An Autopoietic Aesthetic for Interactive Robotic Installation

Abstract

An autopoietic system is one that is either biologically or mechanically self-created. Rather than producing a new entity from reproduction, autopoiesis is another way to understand life as a system of generating 'more of itself'. The autopoietic process involves individual entities negotiating a self-propelled exchange between demarcated systems, and is usually undertaken to provide each participant some sort of life-sustaining or evolutionary opportunity. The autopoietic aesthetic arises from human interaction with an art system that is self-propelled through the functioning of its own structure, being either mechanically generated or replicated through computer code. The autopoietic exchange establishes a new boundary between the semi-permeable membranes of demarcation between viewer and object, producing a second level union that constitutes the topological domain of all these parts as a whole in an aesthetic network.

Introduction

Autopoiesis engenders a fundamental dialectic between structure and function of both cellular consciousness (Maturana, Varela, Damásio), and an interactive aesthetic. The robotic artworks created by the artists (Rinaldo, Penny, Youngs) have the functioning of self-production. Francisco Varela coined the term autopoiesis, to refer to biological cognition and to mechanical processes. Applied to aesthetics, autopoiesis replaces an external objective view of art with an internal relativistic understanding of creation. This can be described as a self-functioning system of aesthetics that is open to negotiation. To a degree, the observer and the art object become co-organizers in an evolutionary system of patterns within the interactive artwork, creating an aesthetics of emergence. This relationship or lateral exchange between observer and artwork is codependent and fully negotiated. Therefore, challenging the established relationship between viewer and object that are often obtained in high art.

Built on the ethical premises that living systems cannot be owned by humankind, the exchange between an observer and an autopoietic work of art should be considered an equal relationship. Autopoietic aesthetics must therefore be positioned as part of a larger system of evolutionary forms that coexist together, rather than thought of in terms of a relationship where one takes from the other. Such an idea articulates the phenomenal in ways that stress an interrelationship, rather than hierarchal, one-way causality. For each element has properties of self-motivation and self-action. A self-organizing mechanical system has a self-purposefulness, when it is intentionally designed with foresight to sustain it's own functioning.

In his writing on *Autopoiesis and Cognition,* Francisco Varela refers to both biological and mechanical forms, as he argues for the presence of autopoiesis:

> *Autopoiesis in the physical space is necessary and sufficient to characterize a system as a living system … Hence, the biological phenomenology is the phenomenology of autopoietic systems in the physical space* [i].

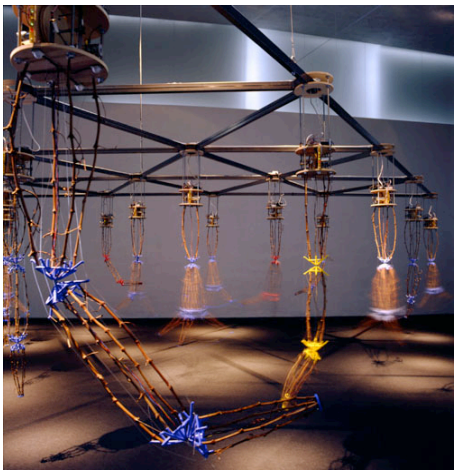
This physical space that Varela describes is, also, found in the autopoietic unity of what he describes as a '*living machine'* [ii]. So, when we, as observers of art, interact with an autopoietic machine, we see both its functioning and an exchange response, which acts as a register for presence. In other words, the exchange is both an instrument and an outcome. Built into the outcome is a functional quest to reach beyond one's own sense of autonomy - to establish a more complete experience. It also moves the aesthetic experience away from the imperializing gaze in high art and towards an exchangeable negotiation between participants. The autopoietic unity becomes a metanomy - a part standing for a whole, and is a window into how evolutionary strategies are at play within aesthetics.

The search for authenticity in the aesthetic experience, autopoiesis operates as a solitary state that looks to itself as a trigger. So, if a system refers only to itself, one might ask, how does it work to awaken or interact with anything but itself? The key to unlocking the autonomous meaning, in this case, is to re-conceptualize the notion of 'interacting'. Built into the autopoietic system is the function of self-reproduction – the need to make more of, for instance, the cells of a flower's stem in order for it to grow taller. In order for this flower to sustain life, it must grow tall enough to catch the wind or to lure the bugs that will use their locomotive abilities to carry

the pollen away. Built into natural autopoiesis, then, is a state of negotiated action between agents. In the case of the cell of the flower stem, it is a permeable cell structure that both holds the cell together and shares in a thermodynamically exchange of matter and energy, with both neighboring cells and the surrounding environment. In order to sustain its own autonomy, its permeable cell wall participates in an arrangement of interaction with the world while satisfying a need of self-sustainability.

An aesthetic autopoietic system can, therefore, position the art observer as part of the evolutionary emergence of everything that is part of our own identity. Rather than looking at identity as a form constituted by finding what is *not* of oneself, we can find in ourselves both an autonomous (unique in form and character) and interlocking self (one created by relationships), though the effects of engaging interactive art, which implies a similar process in the action of experience. Life can be viewed as an endless search for exchange, sustaining both the individual and the collective. Acts of exchange allow moments of consciousness and the reflexivity of introspection. In neuroscience today, one can detect that it is *gesture* that leads to a kinetic resonance in each individual brain cell. In the search for one brain cell to make contact with other brain cells, we find a compulsive need to create ordered relationships. These relationships are not at all unlike how individual people make their gestures within the larger human social sphere. Within this body gesture, the excitable cell resonates outward into the larger primordial openness of the life world (what neuroscientist Daniel Dennet calls the *qualia*, and what phenomenologist Merleau-Ponty describes as the *lebenswelt*). At the same time, each cell receives life force from the larger social sphere. If we can accept this phenomenological exchange of human experience, existence may be essentially perceived as co-existence. Interactivity becomes the choice and the aim of this coupling and works as a trigger to awaken consciousness. Interactivity is both an instrument and an outcome: a desire to reach beyond one's own sense of autonomy in order to establish contact with the general condition of reality. Interactivity is part of the mechanics of self-sustainability. It is the choice and the aim of coupling, and works as a trigger to awaken a system at both the level of individual introspection and that of a whole world relationship. Perhaps, just as importantly, we may have come to a historic moment that rejects distinctions between the life of the viewer and the life of the artwork. The life of the mechanical and life of the biological can appear the same in their functioning, particularly when viewed from withn the dynamics of autopoiesis. Biological and mechanical life has already transformed in a variety of ways in society. From this post-biological position, a new symbiosis of interactivity in art has emerged.

