A SYSTEMIC PERSPECTIVE FOR SONIFICATION AESTHETICS

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ABSTRACT

For more than twenty-five years, the sonification field has been attempting to establish itself as a primary body of knowledge communicating through sound. Despite multiple efforts to embrace the interdisciplinary nature of the field and the subjective nature of sound, we wonder: is the tendency for dealing with such challenges through an objective, functional communication, with a single interpretation criterion, limiting the epistemic boundaries of action? How can a subjectively perceived medium such as sound be embraced in all its aesthetic dimensions? We propose a conceptual transition through the reframing of a sonification as a living system for creating aesthetic experiences. This will be achieved by drawing notions from phenomenology, embodied perception, human-computer interaction and soundscape theory. A systemic sonification distinguishes itself as an ever-evolving system built on dynamic structures that actively responds to changes in its environment and interactions from surrounding beings. Driven by a series of emerging concepts of non-linearity, networks, nested systems and intertwined relationships, the system's resilience and adaptability grows with each interaction, recentring the human protagonist as the weaver of his/her aesthetic experience through a self-transcendent process that expands the perception field.

1. BRIEF CONTEXTUALISATION: FROM SONIFICATION TO AESTHETICS

More than a quarter-century has passed since the establishment of Auditory Display as a research field focused on how to use sound as a communication interface. The sonification sub-field, centred in exploring the transformation of data relations into acoustic relations to facilitate communication or interpretation [1], has been dwelling with a lack of credibility and solidity, emphasising the following problems according to Neuhoff [2]: 1. the precision of vision versus audition and how the perceptual differences have not been properly tamed for sound communication, 2. the individual differences of each listener whose subjective interpretation must be acknowledged, 3. the fuzzy boundaries between art and science within the field, which questions the place of sonification as an inevitable interdisciplinary field and, therefore, of dense complexity.

Studies have emerged in the last decade seeking to deconstruct this art-science duality through the reflection about the aesthetic

dimension of a sonification and its relevance. The term "aesthetics" comes from the Greek word *aisthētikós* (i.e., perceived by the senses) [3]. This was a persistent perspective, with aesthetics staying limited as the appreciation of beauty in art, and "the measurement of beauty" [4]. Time has expanded this notion of aesthetics as the awareness of the beautiful through the human senses, restructuring what Aesthetics really encompasses. For auditory display, it has been regarded as an important piece for altering perception and transforming the experience of a sound artefact, exploring embodied interactions through mental, interpretive processes in search for the "pure meaning" of data. This expression encompasses the standing view within the field of a successful dataset communication through a single interpretation criterion, leading the listener to understand with precision the sonified data, or a certain relationship / pattern within it. Following a straight communication flow of "information source reaches its human receiver through an information display" [5], the sonification field has been dominated by what we will designate as this *functional* perspective of data translation through sound. We argue that this unequivocal relation between data and interpretation might be a reductionist vision on how to shape a sonification, which might explain Neuhoff's list of issues [2] that still haunts the field.

Exploring the aesthetic dimension has emerged as a form of encompassing the subjective nature of sound and its listener. This structure is flexible enough to accept the relationship between music and sonification, the "transmodal nature of musical understanding (...) through the perspective of embodiment" [6], while still integrating a functional perspective of data analytics. Aesthetics rises as a way of guiding the listening as a "perception-action aesthetics" that promotes active listening in search of meaning [6]. It becomes a structural conceptualisation on how to represent a sonification that may create tension between a "sonification's perceived function and its potential status as an artwork", embodying the dualisms of art-science / sonification-music in redirecting the listener's attention from an informational-functionalist perspective to other interpreting forms. Besides the encoding process of coupling the sound and data through a valid metaphor, it considers the listener as the perceiver of sonification that develops a relationship with the artefact through interaction (decoding process), which requires him/her to be placed in the centre of the experience. Following this notion, we can "escape the strictures of taxonomy" [6] for designing a sonification experience. However, despite the authors mentioning the idea of an "ecosystemic network of experiences, memories, imaginings and expectations" that integrates the users and their subjective backgrounds, the experience is still mostly constrained by the designer's choices, of what he/she chooses to sonify and communicate from the dataset. In the end, isn't this

intention similar to the "pure meaning" utopia of functionalism?

If the participant is to be taken as the central element of the experience, full of pre-expectations, memories, cognitive foundations and emotional patterns, can there even be a single meaning? A shift of the space of possibilities on how to conceptualise a sonification process might stir needed transitions within the field, and open space for new questions. Following this proposition, how could the transition for multiple meanings be integrated as part of designing for the listener's interpretive process, or even multiple listeners with multiple interpretations simultaneously? What could we consider as aesthetics, in this scenario? And, most importantly: how could we then devise an aesthetic experience of a sonification? From the notion of "ecosystemic network" [6], we propose a conceptual transition through the lens of a sonification as a living system, incorporating systemic knowledge [7, 8] to portray a 5-stage aesthetic experience of a sonification [9], notions from phenomenology [10] and embodied perception through bodily interactions [11] with a welcoming degree of ambiguity [12], and yet concepts of the soundscape theory [13, 14].

