Visual and Cognitive Ergonomics:

Formulating a Model through which Neurobiology and Aesthetics are Linked.

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“Style attests to the existence of a physiology...” —Norman Bryson1

“Culture is sculpting the brain—that’s what visual ergonomics is.” —from a conversation with a friend

The word ergonomics comes from the Greek words ergon, to work, and nomos, pertaining to a set of laws. Ergonomics is concerned with designing the most efficient and physically effective interface between humans and their workstations.2 In creating an ergonomic design, the object, system, or environment should be designed according to the physical and mental characteristics of its human users.3 In its early manifestations, ergonomically astute designers limited themselves to the proportions of the musculoskeletal system. Designers have also realized the importance of creating spaces that are ergonomically cued to the senses such as sound and sight (Figure 14). Recently cognitive ergonomics, which takes into account perceptual and cognitive strategies in the design of computer-worker interfaces, has come into being.4

I use “Visual and Cognitive Ergonomics” to describe fundamentally historical processes that are rooted both in neurobiology and aesthetics. They are my terms, or tools, for describing the way objects, their relations, and the spaces they occupy, affect changes in the brain. What is of particular concern is that aesthetics, as a study of principles and codes that affect the way we understand or experience a work of art, must be understood as having an effect on our strategies of seeing (Figure 15). As Norman Bryson puts it: “What the painter does, what the scientist does, is to test… schemata against experimental observation: their production will not be an Essential Copy reflecting the universe in terms of transcendent truth: it will be a provisional and interim improvement on the existing corpus of hypotheses or schemata, improved because it is tested against the world….”5 Bryson then describes how the canvas is more than just a surface upon which the history of a particular art form is displayed. In fact, my argument is that it displays a map of neurobiological visual perception as it develops, in history, over time and place, and that it can be used to make comments on the ontological development of the nervous system. For the canvas and the brain are both in a constant state of mutation as they are configured and reconfigured by a group of immaterial relations such as psychological dispositions, social upheavals, political intrigues as well as historical reformulations, which express themselves simultaneously—although quite differently—in the shape of sculpted marble and the arrangement of the neurons in the neural networks of the brain.

But there is another story that parallels this story of art and the brain, but which has important implications for both—a story that traces an ever more refined and changing instrumentalization and technique with which to visualize and concretize these relations. Some might argue that this history begins with the implementation of the technique of perspectival renderings as they were described in Alberti's De Pictura and manifested in the canvases of the High Renaissance. Others might begin the story with the camera obscura, tracing a path from it through the nineteenth-century stereoscope and stereopticon cards, zoetrope and phenakistescope, into twentieth-century cinema, landing in the twenty-first century in tele-operated environments and virtual reality (Figure 16). Wherever you locate the beginning of this process, the ontogeny (I deliberately use the biological term here) of such optical devices details a progression from a Euclidian, three-dimensional monocularly-based static "truth" or reality, to one that is binocular and mobile. The devices come to stand in for how we see, or know, the physical world. Michelangelo Antonioni's Blow Up is a perfect example. The plot involves a fashion photographer, modeled after the sixties London fashion photographer David Bailey, who doubts his own perceptions and memories of a murder he may or may not have witnessed. He relies upon and trusts the photographs he took of the crime scene, rather than his own bodily sensations. These artificial images and the memories they conjure are more real for him than actual sensorial perceptions elicited from "real" objects in the real world. What are the reasons for this and how did this come about? These are the questions I hope to answer with my definitions of visual and cognitive ergonomics—terms that I appropriated from their original contexts of design and architecture into terms used to investigate the ontogeny of "image species."