***Autopoiesis* by Ken Rinaldo**



Autopoiesis by Ken Rinaldo. Copyright 2000. The intra-action of robotic arms connecting with each other through a closed software system.

The installation *Autopoiesis*, by Ken Rinaldo, is a collection of intra-action robotic arms connecting with each other through the traditional notion of a closed software system - a biological ontology. In this artwork, autopoiesis is a system which could be considered as part flesh and part machine. The parts as a whole: human, machine, software, and triggering devices are all components that co-mingle. The machine can be described as a unique independent entity, as can the human observer. Together, they make a second order autopoietic system that activates through a highly complex negotiated system of organized functioning of its parts.

Ken Rinaldo's artwork is generally placed within the movement of generative art, a system oriented practice where the common denominator is the use of living systems as a production method. Unlike many art movements that have focused on natural form, generative art

relies upon the "*structurally coupled relationship of a self-sustained internal processing and an external mechanical functioning of the artwork*"[iii]. Rinaldo references aesthetics within a biological schema. His aesthetic systems behave in ways that alter how we physically interact with them. So, although the closed system of the art can be experienced as complete within itself, the observer/participant can also alter this system. This physical interaction, in turn, enfolds the observer/participant within the totality of a new sensory-motor system that is a hybrid of both the mechanical autopoietic system and the open potential, once the latter stimulates the artwork into action. In this way, a seemingly closed system can acquire permeable boundaries, opening itself up to the larger phenomenological world. When stimulated, this artificial "living" system will reorganize itself internally, making itself unique, reflexive, and self-perpetuating, in response to the diverse actions of the given observer,. We can see that an autopoietic system as a closed system with permeable boundaries, functions as an autonomous entity, made of both the biological and mechanical parts, and as an operationally open "life form", when coupled with its phenomenological environment through interactivity. In both of these respects, mechanical/structural mimics biological process, making such process the subject of aesthetic reflection.

In describing the biology of cognition, Humbert Maturana begins his introduction to a description of autopoiesis with the following:

> *The space defined by an autopoietic system is self-contained and cannot be described by using dimensions that define another space. When we refer to our interactions with a concrete autopoietic system, however, we project this system on the space of our manipulations and make a description of this projection.*[iv]

According to both Maturana and Varela, who coined the term, autopoiesis is a homeostatic circular system. A self-sustaining property of autopoiesis is built directly into Rinaldo's installation within the physical and technological elements. Each is configured to allow communication with and for the other, using only rule-based procedures provided in software. The system functions to communicate with itself -the movements that emerge from the arms of the sculpture are outcomes of an action set upon itself.

When multiple robotic arms interact, they do so in ways analogous to higher-order, structurally based systems, such as the relationship among neurons structuring cognitive activities. The gesticulating arms of Rinaldo's artwork use telephone tones as a "language" to "communicate" among themselves. On each arm, a series of light-emitting diodes signal the status of information input and exchange among the group. Computer-controlled feedback loops, smart sensor configurations, and randomization algorithms produce and control movement. As in the biological, neural, and growth structures found in evolution, the artwork creates its own internal stasis, the effect of which is, paradoxically, continuous exchange. Through the interaction of the viewer/participant, the piece, as evidenced through the software systems, evolves, producing unexpected, emergent behavior and emotive sounds. From the perspective of systems' critique, the viewer/participant opens the closed system with her/his interactivity, thereby challenging the notion of an insentient machine.

The arms need to know where they exist in space, so that they do not collide into a visitor to the installation. For this reason, they track anything or anyone that enters the space. Their domain is defined by the spatial limitation, which they can, however, physically extend. But not unlike organic systems that are rooted, such as a forest of trees or a cluster of synapses connecting the cells of a brain. Their systematic and distributed communication mechanisms provide a complex comingling of resources and information. The individual arms can see and feel through cameras and sensors, making autonomous choices on where to go and how to expend energy. At the same time, the system, as a whole, is able to strategize, remaining a singular entity that is self-contained and self-motivated. Here, an autopoietic drive, negotiating an improvised coupling with the observer's determinant input, becomes a central agent to the production of aesthetic experience.

Internal/External Living Gesture

Rinaldo's installation provides a view into the invisible neurobiological functioning of interaction between the body of the viewer and the sculptural form. In an act of compromise, parts of interaction are taken by the viewer and

others are taken by the installation. Both redistribute interaction back into the exchange in non-linear time. Time that reflects the interdisciplinary of past, present, future by intentionality. In phenomenology, the feedforward state of consciousness is called the *pre-objective*. In this case, the entwinement of biology, mechanics, and experience, effected by the installation, yields to the observer in a *pre-reflective* contact with the self through the artwork. Thus, the aesthetic encounter triggers a distinctive mode of consciousness. Called the *feedforward sweep*. In neurobiology, the brain creates knowledge of all experience *before* it is parsed to consciousness. In neurophilosophy, this would be identified as the *non-thetic* or *non-posting* sequence of the experience. Whatever we call it, this part of experience dresses the stage for interaction. Rather than focusing on the specific content of any particular interaction, it looks at the patterns and the relationships of things to things, in a more general way. One thinks, *Prepare myself, for I am entering into an activity where I will need to think about my relationship to another living thing*. The first part of experience produces a second-order reflection in which action unravels through self-consciousness. This brain process is akin to how the observer comes to meet the artwork in the larger world. In a sort of hyper-consciousness, the experience begins to take form in an exchange that is not only introspective and projected, but also visceral and mediated.