This paper is organised as follows. Section 2 overviews definitions and implications of Aesthetics, and a cognitive model of an aesthetic experience. Section 3 presents six perceptual shifts of a systemic view, from which we propose an adaptation to a sonification process in Section 4. Section 5 proposes a systemic model for devising a sonification, and how the established Model-Based Sonification can be considered an iteration of this model. Section 6 encloses how a systemic thinking may provide scenarios for aesthetic experiences, with our final remarks concluding the paper with arising questions and future directions.

2. AESTHETICS: DEFINITION, RESEARCH OVERVIEW AND IMPLICATIONS

As introduced previously, the term *aesthetics* has long evolved since being finitely considered a beauty judgment. A concept that defined an aesthetic consciousness was the idea of a "special mental attitude" [15] where the experiencer is separated from the object experienced, which demanded a physical and mental distancing, surpassing immediate judgments to fully appreciate its qualities. Kant pursued this view, where an aesthetic experience was only possible depriving bodily desires [16]. Theorists of this attitude viewed an aesthetic scenario as a deep, mental activity of an observer, detached from the physical experience. Alternative, contemporary perspectives critiqued this view, countering the notion of a particular psychological state to foster that experience with an embrace of practical and cognitive perceptions that drive from it [15]. Artistic objects cannot be separated from the origin and practicality of experience, with the aesthetic dimension being regarded as a clarifier and intensifier of qualities of "every normally complete experience" [17].

Aesthetics applied to computing emerged in the 2000s, translating a concern with human sensing, cultural aspects and social interaction in designing computational applications. The notion of the human as a bodily, multisensorial being motivated the study of Aesthetics in HCI for the last twenty years. The human is regarded as a producer of "high-level experiences" and a "guiding system" that leads the design process and the user interaction from which users carve out meaning [18]. Udsen & Jørgensen [19] coined this shift *the aesthetic turn*, exploring the relationship between the aesthetic object and the user's aesthetic experience through four approaches: cultural, functionalist, experience-based and techno-

futurist. In 2004, Petersen et al. [20] proposed the concept of *Pragmatist Aesthetics*, which sees aesthetics as an emerging potential in the relations with our surroundings and everyday experiences. These connections occur through the interdependence of mind and body, emphasising the "experiential aspects of interactive systems" and the user's exploratory attitude, while encouraging play and discovery to experience the system. Pragmatist Aesthetics has been applied since, translated as a design approach to create "intelligent, 'behaving' products" [21] and extended in three dimensions [22]: 1. an holistic approach of four threads (sensual, emotional, compositional and spatio-temporal), 2. a continuous engagement and sense-making act 3. and a relational / dialogical approach between participant, object and setting.

For auditory display, a few considerations on how to explore the aesthetic dimension have emerged in the last decade. Beforehand, it was primarily focused on sound aesthetics for user satisfaction [23], concept also used to devise a user-centred customisable toolkit [24]. Vickers & Hogg [25] proposed a circular scheme based on two axis: the *ars informatica / ars musica* to contrast scientific sonifications from musical compositions, and *musique concrète / musique abstraite* to distinguish data-to-sound mappings from tonal and atonal music. Barrass [26] proposed an integrative design approach concerning aesthetics using his TaDa design process, while Grond & Hermann [27] listed a set of important aesthetic guidelines relative to sound metaphors and parameters applied to sonification design. Filimowicz [28] proposed a two-dimensional space of two opposite personae, characterising the *data-in-itself* and *listener-for-itself*, seeking a balance between both tensions. Roddy [29] explored the concept of embodied auditory cognition, through which the meaning-making faculties of the listener originate aesthetic, meaningful experiences.

Various proposals of cognitive models were made to tackle the inherent stages for aesthetic appreciation of art. Leder et al.'s model [30] focused on a particular experience in a museum/gallery context that resulted in two outputs: aesthetic emotions (pleasure/ happiness or insatisfaction) and aesthetic judgments. Marković's model [31] characterises an aesthetic experience as four parallel streams of information processing through cognitive processes that originate emotional responses, with underlying dispositions in three dimensions (information, cognition and emotion). The focus is on the object, and the appraisal and unifying relationship it creates with its viewer.

2.1. A Cognitive Model for Aesthetic Experience

Pelowski & Akiba's [9] proposal of cognitive flow model is centred, in turn, on the individual and the concept of self-transformation, and how a cognitive discrepancy is needed to allow a deeper reflection for true cognitive mastery and, ultimately, a renewed self. In a nutshell, this model is comprised by five sequential stages:

1. The first comprises the user's *pre-state* of self-image, who holds a set of pre-expectations, tendentious behaviour and self-traits in response to the environment. Every external interaction is followed by an internal comparison between the self's fundamental meanings and transient meanings (relative to current, ongoing experiences);

2. The second is a process of *cognitive mastery* as a first assessment and attempt to classify, categorise and make sense of an artefact. In an effort to build inferences about the artefact, either its purpose, function, meaning or some kind of

emotional reaction it triggers, the user tries to interpret it, in a circular process of understanding - evaluation. This cycle, when the comparison between what is expected and what is perceived does not coincide, leads to discrepancy, which the user then attempts to solve by ignoring or reassessing it;

3. The third stage happens when this discrepancy is not rectified, which leads to an increase of conscious, cognitive senses and urgency to solve the tension. An attempt for *secondary control* is conducted, changing variables in the environment and reclassifying the artefact to reach consensus. Escaping, either mentally or physically, can become an outcome if the reclassification fails;

4. A *meta cognitive reassessment* follows as the fourth, transformational stage, where the user is forced to revise his/her expectations, former knowledge and future possibilities. An active, conscious process for transforming the user's self-image and involvement in the situation invites the user to "look outside" the problem [9], out of himself/herself and, in a way, to lose control.

