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LEONARDO ELECTRONIC ALMANAC

VOL 17 NO 1 A collection of articles, reviews and opinion pieces that discuss and analyze the complexity of mixing things together as a process that is not necessarily undertaken in an orderly and organized manner. Wide open opportunity to discuss issues in interdisciplinary education; art, science and technology interactions; personal artistic practices; history of re-combinatory practices; hybridizations between old and new media; cultural creolization; curatorial studies and more.

Contributions from

Frieder Nake, Stelarc, Paul Catanese

and other important cultural operators.

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Some Thoughts Connecting Deterministic Chaos, Neuronal Dynamics and Aesthetic Experience

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A B S T R A C T

The apparent randomness of deterministic chaos is differentiated from stochastic randomness and linked to natural processes, time's irreversibility and the creation of meaning. *Current neuroscience research strongly suggests that chaotic dynamics govern the physiological functioning of the brain/mind. The brain/mind is conceived as a multi-attractor system functioning at a far from equilibrium state poised for instantaneous state changes and transitions. Chaotic itinerancy has been suggested as a process by which chaotic transitions among attractors may be made and dynamically integrated in a multi-attractor chaotic system such as the brain. The article outlines a theory suggesting that the general characteristics of aesthetic experience are determined by the chaotic dynamics of the brain/mind and by the dynamics of chaotic itinerancy. Two examples, a novel by W.G. Sebald and the installation art of Jenny Holzer are described in terms of this new aesthetic theory.*