Interactive art, such as Rinaldo's suggests that the patterns of interaction that serve as the foundation of the phenomenological field are also found within structural patterns of the mind. These are not, by any means, exclusively visual; rather, the "interactive gesture" of the participating subject relies upon fully embodied patterns of action and reaction. Contemporary artists such as Rinaldo, appear to intuit these internal patterns and develop artworks with interactive elements that fit into them sufficiently to elicit and engage the viewer's patterns of cognition, as attested by art's ability to induce some kind of sensorial experience in viewers. In particular, the interactive aesthetic relies less on what an artwork looks like and more on what it stimulated in terms of phenomenological embodied patterns of action and reaction, between the functioning of the viewer and sculpture. By such means, experience becomes physically accessible for contemplation and enables us to "perceive ourselves perceiving."

***Petit Mal* by Simon Penny**

Petit Mal by Simon Penny. Copyright 2004.
A robotic momentary loss of consciousness.

Petit Mal, is in some sense, an anti-robot because it is truly autonomous. Most conventional robots are elaborations of von Neumann's notion of the universal machine, in which the physical machine is simply a formless form to be filled with software content. This attitude within robotics is an unfortunate application of the Cartesian idea of the mind-body split. *Petit Mal* is an attempt to build a robot which opposes this duality of experience, because it is impossible to distinguish where the observer leaves off an action and where the robot picks up a response. Hardware and software work in a seamless continuity consistent with autopoietic systems. Its behavior arises from the dynamics of its "body," a notion which introduces the phenomenological aspect as a seminal component of the system's functioning. In its evocation of "body" sensations and operations, *Petit Mal* is an anthropocentric project: the observer is called to critique her own sense of spatial self.

A cognitive reading of *Petit Mal* would present it as temporalizing involuntary participation in the world – one that is not projected out of the gaze, as we see in Rinaldo's sculpture, but one that links the quest for equalizing to a perpetual response to intentionally generated disequilibrium. Its action implicates both sculpture and the participant in the search for stasis. In neurological terminology, a Petit Mal inhibits and mimics momentary loss of consciousness. It is important that the *Petit Mal* sculpture presents itself as just a little out of control. It is a reaction to oppressive theories of control, for the principles of its design constitute long ubiquitous processes in computer science.

In fact, Penny describes this robot as an engineering nightmare [v]. Although the mechanical structure is inherently stable, it has a chaotic motion generator at its heart, with a double pendulum offsetting its center of gravity, thereby creating a range of unpredictable motion. By design, the robot relies on its own movement through time and space to find stasis – at any given moment, it is wildly out of balance and barely in control.

The viewer must interact with *Petit Mal* in a manor different from the interactions solicited by other robotic systems, ones that present a predictability of motion flow. With *Petit Mal*, the viewer spends much of her time interacting with space, projecting herself into the state of mind of a Petit Mal in order to formulate a knowable pattern against her own movement and her own mind. She processes minds in thinking about minds. In current neuroscience, this process is known as mind reading, and is about the co-organizing of some one else's mental state. In his groundbreaking book, *Simulating Minds*, Alvin I. Goldman suggests that, "*the notion of mentalizing anchors the fabric of social life* "[vi]. An 'anchor' is an appropriate model for *Petit Mal* because it is a system that does not provide a simple model of presence. Goldman would say that the anchoring happens in the body of the viewer when s/he theorizes, rationalizes, or simulates the external experience of other minds. Reading minds is an extended form of involuntary empathy. Sometimes called simulation theory, it is not to be confused with simulation such as Plato's 'imitation' or Antonin Artaud's 'virtual reality'. It entails sensory enactment or imagined state of mind. Indeed one's own development emerges from interaction with what one simulates of other people' minds. The infant *feels* the mother's delight in encountering the body (herself) in a game of peek-a-boo, and responds with joyful laughter to the other's pleasure - a pleasure simulated in the infant's own mental process. As a kind of exchange, or communication between individuals, simulation can be thought about it in terms of the developmental strategies for one's own consciousness. Mindreading or simulation is this pre-thetic state of consciousness where the mind projects outward to find connections, yet still remains as a self-serving, autonomous gesture, bringing immediate experience to the other into its own experience of well-being and equilibrium. So, *Petit Mal* points us to an essential core of self where we need social interaction.

Goodman discusses how this involuntary and immediate mental interaction simulates the mind for the other. The mirror neurons obliviate the mind/world split. "*As a network, it encompass(es) environmental stimuli, internal states, and behavior*"[vii]. Goodman describes a physicalist's story about the mental states and the physical states as one. It is, also, interaction accommodating the functionalism of the mental and the behavior of the person as a single event. So, we can see both an autonomous and an interpersonal functioning for the mirror neurons. The casual relations binding mental states, sensory stimuli, and motor responses give use to intentional stances within an ontology that does not separate thoughts and objects or privileges one over the other. This is another way of saying that what things might be, what constitutes their singularity, is likely to be found in their relations and interactions rather than in themselves alone. Simulation recuperates the self through the other.

In the light of simulation theory, the notion of cooperation can also be understood as a hybrid where egocentric bias becomes displaced or disrupted by necessary entwinement with the simulated affective experience of others. In a mechanistic way, dual processing of ones' own, altered mental states allows for the simultaneity of autonomous activity with reciprocal hedonic benefits. Cognition, then, becomes characterized by the controlled flow between the perspective of taking and receiving. In what Goldman calls 'enactment imagination', in which ones own neural structure "enacts" what it "imagines" of another's mental activity. The act, itself, provides the essential attributes of the other taken in the self. Mimicry involves mechanisms beyond decoding a visual surface, such as the visual read of a face interrupted through the signs of its realities. The other's real or imagined action, within the perceiving mind, a neural "enactment" that he describes as grounding self-other symmetry[viii].

