.94	0.86	0.79	0.73	0.68	0.63	0.6	0.56	0.53	0.5	0.48	0.46	0.44	0.42	0.4
1.6	1.45	1.23	1.06	0.94	0.84	0.76	0.69	0.64	0.59	0.55	0.51	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.34	0.32

Table 1. nonserial matrix

Five three-dimensional vortices were modelled and then mapped upon a two-dimensional space, where the relative height of each point was translated into pitch. However, for time and rhythm, I did not develop a new matrix for each vortex, as it was important to build in as much redundancy as possible, while still retaining a certain level of real-world complexity (see fig. 15).

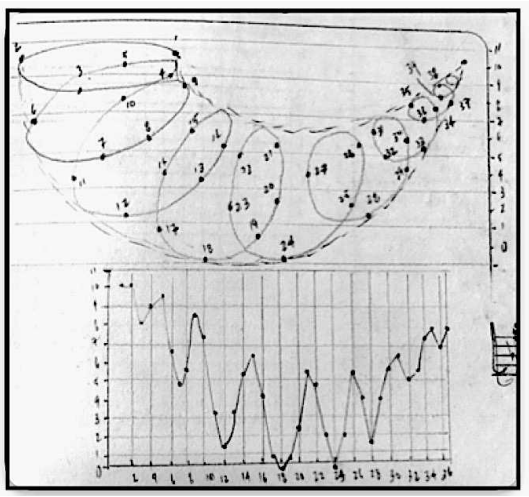

Figure 15. mapping of distance between nodes

How did I translate numbers into rhythm? Below I show one example. It was important for me that the process allowed for intuition and not mechanical reproduction. If we look at table one, I chose to interpret the matrix beginning with a descending series (not inversion in the classical 12-tone matrix)(Scheonberg 1995) at 4.14 moving to 3.94, then to 3.68, etc. Then to interpret each number sequence, I followed the general process:

How did integers become rhythms?

> I. Generally, the first integer defines the division/subdivision or iteration of the allotted timespan, then
>
> II. the second integer defines the division of any sub-unit, then
>
> III. the last integer defines the closing of the gesture

Figure 16 presents an interpretation of 3.94.

The first number (3) identified a division or iteration of the time span allotted to the figure. For example, in fig 16 the numbers used were 3.94. As we can see the overall length of the timespan is divided by a triplet.

Next, the second number (9) is asked to control one of the pre-final sub-units. In figure 16 we see that the first pulse is a single half-note. This is followed by 9-tet (9:2) spanning the second and third elements of the triplet.

Then, the third number (4) defines the closing part of the gesture. In this example, the final number becomes a 4:3 tuplet (see fig 16 and sound 4)

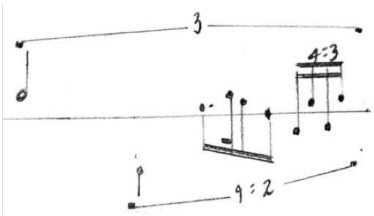

Figure 16. application of integers to rhythmic notation

Sound 4. Edgerton. Der Rufer, *integer to rhythm*

4. VORTICES, BEND AND TWIST. Feynman proposed that superfluids rotate in more complicated ways than normal fluid. So, in *Der Rufer*, I focused on the idea that normal and superfluid flows can bend and twist vortex cores if/when they come within a critical bandwidth. In *Der Rufer,* there are three appearances of this influence, which were musically interpreted as unusually sustained legato gestures pairing marimba and vibraphone with voice (see fig. 17 and sound 5).

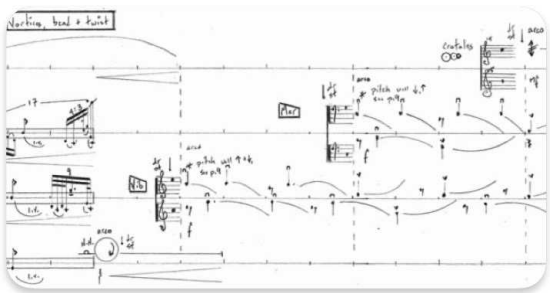

Figure 17. interpretation of bent vortex

Sound 5. Edgerton. Der Rufer, *vortices, bend and twist*

When the voice appears, it is playing the role of *Der Rufer*. The voice should be nasal and pressed. In the first appearance of this material, the voice should be in a moderately high tessitura as it mimics the gestures of the vibraphone. In the second appearance of this material, the voice is to mimic the marimba which is played arco-rub with a superball mallet, which will produce pitch contours in a considerably lower tessitura than when vib is rubbed with drumstick. While mimicking the instruments, the voice performer is asked to sing a Greek text (notated with IPA symbols) which could be the sort of thing a stentor would intone to his troops on the way to battle. The texts, written by me in Greek, are translated into English below:

"send young man on foot into holy sea,
away from war with truth"

"fear not child"

"fear not death"

"work with God"

"write with truth".

In the final section, the voice reappears, again in a higher tessitura and this time accompanying him/herself with a large tom-tom to emphasize and reinforce the strong nature of the message s/he is sending. At the end of the piece, all instruments, including the voice become softer. However, the performer is asked not to lose energy, as the idea here is that the sounds become softer due to distance, as if the soldiers were marching further away in the distance (see fig. 18 and sound 6).

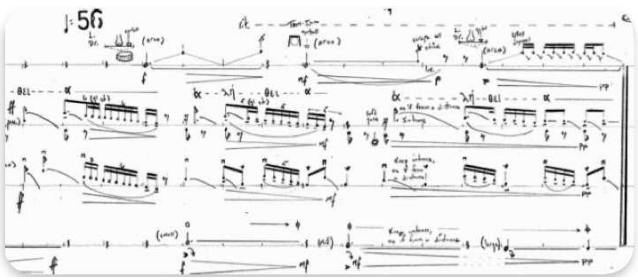

Figure 18. vortices, bend and twist

Sound 6. Edgerton. Der Rufer, *idea of stentor*

5. BIFURCATION (Quantum Leap). Here, I focused on the idea that in quantum mechanics an atom must occupy only one energy level, and that only high energy disturbances can drive fluid into a higher state. Based upon energy change, these quantum Leap gestures are accompanied by a change of tempo and dynamic.

Then, since a high energy disturbance is needed to drive the fluid to a higher level, I produced energy changes using cresc/decresc with the sustained rubbing of the Tibetan cymbal or tam-tam (see fig 19 and sound 7).

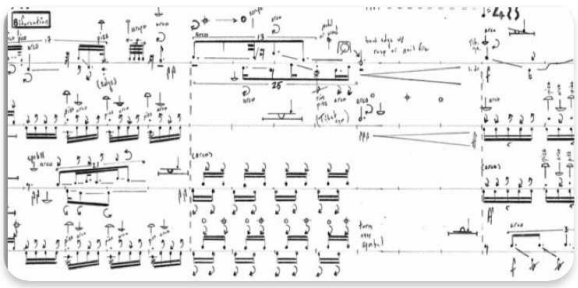

Figure 19. quantum leap

Sound 7. Edgerton. Der Rufer, *bifurcation*
Sound 7b. Edgerton. Der Rufer, *bifurcation on steriods*

6. MUTUAL FRICTION. In mutual friction, I focused on the idea of attachment between normal fluid and superfluid, so that they drag each other around.

In this material, superfluid is represented by arco-rub on handheld cymbals, while normal fluid is represented by rhythmically active pizz and arco gestures on the other instruments. Representing friction, I've asked the performers to produce timbral changes to the arco rub motions on the handheld cymbals (see fig. 20 and sound 8).

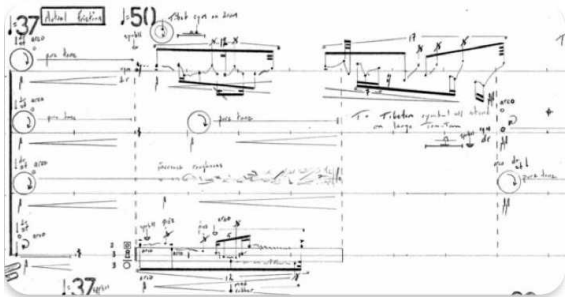

Figure 20. mutual friction

Sound 8. Edgerton. Der Rufer, *mutual friction*

7. TURBULENCE, PAST AN OBSTACLE. Focusing on the idea that turbulence which occurs downstream of an obstacle progressively decays over time, I wanted to build in a quasi-narrative structure in which laminar flow is interrupted by a loud crash, imitating an obstacle in a stream. After this obstacle, turbulence is represented by soft rattles, scratches, tremolo and all manner of eddies and whirlpools, all which decay over time (see fig. 21 and sound 9).

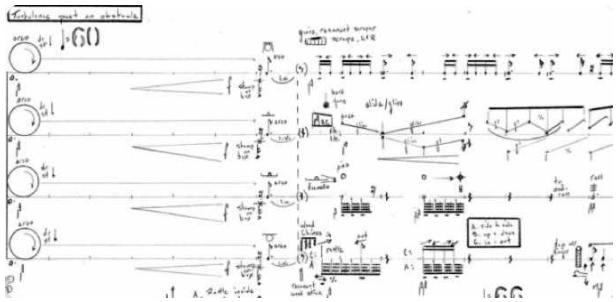

Figure 21. Turbulence past an obstacle

Sound 9. Edgerton. Der Rufer, *turbulence, past an obstacle*
Sound 9b. Edgerton. Der Rufer, *turbulence, to an obstacle*

8. SECOND SOUND. I set up a process in which a wavelike phenomenon features alternating regions of tightly and loosely packed normal fluid molecules, while the superfluid remains unaffected since S has no viscosity.

In these sections, Superfluidity is represented by arco-rub on handheld cymbals, while normal fluid is portrayed by pizz and arco production within their corresponding multipercussion setups (see fig. 22 and sound 10).

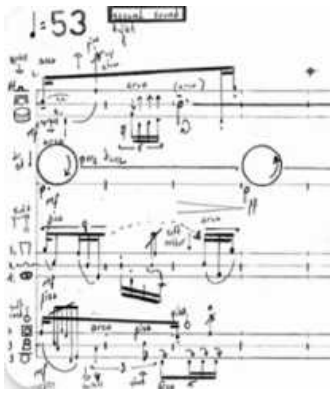

Figure 22. second sound

Sound 10. Edgerton. Der Rufer, *second sound alternation of tightly and loosely packed fluid*

The materials were organized around four principles that were mixed and matched including: (1) tightly packed normal fluids, (2) loosely packed normal fluids, (3) normal fluid, featuring high viscosity, (4) superfluid featuring low/no viscosity. A final controlling principle in these gestures are that the overall density must stay constant. In general, the character of the second sound material features heterogeneous textures of rhythmically active + tightly packed motion versus more static + loosely packed motion (see fig. 23 and sound 11).

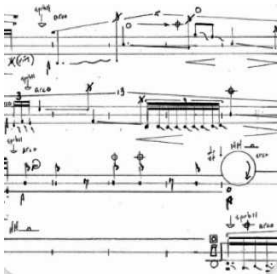

Figure 23. second sound

Sound 11. Edgerton. Der Rufer, *overall density stays constant whether heterogenous or homogenous texture*

The title, "Der Rufer" refers to what?

The title, "Der Rufer", refers to a sculpture in Bremen by Gerhard Marcks that refers to a Greek Herald from Homer's Iliad (see fig. 24).

Figure 24. Sculpture Der Rufer by Gerhard Marcks in Bremen, Germany

On the base of the sculpture is written:

> Der Rufer von Gerhard Marcks (1889 –1981)
>
> Der Rufer ist der Figur des Stentor nachempfunden, der mit gröherziger und ehernen Stimme so laut rief wie fünfzig Männer. (Homer, Ilias, 730 v. Chr.)

Der Rufer is modeled on the figure of the stentor (Herald, bard, or crier) who shouted as loudly as fifty men in a generous and brazen voice. (Homer, Iliad, 730 BC)

> Die drei Meter hohe Bronzeskulptur wurde 1967 von Gerhard Marcks im Auftrag von Radio Bremen geschaffen. Am 25 November 2007 wurde der Rufer vor dem Neubau von Radio Bremen an der Weser aufgestellt.

The three-meter-high bronze sculpture was created in 1967 by Gerhard Marcks on behalf of Radio Bremen. On November 25, 2007, *Der Rufer* was placed in front of the new Radio Bremen building on the Weser river.

Conclusion

In conclusion, we show how concepts and ideas from the advanced physics of cryogenics was useful for the creation of a new artistic work. Specifically, this involved translating eight principles from ultra-cold physics into sound, including: anisotropy, isotrophy, vortices, vortex rotation, bifurcations, mutual friction, turbulence past an obstacle, and second sound. Each of these principles were loosely modeled into music in ways that translated an active process across modalities. One such example was that of Anisotropy, or the idea that something will look different from a different perspective. When translated into sound, one interpretation was that an active rhythmic gesture was heard from different perspectives by varying the intervals of a fast-moving passage from a stepwise motion into passages with large leaps thrown in, while continuing to play fast; or by damping the bars of vibraphone and marimba nearly completely, so the effect of extreme amplitude difference become holes within a flowing stream of corrupted information. In this paper there is no claim regarding the effectiveness of method in this transference of ideas and/or processes from science to art. There is no attempt to posit any grand narrative, while *Der Rufer* on the surface bears resemblance to modernist narratives, my feeling is that there is something else at work here; which, while not having any overt resemblance to nature, still does retain some percept to real life.

European Spallation Source. ESS, based on the world's most powerful linear accelerator, is one of the largest users of He II in Europe. At ESS, He II cools the superconducting RF cavities that provide the bulk of acceleration for the proton accelerator that drives what will be the world's brightest neutron source. Research using neutrons at ESS will enable scientific breakthroughs in a wide range of fields including: materials, health, energy, the environment and engineering. More information on ESS may be found here: https://europeanspallationsource.se

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[Abstract in Korean | 국문 요약]

제2음파의 음악: 어떻게 진보물리학이 타악기사중주를 위한 요한상을 이끌어내었나

마이클 에드워드 에저튼

이 글은 극저온학의 진보물리학 원리가 저자의 작품, 타악기 4중주를 위한 요한상Der Rufer(고문의 희생자를 추모하며 평화를 의미하는 독일의 동상) 작곡에 어떤 영향을 미쳤는지 논의한다. 이 논문에서 저자는 초유체 헬륨He II의 정보와 개념을 음악 작품으로 어떻게 변환했는지 설명한다. 순전히 직관적인 것부터 준정량적인 것까지 여러 다양한 방법을 사용하여, 초저온 물리학의 다음 8가지 원리를 따라 체계적으로 사운드로 전환해내었다: 여기에는 등방성과 이방성, 소용돌이와 소용돌이 회전, 분기점, 상호 마찰, 장애물을 지나는 난류 및 제2음파가 포함된다. 브레멘 타악기 4중주단의 지휘자인 올라프 츠초프Olaf Tzschoppe 교수를 위해 작곡된 이 작품은 유럽파쇄원European Spallation Source(E.S.S.)의 가속기 프로젝트 부국장인 바이젠트2세J.G.Weisend II와의 장기 협력 계획의 첫 번째 결과물이다.

주제어: 유럽 파쇄원(E.S.S.), 초유체 난류, 음악 작곡, 예술과 과학의 협업, 타악기.

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Jonathan Harvey's *Mortuos Plango, Vivos Voco*: The Electronic Sacred

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Jonathan Harvey's 1980 electroacoustic piece *Mortuos plango, vivos voco* features compositional strategies with a strong mystical side. Its dualism of life/death elements, both linked to different sound materials (voice and bell respectively), encourages a meditation that involves the listener's inner dimension, thus providing the basis for a re-humanization of electronic music.

Keywords: J.Harvey, electroacoustic repertoire, electronic sacred music

Mortuos plango, vivos voco is an eight-channel electronic piece that Jonathan Harvey composed in 1980 following an invitation to IRCAM by Pierre Boulez: an event that would profoundly mark Harvey's style throughout his subsequent musical career.

This turning point is evident in the analysis of Harvey's catalogue, from which it is clear that the British composer had sporadically dedicated himself to electronic compositions before. *Mortuos plango, vivos voco* is an actual manipulation of a bell sound, analysed in its spectral content and synthesized together with a treble voice, resulting in a most interesting bell-boy effect (Roads 1996) which provides each sound with the spectral characteristics of the other. (Downes 2009)

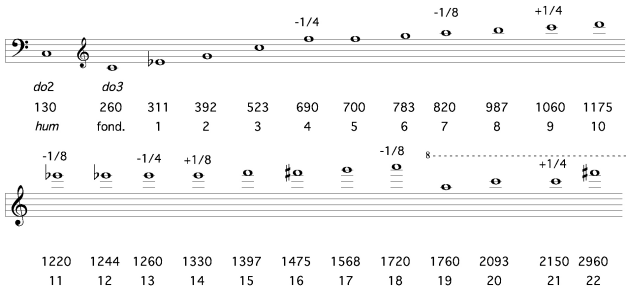

Figure 1. The first 22 partials of the bell's sound show the complexity of its spectrum.

Context

The creative and generative idea behind *Mortuos plango, vivos voco* is explained by Harvey himself.