5. Finally, the fifth and final stage comprises the major outcome and the core of what is considered to be the *aesthetic outcome* of the experience, a readjustment of the self, employing "a new set of schema that may then allow renewed/deepened cognitive mastery" [9]. True self-transformation happens in a moment of transcendence and epiphanic emotions, from where a conscious, self-contemplation period completes the new, found self.

Reflecting upon this notion of circular mastery process of interpretation and self-renovation, the notion of perception as an active attitude for seeking meaning has a substantial similarity with actively focusing and understanding a phenomenon to find its essence. "Inexact essences" [10] are simultaneously found during this process, where the term "inexact" does not mean a discredit, but a relaxation of the need for exact definitions, welcoming ambiguity in the process of discovery. To discover new universes for the perception of a sonification, one must step out of a linear process of thought and stimulus creation, and emerge in an integrative, dynamic space of stimuli.

3. SIX PERCEPTUAL SHIFTS IN A SYSTEM'S VIEW OF LIFE

A key sentence that drives our conceptual space is Merleau-Ponty' statement: "perception requires action" [11]. To fully grasp the behaviour and inherent meaning(s) of an artefact, one must look, listen, touch, embody and fully interact with it through a sequence of interpretive exchanges. While embracing the need for a perceptual shift, the living systems theory emerged with the concepts of non-linearity, circularity and networks that maintain the system's resilience and adaptability. Particularly, Capra stated six perceptual shifts needed for designing sustainable societies based on nature's ecosystems in terms of "relationships, connectedness and context" [7]. From these notions, we propose an alternative to the classical sonification research, grounded on the concept of a sonification as a living system, which we designated as a **systemic sonification**.

A systemic sonification is regarded as a dynamic, ever-evolving system that actively responds to changes in its environment and interactions with surrounding beings. We can envision a sonification as a complex system of intertwined dimensions,

whose behaviour and interrelations determine the course of evolution of the system. The theory of living systems then arises, and the concept of devising a sustainable, organised scheme guided by our nature's ecosystems and natural principles of organisation. Describing Capra's proposal of society as a living system, "non-linear and rooted in patterns of relationships" [7], his systemic thinking demanded a perceptual shift along six main dimensions:

1. From the *parts* to the *whole*: a living system as an integrated whole, driven by systemic properties independent of the properties of its parts, which cannot be reduced to their simple sum and individual existence;

2. From *objects* to *relationships*: concept of a community, where we rise from objects to what connects them, as networks of relationships that feed community-based tendencies for cooperation and consensual decision-making;

3. From *objective knowledge* to *contextual knowledge*: the properties of each part exist and can only be understood within a context, considering both the context of the whole and their environment;

4. From *quantity* to *quality*: understanding networks of relationships demand a qualitative form of measuring and scaling as a scientific model, contrasting the tendency for "only what is quantifiable is valid";

5. From *structure* to *process*: more important than the structural foundations is how they evolve and develop over time, in a constant process of renewal and transformation;

6. From *contents* to *patterns*: the networks of relationships unveil tendencies and repeatable configurations that create patterns, growing from constituting elements to how they are integrated;

A living system sets its ground on shared principles and a structural organisation that drives an holistic, integrative approach to life. More than content and matter, it's the form from which every element is born and grows that counts; more than *what* we communicate, it's *how* we communicate, the meta level of every interrelation in a balanced ecosystem.

4. CONCEPTUALISING A SONIFICATION FROM SIX DIMENSIONAL SHIFTS

Driving from the idea that action is the stream for conscious perception, the six dimensions proposed by Capra [7] can be expanded and adapted to the design of a sonification experience.

4.1. Parts → WHOLE

Each sound variable chosen to translate a given data parameter can be seen as an element of our ecosystem. Each element suffers a series of transformations, defined by an overall sound metaphor that establishes the systemic properties of the sonification and provides a unity of sense [9]. We can consider this change over time as each element evolves in response to an ever-changing environment, either by influence of other data-driven elements, or by human agents who enter to experience this habitat. Each element and respective transformations must create a balanced soundscape that provides a variety of acoustic elements while maintaining a controlled complexity [14], feeding the inherent diversity of the

system, and providing the resilience it needs to survive. This resilience, when transported to a sound dimension, may need to include silent moments "to regain mental and spiritual composure" in a primarily hi-fi soundscape [13].