Egocentric bias is released through such acts of cognitive processes. Indeed, the pull of mimicking is such that the other's actions seem invitations for self to participate. This object is no longer singular and, in this way, undercuts the autonomy of individual as a singular existence. Often applied to aesthetics, this model allows cooperation, rather that mastery of the object, to

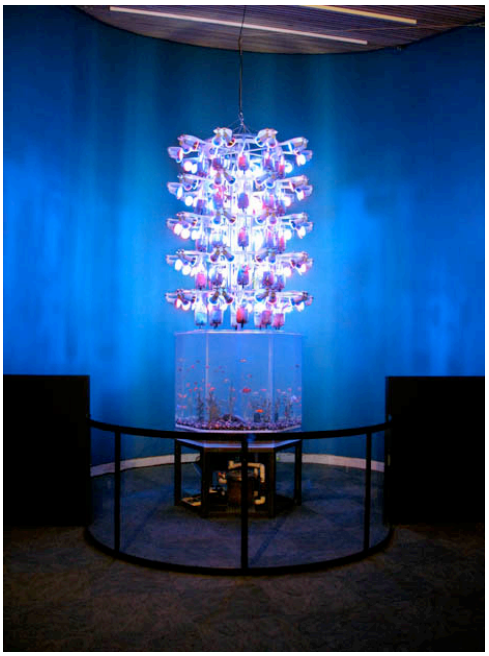
become the reflexive and preferred act of aesthetic exchange.

(auto)Action/(auto)Reaction
Penny's *Petit Mal* creates another kind of simulation - a self-other symmetry with the viewer. Because the (auto)action of Penny's *Petit Mal* is consistently unexpected, the viewer positions herself in a manner akin to the physicalist story of (re)action. Anne Marie Duguet, author of the *2006 Transmediale Catalogue, Berlin Germany,* seeks to delineate this dynamic. In her view, the action of constant adjustment to the viewing state brings out the humanness in the viewer, triggering emotions and desire for relationship. Moreover, the viewer is placed in the position of "catch-up" to the interaction and what becomes subservient to the nature of the robots' behavior, another unexpected reversal:

> *…a trace of autonomy is perceptible, all this non-resemblance falls into oblivion and a "human effect" is activated, inciting the viewer to project endlessly. Thus, the object of humor may become the viewer himself interpreting a slight step back as fear, and a step forward as curiosity. Sensitive to the environment, capable to diversify and to involve its reactions, the robot tries to have a relationship to the human being, and this relationship is constituted from the beginning as a human relationship, one of domination or of sympathy. The robot is no longer the slave, it enslaves the other. This kind of reversal is a satire of human psychology and of the expression of the platitude of the threat that represents the development of such autonomous "creatures" for the human being.*[ix]

Duguet's description defines an interaction that is far from one of cooperation. The viewer must rely on the action of the robot for the aesthetic experience. But it is the 'stepback/stepforward' positing of that viewer that creates an uneven projection ranging between fear and curosity. Confusion arises from this unexpected negotiation and a dance to find a homeostatic balance ensues between them. Neuroscientists tell us that the physical action of reaching and pulling within ones own body is also a brain-generated simulation -- a feeding back of experience into the temporal regions. The temporal region is believed to the caretaker of our senses and our emotions. In these regions, what we feel is neurologically mapped with what we experience. *Petit Mal* reminds us that behavior evolves. Perhaps, in the play between these two sentient forms, installation and viewer, we realize that each is reliant upon the other for their mutual evolution. We also come to understand that interactive art leaves the viewer to experience certain things that lead to reflection that, then, lead to other things. Ironically, the intelligence of embodiment, such installations highlights how the enactment of the physical shapes the psychological, which constitutes another way that we learn.

Farm Fountain by Amy Youngs and Ken Rinaldo.



Farm Fountain by Amy Youngs and Ken Rinaldo. Copyright 2009. Based on the technique of aquaponics, the plants and bacteria in the system serve to cleanse and purify the water for the fish.

Introduction to Farm Fountain by Amy Youngs and Ken Rinaldo
Youngs' and Rinaldo's *Farm Fountain* is a transition from biological autopoiesis to a mechanical or hybrid system. The installation is both a sculpture and a system for growing edible and ornamental fish and plants in a constructed, indoor ecosystem. Based on the technique of aquaponics, this hanging garden fountain uses a

simple pond pump, along with gravity, to flow the nutrients from fish waste through the plant roots. The plants and bacteria in the system serve to cleanse and purify the water for the fish.

Hybridist Forms: Human as Caretaker

Perhaps in an act of self-preservation, the mammalian brain is in constant search for connection between individuals. From a structural perspective, there are neurobiological processes that are constantly readying themselves for such emotional attachment to our own species. The question then arises, are we able to have such an exchange with other living species? The hybridist forms of Amy Youngs challenge our notion of any absolute autonomy because the viewers find themselves place outside paradigm of utilization and service. Instead, they find themselves in relations of exchange that foster appreciation for the system's life producing bounty.

In his pending book, *Green Light: Toward an Art of Evolution*, George Gessert describes the "slow art" of plant breeding, and how we create new life that takes into account a combination of what we know about ecology, aesthetics, and ourselves. The eco-artist has been part of the hybridization of plants for thousands of years, but such results first exhibited as fine art in 1936, when the Museum of Modern Art, in New York, showed Edward Steichen's hybrid delphiniums. Since then, bio art has become a genre; artists work with a variety of living things, including plants, animals, bacteria, slime molds, and fungi. Our plants have not only transformed to answer our needs, we have also evolved to take care of our plants. We have assisted in their transformation and their evolution, which binds us together in a most intimate negotiation. In a co-evolutionary bargain struck between a person and a plant, the two parties act on another for their personal interests, but wind up trading favors in the process of exchange. As a sort of victory over the selfishness endemic to being human, ethics may provide us a conscious guide that follows such biological coordination in addressing the ever-morphing shape of society. As plants and people sustain one another, society also provides protection for the individual who needs identity to reap the benefits of autotelic growth. Indeed, the evolution of the self is neatly bound up with the security that the collective provides. Similarly. a complex array of chemical negotiations must also be undertaken in order for systems of humans and plants to coexist. Part of the viewer experience in *Farm Fountain* establishes a cooperation that extends from the physiological experience of the installation to the society that its encounter opens up. Such progress goes against a simplified notion of the individual role in society, thereby, pushing us toward an appreciation for our relationship to the whole system.

