Self-organization and novelty: pre-configurations of emergence in early British Cybernetics

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Abstract— **Emergence appears in the literature as related to self-organization and novelty. For many authors it is the result of multiple interactions among agents within a system, which generate phenomena that could not be understood, nor anticipated, through the analysis of the elements and their behaviors in isolation. For others, emergent phenomena are related to fundamental novelty and, thus, to creativity. These two formulations of emergence can be traced back to the experimental work of some key early cybernetic experimental devices by Ross Ashby, Grey Walter and Gordon Pask. As a group, the devices illustrate the potential of both formulations of emergence and of its combination. As such, they can help with the elaboration of a framework to understand emergence in the context of interactive art and communication, both to analyze its presence in interactive systems and to design systems that aim to generate them.**

Keywords— emergence; cybernetics; artificial life; artificial life art; interactive systems; interactive art; design methodology.

I. INTRODUCTION

Emergence appears in the academic literature as related to two phenomena: self-organization and the appearance of novelty. For many authors it is the result of multiple interactions among agents within a system, in the form of patterns of behavior of the system as a whole. Such patterns are emergent phenomena in the sense that they could not be understood, nor anticipated, through the analysis of the elements and their behaviors in isolation [1-3]. This is the classic idea of the whole being more than the sum of its parts. The explanations are usually articulated in terms of different levels of complexity, in which the lower levels (the parts) generate processes that appear at the upper levels (the whole) as emergent, i.e. not explainable by a classic cause-effect relationship. Typical examples include the behavior of ant colonies and their social complexity, chemical clocks in non-equilibrium thermodynamics, or the complexity generated from the simple rules of cellular automata. For others, emergent phenomena are related to fundamental novelty and, thus, to creativity. For them, emergence is synonymous to the appearance of new functions or behaviors in a known system [4-7].

These two formulations of emergence can be traced back to the experimental work of some key early cybernetic experimental devices: Ross Ashby's Homeostat, Grey Walter's tortoises and Gordon Pask's Musicolour, electrochemical devices and Colloquy of Mobiles. These authors are known to have anticipated both Artificial Life [8-10] and the context for emergence to acquire a central role in the scientific discourse [11, 12]. This anticipation is both thematic and in the bottom up approach of generating complex behaviors from simple interconnected parts. Walter was explicit in this objective: his tortoises were built to prove how only a very limited set of connections could result in a behavior that resembled something as complex as animal behavior [13]. The Homeostat and the Colloquy resonate with the idea of self-organization, as they too rely on the chaining of simple behaviors to generate a complex whole (process). In parallel to that, these cybernetic devices usually sought to attain the appearance of novel behavior. This is most clear in Pask's electrochemical devices, but also in the tortoises the occurrence of unexpected behaviors was noted by Walter.

As a group, the devices illustrate the potential of both formulations of emergence and of its combination. As such, they can help with the elaboration of a framework to understand emergence in the context of interactive art and of interactive communication, both to analyze its presence in interactive systems and to design systems that aim to generate them.

II. INTERACTIVITY AND EMERGENCE

Interactive art is a space where interaction is freed from the constraints of functionality, as artists experiment in the spectrum between randomness and predictability: the space of poetic interaction [14] where interactivity becomes a major aesthetic concern [15]. These interactive systems are usually programmed with a set of pre-specified behaviors that aim to engage with the user. Some attempts have been made to eliminate the constraint of pre-specification. Prominently, those originated within the Artificial Life (ALife) Art movement in the early 1990s, which proposed Emergent Interactive Behavior as a new paradigm to be explored [16].

The goal of explicitly combining the ideas of emergence and interactive art originated in parallel with the appearance of Complexity Sciences in the late 1980s, and, in particular, of

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Artificial Life. Emergent Interactive Behavior was proposed as a paradigm that aims to create systems that can behave beyond what is explicitly specified in their design [16]. I.e. these systems should exhibit behaviors that surprise their own designer. This element of surprise is not desirable in most cases when dealing with interactive devices. Functional interactivity is what one expects to find when using a word processor or a database interface. But in an artistic context interactivity becomes an idea to experiment with, and notions such as emergent interactive behavior or evolved behaviors became central for some of the ALife Art practitioners.