At the beginning of our ecosystem, the constituting elements can be seen as identically important species to provide this balanced soundscape. The *horizontalization* [10] of every part rejects any kind of hierarchy, promoting an equalization of all sound phenomena. It is from this neutral initial state that each element can evolve according to its structural genetics born from data, composing an emergent acoustic hierarchy depending on how each element is stimulated by interactive agents. Considering that every data variable in the data is included as an agent in the ecosystem, a minimal amount, or even none, of pre-choice and filter should be applied in the mapping, with every parameter translated to the acoustic environment. This demands a neutral attitude from the creator of such system, not imposing nor controlling a given feature choice in advance, thus holding off pre-judgements as the phenomenological *epoché* [10] expects. The presence of each sound being is then gradually defined by how the data itself evolves over time, and how each agent seeks to explore it. This exploration can include a wide variety of detail levels, which can make microelements, or subspecies, emerge in the greater picture, as nested systems embedded within the overall ecosystem.

4.2. Objects → RELATIONSHIPS

The focus of a systemic sonification grows from devising each sound parameter as isolated, "straight from data" values, to how they create sonic relationships with each other in a constant perceptual change. It embodies the notion of a *network*, as each part, each sound plays a role in composing the entire soundscape ecosystem that thrives from the development of each individual. As such, the perception of each sound variable is interdependent of each other, in a flowing dynamic exchange of "cooperation, partnership and networking" [7].

These intertwined connections contain an inevitable degree of subjectivity and inherent complexity, especially when dealing with sound elements in an ocularcentric society. The concept of *ambiguity* is then encompassed as it is, primarily, encompassing. Characterised as "intriguing, mysterious, delightful" [12], it embodies the perspective of the creator, while also allowing a space for interpretation for every single individual, openly inviting him/her to participate in the meaning-making process. As such, a degree of deliberate imprecision, inaccuracy, contradictions or uncertainty brings space for speculation, enticing curiosity and self-awareness. This meets Pelowski & Akiba's second stage and rise of *discrepancy* [9] after failed expectations, which incites the process of reframing the self for renewal and true knowledge mastery. The moment when each individual is facing difficulty or non-clarity, at least as a first reaction, relates to a "displacement of the familiar" that leads to the *essential obscurity*, the first stage of a phenomenological approach [10]. As a decisive stage for learning, it marks a shift between paradigms, the transition between the old, comfortable, known perspectives and the novel, emerging ones. This uncertainty can be translated into a systemic sonification in two ways: on one side, in the unpredictability of how each element will acoustically unfold across time relative to other internal elements and external influences; on the other, in how these perceptive agents will iteratively interact, incite the presence of each sound being and uncover underlying patterns, entering circu-

lar processes [9] of doubt-discovery while existing in this ecosystem.

4.3. Contents → PATTERNS

The networks of relationships that spread within the ecosystem reveal patterns across elements as their individual paths of evolution and conjoined paths over time. These relationships can translate the patterns and abstract connections within data itself, typically present in long-term, dynamic temporal data [32]. A dynamic balance [7] is then crucial for providing a flexible stability in the ecosystem, translating Truax's variety / complexity balance for an healthy soundscape [14]. These growing patterns that form a dynamic sound composition invite interpretive attempts to retrieve their order, structure and meaning, which merges with Pelowski & Akiba's second stage of *meta-cognitive reflection* [9]. This assessment and need for classification means consciously thinking about the experience while living it, "involved, immersed in the project of the moment" that demands simultaneously a reflection of the straightforward experience [10] and a self-reflection of the intellectual, emotional and moral relationships formed [12].

Patterns, more than its individual, isolated contents, embody inherent complexity within the relations between data variables, that may be characterised as essential features of the phenomena, or its *structural / invariant features* [10], which should be the active seeking-purpose or, at least, features that would naturally emerge as the distinctive features of a given dataset. As such, sound patterns appear through sonic blendings that, in turn, emerge from the evolution of each element's interactions in their community.

4.4. Quantity → Quality

Relationships and context cannot be measured through a success-rating, numerical scale. Even arguing that a self-reflection moment is triggered through a network of intertwined connections, can we point out success metrics for each variable implicated? To truly evaluate the experience of a systemic sonification, one must invoke qualitative approaches that see the experience through the eyes (or in this case, the ears) of its beholder, assessing introspective and extrospective phenomena through intentionality that "correlates all things experienced with the mode of experience" [10]. The shift for perceptual transformations inevitably requires a qualitative focus of how these changes take place while *being-in-the-world*, where one's body is an "undivided unity" grounded on all human senses, situated in a physical environment, and driven by an "embodied intentionality" towards the world [11]. This fourth shift is the foundational concept of all other dimensions, directly connected to Ponty's motto of "perception requires action" [11]; or even *perception IS action*, as the meaning-making process only truly occurs through exchangeable interactions with the environment.

4.5. Objective Knowledge → CONTEXTUAL KNOWLEDGE

The interpretive journey of the individual while wandering the ecosystem occurs within its personal context, built on a foundational sound metaphor that composes its sonic environment. This soundscape is the acoustic field where each acoustic figure stands in a ground of elements for perceptive focus [13]. Besides the context of his/her surroundings, each human agent carries with

him/her a set of pre-expectations [9], based on a personality structure, behaviour and cognitive basis that leads to possible reactions, aspirations and emotional responses. These constitute the lifeworld of the user, "the cultural and personal background that serves as a frame of reference" [11] on how each person will experience a given phenomenon. This world also reconfigures the phenomenal field for each individual, opposing the phenomenological lens of *epoché* that demands a suspension from usual assumptions and personal perspective to shape a broader, universal way of perceiving a phenomenon [10]. Moreover, not only does this personal world shapes the way an individual perceives a phenomenon, but also how the individual perceives himself/herself, the self-image, starting state of the flow of aesthetic experience [9] that encompasses a collection of personal traits and concepts.