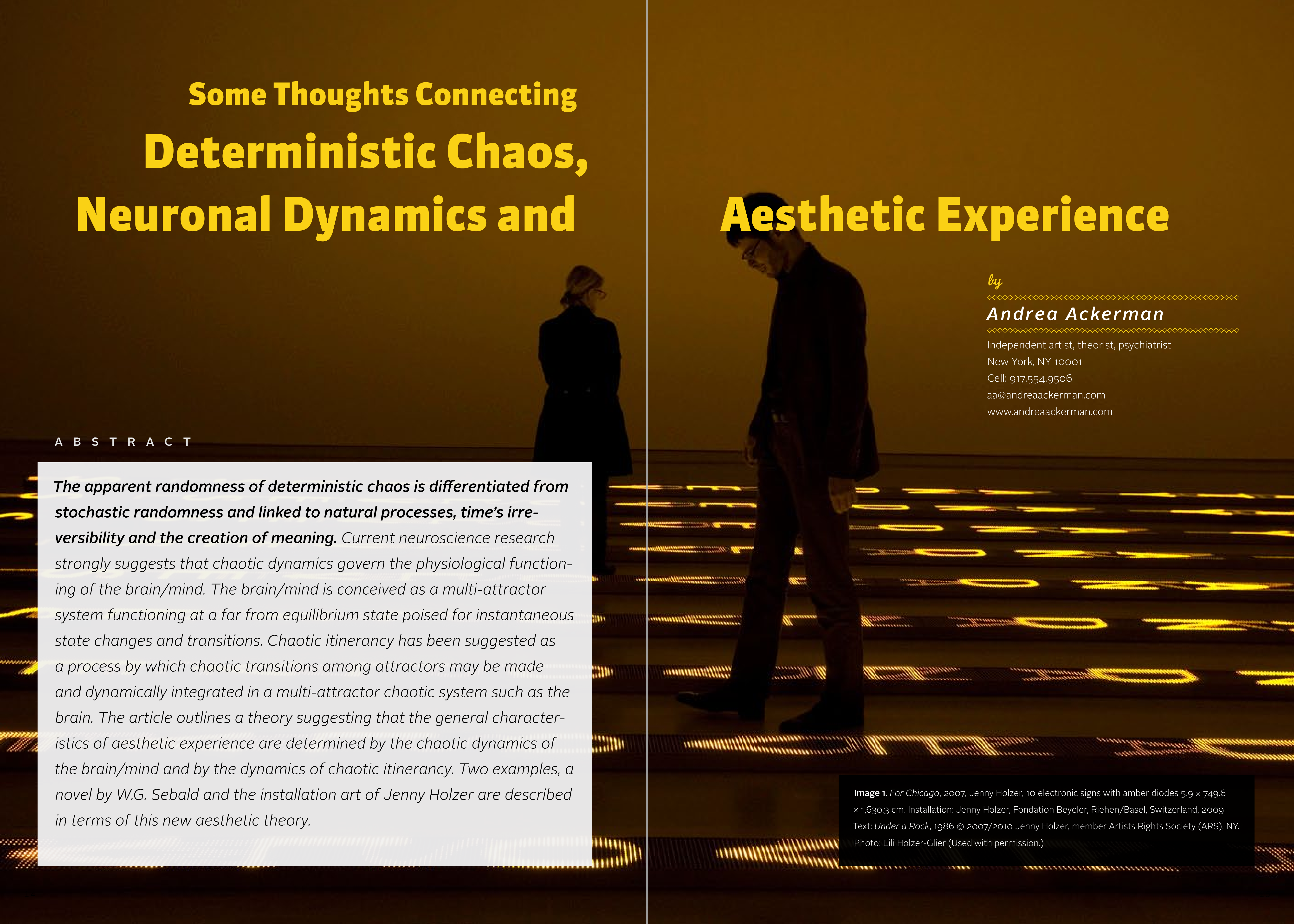

Image 1. *For Chicago*, 2007, Jenny Holzer, 10 electronic signs with amber diodes 5.9 × 749.6 × 1,630.3 cm. Installation: Jenny Holzer, Fondation Beyeler, Riehen/Basel, Switzerland, 2009 Text: *Under a Rock*, 1986 © 2007/2010 Jenny Holzer, member Artists Rights Society (ARS), NY. Photo: Lili Holzer-Glier (Used with permission.)

Randomness is not a single concept. There are kinds of randomness and degrees of randomness. One form is the classical, traditional, true, statistical, stochastic, unbiased randomness, the randomness of pure chance, pure noise, total unpredictability. Another form is the apparent randomness occurring in deterministic chaos.

True stochastic randomness is independent of system history and insensitive to initial conditions. It has no state configuration or *attractor* towards which it tends. It is associated with inorganic, artificial, mechanical or electronic processes, or with external impingements from outside a known closed system. When thought of in contrast to the absolute determinism of Newtonian mechanics, it is associated with free will, equality of all directions but like Newtonian physics, it is associated with the reversibility of time. Under certain conditions, especially when randomness is novel, it may be experienced as a sense of freedom, as interesting or pleasurable; but the extended experience of pure randomness lacks complexity and tends towards boredom, engendering eventually, a sense of meaninglessness. Although true randomness has an important place in the understanding of fundamental processes, the presence of purely random processes has been overestimated and its impact overrated; this is in part because the pseudo-randomness of deterministic chaos is difficult to differentiate from true stochastic randomness. Specialized mathematical tests, such as the method of surrogate data are required to differentiate stochastic randomness from the apparent randomness of deterministic chaos. [1]

Systems characterized by deterministic chaos transform - appear more random in chaotic phases and more deterministic in periodic or static phases, even though a set of simple recursively iterated equations describe their dynamics. In chaotic phases the attractor explodes, bifurcating repeatedly, wildly multiplying, only to suddenly quiet down again into a single limit cycle which then bifurcates again. The "random" chaotic phase of deterministic chaos is a fractal, a strange attractor, containing an infinite number of possible trajectories through which the system cycles while creating its own unique history. The trajectories of neighboring initial points, exquisitely sensitive to initial conditions, rapidly diverge after a few (mixing) iterations. Psychologically, the dynamics of deterministic chaos induces a sense of time's irreversibility, a sense of unique history (choices occurring at attractor bifurcation points), leading inexorably to experiences of meaning and value. The dynamic complexity and (practical) unpredictability of deterministic chaos generates a sustained interest in us and often engenders a deep feeling of beauty.

While stochastic randomness may play certain roles in brain development and functioning, current research in neuroscience and artificial neural networks suggest that deterministic chaos better describes the physiological dynamics of thought processes in the brain. Biological neurons have chaotic nonlinear dynamics and the dynamics of biological and artificial neural networks are described experimentally by fractal/strange/chaotic attractors. The brain integrates in real time vast amounts of information across numerous brain regions without the need for a central controller; this global integration is the functional result of the dynamic interactions within the brain. The chaotic dynamics of certain small-world networks satisfies both the requirements of local and global processing and suggests how local neural networks are synchronized and synchronized/integrated with the global net-

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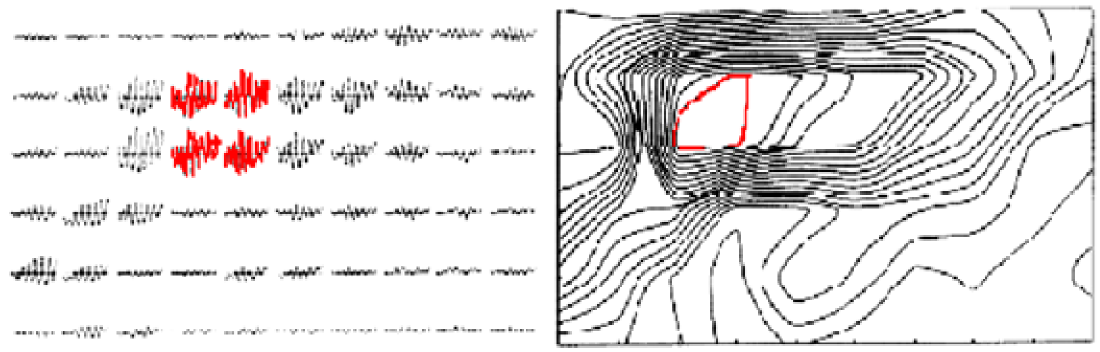