In *Origins of the Species*, Darwin posits artificial selection as the process that reflects human will. In artificial selection, nature provides a variety of traits, as in natural selection, but it is humans who decide which will be the traits passed down to further generations. In the process of domestication, human action plays the same role as blind nature does, albeit a bit faster. This process of choice constitutes fitness, and, over time, leads to new forms of human negotiation – a cultural modification of descent. By blurring the line that separated natural selection with artificial selection, Darwin opened the door also, blurring the distinction between nature and human action of all kinds. What we may think of the high-level functioning of our ethical mores can be traced back to the primal skills of human survival, as indeed the correlations of "ethos" in archaic greed suggests.

However, the fact that one has become aware of the desires of the exchange makes no difference in why we take part in the arrangement of artificial selection. An autopoietic system's only interest is to make copies of itself without any apparent use of natural selection. We can understand an interaction with *Farm Fountain* is part of the evolutionary process of artificial selection, with its foremost interest in sustaining the heath of the sculpture itself. The sculpture moves from object to subject, acting *upon* the viewer, getting the viewer to do things it could not do for itself. The aesthetic mirrors some of nature's greatest success stories in biological systems and links the interactivity of artificial selection links to our larger understanding of evolution.

Young's *Farm Fountain* posits a model of an aesthetized and domesticated co-evolution. Our genes are the archives of our cultural and natural information, containing detailed instructions on experiences we enjoy. We have spent the last few thousand years remaking our food supply through natural selection and transforming usability for our needs. Plants have been going about their business of remaking us as their

caretakers. The endless beauty of a garden identifies emotions in us and they gratify all of our senses. We, in turn, look after them. Through Darwin's artificial selection, the thing or the product comes to reflect human will. Nature proves a variety of traits from which humans may also decide to select. Human nature can play the same role as blind nature does in the process of domestication or we can choose to keep our own autonomy for a time. Constituting what is fitness thus thereby autonomy is a hybrid system. The line that separated natural with artificial selection has blurred and so has out relationship to other forms of life.

Generative Art and Neural Processing

Living systems exist in an ambience and cannot be fully understood apart from that ambience with which they interact. This is why experience is difficult, if not impossible, to duplicate. Even during well-calibrated cognitive tasks, successive brain responses to repeated identical stimulations are highly variable [x]. Living systems are multible causal circular processes that allow for complex evolutionary trajectories. But the function always follows the form. Change is similar in the way a biological circulatory system is maintained, but not for loss of circulation itself. An individual cell would collapse if not for the pumping of fluids though its efficient, structural wall. Rinaldo, Penny, and Youngs have created art that underscores the role of ambiance in the structures of sustainability. They produce circular systems that run their tasks with endless precision, but that eventually would cease to exist without participation from the outside. By definition, an autopoietic system will only take on external negotiation as a kind of bargaining chip, for the sole purpose of survival. So, although an autopoietic interaction is self-serving, there are collective, advantantaged, generative outcomes. Neurons in one's brain, for example, have one hundred trillion cellular robots, and they care not about you or your consciousness or your intentions. The more the brain processes external stimuli, the more energy is produced in the neuron and its surrounding material. This, in turn, creates the need for more neurons to handle the load. Another example is how energy is created by the system of Youngs' *Farm Fountain*. *S*timulation of the light exchanges energy to grow the plants that create the food for the fish, that creates the fertilizer to feed the plants. Both the neural process in the brain and the generative process of *Farm Fountain* use dynamic emergent systems, arising from external stimuli. Each moment will be distinctive from to the one that has come before. The response of the system is replicated in the variety of responses that a participant has to the art. The feedback loop creates a rhythmic, or synchronous, activity between the parts within time and space.

A similar rhythmic pulse between brain regions has been observed during, or associated with, many neuro-biological functions, these include timing-dependent plasticity of synaptic growth, and a particular chemical exchange in one lobe of the brain acting as a global stimulus to all parts. According to the dynamical systems view, the neural processes most relevant to an understanding of our overall consciousness are to be found at the level of '*dynamical brain signatures'* [xi], understood as large-scale patterns of activity over multiple frequency bands, rather than the structural level of specific circuits or classes of neurons. In other words, a moment of coherent consciousness is the unfolding in multiple synaptic firings, but, also, a dynamic remapping of the entire brain. The dynamical approach emphasizes that perception and cognition are intrinsically temporal phenomena - they happen *in* time, not simply *over* time [xii]. This is important to consider when we compare brain function to the unfolding interactive art, for the location of experience is both dynamic in space and time. Here is a reciprocal pattern between the individual parts and the mapping of the whole that make the formation of experience, rather that the singular comparative observation.

Ambient Exchange as part of Self-Propagation

Mirror neurons assist in our understanding of the individual and the collective [xiii]. As brain functioning may suggest how we behave in the larger world of being, aesthetics may function as a way to locate these perceptual exchanges within the multiplicity of self-awareness. This is the heart of the interactive experience with all three interactive artworks. A participant must navigate an environment that is constantly shifting, where one becomes hyperaware of both one's own body and the exchange of actions with object. One's own sense of self becomes sprawled across the installations, picked up by one element and reconfigured in the reactionary movement of another. The experience becomes both *here* and *there* or *oneself* and *not of oneself*.

Art is a systematic sharing of this awareness *per se*. Louis Glannetti, a new media theorist, coined the term 'Endo-aesthetics' in describing the interactive in new media art. It describes the complete and radical removal of the subject-object distinction, with only a focus on the action or activity of the event. His claim is that there is a sameness governing thought and action at the interactive moment. A neuroscientist might say that the activities of thought and the laws of physics have mutual permeability. Both art theorists and scientists are connecting understanding within the self to the larger works of being-in-motion. Nancy might refer to them as the circulation of events into events; the internal return of coming and passing between that which creates awareness and aesthetic transparency. It provides a kind of sympathy within what we experience, perhaps because what we offer in the exchange is a part of ourselves.