In the centre of the experience and as the leading agent of evolution, we encounter each perceptive agent who explores the system. Each agent treads his/her experience, as the main *bearer of experience ("I")* [10] who acts in the environment. Following these phenomenological concepts, action is the conductor of experience, where logic and sense are learned by doing, where knowledge comes from experimentation and becomes empirically-constructed and validated. This act of learning happens through an embodied interaction, where perception is actively tailored using "the body's ability to extend its sensorial apparatus" [11] and the self's *lived body*, that transcends the corporeal element and ascends to a perceptive, conscious mental shaping of the body's actions in the world. The kinaesthetic notion then evolves to *kinaesthetic creativity* as this active, aware process of the body in intervening in the environment, and an instrument for exploring a multitude of scenarios. It is with this direct, individual involvement in the meaning-making process as participatory agents of understanding that a "deep, conceptual appropriation of the artefact" [12] takes place and each individual can feel the artefact as his/hers.

4.6. Structure → PROCESS

The ecosystem is initially defined by a structural group of living elements. In a classical sonification, the foundational structure translates the "data-to-sound" mapping that usually follows a pre-stage of filtering the relevant data features. In a systemic sonification, more important than the initial stage of the system is how it develops over time in a continuous interaction with other elements. The process becomes the key concept, from which the progression through disruption of pre-expectations and self-schemas take place, leading to true epiphanic moments and stimulating self-transformations [9]. The shattering of our internal world and opening of spaces for interpretation raises questions attempting to explain emerging doubts, uncertainties, discrepancies and disquieting implications. Apprehensions which emerge not only about the artefact itself and the context in which we experience it, but also, and maybe most importantly, ourselves, potentially stirring new beliefs, values and attitudes [12]. This renewal process of substituting old self-schema for new knowledge relates to Heidegger's *destructive hermeneutics*, where the "traditional interpretation instrument breaks down" [9] for transformation and sense-making to occur. There is also an emotional progress during this cognitive evolution, where emotional responses become signs for "cognitive and psychological reorganisation", leading to epiphanic emotions, cathartic releases and final enlightenment and pleasure, which comprise the *feel dimension* of an experience [11].

This is not linear: mastery is a circular process, in a "successive cyclic interpretation check after each new piece of syntactic structure is built" [9], as the foundational blocks of each individual are challenged, removed or renewed, continuously. Every living community sustains itself in this intertwined cycle, where species evolve and adapt to surrounding changes, surviving through balanced exchanges between nature and their needs in a co-dependence of energy flows [7]. Ideally, all living systems should function as no-waste ecosystems, with sustainable exchanges as priorities for long-term survival. The continuous exchanges between elements of such an ecosystem embody a learning process to adapt to new realities, in a *development through successive stages* from which life is creatively (un)folded [7]. In the end, transformative insights and personal growth set the final outcome and true value of an aesthetic experience, as a true transcendence of the self in a visceral experience. The experience offers transcendence as it is founded, phenomenologically, through "intentionality as transcendental" [10]. The system's invariants ground a global condition of multiple and unknown possibilities of experimentation, where the journey of each individual becomes the directional phenomenon shaping the experience.

5. A SYSTEMIC SONIFICATION OVERVIEW

The concept of systemism, as proposed by Bunge [8], is the integrative perspective of elements and symbols, where "every thing is a system or a component of one", tied together as intertwined, stable dimensions whose bonds and relationships maintain the functionality of the whole embedded within a context. The author proposed the CESM model to characterise a system, where any system s is comprised by 1. a composition $C(s)$ as the collection of all elements of s, 2. an environment $E(s)$ as the collection of external elements which bidirectionally interact with s, 3. a structure $S(s)$ as the collection of relationships and bonds between the elements of s and between these and external elements of $E(s)$, 4. and a mechanism $M(s)$ as the collection of behavioural processes of s.
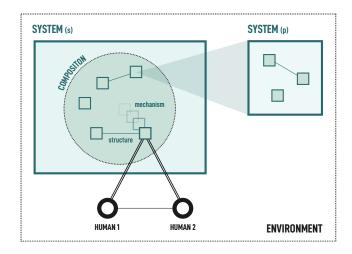

Figure 1: Schematic representation of a systemic sonification model

We can apply this model to a systemic sonification (see Fig. 1), our s, and characterise it as follows:

1. **Composition** $C(s)$ = a collection of sound beings p as

nested systems;

2. **Environment *E(s)*** = a collection of external agents embedded within a context that can act on and be acted upon by the beings of *s*;

3. **Structure *S(s)*** = the acoustic relationships and bonds formed between the sound beings, and the ones formed between them and the external agents;