Image 2. *Left, one of 60 EEGs showing the spatial pattern of amplitude from the olfactory cortex of a rabbit as it recognized a scent.* The shape of the EEG waves do not identify the scent. *Right, the spatial pattern of amplitude across the cortex displayed as a contour plot does uniquely identify the scent.* The red contour is the highest amplitude; successive contours represent the lower amplitudes. 1991, Walter Freeman, "The Physiology of Perception" *Scientific American* 264 (1991): 78–85, archived in *Walter J. Freeman Neurobiology Full Manuscript Archives*, http://sulcus.berkeley.edu/FreemanWWW/manuscripts/wjfmanuscripts.html, Licensed under Creative Commons License: Attribution-ShareAlike 2.0 Generic. © W.J. Freeman.

work. [2] [3] [4] [5] [6] [7] Experimental evidence indicates that cognition depends critically, not only upon the brain's dynamic synaptically (physically) connected Hebbian networks, but upon the emergent fluid synchronization and desynchronization of neuronal groups in the brain, the traces of which are manifest in the electroencephalogram (EEG). [8] [9] [10] [11] [12] [13] [14] The electrical or chemical mechanism of synchronization remains unknown, however some researchers suspect the poorly understood gap junction that electrically couples neurons may play a crucial role. [15]

If chaotic dynamics governs the physiological functioning of the brain, it then, according to the connectionist view of the brain/mind duality, determines the nature of mental experience. To understand the characteristics inherent in the dynamics of deterministic chaos is to understand the characteristic dynamics *native* to the brain, *native* to the mind and *native* to *aesthetic experience.* Evidence for this inference is that the exploration of chaotic dynamics as it functions in the brain/mind and as it is fundamental to the nature of our experience, is an important theme in contemporary art.

SCIENTIFIC EVIDENCE FOR CHAOS IN THE BRAIN

Over twenty five years ago, Walter J. Freeman implanted electrode arrays in the olfactory bulb of rabbits, exposed them to different smells and trained them to discriminate each unique smell. He recorded the EEGs during these experiences and mapped the synchronous functioning of the olfactory bulb's neuronal assemblies within the space of the electrode array. The chaotic dynamics of the olfactory bulb's neuronal assemblies were not apparent in the EEG tracings, but the transformation of the EEGs into topographical maps revealed the presence of chaotic attractors. The baseline state of the bulb, a low amplitude, chaotic attractor almost instantaneously transforms into a more distinct, more regular, more coherent, almost-quasi-periodic toroidal chaotic attractor upon exposure to a particular learned smell. Learning stimulates a small group of neurons (feature detectors) which recruit associated neurons, in a self-organizing process, constructing a synchronous assembly, the attractor. The spatial map of each unique smell attractor has the appearance of a topographical contour map of a hilly landscape and is stable

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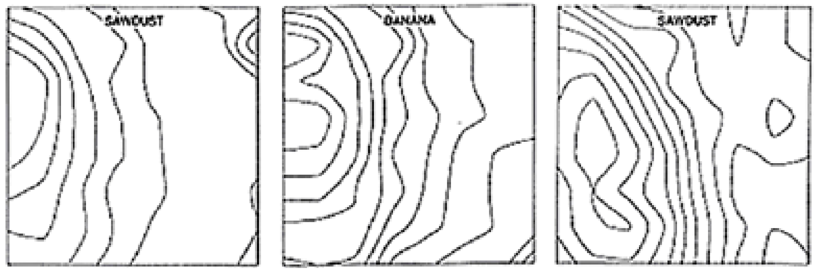

Image 3. *Left, contour plot from bulbar EEG's exposed to sawdust scent. Middle, after the animal learned to recognize the smell of banana. Right, re-exposure to sawdust led to the emergence of a new sawdust plot.* The change shows that bulbar activity is dominated more by experience than by stimuli; otherwise, sawdust would always give rise to the same plot. 1991, Walter Freeman, "The Physiology of Perception" *Scientific American* 264 (1991): 78–85, archived in *Walter J. Freeman Neurobiology Full Manuscript Archives*, http://sulcus.berkeley.edu/FreemanWWW/manuscripts/wjfmanuscripts.html, Licensed under Creative Commons License: Attribution-ShareAlike 2.0 Generic. © W.J. Freeman.

over months; it is modified only when a new smell is learned. Freeman concluded the bulb's baseline chaotic attractor has special properties allowing almost instant dynamic flexibility after *minimal* perturbation, enabling it to switch abruptly from one spatial pattern to another, "easily [fulfilling] the most stringent timing requirements encountered in object recognition", timing requirements which are too stringent for synaptic transmission and axonal conduction. [16] [17] [18]