Let us consider a small neurological event in the human brain. The neurobiologist has found a particular individual event that exhibits the collective ability of the individual. It is what the cognitive scientist calls the Mirror Neuron - a single cell that responds to the larger cluster of brain activity, but that also has the functional properties to trigger signals from someone else's experience. The Italian neurophilosopher, Corrado Sinigaglia, claims that both mirroring the emotional system and the fact that mirroring for action occurs in a single cell, represents a specific way of understanding the actions and intentions of others. Neurons in the brain send out sophisticated signals down the spinal cord that orchestrate skilled movements. These are considered "ordinary" motor command neurons. But some of them, known as Mirror Neurons, also fire when you merely watch another person perform a similar act. It is as if the neuron (more strictly, the network of which the neuron is part) uses the visual input to do a sort mimicking of the other persons actions - allowing one to empathize with another's view from within one's own point of view. It can be, therefore, speculated that these neurons can not only help simulate other peoples' behavior, but as they turn "inward", they create a second-order sense of self or a metarepresentation of one's own earlier brain processes. This activity of mirroring the individuals around us could be the neural basis of introspection and of the reciprocity of self-awareness. A 'being-like-me' quality to humanness is wired into the material nature of the brain as a feedback loop of the entire system.

The neurological purpose for aesthetics can be part of a complex system of perception that cannot be separated from other functioning. For instance, by observing consciousness through a materialist lens, aesthetics may function as a way to develop empathy. Mimicking of another persons actions, triggers Mirror Neurons. This process allows one to empathize with another's view from within one's own point of view. The mental space projected by Penny's *Petit Mal* creates this kind of metarepresentation of experience. The participant is in constant expression – comparing the immediate past with the immediate present and replacing the old model with the new model. With little time for reflection, the exchange is an automatic kinesthetic comparison and response.

This activity of mirroring the individuals around us could be the neural basis of introspection and of the reciprocity of self-awareness and aesthetic appreciation itself. For instance, the implications in Youngs' *Farm Fountain* is slightly different because the use of the Mirror Neuron is used to project into a system that has no sustainable use for the viewer except as caretaker. So, the aesthetic descriptors for the general audience are visual projection into the autopoietic system and a model for an ambient cooperative evolution. The installations supply a redundant echo of their own external action, while, also, projecting the experience towards the viewer, who must relinquish her own authorship over the aesthetic experience to participate.

"Touch mirror neurons" fire not when one's own skin is touched, but when one watches someone else being touched. This raises an interesting question: How does the neuron know who the other is? Why doesn't the activity of these neurons lead to *literally* experiencing the touch delivered to another sentient being? The neuroscientist has two answers: First, the tactile receptors in your skin tell the other touched neurons in the cortex (the non-mirror neurons) that they are not being touched, and this null signal selectively vetoes some of the outputs of mirror neurons. A second reason why mirror neurons don't lead people to mimic everyone else all the time (or to literally experience another's tactile sensations) might be that the brain's frontal lobes send feedback signals partially inhibiting the mirror neurons' output. (It can't completely inhibit them, otherwise there would be no point having mirror neurons in the first

place.) As expected, if the frontal lobes are damaged you do start miming people. Echopraxia, the medical condition of involuntary repetition or imitation of the observed movements of another, is a feedback loop of consciousness without a filter to define boundaries [xiv]. A redundant eco of action, or praxia, produces the loss of an individual distinction, which makes it impossible the release an autonomous self into the world all altogether.

The process expressed in echopraxia may be identified with untamed qualities opened by interactive aesthetics. The loss of distinction between the object and the viewer initiates the collapse of non-contingent, autonomous identity. In what can be seen as a map for empathy, the schopraxia sensation may, also, be biologically hardwired into people. Perhaps it is the need for communication or an intrinsic material value for art making and aesthetic appreciation. Autonomous expression becomes a device that is correlated with the primitive actions of the brain, and bundled with the fundamental properties of human existence. In interactive expression, we must access both autonomy and empathy. Along with the ordinary life of a human cell, humans have an internal editing device that keeps us from completely losing track of ourselves in the context of the larger world. So, from an inter-subjective perspective, we are able to retain a sense of self-identity with the contemporary art experience that is in constant campaign to collapse any such distinction. The aesthetic experience becomes a system of constant echo-praxic exchange and struggle. Despite all of the pride that the self takes in its individuality and privacy, the material that separates you from me is a small subset of neural circuits in our frontal lobes interacting with Mirror Neurons.

Using this neuro-scientific ontology, interactive art develops through systems of self-reflexive connections – between the forms of the autopoietic object and the observer. The use of an autopoietic mechanism, along with the observational learning that occurs with structural functions such as Mirror Neurons, provides a method to identify the material for thought and new knowledge. In this way, interactive aesthetics moves from the outer manifestations of human action into inner meaning and back out again into the aesthetic interface, in endless circulation without loss of autonomy. It becomes evident that experience and expression cannot be neatly separated, and singularity of perception dissolves. Meanings emerge into the whole life world of experience through a biophysical co-evolution. The many varieties of exchange describing the autopoiesis aesthetic are entangled within this force.

Conclusion

"You who are looking for the way, please do not lose the present moment" [xv].
-- Sekito Kisen, Soto Zen Master, 700 AD

Art has embraced some of the key terminology, concepts, and features of the new biophysics. Coherence, long-range interactions, non-linearity, self-organization, self-regulation, communication networks, and non-locality, are some of the new credentials that contemporary art deploys. Interactive art matches the cognitive attributes of a coming-to-being in a perfect formation of an already expected moment. The reflexive experience of an aesthetic consciousness can be understood as a fast forwarding of the mind's activities to catch up to that which is about the occur. In the collapse between the object and the observer, on this new modeling of an event, there is a transformative negotiation of the interactive moment embodied in both machine and biology. Because Varela's embodied mind is directly associated with the embodied machine, we have an expanded understanding of self or, perhaps, more precisely, a distributed self that occurs within a system of individual selves.

Arguments about embodied minds, to some degree, are still weighed down with an implicit dualism. We must look at the self as a moment upon the potential of many moments. The idea of the distributed self posits that the self exist within, because of, and with affect upon, various networks of relative agency at large. The self does not exist in this context as an identifiable thing but rather as an ever-emergent phenomena that appears to have some degree of coherence.