> From 1976 to 1980 my son Dominic was a chorister at Winchester cathedral. During that period, and ever since, I have written a number of works associated with that wonderful building and choir. Listening to the choir rehearse, as I often did, with the bells simultaneously ringing above, was one of the mingled impressions which started me on this work: it is entirely based on the boy's voice and that of the largest bell. On this huge black bell is inscribed in beautiful lettering the following text: HORAS AVOLANTES NUMERO, MORTUOS PLANGO, VIVOS AD PRECES VOCO [I count the feeling hours, I lament the dead, I call the living to prayer]. (BBC archive 2005)

The spectral analysis of the ringing of the Winchester Cathedral bell revealed that it is made up of 33 partials. During the creation of the piece, the composer, assisted by IRCAM technicians, found himself able to pass seamlessly from the pure voice of his son to the spectrum of the bell, and the entire compositional structure is based on these pitches and on the harmonies which are generated by them. As for the analysis and re-synthesis part of the bell spectrum, the software Harvey used is MUSIC V implemented by Max Mathews. (Mathews 1969)

Other software used in the creative process of *Mortuos plango, vivos voco* is CHANT, developed by Gerald Bennett and Xavier Rodet, which was used for the vocal synthesis of the boy's voice synthesized starting from a live analog recording. (Dirks 2007)

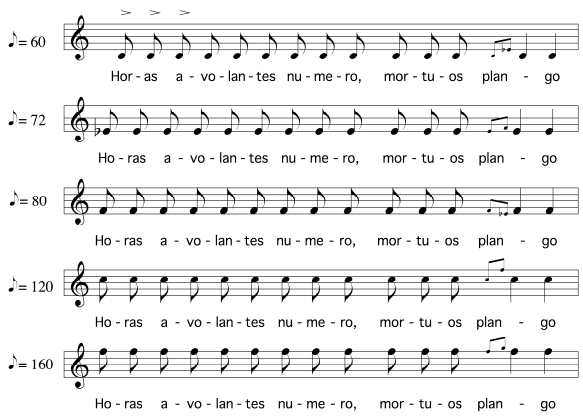

Figure 2. The text sung by Dominic Harvey.

The complexity of the bell sound has been pointed out by IRCAM scholars. (Harvey 1981)

Compositional strategies and significance

The choice of the presence of a bell sound and a human voice together is explained by Harvey himself in philosophical rather than aesthetic terms: the bell, which marks time, represents the element linked to death; the son's voice, on the other hand, represents life, the vivid spirit that Harvey puts into the electronic composition in order not to produce a completely dehumanized piece. Furthermore, the physicality of the bell represents a sort of a container in which the listener is ideally placed, while the boy's voice flies around him, in the composer's intentions, "like a free spirit". (BBC archive 2005)

The continuous, uninterrupted passage from the synthetic simulations of the bell to the voice of his son, as Harvey himself said, produces an alienating effect of a journey into an unknown territory, due precisely to the sophisticated mix of live sounds and synthetic sounds that the piece implements.

Mortuos plango, vivos voco is divided into eight sections, each of which is announced by one of the principal partials of the bell spectrum. The higher the partial, the shorter the duration of its own section. (Dirks 2007)

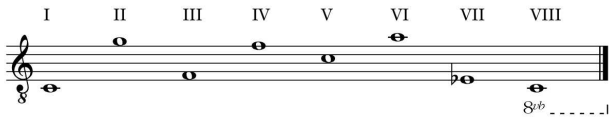

Figure 3. The eight partials of the bell introducing each section of the composition.

The compositional strategies implemented in *Mortuos plango, vivos voco* reveal a structure by juxtaposition in which the eight formal sections into which the piece is divided are exposed one after the other. The constitutive structure is therefore precisely of the type A B C D E F G H, with each section clearly identified by the initial tolling of the bell, highlighted by some scholars as a very important element at the level of sound objects and therefore developed in each section. (Giomi-Ligabue 1996)

The analysis of the formal layout of the composition results in a first section with an introductory function, while the subsequent five sections exhibit a characteristic of autonomy; without constituting a real development, they nevertheless introduce new or reworked elements from time to time, always characterized by a spectral uniformity.

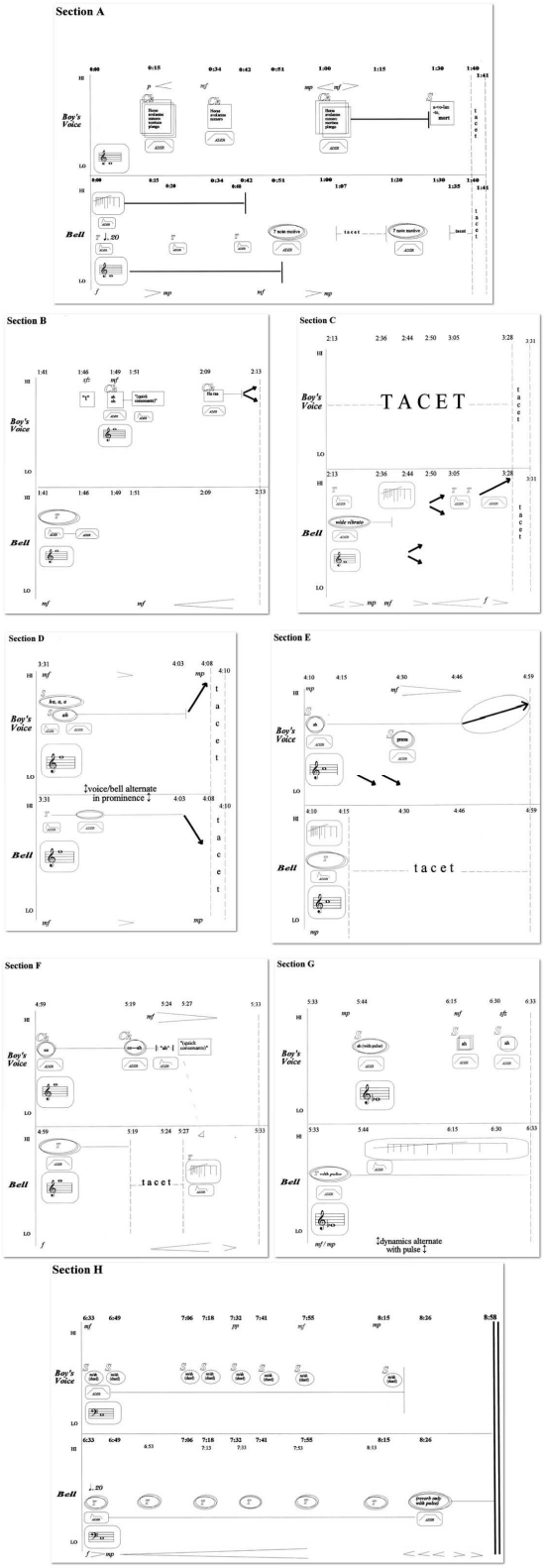

Figure 4. The eight sections of the composition.

This interrelation between elements constitutes the organizational nucleus of the sound material: it appears to flow into a linguistic whole which, in accordance with the *Gestalt* principle, is very different from the mere sum of the parts, and therefore assumes a peculiar perceptive meaning. (Koffka 1935)

The last two sections act as a finale, always characterized by the general sense of absence of motion which constitutes perhaps the main formal element in *Mortuos plango, vivos voco*.

From a structural point of view, a homogeneous tension can be seen in the first four sections, followed by a slight intensification of expectations up to the final relaxation. However, these structural movements do not form an actual arch, but rather show a meditative and generally unchanging character.

Re-humanizing the electronic experience: a mystical path

Mortuos plango, vivos voco is a piece that skilfully implements an expressive connection between the inner dimension of prayer, intended in an almost psychological sense and in any case from an inter-religious perspective, and the extrinsic dimension of musical fruition, also thanks to the semantic multiplicity assumed by the elements of the piece itself.

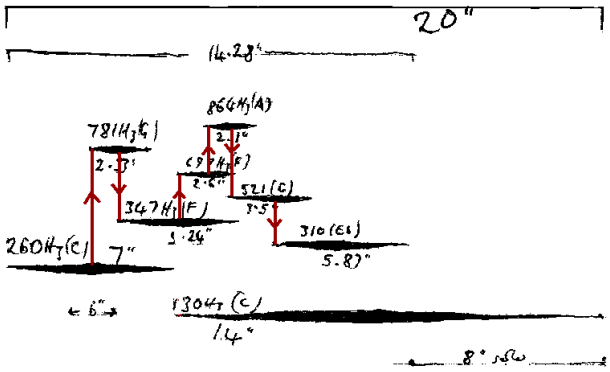

Figure 5. A page from Jonathan Harvey's developing notes.

The formal arrangement constituted by the presence of the two timbres, which intertwine in order to become the very structure of the piece, has as a counterpart the resolution of the dualism between elements linked to life and elements linked to death.

In this regard, it should be noted that although the composer, in his own expressive imagination, has declared that he has associated the sound of the bell with something dead and his son's vocals with something alive, in reality the spectral richness of the bell, combined with the humanity of the boy's voice, determines an inseparable whole where the elements of life and death, two sides of the same reality, provide the occasion for a deep individual meditation on the piece, where the sacred is represented both by the purity of the boy's voice and the bell itself with its connections to churches. (Metzer 2009)

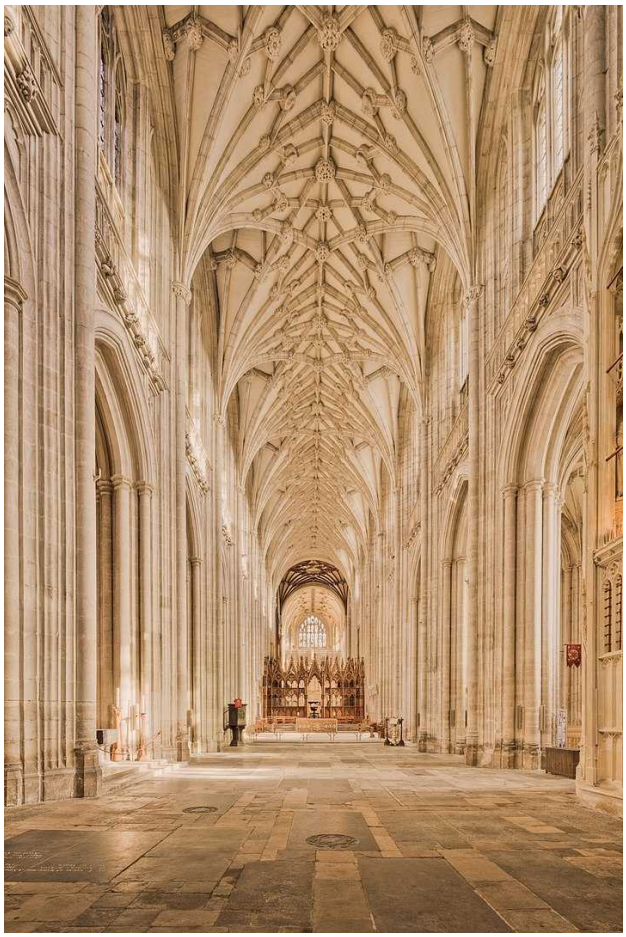

Figure 6. Winchester Cathedral.

Harvey's intention of trying to place the listener inside the bell itself has the idea of an extreme emotional and almost psychoanalytic involvement in the sound experience with its semantic implication, which literally surrounds the listener: according to Harvey's own words, the attempt is to become music ourselves, overcoming any dualism and any separation from it. (Emmerson 2017)

The meditative and mystical side of this total immersion into music is evident. "Far from creating spectacular effects, sound textures reflect the unity and intimate mixing of human beings who are at once physically rooted in a limited temporality and connected to a timeless and impalpable spirituality". (Bossis 2008)

The expressive resonances deriving from the spectral processing between the frequencies of the voice and the

frequencies of the bell are the ultimate mystical space of the composition. The space of resonances of the boy-bell, despite its spectral richness and structural complexity, can be filled by the listeners with their own individual feelings and with the projection of their own inner experience into the body of the bell, in a mystical experience of constant, calm meditation. For Jonathan Harvey, musical expression goes beyond "dichotomy between object and subject. The music is aimed at a *beyond*, both embracing this duality object/subject in a higher unity, and content in renunciation and emptiness". (Bossis 2008)

In *Mortuos plango, vivos voco* electronic elements are far from being a mere scientific research that may appear distant from spirituality and meditation. On the contrary, the manipulation of the spectrum of electronic sounds provides a strong connection with the inner dimension of the human soul.

> The spectral manipulation is also an open window to contemplation. To directly organize inside the sounds, it is necessary to compose outside and inside of any music. Acting both on the verticality of the frequencies of the partials and on the horizontality of the sounds' temporal morphology, the spectral work using electronics involves a principle of unity. The spectral manipulation also questioned the ambiguity between a chord or a cluster of notes and a unique sound including partials. Intervallicism can shade into and out of spectralism, and it is in this ambiguity that much of the richness in this approach lies. (Bossis 2008)

Thus, the transcendent qualities of the sounds are highlighted and made available by the manipulation of the spectrum; the electronic sound also reveals a mysterious universe of hybridization, mystical qualities, ambiguity and a poignant, intense dimension of spirituality. "The composer reveals the inmost essence of the world and utters the most profound wisdom in a language which his reason does not understand". (Schoenberg 1950)

Such words perfectly fit the world of electronic music, too, and definitely look at a future of re-humanization of the electronic sound including the importance of its sacred, mystical and transcendent elements.

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[Abstract in Korean | 국문 요약]
조나단 하비의 '죽은 자를 애도하고 산 자를 부르는': 전자적 신성함

카를로타 페라리

조나단 하비Jonathan Harvey의 1980년 전자음향 작품 '죽은 자를 애도하고 산 자를 부르는Mortuos plango, vivos voco'은 강력한 신비로운 측면을 지닌 작곡 전략을 특징으로 한다. 인성과 벨소리의 서로 다른 음향 재료들을 각각 삶과 죽음의 요소와 이중적으로 연결하여, 이 이중성이 청취자의 내면적인 사색과 명상을 유도하게 하고, 그에 따라 전자 음악을 인간적으로 만드는 기반이 되도록 한다.

주제어: 조나단 하비, 전자음향 레퍼토리, 전자 종교음악

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To mix or not to mix: unifying the creative process in composing for instruments and electronics

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The design and composition of music and sound art performance that involves instruments in combination with a variety of electronic components demands a diverse and extensive skill and knowledge set. Pedagogical approaches that guide young practitioners in the creation of "mixed music" composition confront the challenge of striving to equip the composer with the necessary skills and experience drawn from many diverse practices and technologies, some of which are rarely considered in conventional pedagogical contexts. Categories of mixed music, mixed music studies, pedagogical approaches to the teaching of mixed music, and the skills and roles involved in mixed music production are discussed. The objective is to provide a global overview and consideration of the issues involved in teaching, learning and creating mixed music.

Keywords: mixed music, musical pedagogy, mixed music production, electroacoustic music composition.

The term "mixed music" describes the combination of acoustic instruments and voices with a variety of electronic components including pre-recorded audio, live signal processing of an acoustic performance, spatialization of the acoustic performance and/or the resulting processed audio, the use of pre-recorded or live video processing, and the use of electronic instruments, controllers and sensors of many kinds. In most cases, the term implies that there is a combination of several distinct sound worlds, several creative domains requiring specific skills and expertise, and, by extension, a mixture of several distinct modes of design and composition, several separate spheres of knowledge and creativity that are brought together to provide a unique creative framework and result.

In an article penned more than ten years ago, a study was made of the combination and deployment of skills, sounds, techniques and affordances drawn from a number of established categories of compositional endeavor towards a unified mixed music practice (Radford 2008). The focus at that time was on the instrumental forces and technologies employed, their manipulation and effective combination, the types of materials developed, and the sonic and compositional discourse that they afforded. The range of the creative projects reflected to some extent Daniel Teruggi's chronological *taxonomie des musique mixtes* (Teruggi 2016). (See Table 1.)

instruments and tape/pre-recorded audio
electronic instrument(s)
instrument(s) processed in real-time and spatialized
instrument(s) processed in real-time + pre-recorded audio
instrument(s) controlling software via sensors or measurement of frequency, amplitude, movement

Table 1. Taxonomy of mixed music (Teruggi)

A framework of relationships between instrument, technology, sound, time, and compositional concept was explored through a series of projects that emphasized an iterative feedback process and a creative territory shared by and contributed to by all of the components, a context in which constant aural and visual feedback of a technological system supported selection, rejection and decision. Strategies and categories of engagement and exchange of materials, processes and concepts were identified as Dialogue, Adoption, Imitation, and Fusion, with the objective of finding elements and methodologies that unified the creative act as well as the resulting performance and sonic realization. (See Figure 1.) Dialogue depicts distinct elements deployed in instruments and electronics that can function in a complementary or adversarial manner. Adoption indicates a modified or unmodified use of elements from one to the other. Imitation describes a perceivable transfer of either simple or complex elements and processes from instrument to electronics or vice versa. Fusion indicates elements and processes that create a common ground between instruments and electronics, that draws them towards similar and singular sonic structures and energies unfolding over time. This conceptual approach provided clarity in negotiating the trajectories between purely instrumental music, mixed music, acousmatic composition, and the gradual inclusion of interaction and image, moving materials and technologies from one to the other in overtly sonic and sometimes metaphorical ways.

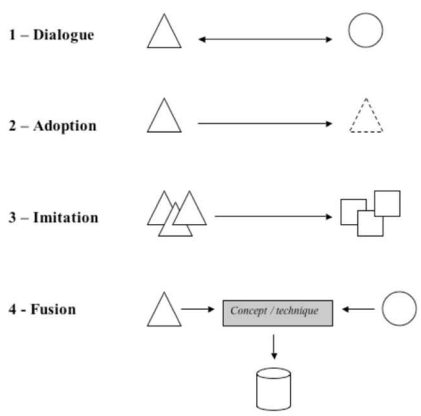

Figure 1. Categories of exchange in mixed music production.

If we jump forward a decade and more from this earlier study, we must update Teruggi's *taxonomie* to accurately reflect the technologies, tools, instrumentation and performance practices that now make up the mixed music palette. (See Table 2.) These numerous preoccupations and developments offer additional potential for new expressive means and equally the additional challenges they represent for the act of unifying the creative process. Perhaps even more challenging is the development and application of effective pedagogical methods that strive for the same unified objectives, methods and creative environments to promote a meaningful journey, decisive or exploratory, between the contributing components, from instruments to software to sound studies to spatial tests to notation to code to performance affirmation and around again according to concept, duration, aesthetics, style, process, and intention.

instrument(s) processed in real-time with video (real-time or pre-constructed)
performance capture (sensors, measurement of frequency, amplitude, movement, signal processing control, spatialization, video, lighting)
video (pre-recorded playback, generation, interaction)
robotics, reactable objects/agents
NIME instruments
DIY/Circuit-bending instruments

Table 2. Current additional instruments and practices in mixed music.