Freeman, followed by others conclude that neuronal networks construct attractors which are encodings of experience; synchronization/desynchronization appears to be the key mechanism of the near instantaneous shifts from one attractor to another, from one mental experience to another (the stream of consciousness). The exact electro-chemical mechanism of synchronization in the brain is not known, however it is an area of growing theoretical and experimental research. [19]

THE ROLE OF SYNCHRONIZATION

Synchronization has been shown to be an emergent property of a networked population of weakly coupled limit cycle oscillators (neurons) whose frequencies are probabilistically distributed over a narrow range. Synchronization emerges spontaneously when the system's behavior follows some simple rules:

- » if an oscillator's phase is ahead of the group it speeds up a little
- » if an oscillator's phase is behind it slows down a little
- » each oscillator is influenced only by the frequency of the whole system and not by individual oscillators.

If a few oscillators happen to synchronize, their combined, coherent signal rises above the background activity and amplifies the signal. This positive feedback loop leads to a rapidly accelerating percolation effect and global synchronization, excluding only oscillators with frequencies too far out of range. The emergent global synchronization represents a phase transition of the network, just as freezing is a phase transition of water. [20] [21] [22] At the critical point of phase transition, the system has special properties; the geometry is fractal, the capacity to transfer information throughout the system is maximal and the system state is relatively resistant to external perturbation. The brain may exploit these critical point properties to maximize processing efficiency – constructing chaotic attractors and synchronizing/desynchronizing neuronal assemblies that exist in states hovering at or near critical points. [23] [24] [25] [26] [27]

Synchronization may be essential to making perceptual experiences conscious and in the creation of consciousness itself. Sensory neurons show well-defined stimulus preferences, such as for direction and orientation of a stimulus bar. In one experiment, a single moving stimulus bar, whose direction of motion was intermediate between the preferences of two sets of neurons, led to a pronounced synchronization of the two sets. [28] In another experiment, responses containing synchronized signals had a higher probability of further processing and conscious perception than responses lacking synchronization. In experiments of binocular rivalry in cats, neurons mediating responses of the eye with the conscious information increased their synchronization upon the presentation of a rivalrous stimulus and neurons driven by the suppressed eye input decreased their synchrony. [29] In one experiment on humans, EEGS were recorded during the processing of visible and invisible words in a delayed matching-to-sample task. Both consciously perceived and non-consciously perceived words caused a similar increase of local gamma oscillations in the EEG, but only consciously perceived words induced a transient *long-distance* synchronization of gamma oscillations across widely separated regions of the brain. The early, transient, global increase of phase synchrony of oscillatory activity in the gamma frequency range is proposed as the critical process mediating the access to conscious perception; it was also noted that baseline EEG desynchronization drastically facilitated the stimulus-specific synchronization of neuronal responses. [30] In these experiments, synchronization increased saliency, selected relevant input, suppressed irrelevant input and tended to lead to further processing and conscious perception. Early synchronization, especially of global long-distance oscillations was associated with conscious perception. From these kinds of experimental data, some researchers hypothesize that synchronization fulfills the requirements postulated for the "binding mechanism" a term used to refer to how the brain/mind integrates aspects of experience into one continuously updating whole. [31] [32] One interesting model of consciousness proposes that the simultaneous firing of select neuronal assemblies leads to neuronal synchrony, by triggering looping activation in associated cortical