Autopoiesis offers us a kind of co-evolution of interspecies and living/non-living systems where art and viewer are part of the same system of experience. In this way, autopoiesis presents the question about the end of simulation - because we can understand experience as an interacting system, rather than one being a reflection of another. As hybrid systems that must interface with the larger environment, systems of

autopoiesis can no longer be considered simply another kind of other. Some aspects of their functioning may reference only their internal qualities, but total success relies on the materiality of a larger existence, beyond insular feedback mechanisms. As an example, the interactions of Rinaldo's individual robotic arms are defined within a set group of rules for their behavior, individually and collectively, which can be considered their structural identities. With a provocation, actions elicited are generated not by the source of stimulus, but only by the possibilities inherent in the robot's programming repertoire and material constraints. This structural identity in this physical sense is what defines the structural identity of actions, and a central notion to autopoietic theory. First, nothing is a model for anything else; everything has its own essential grounding that we can see as similar to other systems. Second, locomotion of the singular always co-mingles with the other. The other, being the partial story, is deployed as a state of multiplicity of the now and the here. With the mind being internally coherent, the world 'comes up' to being through the sheer confusion of experience. But out of the clash of the internal and the external comes this sensation of a very stable reality. The brain looks for these points of placidity in every moment to create stable realities. It takes the brain to make solid the forms of experience.

It is wrong to propose an objective world, independent of the observer. For an artist, the observers place is essential. So the world in which we see and that which appears objective to us is not independent of the observer. The combination of the objective and the subjective becomes the lived experience of any visual artwork. This is the aesthetic space that moves beyond perception. It is something that we all do together and is as dynamic as every moment. We simply are not subject to unique fixed laws.

According to Varela, evolution has less to do with getting better through adaptation and more to do with what we choose through experience. The tempo-spatial mechanisms of material form such as a brain cell or a kinetic sculpture gives the moment its character and behavior. As a cell grows and lives, the development of all the functionality of life comes from itself and continues to do so until it dies. The autopoietic cycle ceases. One interesting similarity between a living cell and a mechanical autopoietic system is the cell's inability to make qualitative judgments about survival without an external connection. For instance, the cell takes in chemicals for growth, but to the cell's components there is no real difference between food and a toxin. They are both perturbations – affecting the efficacy of self-propagation, favorably or not. It is only with response to perturbations by the environment or medium in which it exists, that the cell will adapt or evolve to maintain the structural integrity of its components. In other words, autopoiesis is contingent upon the larger environment in which the material entity presents itself alone. Aesthetic autopoiesis is the contemporary observation that simultaneously presents this truth. The autonomy and resiliency of art as part of its own identity is, also, partly, its own non-identity.

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References

[i] Francisco J Varela, Autopoiesis and Cognition, (Kluwer Press 1972) 112.

[ii] Ibid.

[iii] Ken Rinaldo, Website http://accad.osu.edu/~rinaldo.

[iv] Francisco J Varela and Humbert R Maturana, Autopoiesis and Cognition: the Realization of the Living. (Kluwer Press, 1972) 89.

[v] Simon Penny, In conversation with the author regarding a prototype of Petit Mal (International Art Science Conference, Sydney Australia 1992).

[vi] Alvin I Goldman. Simulating Minds: The Philosophy, Psychology, and Neuroscience of Mindreading, (Oxford University Press, 2006) 6.

[vii] Ibid, 92.

[viii] Ibid.

[ix] Anne Marie Duguet. Transmediale Catalogue, (Berlin Germany 2006).

[x] George Gessert, Green Light: Toward an Art of Evolution, (MIT Press 2010) 1.

[xi] Lutz, A.; J.P. Martinerie; J. Martinerie; and F.J. Varela, Guiding the study of brain dynamics by using first-person data: Synchrony patterns correlate with ongoing conscious states during a simple visual task, (*Proceedings of the National Academy of Sciences 2002)*: http://www.pnas.org/cgi/doi/10.1073/pnas.032658199

[xii] T Van Gelder, (1999), Dynamic approaches to cognition, in The MIT Encyclopedia of Cognitive Science, (MIT Press) 244.

[xiii] Giacomo Rizzolatti , and L. Graighero, The Mirror-Neuron System, (Annual Review of Neuroscience 27, 2004) 169-92.

[xiv] Lutz, A.; J.P. Martinerie; J. Martinerie; and F.J. Varela, Guiding the study of brain dynamics by using first-person data: Synchrony patterns correlate with ongoing conscious states during a simple visual task, (*Proceedings of the National Academy of Sciences 2002)*: http://www.pnas.org/cgi/doi/10.1073/pnas.032658199

[xv] Suzuki Shunryu's translation of Sekito Kisens, Sandōkai, Branching Streams Flow in the Darkness: Zen Talks in the Sandoai, (University of California Press, 1999) 20.

Bibliography

Books

Bennett, Maxwell, Dennett, Daniel. Hacker, Peter; Searle John. Neuroscience and Philosophy: Brain, Mind, and Language. 2009

Bernard, Claude. An Introduction to the Study of Experimental Medicine, 1865. First English translation by Henry Copley Greene, published by Macmillan & Co., Ltd., 1927; reprinted in 1949

Bickle, John. Philosophy and Neuroscience: A Ruthlessly Reductive Approach. Boston: Kluwer, 2003

Changeux, Jean-Pierre and Ricoeur, Paul and What Makes Us Think?: A Neuroscientist and a Philosopher Argue about Ethics, Human Nature, and the Brain. Princeton University Press, New Jersey, 2000

Clark, Andy. Supersizing the Mind: Embodiment, Action, and Cognitive Extension (Philosophy of the Mind). Oxford University Press, Inc. NY, NY, 2008

Damasio, Antonio. The Feeling of What Happens: The Body and Emotion in the Making of Consciousness. Harcourt Books, N.Y, NY. 1999

Gallagher, Shaun. How the Body Shapes the Mind. Oxford University Press, Inc. NY, NY, 2003