Before we go on, I think it necessary to distinguish the terms visual and cognitive ergonomics. Visual and cognitive ergonomics are distinguished in a number of ways. Visual ergonomics developed first and is tethered to early forms of representation such as painting, sculpture, and drawing. It is primarily concerned with the representation of static space. It delineates a process through which natural space is coded to be represented as space on a canvas, and it describes a historical process by which that space becomes palpable and haptic. It is tied to such formulations as early perspectival renderings and to chiaroscuro or claire-obscura as it is also called. It is also tied to a mutating population of observers. That is to say that there are two parallel and dependent processes occurring simultaneously. On one hand there is the genealogy of techniques that render and reformulate space through aesthetic codes, and on the other hand there is a genealogy that describes a more educated viewer who constantly demands more from the image. The demands of that viewer are the result of many concurrent processes that act on society as well as the individual, especially the individual's perceptual-cognitive system. Those changes are the result of actual changes in the way that the rendering of space, which is itself an instantiation of the changing values of a particular society as expressed in fashion, design, and architecture, reconfigures networked relations in the brain. How this happens will be discussed later but let us mention here that the result of visual ergonomics is a refinement of the techniques of creating images and the images themselves. These refinements are visually ergonomic because they are more tuned to the requirements of the nervous system and are therefore processed by it more efficiently. This efficiency renders those neural networks that perceive it greater efficiency of coding, and they are therefore selected over those neural networks that are less efficient. Visual ergonomics is linked to traditional forms and materials of representation like painting; but because certain ideas of space and its representation discovered in, say, landscape painting, were carried over to photography and later cinema, it also has some relevance to them.

Cognitive ergonomics is a later phenomenon and is involved in delineating dynamic processes. Whereas visual ergonomics was involved in defining space, cognitive ergonomics is involved in describing temporality. I stated earlier that it emerged out of the science of determining the most efficient viewing strategies for worker-computer interfaces. As such it is much more pertinent to recent digital and internet art. In this regard it is involved in determining the process through which information on a computer screen is obtained, and for that it relies on knowledge of how cognitive systems operate. We all know this from working on a computer, for instance using any word program. We can access information in different ways according to different menus that are set up in specific places that lead us to other places where other kinds of information are available. Working on a computer, playing computer games, or interacting in virtual reality are about moving and progressing through different kinds of space over time.

Cognitive ergonomics, as its name implies, takes into account the whole brain and conceptual system, as is necessary when organizing technologies that interface with the entire body and being. What complicates the representation of virtual worlds is the need for an immense database that contains all the objects viewed within the virtual environment, their motions and behavior, within the limited range of computer memory. Even when one takes into account the ability of the brain-mind to fill in so that it is not absolutely necessary to mimic all the stimulation of the real world, the memory size required to store such information is still huge.6 Limitations of database compression techniques and limitations in image retrieval and display create a need for ergonomically sophisticated methods that will maximize the efficiency of the information at hand to create the clearest, i.e., most familiar and therefore “real” display.

Jonathan Crary’s Techniques of the Observer7 and Rosalind Krauss’s The Optical Unconscious8 have much to tell us about how aesthetic systems were influenced by optical devices. Discussing Max Ernst, Krauss recounts the artist’s fascination with the magazine La Nature, in which details of the many optical devices of his day were presented. Later he would use this material in his collage novel A Little Girl Dreams of Taking the Veil, in which his heroine finds herself in the middle of a zoetrope.9 Other authors have alluded to how the camera obscura and the Claude glass were used to aid artists in the representation of nature by producing a stable, miniaturized image.10 In turn Duchamp’s fascination with optical machines and opticality lead him to create his Handmade Stereopticon Slide (1918-1919) and to include his Oculist Witness (1920) in the The Bride Stripped Bare by Her Bachelors, Even (1915-1923; see Figures 9 and 10). In the latter case, the decontextualization of the oculist device from the doctor’s chambers into the lower panel of glass, the bachelor’s section, alluded to the work of art itself as an optical machine through which the world might be reinterpreted. The effect of cinema on the work of Duchamp, specifically Nude Descending a Staircase #1 (1911), as well as on the Futurists is well known. A fascination with cinema as an optical device continues today in Douglas Gordon’s recent piece Double Vision, as well as in my own work Brainwash in which the optokineticnystagmus drum used in the diagnosis of diseases of gaze and balance has an uncanny resemblance to the aforementioned protocinematic devices and "shot/reverse-shot" in which a cinematic convention simultaneously plays opposite roles of visual articulation and disarticulation (Figure 7). Recent works by such artists as Jeremy Blake and Gary Hill elucidate the visual structures found in video games and virtual reality.