However, ALife Art is not always about interactivity. It is a discipline at the intersection of science and art that has produced many simulated environments and animations. Many of the works produced by ALife artist are not concerned with interactivity. But there are also examples of interactive pieces, such as Simon Penny's Petit Mal [17] and Sympathetic Sentience [18] or Ken Rinaldo's Autopoiesis [19] among many others.

This paper presents a line of work that is driven towards an understanding of emergence in the context of interactive art. The goal is to define a framework that is useful in order to discern the presence of emergent behavior and phenomena in interactive systems, both as self-organization and as the appearance of novelty, in the terms discussed below. A further goal will be to set up later the guidelines for designing systems that possess the conditions for such phenomena to present themselves. Both as self-organization and as generation of novelty, emergence is a compelling idea within the perspective of amplifying the behavioral possibilities of interactive art pieces, which are often strongly linked to pre-specified behaviors. As said above, the space of poetic interaction can be a very fertile ground for the exploration of the creation of such systems in an artistic context: art pieces that interact with the visitors in manners unanticipated even by their own designers. The goal is not new. It was made explicit in the 1990s, but it can be traced back to the work of some the key British Cybernetic works mentioned in the introduction.

III. Emergence, Self-Organization and Novelty

In scientific discourse 'Emergence' appears as synonymous with non-reducible; in opposition to the pervasive reductionism of modern science. Emergent from meant not reducible to, and this association has survived to the present day, mainly around two (not mutually exclusive) ideas. First, as the possibility for fundamental novelty to appear: if something is not reducible to an underlying level of reality (e.g. thought to the physiology of the brain), it follows that some concept of newness applies. This produces vast ontological discussions in philosophy, but becomes less problematic when considered epistemologically. Second, in relation to self-organization: for some, emergence is not necessarily linked to novelty (i.e. an effect continues to be emergent after it has been initially observed). It is a result of a myriad of local interactions among agents manifested as a pattern of behavior in a superior (group) level.

Historically, the concept of emergence didn't become a concern in academic discourse until the mid–ninetieth century, when John Stuart Mill used the concept to distinguish different types of causation. In an analogy of how, in physics, forces can accumulate when calculated as vectors into a final resulting force, Mill proposed the principle of Composition of Causes, as the case when the effect of several causes is the result of the sum of their separate effects. In contrast, there are cases in which this principle does not apply. In Mill's words, there is a breach, a gap in the continuity of causes: "there are laws which, like those of chemistry and physiology, owe their existence to a breach of the principle of the Composition of Causes" [20]. I.e. some laws and effects in a particular level of complexity (e.g. chemistry) were not, according to Mill, reducible to those in a more fundamental level (e.g. physics). Mill did not use the term emergence. It was the philosopher John Henry Lewes who, a little later, coined the term in discussing Mill's different types of causation, opposing resultant to emergent effects.

After Mill and Lewes, the concept took for the first time a central role in some of the discourses debating evolution at the beginning of the twentieth century. Prominently, and with direct connections to Mill's theories, among the members of British Emergentism [21], which defended that reality is organized in different levels of complexity and that superior levels are not reducible to inferior ones. This movement flourished before the turn of the twentieth century and vanished with the advent of quantum mechanics, and partially because of it [21, 22]. Before that, the previous context allowed little room for such an idea, and after appearing it remained a marginal concept for a long period. Even when science was reshaped by the Twentieth Century revolutions of Relativity and Quantum Mechanics, emergence remained an outsider to scientific discourse. It wasn't until the second part of the century, when a new scientific context was created, that emergence regained importance in the academic debate.

The context for emergence to acquire an important role was first set in Cybernetics discourse on 'self-organization'. The idea of self-organization is present in earlier Cybernetic works by Ashby and Walter, as discussed below. Later, it was explicit and rather ubiquitous in Second Order Cybernetics. Within Chaos Theory and Complexity Sciences (Dynamical Systems Theory, neural networks, Artificial Life, etc.) emergence and emergent properties were consolidated as a central scientific concern.