MIXED MUSIC STUDIES

In-depth analyses and studies of pedagogical methodologies in mixed music that provide quantitative or qualitative surveys and reflections on the strengths and weakness of particular approaches, varieties of method, and considerations of educational objectives in particular contexts in which the practice flourishes seem only recently to have garnered attention. This is not to say that there is not a healthy body of writing about various aspects of mixed music practice, from musicological perspectives and especially from compositional experience that is of value in reflecting upon the phases of learning and knowledge and skill acquisition required for practice in the discipline. The growing interest in "live electronics" in general, involving a variety of traditional and new approaches and practices as well as interest in social, cultural and perceptual perspectives of the activity has blossomed recently and it may be that mixed music studies will find a place within this broader field and as part of attention to pedagogical issues that cross over from one area to another providing benefit from a multi-perspectival consideration.

A serious issue that confronts the teaching of mixed music is the lack of a useful and unified analytical approach to mixed music practice and its output. Given the myriad combinations of instruments, voices and technologies, as well as the potential contributions of established types of analytical procedure that address the instrumental writing, the score, the technological means, the compositional concepts, processes and techniques employed for the instrumental and technological component, and the phenomenology of the total acoustic result in terms of local and global temporal and spatial morphology, it would appear wholly daunting to formulate and propose such an analytical methodology. This situation is highlighted in research by Danieli: "literature on mixed-music is difficult to retrieve, as the term 'mixed-music' is rarely addressed as a subject of research (Danieli 2018)." He cites a number of approaches to mixed music analysis by Lalitte (Lalitte 2016), Lewis and Pestova (Lewis/ Pestova 2012) and Andrade (Andrade 2009) that propose semiotic and acousmatic-based models respectively. For example, Philippe Lalitte's approach investigates the network of relationships that exist between instruments and pre-recorded or live electronics. He proposes employing the categories of fusion/opposition, similarity/difference, balance/imbalance, simultaneity/succession to classify and clarify the relationships in the combination of instruments and electroacoustic music writ large in mixed music.

Tremblay and McLaughin propose a pragmatic approach to conceiving of and creating mixed music that addresses the rift between studio-based experimentation, design and construction, the typical environment where mixed music is conceived and elaborated, and the harsh realities of transferring this work to the concert stage, or in their words, a "translation from one acoustic reality to another [in which] translation always involves altera-

tion[,]" as well as the challenge of combining the acoustic signals of instruments and voices with loudspeaker-projected electronic sounds (Tremblay/McLaughlin 2009). Their solutions involve the use of carefully positioned radial instead of axial loudspeakers in the studio and in performance venues to provide an increased sense of connection and intimacy between acoustic performers and their loudspeaker partners; and the use of Impulse Responses from actual concert venues employed to convolve the working materials in the studio to reflect the target acoustic venue and sound system and thus provide a model that more accurately reflects the acoustic reality of the concert experience. Their work places an emphasis on both the performer and listening experience of chamber music settings of mixed music and speaks to the need for a "unified" method that integrates studio and stage, composer and performer and listener in the conception and working out of the compositional details and components.

In a more general sense of learning and teaching music with technology, Hitchcock proposes "…that learning music comprises a range of processes: deconstruction, reconstruction, construction and the peak activity of origination…[that leads to] an array of progressively complex philosophical, intellectual and creative engagements... (Hitchcock 2017)." This broader topic of learning and knowledge acquisition in the field of mixed music draws attention to related and fundamental topics that may serve as the basis for unifying the diverse activities and requirements of mixed music. Given the complexity and diversity of the instrumentarium employed, it is tempting to concentrate solely on the technical aspects involved and to be swayed and guided by readily available or valiantly conquered techniques and affordances. There is value in stepping back and considering the underlying forces and paradigms that regulate current mixed music creation environments, dominated above all by computation at one level or another. The functions active in these creative environments are what media theorist Lev Manovich calls collectively the Language of New Media (Manovitch 2001), a consideration of aspects of the new media landscape that interrelate via numerical representation, modularity, automation, variability, and transcoding. In numerical representation, the media object is described formally (mathematically) and is subject to algorithmic manipulation. The media object is built of interchangeable modular units and is subject to automated operations during creation, manipulation and access. It is variable, unfixed, and can exist in different, potentially infinite versions and can communicate (transcode) with other files and processes on the level of computing organization.

In mixed music production, the sketch, score, sound, and patch are bound together in a world of numerical representation, are modular by the very nature of the interdisciplinary project, require automation at various levels and phases of conception and realization, and are variable and subject to transcoding during design and performance. (See Figure 2.) The iterative and recursive processes involved in new media production are mirrored in the multitasking functions of mixed music practitioners, negotiating meaningful options and decisions from score to screen, from instrument to loudspeaker, from studio to stage. Understanding how this new media "language" leads to new practices and affords integration with instrumental writing and performance opens up the possibility of a cross-fertilization of methods, and effective, iterative journeys back and forth between components in the mixed music project.

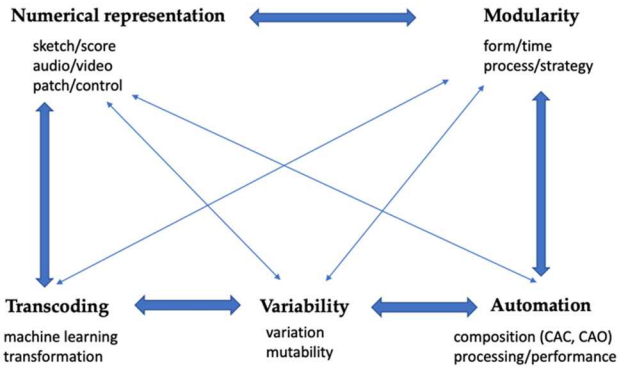

Figure 2. *The Language of Mixed Music* (after Manovich)

Another example of categorical clarification of strategies in mixed music is Robert Rowe's well-known categories for interactive systems, contrasting score versus performance-driven approaches, the use of an instrument versus player paradigm, and the employment of either transformative, generative, or sequenced functions, or some combination of all of the above in music for instruments and computational electronic systems (Rowe 1993). Establishing the technological territory, functions and affordances available at the outset of a mixed music project may frame the various skills required for successfully attaining the creative objectives.

MIXED MUSIC PEDAGOGY

Learning and making music with AV technologies has been increasingly explored in learning in public schools, especially in the United States and the United Kingdom, and have resulted in a growing body of study and research into the varieties of learning environments that music technology provides and its effectiveness for a variety of learning objectives and contexts. In Folkestad,

Hargreaves and Lindstöm's 1998 study of the processes involved in music composition employing computer-based technology, they identified two categories of methodology or approach: a *horizontal method* in which composition, arranging, programming, etc. are separate processes often approached in a linear way in which subsequent decisions during the creative activity are contingent on previous actions and decision, fundamentally teleological in nature; and a *vertical approach* in which the numerous activities of composition with computer-based technology are integrated in the process, intermingled in an iterative and feedback methodology that serves to inform each decision based upon evaluations and re-evaluations of other components of the project (Folkestad et al. 1998). (See Figure 3.)

Adam Bell's case studies of a number of electronic music composers and producers critiqued the *horizontal* and *vertical* approaches to musicking with a variety of current technologies (Bell 2018). He found that it was rare that one could define practitioners' methods as one or the other, and more often, there was a gravitation towards one or the other approach depending on the creative task at hand. In his study, Bell suggested five categories of how individuals learn in the act of music making music employing technology. (See Table 3.)

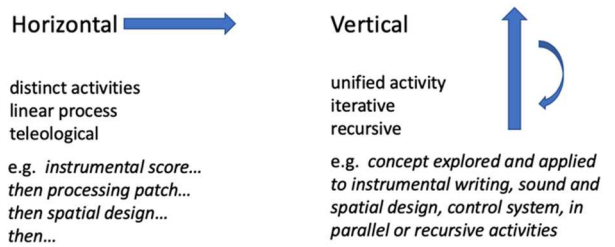

Figure 3. Processes involved in music composition employing computer-based technology.

aural learning, or learning by listening
peer-guided learning
self-directed learning
immersive learning, in which learners assimilate skills and knowledge in haphazard, idiosyncratic, and holistic ways
holistic learning, in which learners integrate listening, performing, improvising, and composing simultaneously throughout the learning process

Table 3. Categories of learning in the act of music making employing technology (Bell)

Musicking that combines acoustic instruments with a variety of processing and interactive audio and visual technologies engages with all of these categories of learning, at different stages of skill and knowledge acquisition, and in different orders and sequences. During the mixed music project per se, these learning paradigms combine with a music technology culture that serves as a map of the mixed music terrain providing "…presets, templates, reused modules, plugins, and shared code that make less cumbersome the creative process that…involves [so] many diverse actions in order to achieve results (Bell 2018)." Bell's last two approaches, immersive and holistic learning, are of especial interest in the mixed music context as they concatenate the first three categories and integrate them into methods that champion trial-and-error, "tinkering," the challenge of "going-beyond-the-presets," of reaching out for assistance to mentors in colleagues, teachers, and online tutorials, and approaches that combine both DIY (do-it-yourself) and DIWO (do-it-with-others) methodologies. In another case, Robertson and Bertelli discuss their experience teaching interactive interface design and composition with their open source "…Conductive Music program [that] incorporates public engagement principles, open-source hardware, DIY ethos, contemporary composition techniques, and educational activities for creative and analytical thinking…[that] impart positive skills through multimedia content delivery for all learning types (Robertson/ Bertelli 2014)." This is related to the general effect of "mediation" with digital tools on compositional practices, not only while using the tools, but the shaping of processes and actions by the impactful presence of the tools within the creative workflow. (See Figure 4.) Dobson and Littleton note that "digital music technologies are anticipatory, they do not need to be present to affect digitally resourced music composition practices" and that these practices are unified in a workflow or "ecology of practice," wherein "the total context of learning and creating – social, psychological, cultural, technological, pedagogical… and the mediational role of cultural artifacts, including tools, sign systems and technologies" is activated (Dobson/ Littleton 2015)."

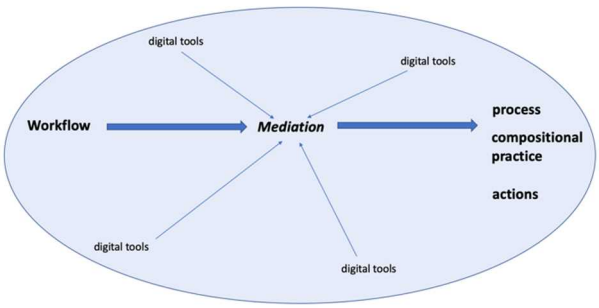

Figure 4. Ecology of practice and the mediation of digital tools.

Chi Wei Chen's work on creative and educational models employing computer-assisted-composition and multime-

dia environments provides some additional guidance for the evaluation and comparison of multiple levels of engagement and activity in learning environments bringing music, sound, image and computation together for teaching mixed music composition (Chen 2006). He delineates the activity into three stages: *Imagination*, involving the conception and gathering of materials and skills; *Application*, an integration of materials and skills into the temporal plan and actuation of the piece; and *Reflection*, a deep evaluation and consideration of the project thus far with revision and problem solving that activates recursive and iterative processes in the creative act. One could adapt this model to a fully mixed music practice and reflect and clarify a similar potential schema for development in the stages of conception, realization, and evaluation over the arc of the creative act.

PEDAGOGICAL RESOURCES

Guillaume Boutard (Boutard/ Gaustavino 2012) and Laura Zattra (Zattra 2016; Zattra et al. 2001), among others, have addressed the issue of preservation of the varied and often plentiful documents and artefacts of mixed music given the relentless onward march of technological innovation and marketplace-designed obsolescence. Access to a sufficient number of these items is obviously necessary for a representation of the composition in performance, but equally so for pedagogical requirements. To study process and engagement with a multitude of technological elements during the creative act, scores, software, hardware, schematics, patches, technical descriptions, manuals, audio and video files and performance recordings, as well as performers' testimonials and notes, must be available in order to formulate adequate descriptions and explanations for illustration and teaching purposes. This poses an immense challenge given the lack of unification of these materials by most music dissemination centers, libraries and agencies. Moreover, composers do not consistently archive the media of their creative output as they move from project to project, adopt new technologies, and invent anew combinations of instruments and technologies.

SKILLS AND ROLES

A young mixed music practitioner recently noted that "The individual roles of Performer, Composer, Engineer and Inventor in electronic music have collapsed and to succeed, especially in performance, it is […] increasingly expected that […] an electronic musician must fulfill several roles (Cackett 2013)." Let us consider a more complete picture of the skills and knowledge sets that are required for mixed music conception, creation, production and performance. These are the roles and skill-sets that are the main focus of pedagogical activities in most academies. (See Table 4.)

composer
orchestrator
notational specialist
interface/controller/sensor specialist and designer
programmer/coder
live score designer specialist
spatial audio specialist, designer and diffuseur
live electronics performer
AV author

Table 4. Roles and skills the focus of pedagogical activities.

Courses, tutorials, demonstrations, prototype testing, practice and then, evaluations, reports, feedback, critique are the tried-and-true route for conveying the skill and knowledge sets that define these roles. Yet, additional skills and knowledge sets that are not typically included in formalized training in mixed music courses and curricula remain essential to a practical conception and realization of mixed music projects. (See Table 5.) Many of these other skills admittedly can only be acquired through experience in mixed music production and performance over a period of time and in a variety of contexts. But in fact, the totality of these skills *is* the territory of mixed music practice.

performer negotiator
tech rider author
demo/mock-up creator/sequencer
equipment sourcing expertise
audio system designer and technician
computer OS trouble shooter
sound system crew negotiator
video projection specialist
electronics/circuit designer and builder
rehearsal schedule coordinator

Table 5. Roles and skills not the focus of pedagogical activities.

CONCLUSION

After more than sixty years of this type of creative activity we call mixed music, driven by unparalleled technological developments and innovative and evolving

performance practices, perhaps it is time to consider that there may no longer be such a genre identifiable as "mixed" music, that composers today approach technology, old or new, simple or complex, practical or abstract, as affording equal possibilities and contributions to the creative act and resulting performance, as part of a complex, multifaceted contemporary instrumentarium from which they pick and choose, construct, deconstruct, fuse and synthesize. The mix in "mixed" music is much more than the admixture of instruments plus electronics. It is, in fact, the mix of all of the required skills, knowledge and experience that feed each other during the many phases of creative production. This continues to present a substantial challenge in working in the field and, for educators, in guiding young composers towards a unified, reiterative approach to creating with this complex "mixture" of technologies and practices.

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[Abstract in Korean | 국문 요약]

혼합할것인가 말것인가: 악기와 전자음향 작곡의 창작 과정 통합하기

로리 래드퍼드

다양한 전자적 요소와 결합된 기기와 악기로 이루어지는 음악 및 사운드 아트 공연을 디자인하고 구성하는데에는 여러 광범위한 기술과 지식이 요구된다. 이러한 "혼합된 음악Mixed music" 작품을 창작할 수 있도록 젊은 실행자들을 안내하는 교육적 접근 방식은 기존의 교육 방식에서는 거의 고려되지 않았던 부분들까지 포괄하여 작곡가가 많은 연습과 다양한 기술을 익히면서 필수적인 실력과 경험을 갖추기 위해 고군분투해야 하는 과제에 맞서있다. 혼합 음악의 범위, 혼합 음악의 연구, 혼합 음악을 가르치기 위한 교육학적 접근법, 혼합 음악 창작과 관련된 스킬과 역할에 대하여 논의한다. 혼합 음악을 가르치거나 배우고, 창작하는 데 연관된 문제점들을 개괄적으로 살펴보고 고찰해 보는 것을 목표로 한다.

주제어: 혼합 음악, 음악 페다고지, 혼합 음악 제작, 전자음향 음악 작곡.

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PROCESSING "REPRESENTATIVE CHARGE": EMBODIED LISTENING AND LUCIANO BERIO'S *VISAGE*

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Literature on electroacoustic music has tended to focus primarily on the mental processes of creating and listening to the genre, reinforcing an Enlightenment-era mind/body dualism. This study offers insights into the embodied aspects of producing and experiencing electroacoustic music. Through an analysis of the sonic material and reception history of Luciano Berio's Visage, the author illuminates the connections retained between mental and physical processes and sensations in the production and reception of the piece. These mental-physical connections attach to both vocal and electronic sounds, complicating and extending experiences of embodiment beyond sounds produced by human bodies. The analysis offers frameworks and avenues for future research into the embodied experience of electroacoustic music.

Keywords: electroacoustic music, Luciano Berio, Visage, embodied listening, Cathy Berberian, electronic music analysis.

In his author's note on *Visage* (n.d.), Luciano Berio explains:

> When I was composing *Visage* what attracted me, as always, was research intended as a way to expand the chances of bringing nearer musical and acoustic processes, and as a means to find musical equivalents of linguistic articulations… [*Visage*] is based on the symbolic and representative charge that is carried by vocal gestures and inflections, with the "shadows of meanings" and the mental associations accompanying them. (para. 1-2)

As the above quote demonstrates, one of Berio's key goals with *Visage* was to bridge what he perceived to be a semiotic gap between nonverbal vocal gestures and electronic sounds. To do this, he created a piece that employed (over the course of 21 minutes) minimally processed recordings of intense vocal affect, intimately intertwined with electronic sounds. Berio relied on the "representative charge" of the vocal sounds, in their close proximity and sometimes mimic-like relationship to the electronic sounds, to imbue the electronic sounds with similar "mental associations." However, Kathy Berberian's strongly emotive vocal gestures convey more than mere "mental associations"; they also communicate physical states, whether real or imagined (Herzfeld-Schild 2011: 132; Mehan 2011: 49). Thus, the electronic sounds not only transmit emotional meaning but also reference to physical sensations, linked to the intense affects Berberian conveys throughout the piece.