Although obvious, we have to remember that all optical devices are constructed with an ideal human viewer in mind. In other words, the image is created by a technology fit for the specifics of human physical and sensorial capabilities (see Figures 13 and 14). A camera, for instance, is made up of lenses in which a series of curved lenses are arranged in a manner to focus the outside world clearly upon the filmic surface. But in most cases the focusing apparatus is linked to the optical properties of the apparatus of the eye. Stereoscopic viewing is the result of the slight difference in the way the outside world is projected upon the retina of each eye. It is this difference, and the normal disparity it causes, that create depth perception. In other words, it is the ability of the human eye to adapt that is engineered into the apparatus so that when the card is moved towards or away from the viewing plane there is an experience of depth perception. In this sense, at the moment of taking a picture or using a stereopticon, mechanical optique and organic optique merge as one. As such they qualify as interdependent visual ergonomic systems. Thus a tacit or real knowledge of optical neurobiology is a prerequisite for the construction of such devices.

At birth, all human brains are endowed with what in neurobiology is called a "primary repertoire." The primary repertoire is the product of genetically determined processes that construct the microbiological architecture of the brain in utero.11 For instance, the area of the brain that controls movement has a very different architecture than that involved in vision. Even within the area that is important for vision, the so-called occipital cortex, one finds architectural differences and refinements that relate to different functional capabilities such as color, form, and motion detection, to which they are linked. These are named V1, V2, V3, V4, V5, and V6 (Figure 11).12 When viewed, the world is parceled—like putting different kinds and shapes of stones in different boxes—into specific qualities of information which are analyzed according to the cellular domain to which they have been routed. As Semir Zeki states in A Vision of the Brain, "Thus a particular visual object elicits responses in a large number of spatially distributed neurons, each of which responds to a partial aspect of the object."13 Only later is this information bound together to create the seamless impression we call physical or visual reality. In other words, the genetically delineated architecture of the brain determines the way in which it is instructed and later selected for by specific partialities of objects in the environment: we do not hold onto the memories of every object and every possible orientation of those objects. Instead we remember categories of characteristics, and these separate categories of characteristics become bound together as a result of learned aesthetic relations, influenced by cultural vernaculars, which are superimposed upon them.

The metamorphosis of the primary repertoire into the secondary repertoire is the result of a process by which, metaphorically speaking, the primary repertoire is sculpted into patterns, or "maps," by the millions of sensations that impose themselves on the developing brain during the post-natal period. Neurons or neuron groups, referred to as maps, i.e., those elements that are repetitively stimulated, develop faster and more efficient firing patterns, giving them a selective advantage over neurons and groups of neurons that are not repetitively stimulated.14 Gradually those neurons which are not stimulated die off, while those that remain continue to recruit other viable neurons, which assist in coding the same stimuli or other stimuli to form novel cell assembly complexes. This complex process provides an explanation for the fact that the human brain, which weighs four hundred grams at birth, expands to four times that weight in its mature form. The secondary repertoire is thus an organization of neural elements, and their connections, created by the specific context into which each individual brain is born. Thus repetitively occurring objects which are organized in real space in specific ways—keeping in mind that how the space is organized might in fact make the objects significant, and this may be aesthetically determined—stimulate their neurobiological counterparts in ways that give those neurons a selective advantage. Multiply these sets of conditions one million times and one has a brain, built by neurobiology but shaped by specific cultural conditions.

In any imperfect system—and most are in fact imperfect—in which there is a transfer of information from one form to another, there is always some loss of information. Such is bound to be the case when one is talking about the way certain patterns of light are coded from radiant energy into the electro-chemical codes that the brain uses. Superimpose on this system the great differences that exist between the topography of the brain, its surface undulations, and twisted inner core—and that of the noumenal and phenomenal world—and one begins to appreciate the immense obstacles nature has had to overcome in order to be represented at all. And it is this process that I call visual and cognitive ergonomics.