Gessert, George. Green Light: Toward an Art of Evolution. MIT Press. Cambridge

Massachussetts, 2010

Goldman, Alvin I. Simulating Minds: The Philosophy, Psychology, and Neuroscience of Mindreading. Oxford: Oxford University Press, 2006

Haraway, Donna J. Situated Knowledge in Simians, Cyborgs, and Women. Routledge, New York: 1991

Heidegger, Martin. Basic Writings. Ed. David Farrell Krell. San Francisco: Harper, 1993

Ledoux, Joseph. Synaptic Self: How our Brains Become Who We Are. Viking Penguin, N.Y., N.Y. 2002

Shunryu, Suzuki, Branching Streams Flow in the Darkness: Zen Talks in the Sandoai. University of California Press, 1999

Thompson Evan. Mind in Life: Biology, Phenomenology, and the sciences of Mind. The Belknap Press of Harvard University Press, Cambridge Massachusetts, 2007

Varela, Francisco J.; Thomas Evan; Rosch, Eleanor. The Embodied Mind: Cognitive Science and Human Experience. MIT Press, Cambridge, MA. 1993

Journals and Papers

Abrams, Marshall. Fitness ''Kinematics'': biological function, altruism, and organism–environment development. Biol Philos (2009) 24:487–504

Avenanti, A. and D. Bueti, G. Galati, et al. "Transcranial Magnetic Stimulation Highlights the Sensorimotor Side of Empathy for Pain," Nature Neuroscience 8: 955-60. 2005

Barlow, H. Single units and sensations: A neuron doctrine for perceptual psychology? Perception 1972 1, 3 71-394

Boyden, E.S. , Zhang, F., Bamberg, E., Nagel, G., & Deisseroth, K. (2005). Millisecond-timescale, genetically targeted optical control of neural activity. Nature Neuroscience, 8, 1263–1268

Carew, Thomas J, Mirror Neurons, Society of Neuroscience Briefings. November 2008. "http://www.sfn.org/briefings" www.sfn.org/briefings

Carr, L., M. Iacobini, M. C. Dubeau, et al. 2003 "Neural Mechanisms of Empathy in Humans: A Relay from Neural Systems for Imitation to Limbic Areas," Proceedings of the National Academy of Sciences 100: 5497-5502

Desmurgel, Michel and Sirigu, Angela "A parietal-premotor network for movement intention and motor awareness", Trends in Cognitive Sciences Volume 13, Issue 10, October 2009, Pages 411-419

Goldman, A., and V. Gallese . Mirror Neurons and the Simulation Theory of Mind-Reading. Trends in Cognitive Science MIT Press.2 (12) (1998): 493-501

Grush, Rick. "In Defense of Some 'Cartesian' Assumptions Concerning the Brain and Its Operation." Biology and Philosophy 18: 53–93, 2003

Han, X. and Boyden, Han, X. and Boyden, E. S. (2007) Multiple-color optical activation, silencing, and desynchronization of neural activity, with single-spike temporal resolution, PLoS ONE 2(3): p. e299

Lewens, Tim. As nature intended: Review of J. Scott Turner (2007), The Tinkerer's Accomplice: How Design Emerges from Life Itself. Biol Philos (2009) 24:417–423

Nisbett, R. E., Peng, K., Choi, I., Norenzayan, A., & others. (2001). Culture and systems of thought: Holistic versus analytic cognition. Psychological Review – New York. 108(2), 291–310.

O'Boyle, M. W., & Gill, H. S. (1998). On the relevance of research findings in cognitive neuroscience to educational practice. Educational Psychology Review, 10(4), 397–409.

Press, Joel. Physical explanations and biological explanations, empirical laws and a priori laws. Biol Philos (2009) 24:359–374

Rudrauf, D. and A. Damasio 2005 "A Conjecture Regarding the Biological Mechanism of Subjectivity and Feeling," Journal of Consciousness Studies 12 (8-10): 236-262.

Rizzolatti G, Umilta MA (submitted), Hand Grasping Motor Neurons know the goal of Action.

Rizzolatti, Giacomo and L. Graighero 2004 "The Mirror-Neuron System," Annual Review of Neuroscience 27: 169-92.

Sinigalia, Corrado. Mirrow Neurons: This is the Question. Journal of Consciousness Studies, 15, 10-11:70-92

Thompson Evan. The Problem of Consciousness: New Essays in Phenomenological Philosophy of Mind. Canadian Journal of Philosophy, Supplementary Volume 29: 2003 University of Alberta Press

Thompson Evan., Between Ourselves: Second Person Issues in the Study of Consciousness. Imprint Academic, 2001. Published also as a special triple issue of the Journal of Consciousness Studies

Zahavi Dan "Killing the straw man: Dennett and Phenomenology", Phenomenology and the Cognitive Sciences 6/1-2, 2007, 21-43

Van Gelder, T. 'Dynamic approaches to cognition', in *The MIT Encyclopedia of Cognitive Science*, ed. R. Wilson and F. Keil (Cambridge, MA: The MIT Press). 1999.

Varela, Francisco J.; and Maturana Humbert R. Autopoiesis and Cognition. Kluwer Press, Boston, MA. 1972

Varela, Francisco J.; Thomas Evan; Rosch, Eleanor. The Embodied Mind: Cognitive Science and Human Experience. MIT Press, Cambridge, MA. 1993

Online

Rinaldo Ken, Website: http://accad.osu.edu/~rinaldo

Lutz, A.; J.P. Martinerie; J. Martinerie; and F.J. Varela, Guiding the study of brain dynamics by using first-person data: Synchrony patterns correlate with ongoing conscious states during a simple visual task, Proceedings of the National Academy of Sciences 2002: http://www.pnas.org/cgi/doi/10.1073/pnas.032658199

Zorzos, A. N., Dietrich, A., Talei Franzesi, G., Chow, B., Han, X., Fonstad, C. G., Boyden, E.S. (2009) Light-proof neural recording electrodes, for Neuroscience, Online : http://www.syntheticneurobology.org