4. **Mechanism *M(s)*** = how each sound being behaves and transforms itself (altering one or multiple components of *p*) through the interaction with other sound beings and external agents;

Each sound being *p* is a system in itself, characterised by its systemic components:

1. **Composition *C(p)*** = a collection of elements responsible for the filtering, analysis and mapping of each data variable;

2. **Environment *E(p)*** = a collection of external agents, other sound beings of *s* and the overall environment of *s*, that can act on and be acted upon by the elements of *p*;

3. **Structure *S(p)*** = the relationships formed or revealed between elements, or between them and the external agents of *E(p)*;

4. **Mechanism *M(p)*** = how each element reacts to inputs from other internal elements, external agents of *s* or its environment (for example, input from human beings);

Dealing with a systemic sonification demands a systemic look over the dataset to be sonified. Let's theoretically illustrate this perspective using an example of a dataset representing the percentage of female members in a parliament by political party. It would evolve from a collection of data variables (year, party and numerical percentage) directly parametrised as sonic variables to a soundscape that represents the entity of the national parliament *s*. In this system, each sound being *p* becomes one member, either female or male, within which the related data variables undergo parametrisation function(s) that define its internal structure and mechanisms. We may say, outside the scope of this example, that each sound being *p* can be born from a sonification technique, more or less complex, such as audification or parameter-mapping. Each sound being, or parliament member in the example, is then part of an overall systemic scenario, where time can be considered a passive or active function for evolution, alongside the ongoing interactions with the environment that originates emergent futures, either parliament members for a given party, for example. As such, the elements of a systemic sonification, when dealing with time-varying data and allowing time to become one behavioural mechanism, are naturally not constant, with the sound beings adapting themselves to reveal data changes over time. These beings are also in constant communication with their surroundings, whose elements also cause impactful, contextualising changes on their expression. The process of active perception within this environment creates a dynamic context that results from action-triggered transformations of each element, and how each transformation is actively perceived in each interaction moment.

The environment, seen as a conceptual space for action, physical or virtual, includes the multitude of human agents that may engage with the system. Each acoustic being interacts with each other, as well as with the surrounding environment, from which bonds are formed. Our *endostructure* portrays the relations between the sound beings, and our *exostructure* the relations between

these and the agents within the environment. Narrowing the concepts to each *p* element, their *endostructure* portrays the relations between the components of how the dataset is transformed to some type of acoustic element, while their *exostructure* defines the relation of each constituent stage with external inputs.

Deepening these concepts, the *input* of the exostructure of *s* portrays the actions taken by the human agents and other environment agents, which cause the system to respond and possibly change a behavioural mechanism as the *output*. This input reaches the internal elements of each *p* system, from which we may state that their endostructure reflects the intrinsic, data relationships and patterns which emerge from the dataset itself, which can not only change the output of each *p*, but consequently the bonds between the collection of *p* systems that compose *s*. The exostructure allows the emergence of these ties to humans, depending on their perceptual actions. Transformations of their endostructure through defined mechanisms may be sonically translated into dynamic fluctuations of frequency, amplitude, panning, delay and any kind of sound effect that produces acoustic variations. The sound journeys of each element *p* can then be unveiled to humans weaving the exostructure, which marks a systemic sonification as an interactionist process of humans shaping their surroundings and being shaped by their interactions with it. This interactionism can also be devised as an individual process, as isolated actions deriving from a single agent or a collective, as collaborative actions designed by multiple agents. We can then assume different outcomes from the system on how it will respond and adapt to these complex interactions, where a bidirectional relationship evolves to a triangular collaboration (represented in Fig. 1) between the system and at least two human agents, whose conjoined interaction can also produce distinct actions over the system.

5.1. Model-Based Sonification as a Systemic Model

Model-Based Sonification (MBS), devised as a dynamic model that incorporates the user as a main driver, also encompasses a systemic thought. It is defined as "the use of dynamic models which mathematically describe the evolution of a system in time" [33], following initial parametrisation and data-based configurations that offer interaction possibilities though the system's excitation. Acoustic responses are triggered, mimicking everyday closed-loop systems where interactions produce acoustic events that are perceived and interpreted by the human. We may systemically characterise it, considering: (1) its composition *C(s)* as the collection of variables in the model space, (2) the environment *E(s)* with the collection of external, human agents that trigger excitation moments from the beings of *s*, (3) the structure *S(s)* as the relationships formed between each variable and the human disruptors, and (4) the mechanisms *M(s)* as the equations of motion that define the dynamical behaviour of the system.