Second Order Cybernetics was a label adopted by philosophically inclined cyberneticists during the early 70s, as they felt the need to distinguish themselves from the mechanistic approaches of computer sciences and engineering, which by then were starting to become fully independent from Cybernetics [23]. Second Order Cybernetics emphasized, in contrast, the importance of autonomy, self-organization and cognition, and a very important emphasis on the role of the observer in modeling a system. Indeed, the difference between first and second order has been also phrased as the difference between the Cybernetics of the observed systems and that of the observing systems [11].

Self-organization is the process by which a group of agents (particles, molecules, animals, robot parts…) generates, through local interactions, an observable pattern of organized behavior at the group level. This process is not directed or coordinated by any singular or specific group of agents. A key concept here, central to Second Order Cybernetics, is the role of the observer: patterns appear in respect to an observer who is analyzing the system, who usually has a different point of view from that of the agents. It is precisely this point of view what allows him or her to consider the events occurring at the group level. This is the most common formulation of emergence, the one that relates to the idea than the whole is more than the sum of the parts. Emergence and Self-organization are interchangeable terms in some disciplines: self-organization is used to refer to the same phenomena in Cybernetics or Complex Systems Theory as emergence in Artificial Life.

It is within this latter discipline, where emergence is a central concern, where efforts to define the term have arisen, e.g. [1-3, 6, 24]. For some [1, 25], emergence is basically equivalent to self-organization. Others do stress, in addition, the importance of the idea of novelty, combining both formulations [2, 26].

Finally, there's a group of authors who move away from formulations built around self-organization and focus on emergence as generation of novelty. Prominent among them, Peter Cariani [4, 5, 12, 27, 28, 30], who moves the theoretical weight of the discourse to an idea of emergence that links it to the generation of novelty within a system and, thus, to creativity.

While some authors relate novelty to internal states of the observer, such as surprise [6] or wonder [29], Cariani articulates a discourse that aims to identify emergence as novelty in a given system in a way that can be scientifically communicated. His approach is epistemological and pragmatic. It is epistemological in the sense that Cariani is interested in how emergence can be perceived by an observer and accounted for. And it is pragmatic because his aim is to set up the foundations to build autonomous creative cybernetic devices; "systems that can autonomously find solution to combinatorically-complex and ill-defined problems" [27].

Cariani's approach is known as 'emergence-relative-to-a-model.' He is concerned with how new functions can appear in systems or devices that perceive and act on their environment. This newness can only be accounted for scientifically if, first, the observer of the system defines the states and state-transitions of the system under observation by creating a model of it. Once this is done, these observations are used to make predictions on the futures states of the system. In this context, emergence occurs whenever unanticipated behaviors, states or functions appear: "emergence is the appearance of novel entities that in one sense or another could not have been predicted from what came before" [28].

The bases of Cariani's modeling are how the system reads and acts on its environment (semantics), how it decides how to act according to this readings (syntactics), and how it evaluates the actions performed according to its goals (pragmatics). All these actions are performed according to the basic building blocks of what the system can operate with: primitives in Cariani's terminology.

Within this framework, Cariani identifies two ways in which emergence can occur. The first is Combinatoric Emergence, which consists in the appearance of new system function through new combinations of the primitives with which the system operates (e.g. genetic algorithms). The second is Creative Emergence, which is the appearance of new functions trough the introduction of new primitives in the computations. This second form of emergence, equivalent to the introduction of a new sensory organ in an animal species through the course of evolution, is extremely rare in artificial systems, and in fact Cariani identifies in his literature only one case: Gordon Pask's electrochemical devices [5, 30]. Despite these difficulties in the case of artificial systems, however, Cariani opens a door to mixed computer-human systems (i.e. interactive systems) to be generators of this latter kind of emergence [5, 28].

IV. Cybernetic Devices

The idea of a system exceeding the expectations of its own designer can be illustrated with the metaphor of the 'unpredictable black box' [31]: the idea is that there is a part of the system that may remain invisible (or un-scrutinized) even to its own designer, as the concern is only in how the behavior of the system relates to its readings and how these relations change over time in creating new behaviors.