As listeners to this "sound track for a play that has never been written" (Berio n.d.: para. 2), we are invited to project physicality onto the vocal and electronic sounds in a way that creates possibilities for empathy with Berberian or an imagined protagonist (Flynn 1975: 388; Hatten 2018: 65). Via this empathetic process, Berio's *Visage* illuminates not only the performer's body but also the listener's body, blurring distinctions between listener and performer, recording and reality. Typically, this process has gone overlooked in analyses and commentary on *Visage*, likely due to the Enlightenment-era mind/body dualism that tends to be applied to electroacoustic music, in which the production and reception of electroacoustic works are placed firmly in the "mind" category. After examining the impact of this framework on Berio and others' writings about *Visage*, I analyze the piece for aural connections between affective and physical states and demonstrate the processes by which electronic sounds become imbued with physical connotations. Though perhaps unintended, Berio's use of Berberian's minimally processed vocal sounds, in close aural relationships with electronic sounds, infuses *Visage* with complex layers of embodied meaning that invite us to consider our bodily relationship with electroacoustic music.

The Invisibility of the Body, and Embodied Listening

For most of the twentieth century, Western Classical Music was underwritten by an Enlightenment-era mind/body dualism that prioritized mind over body and asserted that art-music-making and -reception were processes exclusively located in the mind (sometimes expanded to include "spirit" or "soul") (Cimini 2012: 355; Juntunen/ Westerlund 2001: 205; Pelinski 2005: 1). Electronic music, coming out of this tradition, continued to treat music as though its primary "meaning" were located in the relationships between sounds, recognized

through "acts of mental contemplation" (Brown 2006: 40). Particularly because some sounds were entirely mathematically derived, the "score" was often a recording, and the performing body was often a loudspeaker (or loudspeakers), the presence of the body in electronic music-making and listening was typically significantly obscured (Brown 2006: 38; Corness 2008: 21; see also Crossley 2019: 25).

Berio and others' descriptions of *Visage's* composition process demonstrate this kind of disembodied perspective on music. Richard Dudas used *Visage* as an example of how an electronic composer is a "studio improviser." While he set the scene with Berio and Berberian "recording and re-recording vocal material in an improvisatory fashion," he quickly shifted focus to Berio later experimenting with processing techniques, concluding that Berio was an improviser who used *studio equipment* as his instruments (Dudas 2010: 30). Berberian's body, in this instance, was treated primarily as a sound source to be recorded, edited, arranged, and electronically modified by the true improviser, Berio. Any improvisatory contributions she may have made were purely sonic, and oriented toward providing Berio with pre-recorded material to which he could apply his electronic compositional procedures.

Berio's comments about *Visage* in his text *Remembering the Future* reflect a similarly disembodied compositional framework. Berio explains that during the period in which he wrote *Visage*, he "was busy looking for harmonic coherence between diverse materials, in a musical context made of sounds and not only of notes… [he] was particularly involved in developing different degrees and modes of continuity… between vocal sound-families and interrelated electronic sounds" (2006: 18). To draw these connections, Berio gave the example of causing a sequence of "vocal stereotypes" not typically considered part of a musical vocabulary "to interact by the use of combinatorial criteria" involving placement, duration, resonance, articulation, etc. (68). Berberian also described Berio as wanting to work "within a parabola from the failure of communication, through trivial conversation, to serious emotion, and ultimately to song" (Osmond-Smith/ Berberian 2004: 8). In composing *Visage*, Berio was primarily concerned with finding ways to draw aural connections between socially or culturally disparate sound types. Again, despite an allowance for emotional content, the focus remains in the realm of sounds and their relationships to one another, as interpreted by/in the composer and listeners' minds—as opposed to, for instance, the physicality required to produce said sounds, or any other physical process related to creating or experiencing the piece (and this approach continues; for a recent example, see Oliva 2019).

Nonetheless, music is, quite literally, physical, and there is a substantial body of music-theoretical, musicological, phenomenological, and neurological literature regarding the role embodied experience plays in listening to and finding meaning in music (Brown 2006; Cimini 2012; Corness 2008; Cox 2001; Cox 2011; Crossley 2019; Dyson 2009; Juntunen/ Westerlund 2001; Leman/ Maes 2014; Pelinski 2005). According to Crossley, "engaging with music often involves an imaginative and embodied empathy" with performers that leads us to mirror in our own bodies the actions we imagine performers are taking to produce their sounds (2019: 28). This embodied engagement with music is typically subconscious, however, as we "focus in and out, mobilizing acquired skills and habits in search of (preferably familiar) patterns" (24). Listeners' embodied listening is facilitated in part by our "mirror neurons," which, even in purely sonic contexts, help us to "conceive of an embodied perceptual knowledge of a performer's [actions and] intentions" (Corness 2008: 23). Rather than a process of merely receiving sounds and making sense of them in our minds, listening is an active, engaged experience of meaning-making that uses all of our senses and draws on our embodied knowledge of the world.

The Physical in the Emotional

In *Visage*, Berberian's intense vocal affect, organized by Berio into dramatic "scenes," illuminates the embodied components of electroacoustic music production and reception. For example, at 3:21 (Sound 1, available to listen at www.keams.org/emille) and then again at 7:27 (Sound 2), Berio has created a gesture that transitions immediately from distraught shrieking and moaning to sensual laughter, conjoining sounds typically produced from very different psychophysical states. These sudden semiotic shifts gain affective power from listeners' physical memories and imaginings relating to shrieking/moaning and laughter. One example of an affective "scene" comes from 0:00-1:50, where Berberian enacts a struggle to produce even individual sounds and syllables (Sound 3). This opening, especially Berberian's vocalizations transmitted through a closely placed microphone, confronts listeners with her physicality in a direct and inescapable way. The effect is complicated and contrasted by later vignettes like ca. 3:45-4:50 (Sound 4), where Berberian casually "flirts" and "gossips" in her chatty non-language, communicating relaxation and affection rather than tension and upset. Though both "scenes" convey a particular closeness with the performer (and

her body, real and imagined), the first calls listeners to bear witness to her struggle while the second teases listeners with suggestions of voyeurism and (esp. in concert performance) invites embodied associations listeners might draw from their own experiences of intimacy into the public sphere. Through these "scenes," *Visage* encourages listeners to draw empathetic physical associations with Berberian. Whether they relish in these moments or resist them has depended on the listener.

While some have written about the way *Visage* pulls them into a semiotic maelstrom, the bodily aspect of the sound tends to be either denigrated or overshadowed by the "emotional" qualities of the piece. One critic complained that "[Berberian] found some vocal emissions that come more from the uterus than from the mind," turning *Visage* into "an exploration of these 'undersounds'" rather than a worthy piece of music for voice and electronics (Eco, as cited in Meehan 2011: 49). Another writer described *Visage* as welcoming listeners to "the pleasures of eavesdropping upon intimate conversation in an unfamiliar language [and then inviting listeners] to endure the voice's raw emotional import unmediated by specifics of vocabulary and grammar" to the point of becoming "disturbing," as they explore "the border between pleasure and pain" (Osmond-Smith/ Berberian, 2004: 8). Though Osmond-Smith references the physical states of pleasure and pain, these feelings are subsumed within the "raw emotional import" of the voice.

Composer George Flynn also found the vocal gestures in *Visage* "disturbing," and for similar reasons. For Flynn, *Visage* "invited [the listener] into a teeming world of memories, moods and emotions, expectations, reaction, and reconsiderations" in an immediate, "unavoidable" way (1975: 388). And still, Flynn's vivid description of listeners' experiences focused on mental processes at the exclusion of physical responses. Richard Causton went even further in this direction, declaring that "the turbulent events in ["the dramatic character's"] mind are mapped directly onto those of the audience…" (1995: 19). For Causton, all of the sensations involved in experiencing *Visage* seem based in the psychological processes of the "dramatic character," mapped onto audiences' mental landscapes as Berberian's voice "forces sympathetic resonances in [their] minds" (19). Osmond-Smith, Flynn, and Causton all describe *Visage* as a play of emotions, for the "dramatic character" as well as for listeners. While they recognize empathetic listener responses, they overlook the physical-empathetic responses *Visage* can evoke.

As studies about embodied music-making and listening have proliferated, however, scholars have begun to acknowledge at least the presence of Berberian's body in *Visage*. In "Studien zu Cathy Berberians 'New Vocality'," Marie Louise Herzfeld-Schild is clear that "[Berberian's] physicality is evident through the sound of her voice" (Die Körperlichkeit dieser Frau ist durch den Klang ihrer Stimme anwesend; 2011: 132). By employing the voice to convey intense affect, Berio (via Berberian) brought the body into *Visage.* Additionally, by using Berberian's vocalizations with minimal processing, Berio carried into the piece a greater potential for psycho-physical empathy than had the voice been processed to the point where listeners could no longer imagine their own bodies making similar sounds. In this way, *Visage* functions like a piece of musique concrete; the sound source is recognizable but invisible, so the audience must discern or project situations that might induce the sounds they hear throughout the piece. [1]Berio enhanced this musique-concrete ethos by including only one word, "parole" ("words" in Italian), uttered infrequently throughout the piece and in a variety of contexts. Listeners engage the full semiotics of Berberian's voice, largely unmediated/unobscured by linguistic semantics.

To create psycho-physical meaning from *Visage*, listeners draw on their embodied memories and projections. In this way, listeners' own bodies become present in the piece, as well. As Crossley has noted, "engaged listening often takes the form of role play," where listeners will emulate the movements they imagine performers to be using, whether or not those are the actual actions performers are taking to produce their sounds (2019: 28). Even if these subtle movements typically create a backdrop against which we experience the piece, vocalizations that suggest particularly intense situations can bring this embodied aspect of listening more to the front of our awareness.

Writers have commented indirectly on *Visage's* physicality through discussions of the sexual intimacy and extreme violence suggested by Berberian's vocalizations and their "poetic" organization by Berio (Herzfeld-Schild, 2011: 132; Meehan 2011: 49; Osmond-Smith 2004: 8-9). One common topic is ca. 2:49-3:25 (Sound 5), where the electronic sounds become louder and more percussive, accompanied by a shift in the vocal gestures to predominantly shrieks and moans. This happens again at 6:55-7:33 (Sound 6), this time with longer, more drawn-out whimpering, sobbing and moaning. Both moments suggest physical violence (performed by the electronic sounds) toward the character Berberian is portraying with her vocalizations. Another common topic of commentary involves the sensual laughter that appears repeatedly throughout *Visage* (3:25, 6:05 (Sound 7), 7:33, etc.). The moments from 6:22-6:44 (Sound 8) are particularly sexy, with a variety of sighs, laughs, and giggles that suggest the protagonist is experiencing physical intimacy.

Berberian's vocalizations here invite listeners to empathize with sexuality, a realm of experience listeners are rarely asked to engage within electronic music. The "disturbing" quality, the "obscenity" some have found in *Visage* may stem more from listeners' own physical reactions to the piece than from the mere organization of sounds into intellectually stimulating patterns.

And indeed, listeners' projections of pain onto Berberian's performing body are not merely imaginative. In a 1981 interview with Silvana Ottieri, Berberian related that she

> had to communicate the agony of attempting to speak a syllable and not being capable… In the end my chest was numb for three days, due to the magnitude of my physical and emotional effort. (Ottieri / Berberian 1981, as cited in Meehan 2011: 56)

Berberian, recording vocal sounds for Berio, was unable to avoid the physicality inherent in the production of *Visage*. Her body felt the ramifications of their intense, extended recording sessions. And, because Berio reproduced her vocalizations with minimal processing, listeners have a much closer, clearer experience of that physicality than they might with other, contemporaneous electronic works. Whether or not listeners can accurately emulate the physical gestures Berberian used in her recordings, they (we) can hear the strong suggestions of physical strain in her vocalizations. If we accept that listeners tend to mimic, to some degree, the physical states they observe in or project onto performers, *Visage* becomes an opportunity for listeners not only to "witness" intensely affected vocalizations but also to feel in their bodies some of the meaning they ascribe to those vocal gestures. Listeners derive meaning from both the imagined physical states they project onto Berberian's vocal gestures and their own bodily engagement with the piece. In attempting to create a piece that communicated intense emotional affect, Berio also created a piece that communicated to a greater degree the bodily processes by which it was produced, linking the aural with the physical even as he strove to link the affective with the electronic.

Embodiment and Electronic Sounds

In drawing upon the semiotics of affect-heavy vocal gestures to attach emotional/poetic/musical meaning to electronic sounds, Berio brought the presence of the performer's body prominently into listeners' experiences of the piece as a whole, electronic sounds included. This is because

> The invocation of, on the one hand, electronic sounds which carry no specific connotations, and, on the other, the most meaningful sound of all—the human voice—makes possible the establishment and dissolution of innumerable different interrelationships, and allows Berio freely to exploit the potential for referential ambiguity inherent in the electroacoustic medium. The extreme and carefully calculated tension between the great accuracy of semiotic specificity and the total lack of semantic specificity forces the mind of the listener into creative activity. (Causton 1995: 20)

The close relationships between vocal and electronic sounds causes semiotic content from the vocal gestures to bleed into the electronic sounds—one of Berio's stated goals for the piece. However, the voice evokes physical as well as emotional meaning, so the semiotic blurring between voice and electronics carries with it references to physicality. At the same time, I am not suggesting that this semiotic transference is a clear-cut, 1:1 process. In addition to the inherent diversity of listeners' experiences of the piece, based on their unique embodied memories and imaginings, there is a mixing and recoloring of the electronic sounds' meanings that occur as vocal semiotics and vocal-electronic relationships shift. Throughout *Visage*, the electronic sounds continually take on new functions and new layers of meaning.

The transformation of "white" noise over the course of the piece provides a clear example of these shifting semiotics. From 0:00-0:25 (Sound 9), smooth filtered noise provides a backdrop for Berberian's struggle to form sounds and syllables. At 0:26, the noise develops texture, and at 0:55 the noise is filtered enough to become pitched, though it still retains the sustained and textural identities of the earlier filtered noise gestures. At 1:50, the noise introduces a new aspect of itself: short, percussive "pops," that instigate a shift in the voice to denser, speech-like vocalizations. Until this point, the white noise has been progressing through a parallel process to the voice, beginning with the simplest texture and moving toward speech-like patterns.

Then, at ca. 2:50, the "pops" become more and more dense, eventually moving into a competitive position in the foreground of the sound and conveying violence against the voice. This violence is communicated largely by the voice's "response" to the electronic sounds; the shrieks and moans in close proximity to the loud, percussive filtered noise sounds signal to the listener that these electronic sounds are related to (physical) pain. After this episode, the filtered noise returns at 6:55 for a recapitulation of the increasingly loud percussive gestures that "cause" the voice to whimper and cry out. No longer in the more neutral realm of linguistic mimicry, the filtered noise (esp. via its relationship with Berberian's vocal gestures) has taken on connotations of (physical) violence.

Berio's choices in organizing electronic and vocal sounds created trajectories that involved physical connotations.

From here, the filtered noise sounds join other electronic sounds as part of larger textures, no longer a primary focus. As part of a larger texture, the filtered noise regains some of its quality of vocal imitation, its character of attempted linguistic communication. Then, in the final four minutes of the piece, we meet a new kind of "filtered noise." This time, the "noise" is built additively and has expanded to assume its own identity, occupying the foreground and the background of the sound, entirely distinct from the voice but containing echoes of earlier vocalizations, as though the noise has subsumed the voice within itself. In these final minutes of the piece, listeners are confronted with a wall of electronic sound that contains—and also exceeds—the layered, potentially conflicting, associations and projected physical memories from earlier vocalizations and their electronic counterparts.

Another example of shifting and layering semiotics involves the fluttery, delicate, pitched and unpitched electronic sounds that enter at 3:42 (Sound 10). Here, rather than a show of violence, there is a turn toward intimacy. These sounds, which may evolve out of the filtered noise gesture at 0:55, accompany flirty, friendly, soft vocalizations. The delicate electronic sounds often echo or mimic the cadence and texture of the vocal gestures, and they support the voice, remaining primarily in the background. Throughout this flirty moment, the electronic sounds develop new timbres resembling gently percussive plastic (starting ca. 3:54; Sound 11) and then glass (starting ca. 4:50; Sound 12) objects. Whereas the earlier, more "violent" electronic sounds were imbued with semiotic meaning via their seemingly antagonistic relationship with the voice, these delicate electronic sounds acquire meaning (flirtation, relaxation) over their prolonged proximity to and similarity with the affectionate vocalizations.

Then the unpitched gestures elongate from brief clusters of articulation to granulated sustained sweeps/swells that eventually trade off with metallic drones at 5:52 (Sound 13). This transformation loosens former semiotic attachments but creates a clearer connection with the glass-like gently percussive gestures at 9:31 that become sandy and then buzzing while the voice intermittently laughs seductively. The similarly flirty (though more intense) semiotics of this laughter recalls earlier iterations of these granular gestures, strengthening those associations. However, an assertive metallic granular gesture at 9:41 suggests other potential connotations.

Starting at 12:01, metallic granular swells return, louder, this time leading into a return of distressed vocalizations similar to those associated with the "violent" filtered noise earlier in the piece (Sound 14). Rather than the electronic sounds providing a backdrop for the voice, the vocalizations and electronic sounds are now in close counterpoint, neither entirely in the foreground or background of the texture for very long. This new positioning of the granular gestures within the overall texture shifts their function and also complicates earlier semiotic associations. While they continue their original pattern of emulating the vocal gestures' rhythms/textures, their performative relationship to the voice has changed. Rather than providing support and/or commentary on the vocalizations, here the granular gestures seem to compete with the voice for prominence. Earlier associations with friendship or flirtation are challenged by this new sense of competition and ensuing violence. Any earlier attributions of physical safety and comfort are complicated by this new implication of danger.

Throughout *Visage*, Berio has created a "'humanization' of electronic sounds by means of 'imitation' and extension of and competition with the voice" (Flynn 1975: 392). For listeners, this "humanization" involves a semiotic transference between vocal gestures and electronic sounds such that the electronic sounds acquire some of the voice's embodied meaning. When the psychophysical associations with Berberian's vocalizations blur and begin to attach themselves to the electronic sounds in unstable and conflicting ways, we are presented with the new challenge of vocal-semiotic stimulation without clear links to recognizable embodied experience. These looser relationships carry us through the remainder of the piece, where, at the end, we are left alone with the electronic sounds, imbued with layered and conflicting projected physical memories, our bodies having become the reflective surfaces upon which the electronic sounds' semiotics play.