In both the model-based and systemic proposals, the user is an external force that enters the system with a free, exploratory attitude to discover and understand the system. However, the consequences of the actions that lead to a learning process differ: in MBS, the user excites a balanced, initially silent system to create acoustic responses that uncover data features; in systemic sonification, the user enters the systemic soundscape and produces some kind of acoustic transformations that alter the system's features to make it his/her own. We may say that in MBS the user is a disruptor of the system's equilibrium, while in systemic sonification he/she is a stranger, a visitor who gradually becomes a mem-

ber of the community, disrupting the system as well while living himself/herself an internal disruption process that enhances his/her perceptual horizons. As such, the equivalent of the *listener characteristics* of MBS in a systemic sonification embodies a more profound acknowledgement of each user's phenomenal world, which emerges the moment he/she enters the system. A systemic sonification is then inevitably *macroscopic*, with the user necessarily embedded within the systemic soundscape. In terms of data applicability, MBS is fundamentally used for non time-indexed data [33], while a generic systemic model would also include time series. Another difference deals with the goal itself: as MBS seeks data analysis, the learning success is imperative - the *task* is the purpose; in a systemic sonification, the goal is to offer an aesthetic experience of disruption-transformation that may offer insights towards a deeper understanding of the data and an expansion of consciousness - the *experience* is the purpose.

6. A SYSTEMIC THINKING FOR AN AESTHETIC EXPERIENCE

The integrative view of a sonification process through systemic thinking leads us back to our main conceptual challenge: in a first instance, how can it be an enabler for an aesthetic experience to take place; and secondly, how can this experience expand the perceptual journeys for interpreting the data universe?

Bringing the concept of systemic thinking into a sonification process, a systemic view can be applied at three conceptual levels: 1. over the dataset itself, devising each data variable as an element of a system; 2. over each sound subsystem p, composed of data filtering, analysis and mapping functions constantly communicating and adapting themselves to external inputs; 3. and over a global systemic soundscape s, where each element p lives in continuous interaction with each other and with the environment, from where humans can intervene and transform the system itself. It is through this transformation that the external agent can also experience a self-transforming process, almost as a rebound effect of the changing mechanisms within the system that alter its main structure and, ultimately, its surroundings.

The interactionist process between the external agents and the systemic sonification can encompass the five stages of Pelowski and Akiba's aesthetic experience [9], potentiating the processes of cognitive mastery and consequent reassessment through a dynamic, adaptable attitude of the system's mechanisms. Entailing each human protagonist as a weaver of his/her own experience embodies an active learning process by the act of *doing-while-being-in-the-system*, flexible enough to encompass each human's self-image and phenomenal field, and welcoming his/her embodied presence. This active presence involves bodily directedness [11] towards the system's universe, from which multiple meanings, perhaps even transformative meanings as evolving perceptions over time, arise during the circular process of this cognitive reassessment from where the aesthetic experience is born. These unlocking actions have no associated meaning, but deliberate intentions from which meaning naturally emerge [8]. The exact narrative on how the system's mechanisms and structure will be transformed through these actions is unknown; we can even say that the *what*, the *when* and the *how* of each human participant's disruptive process is impossible to objectively foretell. Even harder for his/her transformative moment. Ambiguity is then inevitably present [12], even if transiently, encompassing the subjective nature of sound as a systemic piece for creating an open space for the

system to grow and for the human to self-expand. It is this self-transcendence that may amplify the perceptual insights of the data space and, ultimately, fulfill and equally transcend the communication purpose that the sonification field thrives to achieve.

7. FINAL REMARKS

We have proposed a new conceptual perspective based on systemic thinking to shape a sonification process, from the choice and framing of the dataset, to its transformation into an ensemble of sound beings that constitute a sonic ecosystem. Gathering notions from systemic epistemologies [7, 8], phenomenology [10], embodied interaction [11], ambiguity in HCI [12] and soundscape theory [13, 14], this dynamic and adaptive ecosystem evolves according to its constant interactions with its environment, from where each human participant can engage with the system and weave his/her experience. The intertwined bonds born in these exchanges allow for unique experiences to arise for each human, possibly surpassing initial expectations, enabling perceptions and insights over the dataset and, ultimately, an internal transcendental process which offers an aesthetic experience of sonification.

From this systemic standpoint, there is a vast potential for future exploration: either from the system's perspective, on how can a dynamic soundscape be devised as an exploratory acoustic space with beings with more or less autonomy, and the environment dimensions, with multiple interaction journeys for each individual, which can be designed as isolated or in collaboration with other participants. John Dewey, in his work on aesthetics, stated: "Only when the past ceases to trouble and anticipations of the future are not perturbing is a being wholly united with his environment and therefore fully alive" [17]. A systemic perspective can offer this grounding to the sonification field, embodying past achievements and functionalist mapping tools to compose sound beings which can, ultimately, place each human protagonist in the centre of the sonification process, expanding perceptual horizons and consciousness of each participant.

8. ACKNOWLEDGMENT

9. REFERENCES

[1] G. Kramer, B. Walker, T. Bonebright, P. Cook, J. H. Flowers, N. Miner, and J. Neuhoff, "Sonification report: Status of the field and research agenda," *Faculty Publications, Department of Psychology*, vol. 444, 2010.

[2] J. G. Neuhoff, "Is sonification doomed to fail?" in *Proceedings of the 25th International Conference on Auditory Display (ICAD 2019)*. Georgia Institute of Technology, 2019.

[3] P. Fishwick, "An introduction to aesthetic computing," *Aesthetic computing*, pp. 3–27, 2006.

[4] A. Lang, "Aesthetics in information visualization," *Trends in information visualization*, vol. 8, 2009.

[5] B. Walker and M. Nees, *The Sonification Handbook*. Berlin, Germany: Logos Verlag, 2011, ch. Theory of Sonification, pp. 9–40.