This resonates with what Andrew Pickering has labeled the performative idiom of Cybernetics, as opposite to the representational idiom of traditional science. An idiom based on a performative ontology: "a decentered perspective that is concerned with agency –doing things in the world– and with the emergent interplay of human and material agency" [32]. In this context, he argues how Cybernetics assumes in fact an ontology that, contrary to the reductionist approach, assumes a certain degree of unknowability, as it "tries to address the problematic of getting along performatively with systems that can always surprise us" [11]. These are what Stafford Beer labeled exceedingly complex systems: Systems that are neither predictable nor susceptible to treatment by the methods of modern science and engineering. Such systems, like the interior of the unpredictable black boxes, are unknowable to some degree. They are too complex to be grasped representationally, and they change over time, so that future behavior cannot be anticipated through current knowledge.

Although the term was rarely used in Cybernetics, the links to emergence are clear. Understood within this context, the following cybernetic devices are examples of pre-configuration of self-organization emergence and of emergence as generation of novelty.

A. Ross Ashby's Homeostat

Norbert Wiener described the Homeostat as the "brilliant idea of the unpurposeful random mechanism which seeks for its own purpose through a process of learning" and qualified it as “one of the great philosophical contributions of the present day” [33]. It was, indeed, a machine with no purpose in regards to the classical sense in which machines have purposes. It was built on the late 1940s and early 1950s in order to interact with other homeostats, and to experiment with homeostasis by doing it. Ashby’s goal was to build a self-regulating system, and he was successful in doing so.

The homeostat was an electromechanical device that converted electrical inputs to electrical outputs, which consisted of four identical units [34]. In each unit, the input passed through a coil that was inside the machine, which generated a magnetic field that exerted a torque on a needle located at the top of the device, which rotated to one direction or another. The position of the needle was to be interpreted as the main variable indicating the state of the homeostat [11, 32]. The unit could either be in a stable position, with the needle resting in a central position, or in an unstable one, with it going out of range (a deviation of above 45 degrees from the resting position), which provoked the circuitry to randomly switch to another state (another set of values in the circuitry) and seek for stability in it. If it didn’t find it, is switched again, and so on.

Isolated, a homeostat unit did close to nothing. It was when connected with others that a system of dynamic feedback loops started to build up, thus forcing each unit to look for its own stability within a changing (dynamic) system, were each unit was affecting all others. As a group of several units, it was a way to prove what Ashby labeled ultrastability: a consequence of the process of adaptation of each unit to the system [34]. When the four units came to a stable state simultaneously, ultrastability had been reached.

The homeostat as a system, as Wiener pointed out, lacked a purpose beyond its own search for stabilization. What was, therefore, the motive in its building? As Pickering points out, the homeostat was a proto-brain designed to model adaptive behavior, “a model of the brain as an adaptive controller of behavior” [32]. The search of each unit in the homeostat for a stable setting within the system is a process of adaptation. Each unit struggles, though its open ended search of possibilities, to find a sate that will be stable as it interacts with the other units, whilst the other units are performing the exact same search. Ultrastability, the moment in which all of the units come to a stable state (i.e., when the system attains homeostasis), can be understood here as the result of a self-organizing process and, therefore, as an emergent property.

Despite the limited number of units in Ashby’s description, we can imagine that the homeostat could theoretically grow its number and the system would behave in the same manner. The interactions are local. Each unit interacts solely with its neighboring units. It is the sum of all the interactions what causes ultrastabilty to appear, with no central command directing the operations and no individual unit having any advantage or stronger influence on the others. Thus, the process of ultrastabilization as a whole is a result of self-organization.

In this respect, Ashby succeeded in creating a machine that could go beyond a fixed repertoire of stimulus-response reactions [35], thus creating a system that was open-ended enough to constantly change responses. Despite the fact that the homeostat was itself not interactive in regards to an external user, it can be argued that in terms of internal interactivity (i.e., regarding one unit in respect of all the others) it went beyond the database paradigm of pre-specified behaviors, and moved towards a more complex approach of creation of non-predefined behaviors.