Conclusions

In his author's note, Berio described *Visage* as "based on the symbolic and representative charge that is carried by vocal gestures and inflections," in which "the vocal dimension of the work is constantly amplified and commented upon by a very close relationship, almost an organic exchange, with the electronic sounds" (n.d., para. 2). However, by employing relatively unprocessed vocal recordings, Berio also illuminated the presence of the body in the processes of performing and listening to the piece. *Visage* challenges us to notice Berberian's body as well as our own, to imagine her body and our own in uncomfortable (or *too* comfortable) situations. As listeners, we experience the physicality of the piece more intensely in our own bodies because Berberian's body is

not present. Our projected empathy has no feedback loop outside of ourselves.

Sounds originating from bodies, like Berberian's vocalizations, better enable us to experience electronically-produced sounds in bodily ways. And this experience extends beyond *Visage.* The unintended connections Berio drew between physical sensations and electronic sounds, through affective correlation and juxtaposition between sounds produced by a body and those produced by a machine, could be located in other works for voice and electronics, as well. Analyzing other electroacoustic pieces that incorporate vocal sound through the lens of embodied listening can offer new insights into their meaning and impact. Additionally, with an understanding of listening as an embodied, empathetic act, there is much room for research into the embodied experience of electroacoustic works that employ sounds produced by other physical processes, both human and non-human. There could also be merit in investigating the content and limits of projected, embodied empathy with electroacoustic works produced entirely by machines, where there is no immediate connection to human bodies beyond that of the listener. How much do we project embodied states or processes onto electroacoustic sounds when there is no initial bodily referent? There is significant analytical work that can be done if we take our bodies seriously as participants in the listening experience.

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[1] This effect was likely complicated in performances where Berberian was present on stage, since listeners would have had visual stimulus that contradicted any remembered or projected scenarios of intimacy or violence; however, this contradictory information would likely have added layers of meaning to the experience rather than negating listeners' psycho-physical imaginings during the piece.

[Abstract in Korean | 국문 요약]
"주요한 감상" 처리: 구체화된 청취와 루치아노 베리오의 '얼굴'

재스민 토마시안

전자음향 음악에 관한 문헌들은 대개 계몽주의 시대의 정신/신체 이원론을 강조하는 장르를 만들어 감상하는 정신적 과정에 주요하게 초점을 맞추는 경향이 있다. 이 연구는 전자음향 음악을 만들고 경험하는 모습을 구현하는 관점으로 이해를 제공하고자 한다. 루치아노 베리오Luciano Berio의 '얼굴Visage'에 대한 음향 재료 및 평판 역사를 분석함으로써, 저자는 작품의 창작 및 수용 시 정신적, 신체적 과정, 느낌과 감각 사이에서 이어져온 연결을 조명한다. 이러한 정신-신체의 연결은 인성 및 전자음향의 두 소리 모두에 부과되어, 사람의 신체에 의해 만들어지는 소리를 넘어선 그 외의 구현까지 경험을 심화시키고 확장한다. 이 분석은 전자음향 음악의 구체화된 경험에 대한 향후 연구를 위한 체계와 방법을 제시할 것이다.

주제어: 전자음향 음악, 루치아노 베리오, 비사지, 구체화된 청취, 캐시 버베리안, 전자음악 분석.

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Compositional Structure and Functional Analysis of 'Globalalia'

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Electroacoustic music has a remarkable place in sound art and music composition. Regarding its complexities and radically different approach compared with conventional music genres, electroacoustic music is often rated as hardly understandable. Hence, this genre does not get enough recognition-especially from musicologists which could dramatically change the understanding of the works in the canon through extensive analysis. In this study Trevor Wishart's well-known work, Globalalia is held under the microscope. Wishart is a well-known composer mostly with his vocal works. Especially, he is known for composing long-scale works that are highly unusual for the field of electroacoustic music. For understanding his long-scale works, our study focuses upon Wishart's means of creating structure, concentrating specifically on one of his longer works, Globalalia. The study utilizes Stéphane Roy's idea about formal functions as a way of unpicking the structural processes that are happening on both micro and macro levels in the piece. Even though there are many articles regarding 'Globalalia', the exhaustive analysis or written work focusing on the structure of the piece has been a novel study and it helps readers to understand the piece better.

Keywords: Electroacoustic Music, Acousmatic Music Composition, Analysis of Electroacoustic Music, Analysis of Electronic and Computer-based Music, Computer-aided Composition/Analysis

Trevor Wishart began "Globalalia" by asking his friends to send recorded footage of people talking on the radio on stations all over the world. In total, the source material includes 134 voices in 26 different languages. This was the sole set of source materials that Wishart used in the piece. The aesthetic aim of the piece was to illustrate what humans have in common, irrespective of language and racial differences (Vassilandonakis/ Wishart 2009).

Since the piece was influenced by the idea of having a "story within a story", inspired by the "Arabian Nights"; the compositional process of "Globalalia" worked its way around a structural idea that relies on the repetition of certain elements throughout the piece. Sound materials with similar characteristics (sounds with the same syllable groups) were grouped (within the database of Sound Loom), and sections in the piece were evolved around the distinct properties of these groups (Vassilandonakis/ Wishart 2009).

Wishart's thoughts on the compositional structure are particularly interesting. He believes that openly stating the principal materials from the outset of the work is crucial when dealing with an electroacoustic composition (Milani/ Wishart 2009). He also mentions the importance of forming climaxes, key moments, repetition, development, and recapitulation of materials to give the listener some hints of where he/she is on the piece (Milani/ Wishart 2009). This, in particular, raises some questions as to whether this approach to the structuring of his works is derived from his 'very traditional' education in music, even though he claims that he has not taken any inspiration from the "composers of the past" (referring to the ones that he was studying in university, notably those of the serial and new complexity traditions) (Milani/ Wishart 2009).

The main aim of this study is to understand the structure in a detailed manner, in order to understand/show how the microstructural ideas affect the formation of the macrostructure (which tells us about how the piece works). In doing so, I also hope to understand how a complex long-scale work like these rewards both repetitive and first-time listening (especially first-time listening).

The secondary goal of this study is to provide a work from which the electroacoustic composers can benefit whether they aim to understand "Globalalia" better or they are investigating compositional structures as an influence for their future compositions whether electroacoustic, instrumental or mixed. This study will not deal with many of the technical processes used to create the piece. Rather, the main focus will be on the structure of the piece, concluding how the piece works at the micro and macro levels.

To understand the piece's micro and macro-level structure, the piece "Globalalia" will be analysed using Stéphane Roy's Four Broad Categories of Formal Functions and Forty-Five Formal Functions (Stewart 2007). According to Roy, the analysis of electroacoustic music derives from two levels of concepts:

- The first one is from the above approach (descriptive spectro-morphological).
- The second is from below which could also be respectively identified as macro and micro levels.

The macro-level needs to be investigated by a method that allows recognition and assessment of the role and relationships of the elements of the work (which Roy refers to as 'units') according to the context of their appearance and development.

On the other hand, the micro-level should be informed by a methodology that classifies the individual and specific spectro-morphological units.

Roy provides a series of forty-five terms that enable listeners to describe the units within specific pieces. Each of these forty-five functions aligns with one of four broad categories (Stewart, 2007):

- Stratification Functions,
- Orientation functions,
- Rhetorical Functions,
- Process Functions.

A unit gains function when it has two of the required characteristics; a unit presenting importance to the perception/carry well-defined morphological boundaries and a unit having a role within a group. Rather than surveying each of the various terms, we shall briefly examine the four main categories in which these terms may be located:

1. Stratification Functions

Stratification functions deal with the units that are part of the vertical compositional structure.

2. Orientation Functions

Orientation functions are labelled to the units which define the musical structure by attaching one unit or section to a directly successive or previous one.

3. Process Functions

Process functions are referred to the events which accompany a directed temporal process. Each event in this category has an opposite equivalent to its temporal reversal.

4. Rhetorical Functions

Rhetorical functions are the most relevant functions when it comes to identifying musical structure. They are divided into two subcategories.

Rhetorical Functions Category 1: Relational Rhetoric

'Relational Rhetoric' focuses on erratic relationships between musical events.

Rhetorical Functions Category 2: Ruptural Rhetoric

'Ruptural Rhetoric' is related to the musical events which switch the listener's attention from one musical argument to a fresh one or to an external discourse that happens outside of the music.

5. Contributions of the Study

This research concentrates on the micro and macrostructure of Wishart's important piece "Globalalia" to have a greater understanding of the piece. The research extracts its finding by using Roy's analytical methods (forty-five formal functions) and Audacity's label tool for unpicking the microstructural elements and their relationships. These findings then start the macrostructural analysis process of the piece and crystallize the main macro relationships between the sections.

Even though there are many articles regarding "Globalalia", the exhaustive analysis or written work focusing on the structure of the piece has been a novel study and it helps readers to understand the piece better.

Analysis

1. Micro Analysis - Roy's Method

To apply the functional analysis of the piece, the open-source sound editing software Audacity's label tool was utilized and the piece was labelled with Roy's forty-five formal function terms.

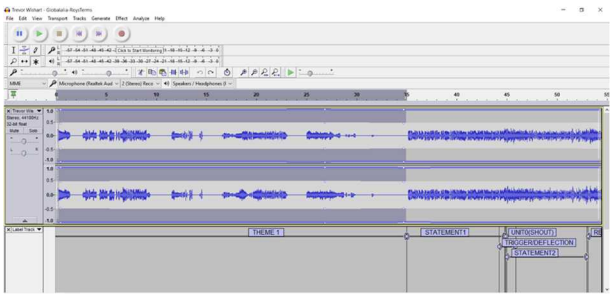

Figure 1. Section from 00:00 to 00:35(Theme1).

This section (Theme1) acts as an introduction to the piece hinting at what is yet to come as well as informing the listener about the importance of Unit 0 (SHOUT) by using it at the start of the section.

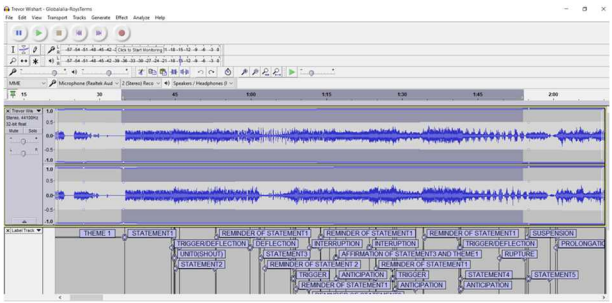

Figure 2. Section from 00:35 to 1:54 (Section1).

This section can be seen as the main role model for the progression of the gestural ideas in the piece. The whole section can be summarized by looking through the relationships and functions of certain sound elements. To start with, unit 0 (SHOUT) is the sound material that has a very specific purpose in this section and throughout the piece. It serves as a tool for heightening the attention and hinting at a

change in the sound world as most of the time the unit serves as a trigger.

There are lots of rhetorical functions in the section with numerous abrupt changes in the statements almost reminding a constant switching of the TV channels via remote control. The section includes a considerable amount of repetition, interruption, deflection, and triggers. As a result, this section works by introducing a statement then interrupting the progression with another statement and re-introducing the previous unit with the progressed/varied version while keeping the same formula and never letting the progression happen in a natural state (always relying on interruptions).

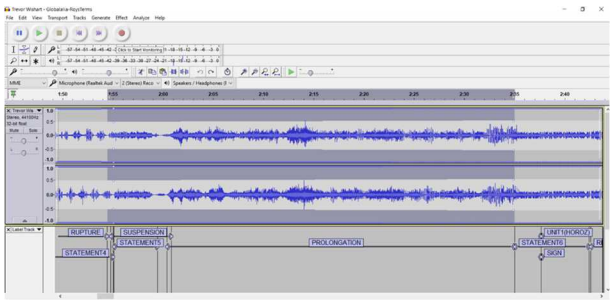

Figure 3. Section from 1:54 to 2:35 (Section2).

This section introduces a new statement (Statement 5) and initiates the prolongation of Statement 5 without allowing newly introduced Statement 5 to develop. Prolongation of statement 5 is highly textural and acts as a breath before continuing the high energetic parts in the next section.

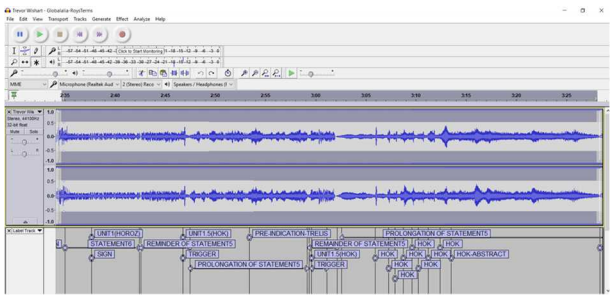

Figure 4. Section from 2:35 to 3:28 (Section3).

The section includes a lot of repetition, triggers with two different units, and prolongation. These functions work great in this context for achieving a balance between giving the previous section and statements that have already been used more solid ground in the composition as well as leaving a chance for improving on the structure. Unit 1 (HOROZ) is only used for introducing fresh little sections that are not radically different from the previous one. However, Unit 1.5 (HOK) significantly changes the sound world when introduced as a trigger. The prolongation of the section is merely a reminder of the prolongation of statement 5 that was introduced in the previous section.

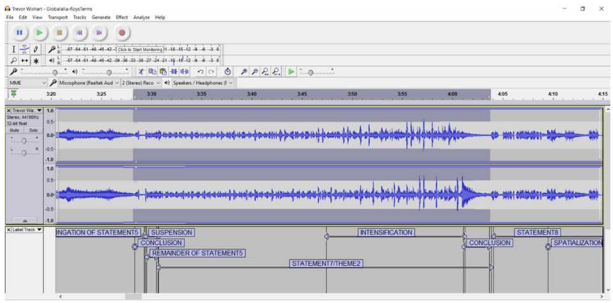

Figure 5. Section from 3:28 to 4:03 (Section4).

This section suddenly starts with a reminder of statement 5 for a very brief moment and directly moves to statement 7, which is highly textural and has many repetitive rhythmical elements in it. The direction of Statement 7 in this section is pretty clear. It intensifies and concludes without any interruption. This section can again be considered to function as a brief breath before diving into a more energetic section.

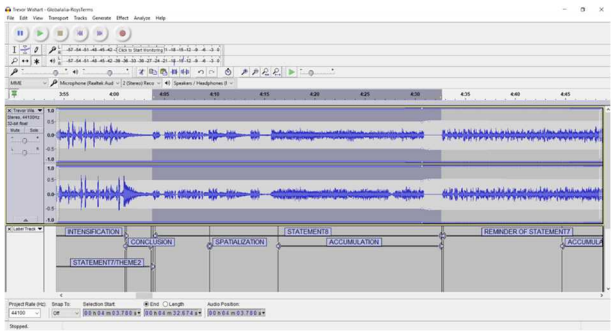

Figure 6. Section from 4:03 to 4:32 (Section5).

This short section has three main elements: introducing a new statement (Statement 8), spatialization, and accumulation. Statement 8 is gestural but with the help of spatialization before the accumulation, Statement 8 smoothly becomes textural right before the next section. Hence, one could say that this section's aim is preparing the structure for the next section.

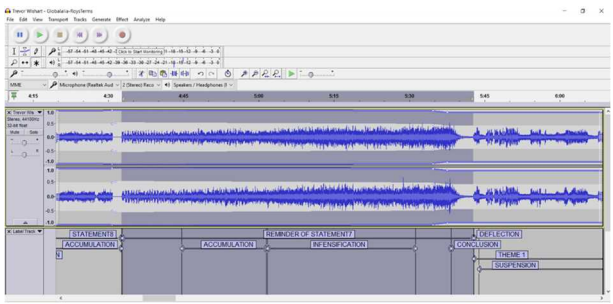

Figure 7. Section from 4:32 to 5:42 (Section6).

This section is quite textural, and process based. The section starts with the reminder of Statement 7 and accumulates. Then, the part intensifies and concludes. This section is functionally very similar to the section from 3:28 to

4:03. Hence, it can be said that this section is a reminder of Section 4.

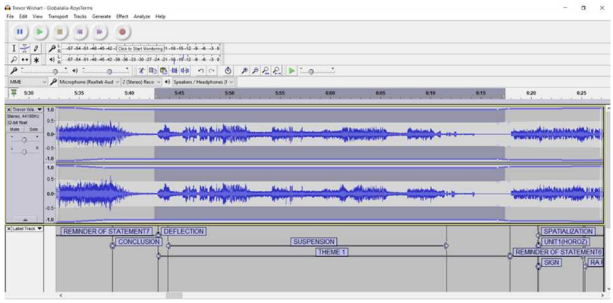

Figure 8. Section from 5:42 to 6:17 (Theme1).

This section acts as a reminder of Theme 1 with an added suspension element. It functions as a concrete musical line in which the listener can understand where he/she is standing on the timeline.

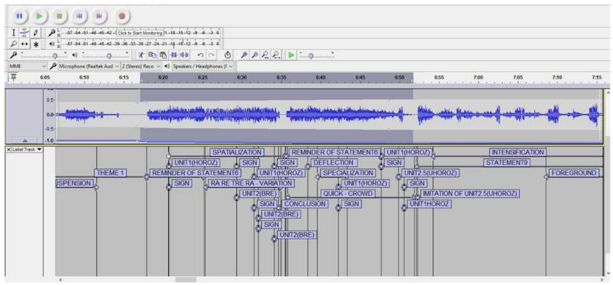

Figure 9. Section from 6:17 to 6:51(Section7).

This section introduces Reminder of Statement 6, uses repetition of the mentioned statement in strategic areas, utilizes spatialization, deflection, and numerous units which none of them act as triggers while some functioning as a sign. As a whole, it can be said that this section serves as a setup for the next section.