At this point, a metaphor may help to illustrate this point. If a photograph is copied over and over again, each time using the copied image as the template, eventually the image will become blurry. There is a sharp decrease in resolution in each successive generation. If instead one were to copy an image file by transferring that image from the computer hard drive to a floppy disc or CD, and then copy that copy on to another disc, the amount of loss of image resolution would be less. Visual and cognitive ergonomics are the tacit processes through which the aesthetic transformation of our perception, and our subsequent cognition of the physical world and its changing nature, affects the way a particular set of stimuli is perceived and cognized. Like the computer example, the amount of resolution loss is minimal in a well-constructed cognitive ergonomic system. In this sense, cognitive ergonomics is simply another factor, along with economic and social factors, which must be considered when discussing the development of artistic practice.

But visual and cognitive ergonomics define a system of relations more sophisticated than these simply materialistic underpinnings. The history of art can be seen as an ever-refined series of ergonomically constructed changes, that may first take place on the surface of the canvas/laboratory and spread out into the world through the contribution of other aesthetic practices such as architecture and design. Such aesthetic practices then cause changes in the way the physicality of the real looks, redesigning, so to speak, the secondary repertoire, resulting in changes in the microbiological structure of the brain. What I am saying is that the seventeenth-century human, bound as he or she is to a set of cultural relations, lives within a visual field that looks and feels much different than the visual field of the late twentieth-century observer. A comparison of the Louvre and Pompidou Center attests to this. As such, the resulting neurobiological configuration that has been organized by the specific spatial and temporal relations of these epochs as they are embedded in their forms of representation may be, or are, quite different. Of course since the morphology of the seventeenth-century visual field and that of the twentieth have certain linkages, as they are connected through a genealogy of changing forms that describes the history of art, those different brains will share commonalities and linkages. The ontogeny of visual apparatus, beautifully elaborated by Jonathan Crary in his Techniques of the Observer, is a tribute to the ingenuity of humanity in its desire to directly visualize these changes.15

At this point I would like to conclude by discussing what in cognitive psychology is called "binding." Binding is a process whereby certain topographically dislocated neurological excitations become associated with one another, constructing the sense of a seamless consciousness in which everything in our cognitive field becomes connected. For instance, an apple, which is perceived as a whole object, is in fact a group of sensorial partialities that are first distributed to the various parts of the visual cortex concerned with shape, color, and movement, and subsequently reconstituted as an apple. But things become more difficult when this apple is passed from one person to another who eats it and enjoys the taste while recounting the story of the apple eaten by Snow White. Recently it has been theorized that binding of populations of neurons could be achieved by taking into account properties of temporality such as synchronization. As Wolf Singer says in his essay "Coherence as an Organizing Principle of Cortical Functions":

"The assumption is that [in] the formation of functionally coherent assemblies, the discharges of neurons undergo a specific temporal patterning so that cells participating in the encoding of related contents eventually come to discharge in synchrony. Thus, neurons having joined into an assembly coding, for the same feature or at higher level, for the same perceptual object…would be identifiable as members of the assembly because their responses would contain episodes during which their discharges were synchronous."16

What allows these disparate areas to discharge together is that they are connected by extensive neural connections that have developed as a result of the formation of the secondary repertoire. Temporal relations that link networked relations in the real world or the real/virtual interface reconfigure networked relations in the brain. Some of these temporal relations are aesthetically driven. In my essays "Blow-up" and "Remapping" I show how cinematic temporal relations such as montage and twenty-four frames per second are embedded in architecture and serve as a template for the developing brain during critical periods. Temporal relations have become invested in installation art and new media, and these have affected all kinds of artists, designers, architects, and filmmakers. As a result our world is invested with these experiments with time, and aesthetics is one set of codes that tether disparate stimuli together around temporal messengers. These constantly evolving spatial and temporal environments configure the secondary repertoire.