B. Grey Walter’s Tortoises

The robotic tortoises of Grey Walter, first presented in 1948, were an example of how he understood the modeling practice: a pragmatic material experiment that would serve as the basis for and orderly and practical classification of complex phenomena [36]. The devices he built were two electromechanical automata that, by their shape, resembled tortoises. He dubbed them Elmer (for Electro MEchanical Robot) and Elsie (Electro mechanical robot, Light-Sensitive with Internal and External stability).

The tortoises had two sensors, for light and touch, and two effectors, for crawling and for steering. They were powered by batteries that they carried with them, and had a hutch were these could be recharged. The technical details of the tortoises were described in detail by Walter himself [13, 37, 38] and by Owen Holland [8, 9], who reconstructed one of the tortoises and has defended importance of Walter’s work as a pioneer (an antecessor, in fact) of Artificial Life. Walter’s ideas are also at the heart of a work that became highly influential of the 1990s robotics: Valentino Braitenberg’s Vehicles [39], first published in 1984, consisted on a series of thought experiments on how very simple assemblages of robotic parts (sensors, effectors and behaviors) could result in remarkably complex behavior. Despite de similarities in the approach, it is likely that Braitenberg wasn’t aware of Walter’s work, since the latter is not credited in the book.

In terms of behavior, Elmer and Elsie’s main goal was to look for a light source. If it was not found, they would wander around the space while a touch sensor allowed them to avoid obstacles trough a very simple procedure: if they couldn’t move forward and detected that they were touching an obstacle, they would perform a series of little bumping movements until the pressure was released, therefore continuing their wandering movement. Along with these movements, a light sensor would be spinning around in cycles, looking for a light source. Once it was found, the whole device would steer and move towards the light, amplifying this action linearly with the intensity of the light source, until a certain threshold was reached. When this happened, the tortoise would saturate and turn away from the light and start over. When their batteries were low, however, the changes in the circuitry would drive them towards the brightest light possible. As it turns out, the hutch that Walter built for them to recharge their batteries was strongly illuminated. Thus, this behavior allowed them to go back home to recharge, and retain full autonomy.

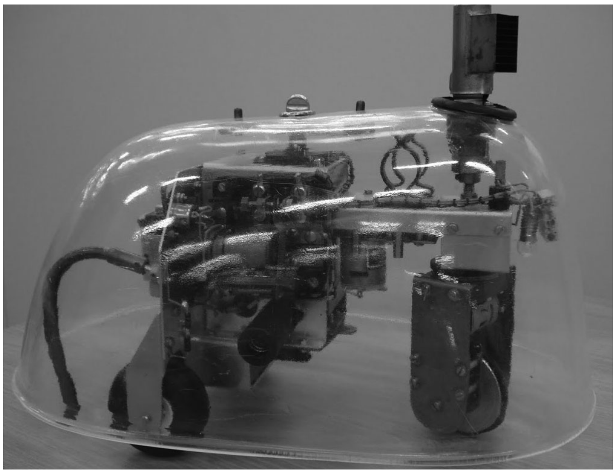

Figure 1. A replica of Walter's tortoises. © Bristol Robotics Laboratory.

From this simple scheme, as Walter himself soon noted, "the behavior of Elmer and Elsie [was] in fact remarkably unpredictable" [13]. This unpredictability was intentional in the design. When Walter described his devices, he pointed out that one of his main objectives was to experiment with one of the aspects of animal behavior: "the uncertainty, randomness, free will or independence so strikingly absent in most well-designed machines." The tortoises would exhibit different behaviors as the environment changed and they adapted to it. For instance, in some experiments lights were mounted on the tortoises. When they carried these light sources with them, they would interact with each other or with their image on a mirror in manners that resembled the behavior of an animal when it recognizes one of its own kind, as they cyclically approached and avoided each other (or its own image on the mirror).

As Walter admitted, his robots were meant to only approximate animal behavior [40], but nonetheless he was convinced that this resemblance was perfectly valid to regard them as a model of behavior, of the adaptiveness of the brain to the environment or even, as he titled his 1950 Scientific American article, as An Imitation of Life. In any case, they are a very clear predecessor of Artificial Life and also a landmark in robotics, and the complexity of their behavior can be regarded as emergent (in the sense of self-organization emergence) in respect to the simplicity of the parts involved in generating them. Along these lines, Andrew Pickering describes them as having "emergent properties relative to what Walter had designed into them" [11]. The local interactions of the sensors with the circuitry generated the patterns of behavior that were not explicitly designed, but appeared only as the system was set in motion and the experimenter could observe them.