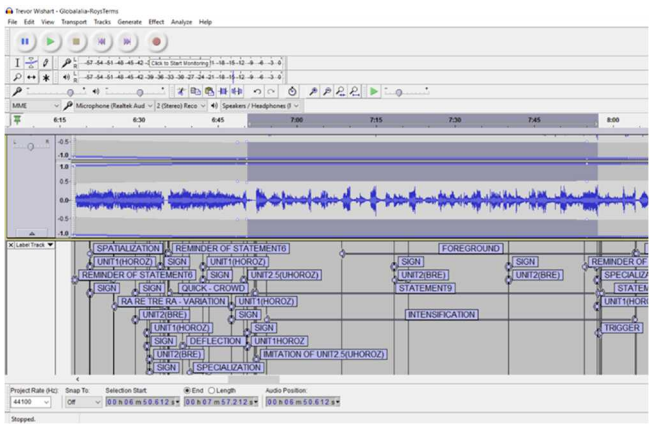

Figure 10. Section from 6:50 to 7:57 (Section8).

This is one of the most memorable sections of the piece. It relies heavily on repetition, but it is different from the other prominent gestural sections in the piece where the repetition is about imitating the statement with an added element (and this usually happens after a certain amount of time from the point when the repeated statement is being heard in the piece). However, in this section, repetition is used without any alterations and spacing on the material, and it is used for a process function (almost like the minimalist approach of Steve Reich). This section's progress happens by introducing voices that are prominent on the other gestural sections of the piece (such as Section from 6:17 to 6:51). One of the first introduced sections (female voice) then acts as a foreground and its timbre gradually evolves/changes into a completely different sonic property-(metallic) while the sound material which initiated the whole section-Unit1(HOROZ) also morphs into a different timbral identity as well as adds two more pitches on its melodic line. On the other hand, these transformations do not explicitly take place thanks to the constantly added voice elements taking away the attention of the listener from the transformations. There is also a sound element-Unit2(BRE) which is used in the section extensively to function as a sign. Another interesting point of the section is its abrupt ending/jumping into the new section by a trigger.

This is a common way of switching the sections throughout the piece which mostly happens in between the studies but almost never on the sections transitioning into the Theme1 (Main theme). Progression into Theme1 (Main theme) is nearly always done by a conclusion which increases the sense of getting to home when landing into Theme1 (Main theme).

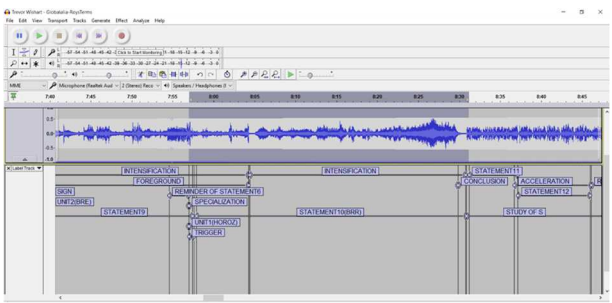

Figure 11. Section from 7:57 to 8:30 (Section9).

The previous section gets abruptly interrupted by the usage of Unit 2.5 (HOROZ) as a trigger. As a consequence, the listener finds himself/herself in Section 9. Statement 10 then gets explored through various spatialization ideas and it gets intensified before reaching a conclusion. The overall section is particularly interesting since the sound materials are acting as a source bonded sounds. It can be concluded that this section functions as a continuation of textural-based elements and introduces more gestural sections before the start of the next section.

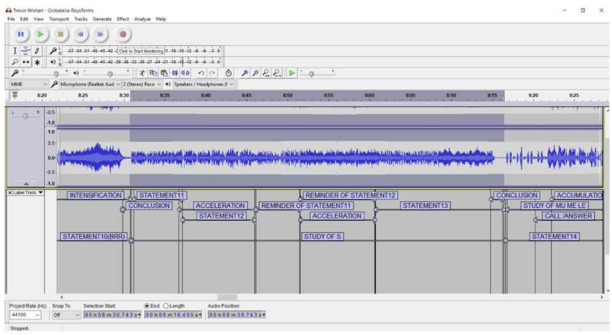

Figure 12. Section from 8:30 to 9:16 (Section10).

This section works by introducing different statements through interruption and acceleration and progresses by repeating the interrupted statements. On each repetition, Wishart adds something new.

It is also worth noting that there is a clear conclusion to the section. As a whole, this section has a very similar function to the section from 00:35 to 1:54.

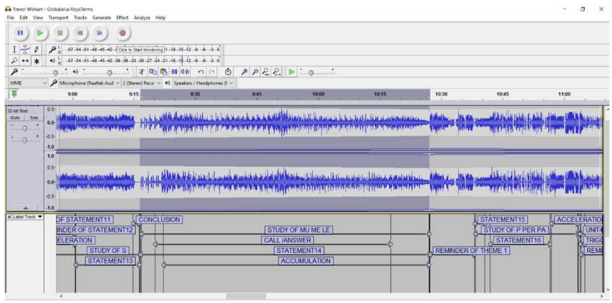

Figure 13. Section from 9:16 to 10:27 (Section11).

This section is textural, rhythmic, and process based. It works by a lot of repetition of certain sound elements in a rhythmical manner and uses the question-and-answer method. The whole statement also utilizes accumulation. This section has a very similar function with section from 3:28 to 4:03, 4:32 to 5:42, and 6:51 to 7:57.

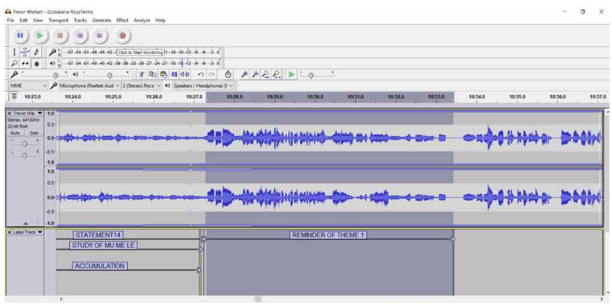

Figure 14. Section from 10:27 to 10:33 (Theme1).

This is a reminder of theme 1 and acts as a concrete musical line in which the listener can understand where he/she is standing on the timeline.

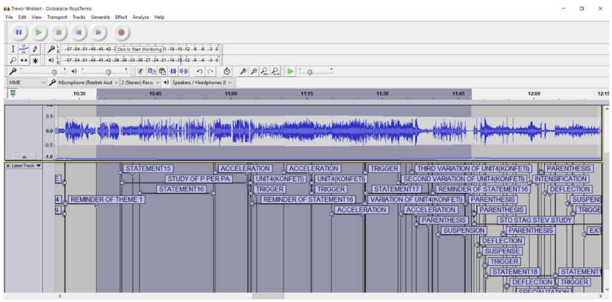

Figure 15. Section from 10:33 to 11:47 (Section12).

This section introduces new statements by interruption, acceleration, and use of triggers. The triggers are placed right at the end of acceleration in each little phrase. Unit 4 (KONFETI) is the main trigger element which also gets processed mostly when the unit does not act as a trigger throughout the section. It is also worth noting that the statements are mainly rhythmic but not used in a textural context (as per sections 3:23 to 4:03, 9:16 to 10:27, 4:32 to 5:42, and 6:51 to 7:57). Overall, this section functions similarly to the sections heard between 8:30 to 9:16, and 00:35 to 1:54. Hence, it can be said that this section is a reminder of Section 1.

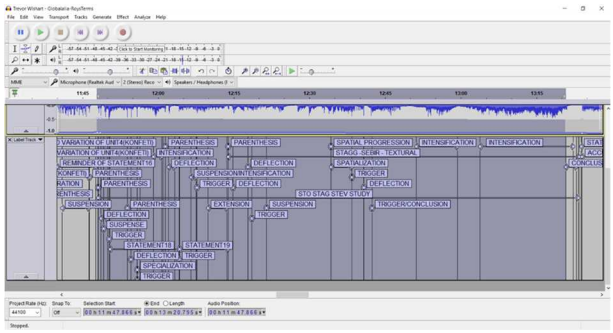

Figure 16. Section from 11:47 to 13:20 (Section 13).

This section is considerably different from the other sections in the piece. It has a clear progression and roles from the sound materials. For instance, the main pattern utilizes parenthesis, deflection, and trigger respectively to initiate some action from other elements. This signature order continues by bringing new materials to the table, alongside the various sound materials responsible for the three functions changes/transforms. Specialization is also a unique and attention-grabbing function that is being experienced throughout the section. Intensification is frequently used, especially where the materials start mimicking the bouncing ball pattern (a pretty common-almost a cliché musical idea in electroacoustic music). The transformation of the bouncing ball pattern mixed with intensification puts the section into a timbrally complex segment where the sense of arriving at a conclusion gets highly accomplished. It is important to mention that the section finishes with a chord that has Major 9th tonality which in fact also has been helpful to set the conclusion successfully.

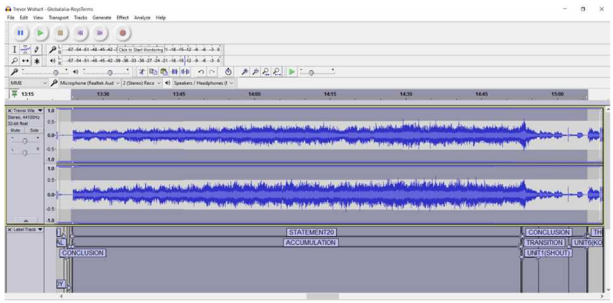

Figure 17. Section from 13:23 to 15:06 (Section 14).

This is a process-based textural section that feels particularly cinematic, thanks to containing many different sound materials that are acting as source-bonded sounds and are easy to relate to a scene that happens around a crowded marketplace. All of the sound materials in this section are granular and very prominent in the low mids of the frequency spectrum. The statement (Statement 20) goes through accumulation until the section transits into a conclusion by introducing Unit 1 (SHOUT) and ending with a musical chord. It is also worth stating that right after conclusion Unit 6 (KOM-GADIN) emerges.

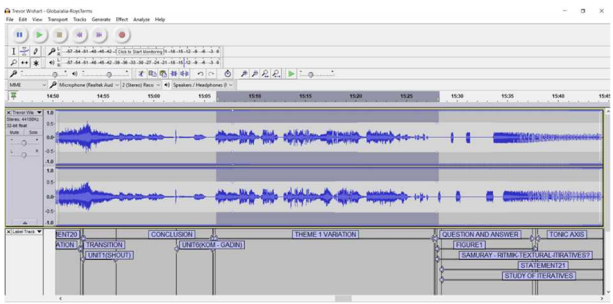

Figure 18. Section from 15:06 to 15:27 (Theme 1).

This is a reminder of theme 1 and acts as a concrete musical line in which the listener can understand where he/she is standing on the timeline.

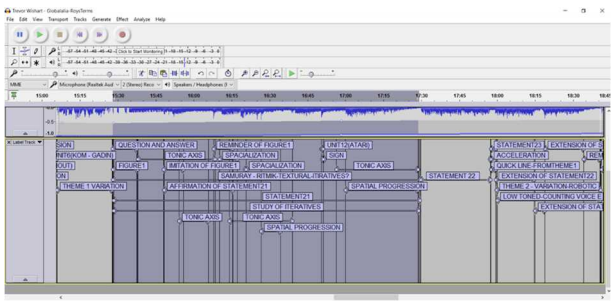

Figure 19. Section from 15:27 to 17:29(Section 15).

This section uses question and answer, a lot of tonic axis, imitations of newly introduced statements, spatialization, and spatial progression. This is again one of the most memorable sections of the piece. The reason for this can be linked to the heavy usage of the tonic axis which stands out as a function through the rest of the piece. Spatialization is also one of the main elements on the section that builds and keeps the tonic axis' interest. This section can be seen as a mainly textural section since the listeners' attention is drawn to the tiny details of the sound elements.

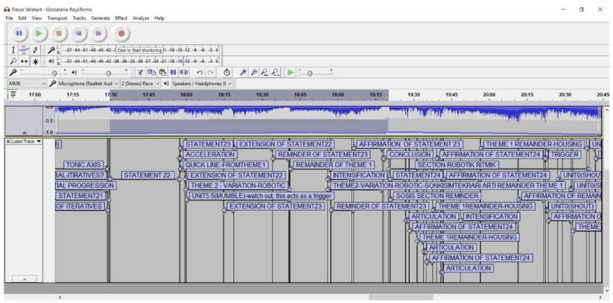

Figure 20. Section from 17:29 to 19:20 (Section 16).

This section works mainly with two newly introduced statements (Statement 22 and Statement 23). Progression of statement 22 gets hindered by the interruption of Statement 23. Extension, reminder, and acceleration functions are prominent. Statement 22's characteristic similarities (low mid-frequency focused mumbles) with the section from 13:23 to 15:06 is also noteworthy. There is also an interesting low-tuned sound unit (Unit 5.5-MUMBLE) acting as foreground. It is also important to state that from 18:40 to 19:00 reminder of theme 1 emerges and from 19:00 to 19:20 the mentioned reminder gets intensified and mixed with the reminder of statement 23. The section then reaches a conclusion right after using affirmation of statement 23. The whole section functions similarly with the sections from 8:30 to 9:16, 00:35 to 1:54.

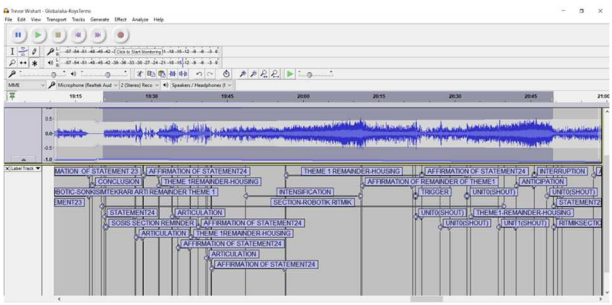

Figure 21. Section from 19:20 to 20:49 (Section 17).

This section deals hugely with the affirmation of statements (new and/or reminder statements) while the progression of the phrase gets interrupted by lots of articulations. It also has many triggers and a very successful rupture near ending. The function and progression of the section are very much alike with sections from 8:30 to 9:16, 00:35 to 1:54. However, it is also different from the mentioned sections purely because of introducing many reminders and affirmation of reminders as well as textural and gestural parts in this section are more balanced. Overall, this section functions as a reminder of the previous sections.

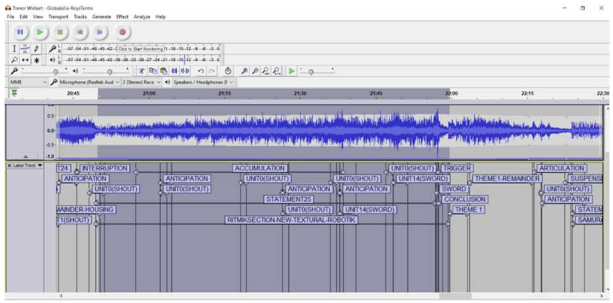

Figure 22. Section from 20:49 to 21:59 (Section 18).

This section is rhythmical, textural, and process based. The progression includes heavy usage of accumulation, Unit0 (SHOUT), and anticipation. The anticipation is achieved by using Unit0 (SHOUT) twice (usually the first one with the higher pitch gets to initiate the anticipation). There is also a significant unit: UNIT14(SWORD) that gets used with the two anticipations and right before the trigger that brings the conclusion. It is also useful to note that the conclusion finishes with a musical chord.

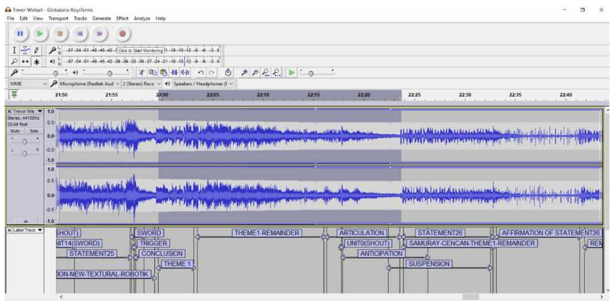

Figure 23. Section from 21:59 to 22:23 (Theme 1).

This is a reminder of theme 1 and acts as a concrete musical line in which the listener can understand where he/she is standing on the timeline.

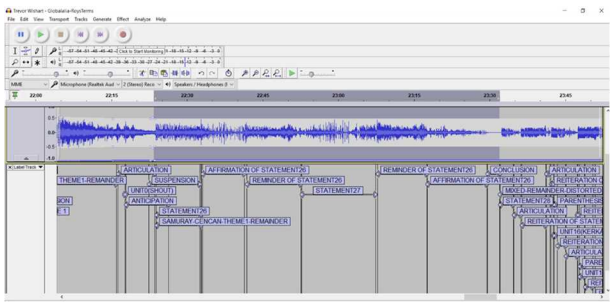

Figure 24. Section from 22:23 to 23:32 (Section 19).

This section mainly uses new statements, affirmations, and reminders. The section also has a clear conclusion. The section follows in the context of using Statement 26, giving affirmation of Statement 26, making a reminder of Statement 26, bringing Statement 27, and then re-introducing the reminder of Statement 26 and affirmation of Statement 26 before arriving at a conclusion. The main purpose of the section is much alike the section from 19:20 to 20:49 which is about reminding the previous sections from the piece to the listener.

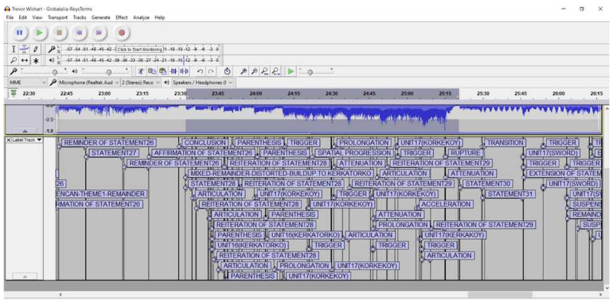

Figure 25. Section from 23:32 to 25:20 (Section 20).