[6] P. Vickers, B. Hogg, and D. Worrall, *Body, Sound and Space in Music and Beyond: Multimodal Explorations*. London and New York: Routledge Taylor Francis Group, 2017, ch. Aesthetics of sonification: taking the subject-position, pp. 89–109.

[7] F. Capra, "Speaking nature's language: Principles for sustainability," *Ecological literacy: Educating our children for a sustainable world*, pp. 18–29, 2005.

[8] M. Bunge, *Emergence and convergence: Qualitative novelty and the unity of knowledge*. University of Toronto Press, 2003.

[9] M. Pelowski and F. Akiba, "A model of art perception, evaluation and emotion in transformative aesthetic experience," *New Ideas in Psychology*, vol. 29, no. 2, pp. 80–97, 2011.

[10] D. Idhe, *Experimental Phenomenology*. New York, USA: State University of New York Press, 1977, ch. Phenomena and the Phenomenological Reductions, pp. 29–54.

[11] D. Svanaes, "Interaction design for and with the lived body: Some implications of merleau-ponty's phenomenology," *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 20, no. 1, p. 8, 2013.

[12] W. W. Gaver, J. Beaver, and S. Benford, "Ambiguity as a resource for design," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2003, pp. 233–240.

[13] R. M. Schafer, *The soundscape: Our sonic environment and the tuning of the world*. Simon and Schuster, 1993.

[14] B. Truax, *Acoustic communication*. Greenwood Publishing Group, 2001.

[15] C. Korsmeyer, "On distinguishing "aesthetic" from "artistic"," *Journal of aesthetic education*, vol. 11, no. 4, pp. 45–57, 1977.

[16] A. Joy and J. F. Sherry Jr, "Speaking of art as embodied imagination: A multisensory approach to understanding aesthetic experience," *Journal of consumer research*, vol. 30, no. 2, pp. 259–282, 2003.

[17] J. Dewey, *Art as experience*. Penguin, 2005.

[18] E. Lenz, S. Diefenbach, and M. Hassenzahl, "Aesthetics of interaction: a literature synthesis," in *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, 2014, pp. 628–637.

[19] L. E. Udsen and A. H. Jørgensen, "The aesthetic turn: Unravelling recent aesthetic approaches to human-computer interaction," *Digital Creativity*, vol. 16, no. 4, pp. 205–216, 2005.

[20] M. G. Petersen, O. S. Iversen, P. G. Krogh, and M. Ludvigsen, "Aesthetic interaction - a pragmatist's aesthetics of interactive systems," in *Proceedings of the 2004 conference on Designing interactive systems processes, practices, methods, and techniques - DIS '04*, Cambridge, Massachusetts, USA, 2004, pp. 269–276.

[21] P. R. Ross and S. A. Wensveen, "Designing aesthetics of behavior in interaction: Using aesthetic experience as a mechanism for design," *International Journal of Design*, vol. 4, no. 2, pp. 3–13, 2010.

[22] P. Wright, J. Wallace, and J. McCarthy, "Aesthetics and experience-centered design," *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 15, no. 4, pp. 1–21, 2008.

[23] G. Leplaitre and I. McGregor, "How to tackle auditory interface aesthetics? discussion and case study." Georgia Institute of Technology, 2004.

[24] K. Beilharz and S. Ferguson, "An interface and framework design for interactive aesthetic sonification," in *Proceedings of the 15th International Conference on Auditory Display*, Copenhagen, Denmark., 2009, pp. 1–8.

[25] P. Vickers and B. Hogg, "Sonification abstraite / sonification concr'ete: An "aesthetic perspective space" for classifying auditory displays in the ars musica domain," in *Proceedings of the 12th International Conference on Auditory Display*, London, UK, 2006, pp. 210–216.

[26] S. Barrass, "The aesthetic turn in sonification towards a social and cultural medium," *AI and Society*, vol. 27, no. 2, pp. 177–181, 2012.

[27] F. Grond and T. Hermann, "Aesthetic strategies in sonification," *AI and Society*, vol. 27, no. 2, pp. 213–222, 2012.

[28] M. Filimowicz, "Peircing fritz and snow: An aesthetic field for sonified data," *Organised Sound*, vol. 19, no. 1, pp. 90–99, 2014.

[29] S. Roddy, "Embodied sonification," Ph.D. dissertation, University of Dublin, Trinity College, 2015.

[30] H. Leder, B. Belke, A. Oeberst, and D. Augustin, "A model of aesthetic appreciation and aesthetic judgments," *British journal of psychology*, vol. 95, no. 4, pp. 489–508, 2004.

[31] S. Marković, "Components of aesthetic experience: aesthetic fascination, aesthetic appraisal, and aesthetic emotion," *i-Perception*, vol. 3, no. 1, pp. 1–17, 2012.

[32] O. Ben-Tal and J. Berger, "Creative aspects of sonification," *Leonardo*, vol. 37, no. 3, pp. 229–233, 2004.

[33] T. Hermann, *The Sonification Handbook*. Berlin, Germany: Logos Verlag, 2011, ch. Model-Based Sonification, pp. 399–428.