The remarkable unpredictability of Elmer and Elsie's behavior can be read as the appearance of these patterns of behavior that Walter observed and described in detail [8]. One didn't know what Elsie or Elmer would exactly do, but could only expect them to behave according to one of the previously observed patterns. According to this, in the cases were a new pattern of behavior was discovered, the idea of emergence as generation of novelty could also be applied. Walter noted, for instance, that he had been taken by surprise by the tortoises' behavior in front of the mirror and with the other tortoises [38]. These behaviors would, therefore, be emergent relative to the model of expected behavior that Walter had elaborated with his first observations.

C. *Gordon Pask's Musicolour*

Pask's first device, and one with capital importance on his path into cybernetics, was the Musicolour. Home-built at the beginning of the fifties, it anticipated the idea of computer visuals accompanying musical performances. I was inspired "by the concept of synaesthesia and the general proposition that the aesthetic value of a work can be enhanced if the work is simultaneously presented in more than one sensory modality" [41]. Neither of the ideas was new, but as Pask notes, at the early 1950s the idea of augmenting sound by light was not yet as overused as it would be in the psychedelic years.

The Musicolour was first demonstrated in 1953. The machine, constructed largely out of war surplus analog electromechanical equipment, was essentially a transducer which, through the input of a microphone, generated a series of visuals from a "predetermined vocabulary of visual symbols; coloured forms which were projected on to a large screen in front of the performer and an audience." As the experiments with it advanced, Pask lost interest in the idea of synesthesia and the focus shifted towards the learning capabilities of the device [41]. The Musicolour became a machine that engaged very strongly with the performer, rather than amused the audience, as musician and machine learned from each other as the performances advanced. This feedback loop "had an almost hypnotic effect upon the performer," whilst, in contrast, it was sometimes disappointing to the audience.

It is easy to understand how these two effects were related. The Musicolour, in its last versions, moved away from the linear relations between sounds and colors. Instead, it exhibited more complex behaviors. Most remarkably, it the performer became too repetitive in trying to provoke a particular response by the system, this would cease to respond, as if it got bored with the reiteration [32]. With this, it would encourage the performer to try something new, and thus to never repeat his or herself too much. As Pask noted, the effect of this complexity of behavior on the audience was rather negative. Whilst the performer could be aware of what was going on, the audience would perceive too much a degree of randomness in the relations between sounds and lights. The perceived randomness would cause them to lose interest in the device as a real-time generator of visuals interpreted as readings to the music. This fail to interest the public can also be read as a symptom of a pre-Cage audience.

The performer of the Musicolour engaged in an experience that Pask described as a game in which the machine and human became one: "He trained the machine and it played a game with him. In this sense, the system acted as an extension for the performer with which he could co-operate to achieve effects that he could not achieve on his own" [41]. Thus, the coupling of the performer's actions and the machine's responses created a stability that was unattainable if one of the two parts was missing. In this respect, these stability, which in this case is the performance itself, would be emergent in the same way that the stability in Ashby's homeostat is. Local interactions create a result that is not intentionally mediated by any of the parts in particular. In this respect, the Musicolour is a case of self-organizing emergence

As an interactive artwork –possibly the first interactive artwork created– the Musicolour was also, at least theoretically, capable of generating novelty. If the Musicolour was open-ended enough, the new actions of the performer could result in non-previously observed responses by the system. The paradigm of agency it inherits from what Pickering labeled the performative idiom of cybernetics is not usually found in later digital interactive works, which are often strongly based on the database paradigm of pre-configured responses. The Musicolour, instead, was built around the possibility of perpetual novelty, as the device was designed to constantly learn from those who interacted with it and change its behavior accordingly.