"Reentry" is the term for the process whereby neural mappings are linked together and thus communicate. Reentry allows disparate parts of the brain to work together while allowing each component part of the brain to also work independently.17 Each neural map is aware of that which shares connectivity, and adjusts itself accordingly. When such neural maps share the same referent, they become part of a large network of synchronous firings. Oliver Sacks quotes a BBC radio interview with Gerald Edelman in which he says:

"Think, if you had a hundred thousand wires randomly connecting four string quartet players and that, even though they weren't speaking words, signals were going back and forth in all kinds of hidden ways (as you usually get by subtle nonverbal interactions between the players) that make the whole set of sounds a unified ensemble. That's how the maps of the brain work by reentry."18

Edelman is picturing an orchestra without a conductor: one that makes its own music.

Could we conjecture then that binding and the process of reentry which allows it to happen is more than just a neurobiological process binding different areas of the brain, but is also a process that operates in the world of networked relations? That just like the disparate areas of the brain that are tethered together by temporal signatures, disparate fragments in the world are also bound together by spatial and, most importantly, temporal signatures? That aesthetics plays a role in this binding by organizing these fragments according to historical antecedents and stylistic and factographic formulas that are in essence really dancing temporal codes that are causing objects to constantly switch their partners according to specific contexts? Visual ergonomic pressure on space and cognitive ergonomic pressure on time act on binding as well, refining its process to create frictionless information flows between these disparate stimuli. Aesthetics may be a response or a mediator in this process.

Aesthetics is constantly reassembling the partialities that make up the perception of physical objects and their relations. The many examples given already in this discussion attest to this. These partialities are linked together by processes analogous to those we saw at work in the brain. Processes analogous to reentry tie these fragments together into wholes. During the development of the secondary repertoire, linkages are created between these two systems of relations, one inside and one outside. Those relations linked by a temporality that is inconsistent with the innate neurobiological temporality will not be incorporated into neural networks. Those relations with an ergonomically consistent temporality will be inscribed into the secondary repertoire.

And so, as I said at the outset, visual ergonomics is about how culture—manifested in physiological stimuli—sculpts the brain. As such, Norman Bryson's statement that "Style attests to the existence of a physiology..." is quite neurobiologically correct for an art historian.19

Notes

1. Norman Bryson, Vision and Painting: The Logic of the Gaze, Yale University Press, 1983.
2. R.S. Bridges, Introduction to Ergonomics, McGraw Hill, 1983.
3. Stephen Pheasant, Body Space, Taylor and Francis, 1996.
4. Cognitive Ergonomics and the Human–Computer Interaction, Ed. J. Long and A. Whitefield, Cambridge University Press, 1989.
5. Ibid., Bryson, 1983.
6. Roy S. Kalansky, The Science of Virtual Reality and Virtual Enviroments, Addison Wesley Publishing Company.
7. Jonathan Crary, Techniques of the Observer, MIT Press, 1990.
8. Rosalind Krauss, Optical Unconscious, MIT Press, 1993.
9. Ibid., Krauss, 1993.
10. Geoffrey Batchen, Burning with Desire: The Conception of Photography, MIT Press, 1997.
11. Gerald Edelman, Neural Darwinism, Basic Books, 1987.
12. Semi Zeki, A Vision of the Brain, Blackwell Press, 1993.
13. Ibid., Zeki, 1993.
14. Ibid., Edelman, 1987.
15. Ibid., Crary, 1990.
16. Wolf Singer, "Coherence as an Organizing Principle of Cortical Function," in Selectionism and the Brain, International Review of Neurobiology, Volume 37, Academic Press, 1994.
17. Gerald Edelman, Remembered Present, Basic Books, 1994.
18. Oliver Sacks, "A Vision of Mind," in Selectionism and the Brain, International Review of Neurobiology, Volume 37, Academic Press, 1994.
19. Ibid., Bryson.