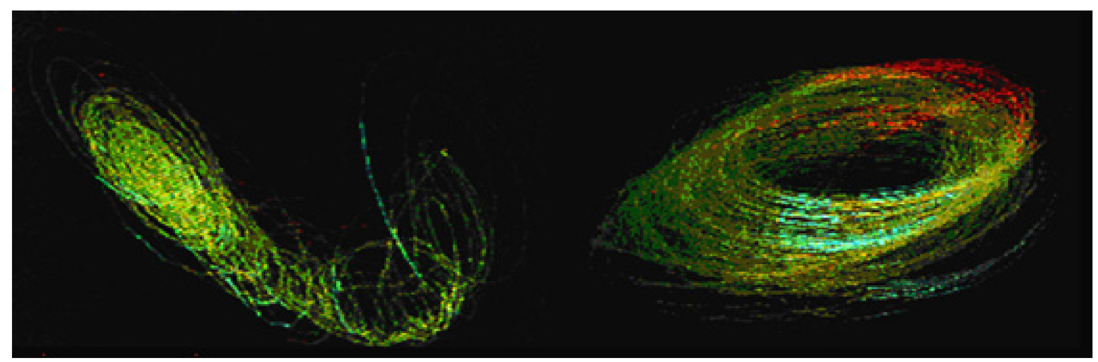

Image 4. *Phase Portraits of the olfactory system.* Computer model time extrapolations of the very brief recorded EEGS. *Left, the overall activity of the olfactory system at rest. Right, during perception of a familiar scent.* Both structured but irregularly coiled trajectories reveal that brain activity in both states is complex with some underlying order that is chaotic. Truly random trajectories would eventually cover the entire state space in an overall scribble. The more regular circular/ toroidal trajectory on the right indicates that during perception of a specific learned smell, olfactory EEGS are more ordered, more nearly periodic, than during rest. 1991, Walter Freeman, "The Physiology of Perception" *Scientific American* 264 (1991): 78–85, archived in *Walter J. Freeman Neurobiology Full Manuscript Archives*, http://sulcus.berkeley.edu/FreemanWWW/manuscripts/wjfmanuscripts.html, Licensed under Creative Commons License: Attribution-ShareAlike 2.0 Generic. © W.J. Freeman.

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circuits that eventually amplifies one loop over the others in a recursive process. The interacting reentry loops reinforce and compete with each other, with the dominant loop(s), whose selection is biased by the prefrontal cortex, becoming conscious. [33]

The brain is thus conceived as a multi-attractor system functioning at a far from equilibrium state poised for instantaneous state changes and transitions. Chaotic attractors are the operators that perform the computations of the system and one central computational mechanism is synchronization/desynchronization of local and global neuronal assemblies. These computations are postulated to include consciousness, memory, imagination and aesthetic experience. [34] [35] [36]

POSSIBLE TYPES OF ATTRACTORS IN THE BRAIN

Researchers are exploring the possible chaotic dynamics for these complex brain/mind computations. Using computer modeled artificial neuronal networks different forms of attractors have been tested for their capacity to simultaneously retrieve multiple associations. Retrieval using fixed-point attractors works if only one memory pattern is retrieved at a time, but cannot achieve the simultaneous retrieval of multiple patterns; retrieval utilizing synchrony of limit cycle attractors leads to errors if the simultaneously retrieved patterns have commonly shared features, but a network of chaotic model neurons has the capacity to keep "several memory patterns...simultaneously active and separated from each other by a dynamic itinerant synchronization between neurons. Neurons representing shared features alternate their synchronization between patterns, thus multiplexing their binding relationships." [37]

CHANCE AND CHAOS

Chaotic dynamics also allows the brain/mind to take advantage of chance experience. Some chaotic attractors are stabilized by noise. In a chaotic system, noise may function to jog a system trajectory out of one basin of attraction into another. Noise may also serve to make shifts in the system trajectory, by recruiting new neurons into synchronization. [38] [39] [40] [41]

TSUDA'S THEORY OF CHAOTIC ITINERANCY

A theoretical and evocative mathematical theory of more complex brain/mind computations such as associative memory has been proposed by Tsuda. [42] [43] He describes a process he calls *chaotic itinerancy* that begins to link, for the first time, possible chaotic dynamics of the brain/mind with a sense of real lived mental experience. Chaotic itinerancy is a process by which chaotic transitions among attractors may be made and dynamically integrated in a multi-attractor chaotic system such as the brain. It is suggested as a mechanism for the stream of consciousness, free association, memory, creative thought, and imagination.

In a multi-state, multi-attractor high dimensional system, such as the brain, each state corresponds to an attractor consisting of a multiplicity of attractors with riddled basins. (A single basin of attraction is the set of points in phase space from which a system will eventually be entrained into the attractor trajectory, but a riddled basin, occurring in a multi-attractor system, is a basin that at every point has points of another attractor's basin arbitrarily close. A map of a riddled basin might look similar to multicolored marbleized paper.) While strong attractors have more strongly defined basins and remain disconnected from each other, the chaotic attractors in the brain must be weakly stable to allow transitions from one basin to another, one attractor to another. Certain types of weakly stable attractors, when destabilized by small, nearby perturbations, transform into new attractors, leaving behind traces of their original structures. The remains of the original attractors Tsuda calls *attractor ruins*. As this process iterates, the destabilized system evolves to a collection of *attractor ruins and itinerant orbits connecting attractor ruins*. Tsuda refers to this new type of attractor as an *itinerant attractor.* It is a singular continuous nowhere differential (SCND) function, which means that although it is continuous, it is not absolutely continuous, it is not necessarily smooth, and is subject to abrupt changes in direction, as in a saw-tooth or stepwise function. (Tsuda uses the fractal Cantor set as the paradigmatic SCND function for his theory.)