D. The Electrochemical Devices

In the 1950s, Gordon Pask started to work on a series of electrochemical computing devices or, as he liked to refer to them (focusing on their properties rather than on the materials they were built of): organic computers [11]. Pask's electrochemical computing devices were extremely open-ended systems with which he aimed to describe the process by which machines think. A conception of thinking that had little to do to what Alan Turing had proposed at the beginning of the same decade [42], but rather in the formation of conceptual categories that allow the thinking entity to separate different objects into them [43]. For Turing, thinking was roughly the equivalent of reasoning in terms of responses given to certain inputs (i.e. functioning as a black box). The machine which eventually passed the Turing test would do so because it would respond as if it processed equivalently to the process of a human intelligence, up to the point where it would mistakenly be taken by human. The enormous complexity of such device had to be implemented in its design from the beginning. Pask's approach was radically different. The thinking of his device had very little to do with emulating human thinking or behavior (or logico-computational models thereof). Like Walter's tortoises or Ashby's Homeostat, the electrochemical ear was designed with very simple sensing and acting capabilities, and the complexity of behavior was expected to appear emergently through the combination and iteration of these simple assemblages.

The electrochemical devices were intended to create a self generating and homeostatic control system. They consisted of various aqueous solutions of metallic salts, in which he introduced electrodes to apply current to them. As the current passed, a series of filaments of iron grew from the tip of the electrodes into the liquid. Pask called these groups of filaments 'threads'. As they grew and encountered others, the threads ended up creating connections among the electrodes. These connections would account for the assemblage's computation capabilities [11, 30].

Pask worked extensively on these assemblages, although in general the details of the exact compositions with which he worked remain obscure. By 1958, he had a working demonstrating device [30]. However, beyond the technical details, the explicitly sought open-endedness of the device is interesting. The goal was to create a machine, a control system, which was capable of creating its own relevance criteria. That is, that the relations among inputs and outputs would not be completely well-defined, but instead the device itself would be capable to choose to what it would react and how. It would evolve its own sensors "to choose, independent of the designer, those aspects of its external environment to which it would react" [30]. And indeed the device was capable of doing so. As he presented it in 1958, it could either be trained to recognize magnetic fields or sound. In about half a day, it was capable of adaptively grow its own connections in order to do so. In the case of sound, once this was done it could also rapidly gain the ability to distinguish between two different frequencies [44]: hence the reference of Cariani and Pask himself to it as an ear.

The electrochemical ear is an important example in Cariani's theory of emergence-relative-to-a-model. It is a proof that artificial systems that evolve their own sensors are a real possibility. The structural autonomy of Pask's device allows it to be informationally open, with a degree of epistemic autonomy that allows it to choose its own relevance criteria. With this, in creating its own sensors the device is able to incorporate new observables into the system of computation, and thus, it is an example of what Cariani calls creative emergence. As said above, this is one of the two ways in which emergence as generation of novelty can be attained, but it is extremely rare to find in artificial systems. It is precisely this difficulty what makes Pask's device such an important example.

E. The Colloquy of Mobiles

A last cybernetic device will be examined here nicely connects with the idea of understanding emergence in interactive art. Gordon Pask's Colloquy of Mobiles is undoubtedly a case of (interactive) Artificial Life Art avant-la-lettre. Not only because the theme of the piece, but also of its approach. The piece was presented in London at the historically unique exhibition Cybernetic Serendipity in 1968, curated by Jasia Reichardt. As Pask described it, it was an aesthetically potent environment. An environment that seeks the artistic enjoyment of the viewer or hearer, and that should be able to interest him or her into exploring it. The piece was aimed towards this goal. Among such environments Pask differentiated between those that were passive and those that were reactive, and proposed his installation as an attempt to go one step further in that direction (i.e. as an interactive piece) [45].

Five 'mobiles' hung from a platform that was suspended from the ceiling. Two of the mobiles had the ability to emit light beams, whilst the other three didn't. Instead, they had mirrors to reflect them. The first kind of mobiles were "as a whimsy", as Pask claimed, labeled as males and the second as females. Each of the mobiles was wired up to have a main goal, and would have to learn how to achieve it, either through competition of through collaboration with the other mobiles. Very much along the lines of Artificial Life Art, Pask built his system around the metaphor of sexual reproduction, or, rather, of mating rituals. Each mobile had two urges or drives that it would try to satisfy, labeled O and P, for the colors they represented them; orange and puce [10]. To reduce either of the drives, the male was required to project the corresponding light beam and to have it projected back to a specific part of its body. This was something for which it needed collaboration from a female, which was equipped with a mirror. The females, according to their current state, would also be required to fulfill either one or the other drive. So if there was a coincidence in the goals of male and female, they female would offer collaboration. During all this, the males would compete with each other, blocking the competitors signal in order to gain the attention of the females for themselves. Sound and different intervals of light beam would send different messages in quite a complex sequence of events, in which each mobile learned how to best satisfy its particular urges.