This is one of the most memorable sections in the piece. The section uses heavy amounts of articulation, reiteration, parenthesis, triggers, and different units such as Unit16 (KERKATORKO), Unit17 (KORKEKOY). Occasional usage of prolongation, appoggiatura, acceleration, spatial progression, attenuation, and rupture are also prominent. One of the main reasons behind the section getting more attention comes from the fact that it is divided into two little very coherent sections. The first one is from 23:32 to 24:11, and the second from 24:11 to 25:20. The first section functions as a build-up to the second section. The build-up is made through using a lot of rhetorical functions in an order such as introducing Statement 28, bringing articulation, the reiteration of statement 28, bringing articulation, the reiteration of Statement 28, and lots of parenthesis with Unit16 (KERKATORKO) which is one of the most important elements throughout the build-up because of the fact that Unit16(KERKATORKO) is the most important unit on the second section. The second section is mainly textural with an intense amount of repetitions of Unit16(KERKATORKO), moderate usage of spatial progression, prolongation, and attenuation.

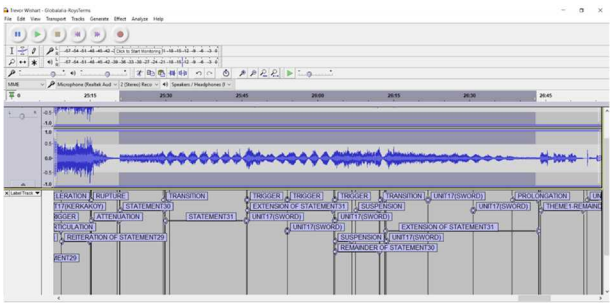

Figure 26. Section from 25:20 to 26:43(Section 21).

This section uses triggers, transitions, extensions, suspensions, prolongations, and re-introduces Unit17(SWORD). Unit17(SWORD) gets mostly used to trigger suspensions as well as extensions in the section. This section is functionally very similar to the sections 3:23 to 4:03, 9:16 to 10:27, 4:32 to 5:42, and 6:51 to 7:57.

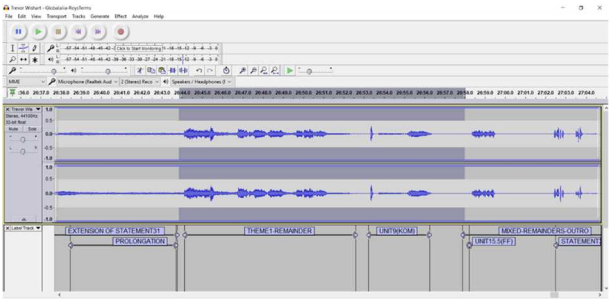

Figure 27. Section from 26:43 to 26:58 (Theme 1).

This is a reminder of theme 1 and acts as a concrete musical line in which the listener can understand where he/she is standing on the timeline. It is also worthwhile to note Unit9(KOM) gets used right at the end of the section.

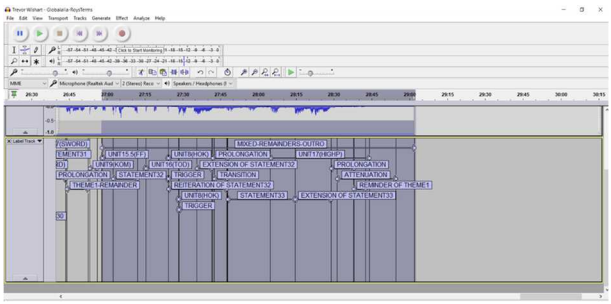

Figure 28. Section from 26:58 to 29:02(Outro).

This section functions as an 'outro' to the piece. Triggers, attenuation, conclusion, prolongation, extension are some of the functions that the section explores. Triggers in the section are highly related to Unit8(HOK). Unit15.5(FF) and Unit16(TOD), Unit17(High-P) are the only fresh sound elements that the section introduces. Aside from the mentioned sound units, the section utilizes sound elements that have been used throughout the piece. This deliberate process of re-introduction of the brief familiar sound elements alongside the use of prolongation, attenuation, and conclusion is what makes the section's instant give-away of the listener's location in the timeline of the piece.

2. Macro Analysis

After taking account of some written information about the Globalalia as well as making an analysis of the piece by using Roy's terms, it is now possible to wrap all of the information up and make some general statements about how the piece works and what makes it unique in the electroacoustic canon in terms of its structure.

Roy's terminology helped to view the piece at a micro-level which, in turn, helps to understand the macro-level relationships that may be found throughout the piece. The global/macrostructure of the piece was crystallized by translating the microstructural findings to the main graphical format by working through three different graphs/tables (Figure 30, 31, and 32) which illustrate the relationship of the piece's sections.

Figure 29. Timeline for Sections (Basic Version).

Overall, the whole piece has twenty-one sections, six Theme 1 sections, and an Outro section. This is particularly interesting and effective when reflecting back on Wishart's idea of a story within a story. The sections are mainly divided into three categories. The first category includes the sections that are mainly gestural with lots of rhetorical functions that project many abrupt changes which are achieved through repetition, interruption, deflection, and triggers. The second category includes the sections that are generally textural with numerous process-based functions such as intensification and spatialization that work with call/answer, accumulation, and rhythmical repetition. The third category is simply for the sections that do not fall into the prior two categories, and they play a significant role in making the structure non-monotonous and fresh.

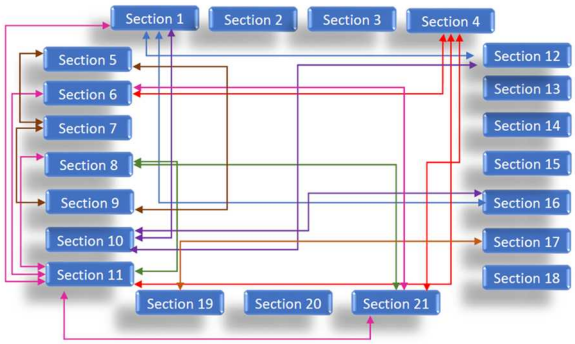

Figure 30. Sectional Relationships.

Figure 30 takes all of the written analysis of separate sections (except Theme 1 and Outro Sections) and connects the sections with similar functionality to see the global form more clearly. (See the previous part of the essay for a detailed explanation of how these sections are connected).

Section	Related Sections
Section 1	Section 11, Section 12, Section 16
Section 4	Section 6, Section 11, Section 21
Section 6	Section 4, Section 11, Section 21
Section 8	Section 11, Section 21
Section 10	Section 1, Section 12, Section 16
Section 11	Section 1, Section 6, Section 8, Section 21
Section 12	Section 1, Section 10
Section 16	Section 1, Section 10
Section 17	Section 19
Section 19	Section 17
Section 21	Section 4, Section 6, Section 8, Section 11

Figure 31. Sectional Relationships (Table Format).

Figure 31 is a simplified version of Figure 30. This simplification was helpful in generating the main graph (Figure 32).

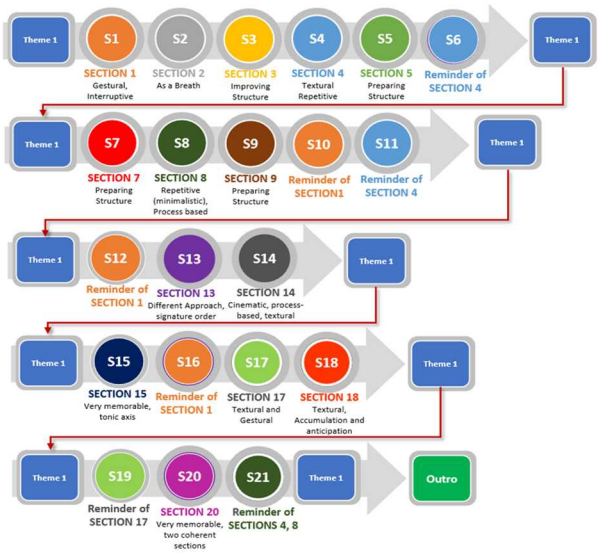

Figure 32. Timeline of Globalalia.

Figure 32 is the macro-structure of Globalalia. By looking at the graph we can easily start to get an idea of how the piece actually works on a global level. To elaborate, it is important to look at each progression between Theme 1s (there are five) in segments. The first segment (Section 1 to 6) mainly introduces the main sections (while also using different sections as a breath as well as building/improving to the proceeding section) which will be used as markers through the rest of the piece to remind the listener of his/her position in the piece (Section 1 and 4).

The second segment (Section 7 to 11), prepares the piece to build on the repetitive textural ideas that are being explored in Section 4 while taking them to another level (Section 8). It then proceeds to take the structure back to the reminders of Sections 1 and 4 before reaching Theme 1. The third segment (Section 12 to 14), starts with a reminder of Section 1 and then introduces two different sections which both explore different ideas at a micro-structural level. The fourth segment (Section 15 to 18), keeps on exploring different ideas with a very unique and memorable section (Section 15) that uses heavy amounts of tonic axis right before getting back to the reminder of Section 1. The section then continues the exploration of different ideas with Sections 17 and 18 before reaching Theme 1. The fifth and final segment (Section 19 to 21), starts with a reminder of Section 17 and then leads into the most memorable section in the piece (Section 20) which consists of two coherent sections. The ending of Section 20 leads to Reminders of Section 4 and 8 before reaching to Theme 1.

To sum the graph up:

- The piece is divided into five segments with every segment starts and ends around Theme 1s
- The first segment is all about introducing the main elements that the piece uses throughout the piece.
- The second segment brings one different section and uses two reminders (reminder of Section 1 and 4).
- The third segment uses one reminder (reminder of Section 1) and two different sections
- The fourth segment uses one reminder (reminder of Section 1) and three different sections (one of them is being very memorable)
- The final segment uses two reminders (reminder of Section 17 and reminder of Section 4 and 8) and uses one extensive very memorable section which contains two coherent little sections then it goes straight into the outro.
- After the final segment, the piece ends with an outro section

Having a clear macrostructure (through the usage of Theme 1, reminders of Section 1 and 4 as a marker throughout the piece, building the introduction of different sections in each segment, and having a clear Outro Section) mixed with complex micro-processes (discussed on the micro-analysis section) is what makes this piece unique as a whole.

Another uncommon but positive side of this work is the ideas that are conveyed through building the structure are not only relevant to the works in electroacoustic context but it is also highly applicable to the instrumental context. It is especially interesting how having a structure that is very applicable to the instrumental world can make a long and complex electroacoustic piece relatively easily digestible by the listener in an effective manner because this system creates clear hierarchical structures throughout the piece.

Even though Wishart claims that there is no influence in his work that is related to the instrumental world, one could suggest that the instrumental music tradition has been impactful in his music for his philosophy on how he sees and operates through the compositional structure in Globalalia since the piece has a clear and hierarchy-based macro structure mixed with long and complex microstructure.

Conclusion

This research focuses on the micro and macrostructure of Wishart's famous piece 'Globalalia' with the intent of having a greater understanding of the piece. The research gathers its finding by using Roy's analytical methods (forty-five formal functions) and Audacity's label tool as a means of unpicking the microstructural elements and their relationships. These findings then initiate the macrostructural analysis process of the piece and crystallize the main macro relationships between the sections.

Even though there are many articles regarding 'Globalalia', the exhaustive analysis or written work focusing on the structure of the piece has been a novel study and it helps readers to understand the piece better.

As future work, a study that incorporates the structural findings with the electroacoustic techniques that are specific to 'Globalalia' can be examined which could lead to a discussion on how a certain technique could impose a certain micro-structural approach.

Acknowledgments. I would love to thank Adam Stanovic for his invaluable support and insight throughout the production of this article. Without his help, this work would not be possible. I also want to thank Adrian Moore for his feedback and help when producing this work.

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[Abstract in Korean | 국문 요약]
'글로바랄리아'의 작곡 구조와 기능 분석

버크 야글리

전자음향 음악은 사운드 아트와 음악 작곡 분야에서 괄목할 만한 위치를 차지하고 있다. 기존의 음악 장르와 비교하여 근본적으로 다른 복잡성과 접근 방식으로 인해 전자음향 음악은 종종 이해하기 어렵다는 평가를 받는다. 그로 인해 이 장르는 충분한 인정을 받지 못한 면이 있는데, 특히 음악학자들이 이 장르의 주요 레퍼토리 작품에 대해 폭넓은 분석을 이루어낸다면 이에 대한 이해를 극적으로 변화시킬 수도 있을 것이다. 이 연구에서는 트래버 위시하트Trevor Wishart의 유명한 작품인 '글로바랄리아Globalalia'를 면밀히 관찰한다. 위시하트는 주로 성악 작품으로 잘 알려진 작곡가이다. 특히 그는 전자음향 음악 분야에서는 보기 드문 장편의 작품을 작곡한 것으로 유명하다. 그의 장편 작품을 이해하기 위해 이 연구는 작품 구조를 구성하는데 위시하트가 사용한 수단에 초점을 맞추고 있으며, 특히 그의 장편 작품 중 하나인 '글로바랄리아'에 집중한다. 이 연구는 작품의 미시적 수준과 거시적 수준에서 발생하는 구조적인 과정을 모두 풀어내는 방법으로 형식의 기능과 작용에 대하여 알아보는 스테파니 로이Stéphane Roy의 아이디어를 활용한다. '글로바랄리아'에 관한 논문은 많지만, 이 연구는 작품의 철저한 분석과 작품 구조에 초점을 맞춘 글로서 독자들이 작품을 더 깊이 이해하는 데 도움이 될 것이라는 점에서 참신하다.

주제어: 전자음향 음악, 음향음악작곡, 전저음향 음악 분석, 전자음악과 컴퓨터 기반 음악 분석, 컴퓨터를 이용한 작곡/분석

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PART II: Reviews

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Create Imagination with Senses: Review of *Seoul International Computer Music Festival 2023*

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Seoul National Computer Music Festival was held from the 6th to 8th October 2023. The festival conducted concerts of instruments, electronics, live electronics, new media and so on. Among the 31 works, 4 works showed potentials that computer acoustics can stimulate our senses and those helped us to make our imaginations extremely. Firstly, we can imagine some appearance by capturing real lives' elements. For example, Panayiotis Kokoras'《AI Phantasy》(2020) uses real-sounds, such as eating sound and environmental noises, by listing various sounds, he captures the moments when our thoughts moved back and forth between reality and unconsciousness, and daydreaming. Also, MinSeok Yang's《Vanishing Point》(2023) captured the landscape vividly and in detail by acoustically seizing the waterhole created by the raindrops through vibraphones, percussion and electronics. The following works, SeongJun Moon's《Halftone》(2023) and HyeonSeok Jeon's《Fragmented Colours》(2023), are designed to draw a single picture in an imaginary space. The former work formed electronic points, and then points make lines and a surface. The last work, I would like to talk, uses Saenghwang and live electronics. It was transformed into a picture with various colours and forms by harmonizing the movements of the sounds produced by Saenghwang and the computer. After all, this work made me to imagine a 'drip technique' painting. To conclude, although the sound produced by computer music differs from the traditional sounds, the specialty caused by using computers allowed us to further stimulate our senses and create an imagination.

감각으로 상상 빚기
: 서울국제컴퓨터음악제 2023 리뷰

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2023 년 10 월 6-8 일 서울교육대학교 종합문화관에서 30 주년 기념의 서울국제컴퓨터음악제 2023 이 진행되었다. 어쿠스틱 악기, 컴퓨터, 전자음향, 영상매체, 뉴미디어 등의 다양한 방식을 사용한 31 곡의 작품과 주앙 페드로 올리베이라 João Pedro Oliveira 의 세미나 그리고 설치전자음악까지 컴퓨터음악에 관한 모든 이야기를 보고 들을 수 있는 시간으로 꾸려졌다. 단순히 컴퓨터를 사용해 전자적 음향을 만든다는 것에서 넘어서서 이제는 전자 기술을 사용해서 만들어낼 수 있는 무수한 가능성을 무대 위에서 펼쳐냈다. 특히 이번 음악제를 참관하며 느낀 것은 컴퓨터음악이 다른 무엇보다도 인간의 오감을 자극시켰고, 개인이 할 수 있는 최대치의 상상력을 만들어낼 수 있게 도와주었다는 것이다.

어릴 적 기억을 떠올려보면 단순한 자극에도 다양한 상상을 펼치곤 한 것 같다. 예를 들어, 하늘 위에 떠있는 구름을 보고 모양 찾기 놀이를 했던 기억이다. 둥그렇게 몰려있는 구름에 구멍이 있으면 돼지코라고 외쳐보기도 하고, 통통한 뫼산

모양의 구름은 자동차라고 붙이기도 했다. 이렇듯 추상적인 시각자극을 통해 어릴 적 상상의 나래를 펼치곤 했던 것이 청각으로 넘어와 소리를 통해 공상을 하기 시작했던 경험도 있는 것 같다. 떨어지는 빗소리에 마음대로 음과 리듬을 붙여 나만의 음악을 만들어보기도 했고, 최근에는 전기버스차에서 들리는 전차의 '땡땡땡' 소리를 듣고는 갑작스레 지금의 버스와는 다른 모양의 자동차나, 외국에서 보았던 귀여운 모노레일 전차를 그려내며 양 옆에 왁자직껄 떠드는 사람들의 모습을 그려보기도 했다.

이렇게 다양한 자극은 우리의 상상력을 자극한다. 어떤 형태를 구체적으로 그려낼 수도 있고 다른 분위기를 머릿속에서 떠올릴 수도 있으며, 기상천외한 소설을 만들어낼 수도 있다. 이번 서울국제컴퓨터음악제에 올라온 31 개의 작품들은 우리가 가진 상상력의 잠재력을 자극하기에 충분했으며, 다양한 상상을 빚을 수 있는 원동력을 제공했다. 음악제 첫날부터 마지막날까지 모두 참관하여 컴퓨터음악의 흐름과 모습을 두 눈과 귀로 담아냈지만, 이 지면에는 특별히 기억에 남은 4 개의 작품을 '상상 빚기'라는 키워드 안에서 공유하고자 한다.