> *In chaotic itinerancy, a dynamical rule for linking orbits emerges. This rule gives rise to a causal relation among memories. The numerical calculations demonstrated that the memories close to each other are likely linked. When one wishes to obtain a certain memory state as an output of a network but has only incomplete information regarding this memory, it is necessary to search in memory space with only this partial knowledge. A random search follows chance...* A search with chaotic itinerancy, on the other hand, simply follows a dynamically changing rule created in the network, which provides a dynamic relation among memories. *Thus the memory in question is output after several linking stages. Then a "trace" such as that consisting of an attractor ruin is a representation of memory and the memory trace is manifested through the transition process. Here the transition process, that is, the linking process of ruins, is reasonable. In other words, memories are realized only when they are linked to each other.* [44]

CHAOTIC DYNAMICS OF ART

A successful work of art can be conceptualized as a kind of reification, an embodiment of an (itinerant) attractor. It is an integrated output of a process of chaotic itinerancy within the artist, which when experienced by an audience, induces within the audience a corresponding process of chaotic itinerancy. The characteristics emergent in the brain/mind governed by chaotic dynamics are: sensitivity to initial conditions, the capacity for almost instantaneous state transformation (i.e. point to periodic to chaotic, synchronous to desynchronous, etc.), the capacity to carry simultaneous signals without interference, the capacity to remember past state configurations, and the capacity to propagate on all levels of brain organization from local to global. These characteristic dynamics facilitate mental experience important for aesthetic experience such as fluidity of thinking, ambiguity, resonance, complexity, and inspiration. In particular, ambiguity is related to complexity and itinerancy, resonance is related to local and global synchronization and inspiration likely related to extensive global synchronization. Chaotic itinerancy may allow art, as an itinerant attractor, to transform attractor ruins, experienced as unresolved conflicts, haunting thoughts or preoccupations and may form one basis for the transformative properties of art.

Each instance of chaotic itinerancy induced in an artwork's audience is unique because of sensitive dependence of initial conditions; these instances will exist within a bounded population or distribution of responses. An artwork as an itinerant attractor has a basin of attraction, that is, positions from which the audience may evolve their experience of the artwork – their trajectories either becoming entrained in the artwork/attractor, or repelled away, unaffected. An artwork that is new and original may not immediately evoke a chaotic itinerant process; new attractors need to be constructed (learned). Once constructed, the artwork/attractor may evoke the constructed brain/mind attractor almost instantaneously. One may conceptualize the range of low to high art as falling along the continuum of attractors, with the experience of lower art forms characterized by simpler attractors, point, periodic, limit cycle, periodic or quasi-periodic toroidal and the experience of the highest art forms, characterized by the true complexity of chaotic itinerant attractors.

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Deterministic Chaos	Aesthetic Experience
Attractors = trajectory system state tends toward. Point, limit cycle (periodicity 1) = a stable, periodic orbit with periodicity 1 that repeats exactly the path with each orbit cycle. Periodic, limit cycle = 2, 3, or more countable orbits through which the system oscillates (periodicity 2 or greater). Quasi periodic, toroidal = system oscillates through trajectories which almost but not exactly repeat themselves as a spiral form on the surface of a torus. Chaotic, strange, fractal = follows a quasi-repeating orbit within a bounded set, but never re-visiting the same exact point, sensitive dependence on initial conditions, trajectories of close initial points eventually diverge radically.	Artwork as attractor experienced interiorly by artist, output as artwork, then induces attractor in the audience. Happens instantaneously or gradually. If attractor not evoked, artwork is not "successful". Low to high art parallels types of attractors, point to chaotic, with most complex high art experience – chaotic.
Chaotic attractor – sensitive dependence on initial conditions	Experience individualized, time and context dependent and exact experience unpredictable within a certain envelope
Complexity levels	Continuum from low art to high art, low complexity to high complexity i.e. point attractor, to chaotic (fractal/strange) attractor. High complexity art has infinite points of experience, and associations within a bounded range.
Complexity, itinerancy	ambiguity
Oscillator network synchronization local global	 resonance inspiration
Noise/randomness stochastic resonance – noise may stimulate chaotic attractor and synchrony	random noise may produce meaningful associations, stimulate creative thought, imagination
Time irreversibility, system history irreversibility, path choice	Unique system history, choice creates meaning, value
Chaotic itinerancy	Memory intrinsic to experience

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THE RINGS OF SATURN AS ITINERANT ATTRACTOR

The Rings of Saturn, a novel length narrative by W. G. Sebald, written entirely from the point of view of the narrator's inner experience, exquisitely embodies Tsuda's process of chaotic itinerancy.

In a text interspersed with dull, uncaptioned, blurry, greyish reproductions (suggestive of images, originally exterior, but now directly output from the mind's eye to paper) the narrator's psychic process, memories, associations, thoughts, and dreams, replete with their linked emotional and bodily experiences, is recounted, accumulating a sense of interconnected, complex, and scalable intimacy with the world. One pluripotent psychic moment, continuous with the next, suddenly inflects, following an apparently unrelated trajectory, but later revealing deep, idiosyncratic connections on a mysterious and infinitely complex surface, reminiscent of the riddled basin of an itinerant attractor, so that every point, every psychic experience is arbitrarily close to some other point or experience, moving predictably, then seemingly unpredictably, creating a continuous wandering path in the mind. Chaotic itinerancy allows the narrator to ramble without warning or introduction, unmarked by punctuation, from past to present to future, from geographically near to far, from fictional to historical, from his own utterances to those of others, knowing that the reader's mental path is intertwined with his own, following it in a crisscrossing path. Sometimes a gentle phrase such as " I could not help thinking..." or "....just as..." signals that the permeable boundaries between two memories, their riddled basins of attractions arbitrarily close to one another, is about to be crossed.