Figure 2. The Colloquy of Mobiles. © Gordon Pask Archive at the Dept of Contemporary History, University of Vienna, Austria.

The Colloquy as a whole was a self-organizing system, as local decisions and interactions created the overall behavior, which could be labeled as emergent in respect to the aggregation of local actions. But, at least theoretically, the door was open to combinatoric emergence through the participant's interactions. Because of its set-up, the Colloquy offered the possibility for the visitor to the installation to intervene. Stepping into the installation space users could block light signals or redirect them with their own mirrors. As noted in [46], the women's make-up mirrors were a good resource for interacting with the piece, and some visitors did spend significant amounts of time on it. Arguably, these visitors' interventions might potentially cause new combinations in how the mobiles interpreted their environment, thus generating combinatorically emergent behavior.

Thus the piece had a double level of activity, which resonates with latter interactive ALife inspired pieces such as Simon Penny's Sympathetic Sentience [18] or Soler-Adillon's Digital Babylon [47, 48]. First, there is the level of the piece running on its own, creating its own equilibrium of self-organized behaviors. And second, there is the possibility for interaction, for the public to enter the space and affect the piece, creating with disturbances that enter the activity loop that forms the overall behavior of the system. The Colloquy is remarkable for anticipating some of the latter developments in computer art, Artificial Life Art, as mentioned above, or even the notion of real-time interactive installations (Myron Krueger's responsive environments) as noted in [10], as Pask integrated in it the active participation of the audience in his aesthetically potent environment.

V. Conclusions and Further Work

Among the rediscovered aspects of Cybernetics, there are many concepts that, towards the end of the 1980s, would form the theoretical basis of Artificial Life: "Many of the ideas central to cybernetics reappear under slightly different terminology in artificial life discourse. Central to cybernetic thinking were questions of self organization and purposive behavior, the relationship of an entity to its (changing) environment, its real time response and adaptability – interactions characterized as 'feedback'. In artificial life, these ideas are clad in terms of autonomous agents, reactive insect like robots, simulated evolution in fitness landscapes, emergence and self-organizing criticality" [49].

Many of the devices described above anticipate not only Artificial Life but also Artificial Life Art. First, it is clear that some of the works of the cybernetitians anticipate it thematically, Walter's tortoises being the most evident example. All the vocabulary and metaphors that Walter utilizes to describe the tortoises and its behaviors resonates with the descriptions that the ALife Art practitioners would adopt. Evidently enough, the devices themselves are called tortoises and even have names, and their parts are referred to as eyes or shell. Accordingly, their behaviors too are described as the tortoises feeling an obstacle, being independent or spontaneous, or learning [13, 37]. Gordon Pask's Colloquy is also a clear example of how both the devices and their behaviors are described in Artificial Life Art terms: the males and females and their actions performed in order to fulfill their drives, seen as a clear metaphor as a mating dance between the two genders of a species. As it has been noted in [10], this anticipates too an elaboration of narratives to explain the behavior of the agents that were strongly gendered.

Another aspect in which Ashby, Walter and Pask anticipate Artificial Life is in the bottom up approach in which they base their experiments. In all these cases the idea is to build simple systems capable of exhibiting complex behaviors. Walter was quite explicit in this objective in [13, 37]. The tortoises were built to prove how only a very limited set of connections could have a result that resembled something as complex as animal behavior. This bottom up approach is in fact an implementation of the idea of self-organization and, thus, a search for emergent behavior. Both this approach and the aim to generate unexpected behaviors in the devices, in the sense of not being fully pre-specified, represent pre-configurations of the idea of emergence that would be articulated a few decades later.

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