포착하듯 상상하다

파나요티 코코라스 Panayiotis Kokoras 의《AI Phantasy》(2020)는 평면적으로 흘러나오는 사운드로 구성되어 있지만, 서라운드 식으로 이루어진 스피커 배치를 통해 공간성을 형성했다. 그리고 그 공간은 다양한 사운드가 지닌 이야기들을 한껏 풀어낼 수 있는 좋은 공간이 되었다. 그리고 코코라스가 프로그램 노트에서 "현실에서 실제와 상상을 거의 구별하지 못한다는 점에서 대게 무의식적"이라고 말한 것처럼 그의 작품은 수많은 사운드스케이프, 녹음 사운드, 악기 소리, 사람 목소리, 그 외의 조합할 수 있는 모든 소리가 혼재됨으로써 무엇이 진실이고 환영인지, 무엇이 현실이고 나의 상상인지 구분하지 못하게 했다. 즉, 무언가를 먹는 소리, 동물 소리, 풍선 터지는 소리 등 일상생활 속에서 들을 수 있는 소리와 우리가 상상의 나래를 펼치며 만들어낼 수 있는 갖가지 소리가 한데 뒤섞여 재생되었다.

이와 같은 소리들은 한 채널에서 들리던 것이 어느 순간 사라지고 다른 곳에 위치한 스피커에서 급작스럽게 다른 소리가 들려옴으로써 한 사람의 무의식적인 의식의 흐름을 포착한 듯하다. 마치 어떤 사람이 주변 소음의 한가운데 앉아 멍하니 앉아있다가 이윽고 옆 테이블에서 들려오는 음식 먹는 소리에 온 귀가 집중하는 모습이 상상되는 것이다. 그러고서는 순식간에 눈 앞의 장면이 바뀌어 어디선가 희미하게 들려오는 풍선터지는 듯한 노이즈가 들려오게 되는데, 눈 앞에 음식을 먹는 모습은 온데 간데없고 놀이공원에서 풍선을 들고 가다 손에서 놓쳐버린 장면으로 전환된다. 이렇게 수없이 바뀌는 음향의 조합과 녹음본의 소리는 작품 안에서 뒤엉키게 되면서 더이상 무엇이 어떤 사건에 종속되는지 구별되지 않는다. 결국 이 혼재된 상황에서 여러 사건을 상기시키는 음향들을 통해 우리의 생각이 이리저리 움직이며 현실과 무의식 그리고 공상의 세계를 왔다갔다하는 그 순간들을 포착하였다.

양민석의《사라지는 지점 Vanishing Point》(2023) 역시 빗방물이 만들어내는 물웅덩이의 모습을 음향적으로 포착하였고, 포착한 순간을 듣는 필자는 그 모습을 충분히 상상할 수 있었다. 비브라폰과 타악기의 연주로 시작되는 도입부는 순식간에 빗물이 떨어지는 모습을 형상화하였는데, 한두방울 떨어지는 듯한 표현을 긴음가로, 소나기가 떨어지는 듯한 표현을 단음가의 빠른 음형으로 잡아내었다. 그러나 악기만 있었다면 빗방울의 하강하는 모습과 지면에 닿는 모습, 그리고 그 뒤에 파장을 남기며 사라지는 모습을 만들어내지 못했을 것이다. 하지만, 양민석은 비브라폰과 타악기를 감싸 안아 감각을 극대화해서 보여줄 수 있는 라이브 일렉트로닉스를 통해 빗방울의 순간순간을 잡았다. 즉, 프로그램노트에서 말했듯이 "생성, 부딪힘, 왜곡, 그리고 소멸 등을 스케치"하기 위해서 비브라폰과 타악기 그리고 라이브 일렉트로닉스를 적절히 배치하여 하나의 풍경을 생동감있고 세밀하게 포착하였다.

흐릿한 날씨와 먹먹한 공기의 밀도를 비브라폰의 음향으로 만들어냈으며, 타악기는 이 날씨 속에서 이리저리 휘날리는 빗물들을 그려냈다. 그러나 점차 이 두 악기가 만들어내는 빗소리는 거세지고, 여기서 생겨나는 "무작위한 소음들"은 라이브 일렉트로닉스의 중첩을 통해 극대화되었다. 라이브 일렉트로닉스는 악기의 음향을 그대로 받아 뒤늦게 송출하거나, 악기의 소리에 대한 잔향을 남기면서 빗방울이 지면에 떨어져 생기는 파장의 모양을 만들어냈다. 심지어는 빗방울이

한번은 굵게, 한번은 얇게 떨어지는 모습과 세찬 소나기를 넘어서 굵은 장대비가 떨어지는 형상을 표현하였는데, 악기 소리를 겹겹이 쌓아 두터운 음향층을 만들거나, 오히려 악기가 만들어낸 소리를 없앰으로써 얇은 음향층을 생성하여 표현하였다. 그러다 중간중간 전자음향의 소멸은 빈 공간을 창출하여 적막을 형성하였고, 더 이상 빗방울이 떨어지지 않는 끝을 보여주었다. 또한 전자음향을 어떻게 구성하고 음색을 만드냐에 따라 한 방울 떨어지는 모습과 소리, 혹은 여러 방울이 세차게 떨어지며 만들어지는 모습들이 머릿속에 구체적으로 그려졌다. 심지어는 작고 둥글둥글한 구슬 모양의 빗방울이 떨어지는 소리와 벽돌같이 넓고 납작하면서 무거운 물체가 웅덩이에 떨어지는 소리가 눈 앞에서 직접 보듯이 귓가에 울려 퍼졌다.

결국 위의 두 작품에서의 전자음향은 기존의 악기로 표현할 수 있는 것에서 넘어서서 기존의 표현방식을 한 차원 더 세밀하고 정교하게 만들어주었다. 특정 행위에 관한 녹음본과 사운드스케이프, 악기 소리 등이 단순히 파편화되어 재생되었으면 의미가 생성되기 어려웠을 것이다. 하지만 파나요티 코코라스의 테이프 음악은 현실과 비현실의 소리를 조각내고, 다시 이어붙이고, 두 그룹의 소리를 조합하고, 분리시킴으로써 다양한 이야기 구조를 만들어내어 인간의 무의식적 흐름을 생생하게 포착해내었다. 양민석의 라이브 일렉트로닉스 음악 역시 전자음향을 덧입힘으로써 빗방울의 일대기(수직낙하-지면과의 만남-웅덩이로의 변화-소멸)를 두 눈으로 보는 듯한 착각을 할 수 있도록 음향적으로 세밀하게 포착해내었다.

그려내듯 상상하다

앞서 언급한 작품들이 현실에서 이루어지는 현상들을 포착하여 우리가 상상할 수 있는 힘을 불어넣어 주었다면, 다음의 두 작품은 상상의 공간에 하나의 그림을 그릴 수 있도록 설계되었다. 문성준의《망점網點/Halftone》(2023)은 '점을 찍어 그물을 그리다'라는 제목처럼 말 그대로 전자음으로 형성된 점들을 통해 하나의 그물망, 그리고 이를 넘어서 하나의 면을 만들었다. 즉, 점에서 시작해 선을 그리고, 선의 움직임이 모이면서 면을 그려낸 것이다.

먼저 하나의 전자적 음향의 단음이 반복적으로 여러 개의 채널을 통해 등장한다. 이윽고 여러 채널에서 여러 개의 전자음이 번갈아가며 들려오게 된다. 이때 한 방향에서 다른 방향으로 넘어가는 포물선이 귀 안에서 그려진다. 이 전자음의 왕복이 반복되면서 점이 선으로 변한다. 그리고 이 선을 이루기 위해 만들어지는 여러 전자음들은 점과 선에서 넘어서서 면을 형성한다. 완벽하게 직조된 촘촘한 면은 아니지만, 음향이 반복적으로 제시되면서 마치 전자화면에 보여지는 여러 픽셀의 움직임으로 느껴진다.

그 다음엔 선과 면의 음향이 교차되면서 마치 붓의 터치와 흐르는 먹의 이미지를 생성한다. 즉, 전자음의 왕복운동을 통해 형성된 선이 여러 채널에서 등장하면서 한 줄이 아닌 여러 줄로 겹쳐지게 되고, 전자음이 움직이는 운동 에너지가 증가함에 따라 강세가 주어지게 되면서 선의 두께가 결정된다. 전자음으로 형성된 그 음향적 선이 강세가 주어지지 않을 때는 얇고 긴 선을 그려내었다면, 2 개의 채널로 이루어진 양방향의 스피커 가운데에서 강세가 주어진 음향이 움직일 때에는 붓이 굵게 떨어지는 부분이 형상화되었다.

세번째로 점과 선 그리고 면이 동시다발적으로 등장한다. 픽셀의 움직임이 다시 청각적으로 재현된 것이다. 한 음이 강하게 움직이면 점으로, 비슷한 음색과 강도를 가진 전자음이 서로 다른 채널에서 움직이면 선으로, 그리고 이것이 겹쳐져 면이 형성되면 <그림 1>과 같은 모습이 구현된다. 마지막으로 점, 선, 면을 모두 거친 다음에 하나의 단음으로 끝을 맺는다. 점으로 끝나는 것이다. 위에서 만들어졌던 구체적인 면, 마치 촘촘하게 베틀을 짜듯 하나의 재료가 된 수많은 점들이 부드러운 하나의 면을 만들었다가 다시 와해가 되면서 면은 온데 간데없고 면과 선이 분리되어 오로지 점으로 남은 듯한 모습을 자아내었다.

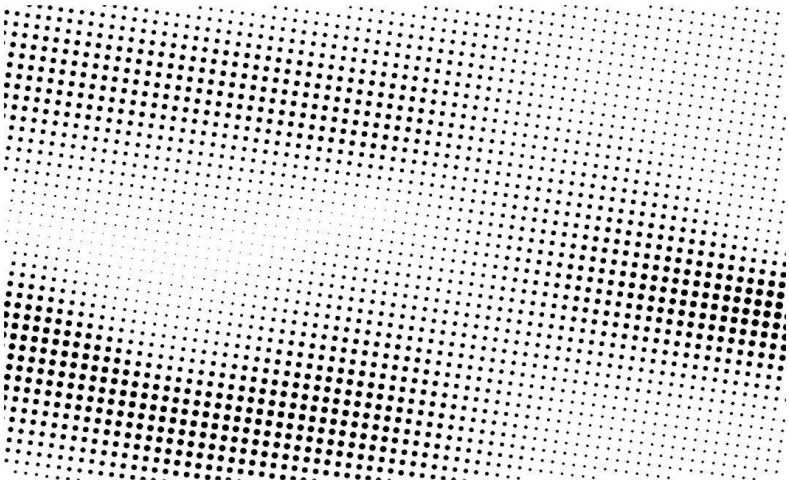

그림 1. 망점 Halftone[1]

다음으로 생황과 라이브 일렉트로닉스로 구성된 전현석의《조각난 색상들 Fragmented Colours》(2023)은 생황과 라이브 일렉트로닉스를 통해 색상의 움직임을 구현한 작품이다. 생황이 만들어내는 단음과 화음은 역동적으로 움직인다. 생황이 한음으로 움직이다가 화음으로 구성되고, 다시 다른 음으로 이동하면서 음들의 운동성이 형성되는 것이다. 여기에 덧붙여 실시간으로 주고받는 컴퓨터 음향은 생황의 음 조직을 극대화한다. 음조직을 분절시키거나 감쇄하는 방식이 아닌, 생황의 음색과 운동성을 보조 및 변용하여 생황의 음향을 한껏 돋우는 것이다.

생황과 라이브 일렉트로닉스의 조화는 새로운 상상력을 더하여주었다. 날카롭지만 독특한 생황 소리에 덧입혀지는 컴퓨터의 음향은 조각난 "색상"들을 세세하게 그려낼 수 있었다. 생황의 음들은 빨강, 노랑, 초록 등의 다양한 색감을 음향적으로 보여주었다. 그리고 생황이 만들어낼 수 있는 화음들은 이러한 색들의 조합으로 이리저리 뒤엉켜 제공되었다. 이때 컴퓨터를 통해 조작되는 파편적 음향들은 하나의 색감이라기 보다는, 생황이 만들어놓은 색깔에 물을 타 점성의 변화를 꾀하고, 도화지 위 물감의 위치를 조정하는 역할을 했다. 결국에 생황과 라이브 일렉트로닉스가 만들어낸 전현석의 작품은 '물감뿌리기 drip technique' 기법을 사용한 그림처럼 여러 색깔의 물감이 비정형적으로 그려졌다. 결국, 모든 사람이 상상할 수 있는 색깔과 모양새는 다르지만, 뿌려진 물감의 크기도, 묽기도, 점성도, 흩뿌려진 모양도 모두 다 다른 그런 화폭이 머리속에서 그려지듯 상상되었다.

[1] 망점에 대한 이해를 돕기 위해 하나의 예시를 들고 왔다. 점으로 이루어져 있지만, 선을 만들기도 하며, 선이 모여 면으로 보이기도 한다. https://www.freepik.com/free-vector/black-wave-halftone-background_7647150.htm#query=halftone&position=3&from_view=keyword&track=sph&uuid=2e4cadba-f5c5-4f32-82b7-cef0a267cfef [2023 년 12 월 14 일 접속].

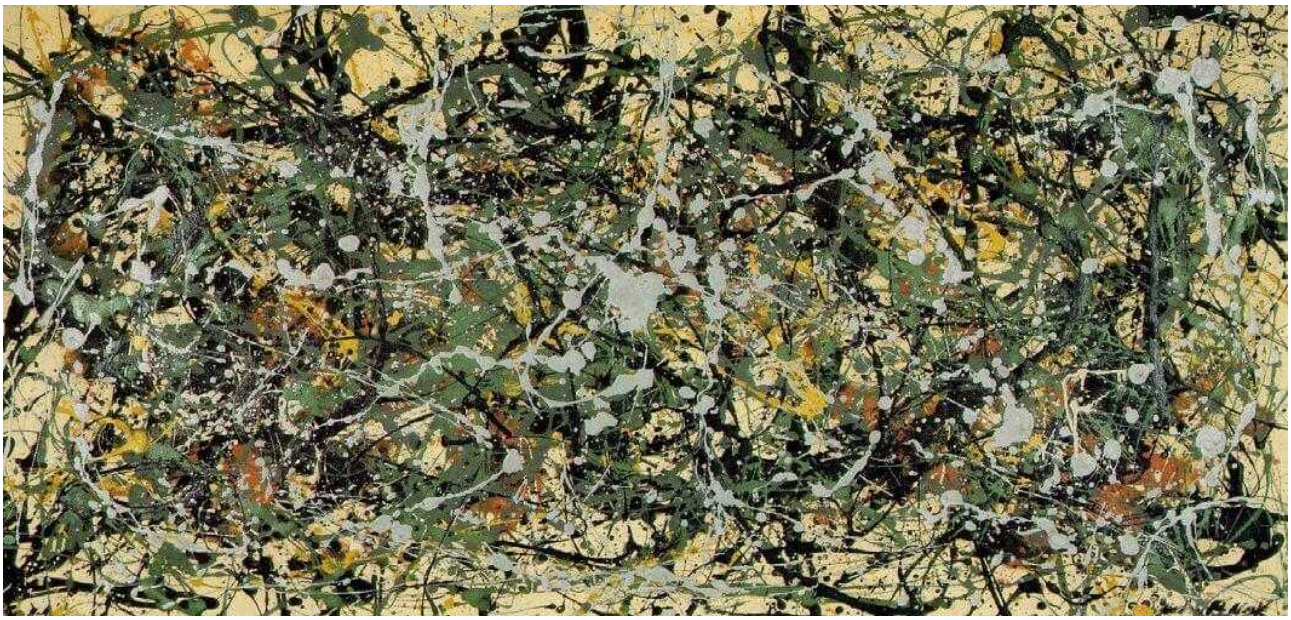

그림 2. 잭슨 폴록 Jackson Pollock, 1912-1956 의《8 번 Number 8》(1949)[2]

이처럼 문성준의 작품은 하나의 음을 통해, 어찌보면 제한적인 상황 속에서 채널을 동시에 쓸 수 있는 이점을 활용하여, 점에서 면으로까지 만들어지는 물체를 그려낼 수 있는 상상의 힘을 음악을 통해 전달했다. 즉, 구체적인 음향적 제시를 통해 청자는 마음 속에 하나의 물체를 그릴 수 있었던 것이다. 전현석의《조각난 색상들》역시 마찬가지다. 생황이 만들어내는 음들의 움직임과 이를 받쳐주는 컴퓨터 음향의 조화를 꾀하여 여러 색감을 가진, 그리고 여러 형태를 가진 그림으로 변모시켰다. 그리고 그 형상은 청각을 통해 머릿속 시각으로 전환되었다.

상상을 마무리하며

필자가 개인적으로 음악이 가진 능력 중에 가장 크다고 생각하는 것은 이야기를 만들어낼 수 있다는 것이다. 21 세기의 컴퓨터를 활용한 음악에서도 이야기를 만들어내고 있다. 테이프 음악처럼 실제 소리를 녹음한 것을 사용함으로써 보다 이야기를 구체적으로 상상도록 유도했다. 또한 기존에 있던 재료에서 벗어나 다양하고 다층적인 사운드 발현 방식을 이용하면서 청자들의 상상력을 자극하였다. 이번 서울국제컴퓨터음악제 2023 에서 선보인 여러 작품 가운데 해당 지면에서 언급한 4 개의 작품은 청각이라는 감각을 통해 시각과 촉각 등의 인간의 모든 감각을 일깨워주었다. 그리고 개개인이 만들어낼 수 있는 상상력을 끌어냈다. 그것도 추상적으로 둥둥 떠다니던 요소들을 구체적으로 상상 속에서 형상화한 것이다. 이러한 지점에서 컴퓨터음악이 만들어내는 음향이 기존의 사운드와 다른 부분이 존재하지만, 컴퓨터를 사용으로부터 오는 특수함 덕분에 우리의 감각을 더욱 자극하여 하나의 상상을 빚어낼 수 있었다.

[2] 필자가 말하고자 하는 '물감뿌리기 기법'을 설명하기 위해 잭슨 폴록 Jackson Pollock 의 작품을 한 예시로 가져왔다. https://www.jackson-pollock.org/number-8.jsp [2023 년 12 월 10 일 접속].