> *... I can remember precisely how, upon being admitted to that room on the eighth floor, I became overwhelmed by the feeling that the Suffolk expanses I had walked on... had shrunk once and for all to a single, blind, insensate spot... a colorless patch of sky framed in the window... I could not help thinking of the scene in which poor Gregor Samsa, his little legs trembling, climbs the armchair and looks out of his room, no longer remembering... the sense of liberation that gazing out of the window had formerly given him. And just as Gregor's dimmed eyes failed to recognize the quiet street... so, I too found the familiar city... an utterly alien place.* [45]

Sebald reifies the structure of the mind, the structure of his narrative and the structure of a work of art as a strange attractor or chaotic itinerant attractor in at least two instances in his book. The first instance involves the narrator's affectionate description of a colleague's office:

> *... in her office there was such quantities of lecture notes, letters, and other documents lying around that it was like standing amidst a flood of paper... a virtual paper landscape had come into being in the course of time, with mountains and valleys. Like a glacier when it reaches the sea, it had broken off at the edges and established new deposits all around on the floor... her response was that the apparent chaos surrounding her represented in reality a perfect kind of order, or an order which at least tended toward perfection... whatever she might be looking for amongst her papers or her books, or in her head, she was generally able to find right away...* [46]

The second instance occurs later in the book:

> ... I was on Duncan heath once more in a dream, walking the endlessly winding paths again and again I could not find my way out of the maze... as dusk fell I gained a raised area... And when I looked down from this vantage point I saw the labyrinth – a pattern simple in comparison with the torturous trail I had left behind me, but one which I knew in my dream with absolute certainty, represented a cross-section of my brain... Although in my dream I was sitting transfixed with amazement... I was at the same time out in the open... as though I stood at the topmost point of the earth within a foot of the very edge, and knew how fearful it is to cast one's eye so low... [47]

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JENNY HOLZER'S LED INSTALLATIONS AS CHAOTIC ATTRACTORS

Jenny Holzer's projections on public surfaces from buildings to ocean waves and her animated LED sculptures are visually spectacular examples of chaotic dynamics. In her works, texts stream at varying velocities, usually almost too fast to read, while reflected lights and backlights flash stroboscopically at different frequencies, creating the sense of fires flaming and hearts beating, in an alternately synchronized and desynchronized rhythm. Although the *Truisms* texts are intentionally provocative clichés, these and Holzer's other texts, because of their emotional and value laden references, have the character of private thoughts. One example is, "YOUR OLDEST FEARS ARE THE WORST ONES" [48] and another related to her favorite themes of violence and abuse is: "I AM CRYING HARD THERE WAS BLOOD NO ONE TOLD ME." [49] Holzer's work is constructed to instantly induce an experience/attractor in the viewer by overwhelming perceptual stimulation with rhythms and frequencies that relate to fundamental mind/body rhythms. When the LED displays stop moving the mesmerizing effect instantly disappears, a sign that the temporarily induced attractor and synchronization have also disappeared. In some displays there are two separate but related overlapping word streams, each distinctly decodable, possibly reflecting that they are being processed, as hypothesized by Tsuda, in a multi-attractor chaotic system with riddled basins [images 1, 5]. The viewer is able to perceptually discriminate these streams because one is brighter and one is duller; one becomes conscious – achieving global synchronization and the other remains preconscious or unconscious unless the viewer's mental focus intentionally shifts. (Holzer's setup in these displays is quite similar to the experiment on binocular rivalry, synchronization and consciousness in cats and the related experiment with visible and invisible words in humans described above.) Paradoxically, Holzer's spectacle, in temporarily mesmerizing the viewer and quickly inducing an overwhelming experience, also inhibits association or itinerancy, rather than facilitating it; the beautiful and repetitive over-stimulation of the displays does not allow the mind to wander anywhere else until after exiting the installation. This restriction of mental association may be related to the resistance to irrelevant stimuli (both internal and external) that experimental evidence suggests occurs in certain states of global synchronization such as focused attention. Normal focused attention is fluid, transient and in the viewer's control. If the viewer lingers long enough in Holzer's web of hypnotic, pulsating lights, the initial pleasure of the spectacle becomes tinged with an uncomfortable sense of mental constriction that subtly recreates the traumatic restriction of the mind to repetitive preoccupations that occurs after experiences of torture and abuse – experiences that constitute a major subject of Holzer's work.

CONCLUSION

The study of the role of chaotic dynamics in the brain/mind is in its infancy; however these findings suggest a general theory of aesthetics that warrants further elaboration. In addition, as digitally based computers do not natively process information using chaotic dynamics, knowledge of the chaotic dynamics of the brain/mind will impact the future development of computers and artificial intelligence. These advances in information technology and aesthetics will change our environment and in an iterative, interactive, evolutionary process may lead eventually to an increase in the human mind's capacity for complex thought, in fact they probably already have. ■

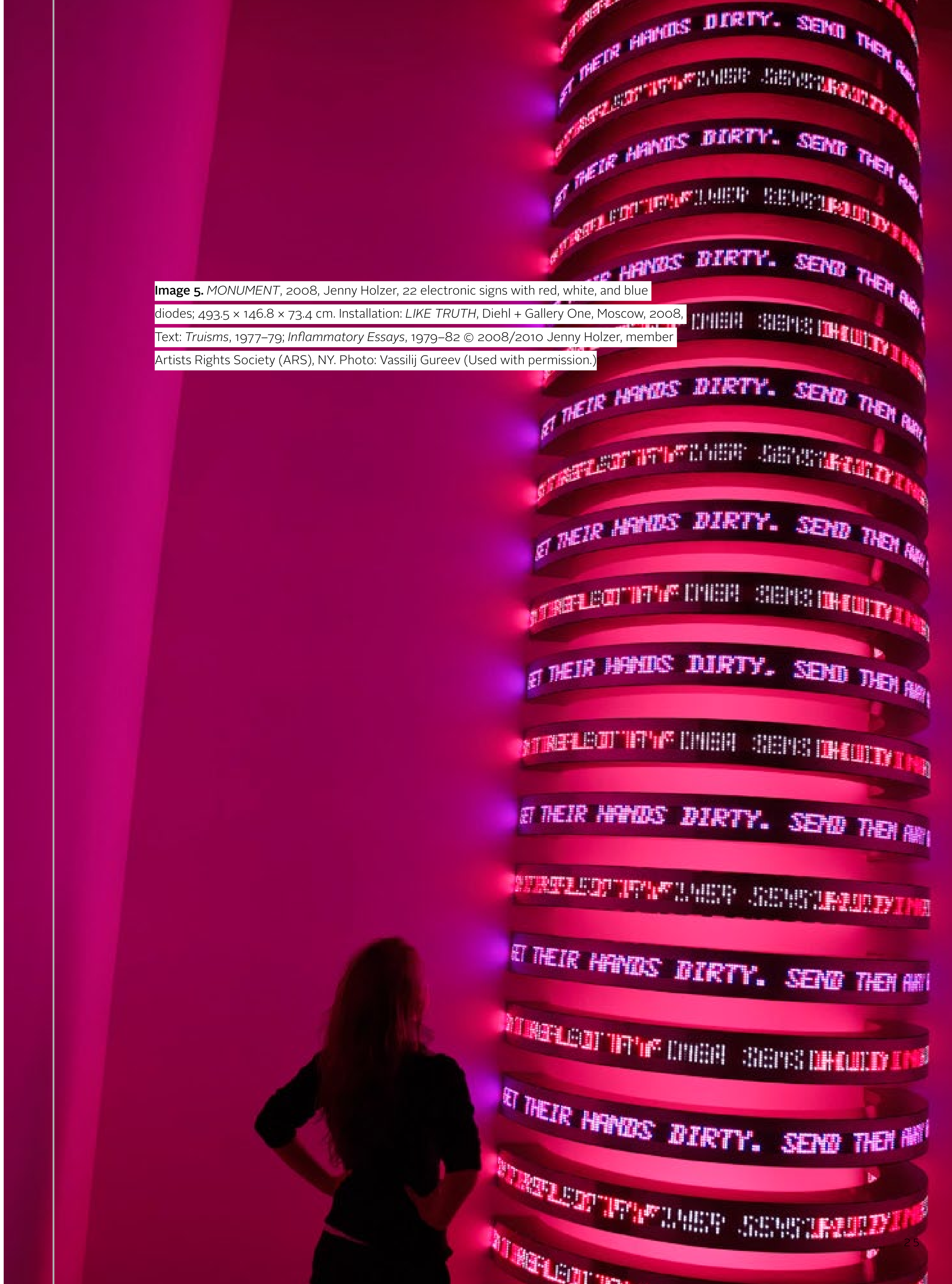

Image 5. *MONUMENT*, 2008, Jenny Holzer, 22 electronic signs with red, white, and blue diodes; 493.5 × 146.8 × 73.4 cm. Installation: *LIKE TRUTH*, Diehl + Gallery One, Moscow, 2008, Text: *Truisms*, 1977–79; *Inflammatory Essays*, 1979–82 © 2008/2010 Jenny Holzer, member Artists Rights Society (ARS), NY. Photo: Vassilij Gureev (Used with permission.)

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