Science and Visual Communication

Ann Marie Barry, Ph.D.
Associate Professor
Boston College, Chestnut Hill, MA, USA
barrya@bc.edu

Since in reality there is no more important or fascinating story to tell than that of science, it seems essential that scientists themselves begin to see the importance of visual storytelling in educating the public mind, and to actively use visual media as a means to establish an awareness in the scientific classroom of what things exist and can exist, and to tell real stories about how things work and how they will evolve.

"How the brain enables the mind is *the* question to be answered in the twenty-first century."

Michael Gazzaniga
The Mind's Past, 2000

Theoretical Perspectives

In this essay, I would like to address the need for improved science communication and the reciprocal relationship between science and visual communication.

The need for improved science communication begins, to my mind, first, with the application of neurological research and accepted psychological principles to the study of visual communication; and secondarily and consequentially, with a general and more advanced public understanding of the ways in which images work to influence attitude, thought and action. Because the visual media has come to dominate how we take in information, visual media has now been established as a primary foundation for both individual and public mind formation. In this endeavor, science is key, and plays a double role:

Through current scientific technology we have gained the ability to understand how the mind/brain receives information, processes it, derives meaning from it, and uses it. By using new neurological insights gained through technology, we gain both an understanding of how our minds continue to develop in this new world where vision predominates, and a firmer foundation for predicting the consequences of the consumption of visual images through the neurological principles that govern visual impact. As I have argued extensively elsewhere (Barry, 1997), all communication theory and all assumptions about the way we process images and the impact they have on us must be compatible with scientific neurological research.

Second, in complement, science can profit from the use of visualization both in learning and in creativity. Visualization enables the imagination in ways that allow science to take advantage of (what might be called) our "visual mind bias." Because visualization has become a predominant way of understanding reality, our predisposition to visualize concepts is an ideal platform for visual artists in science to use advanced visual technologies to reveal the invisible micro- and macro-worlds which science affirms, yet which the average person cannot imagine without what Marshall McLuhan might have called significant "sensory extension."

Science in Visual Communication

Within the past 30 years, primarily through the power of functional magnetic resonance imaging (fMRI), computerized tomography (CT), positron emission tomography (PET), and near-infra-red spectroscopy (NIRS), we can now view exquisitely detailed images of the brain and learn what parts are active in performing various visual, oral, and computative tasks. With the availability of such techniques, neuroscience has been able to build a map of how the brain's modules function and communicate with one another in solving particular problems and undertaking specific tasks. The image that we ultimately perceive is unified not because the mind sees a picture of what is really "out there," but because the specialized areas in the visual cortex link four parallel systems into a vast network, in which reentrant connections allow information to flow both ways.

One of the key characteristics of visual processing advanced by recent scientific experiment is the presence of fundamentally two information-processing systems in the brain—the cortical pathway and the thalamo-amygdala pathway. Until the mid-1980s, it was generally hypothesized that emotion had to come *after* conscious and unconscious thought processing. Richard Lazarus (1982), for example, argued that emotional reaction required cognitive appraisal as a precondition. We now know, however, that the brain accomplishes its goals in the absence of conscious awareness. In visual communication process, sensory signals from the eye travel first to the thalamus and then, in a kind of short circuit, to the amygdala *before* a second signal reach the neocortex. As Neuroscientist Joseph LeDoux explains: "The cortical systems that try to do the understanding are only involved in the emotional process after the fact" (1986, p. 241).

This is because there exists in the brain a "fundamental dichotomy—between thinking and feeling, between cognition and emotion" (LeDoux, 1998, p. 15). This dichotomy, and the primacy of emotions in laying the groundwork for further thought, and their ability to override thought and incite action despite what logic may otherwise dictate, has profound implications for the preconscious impact of visual media—which by the very nature of its business exploits emotional impact to gain box office returns. The higher the emotional impact of the experience, and the more often the experience is repeated, the greater the influence on the subsequent patterns of thought in the individual perceiver.

Thus science reveals through its technology images of how the mind works. And through these images is revealed the power of other visual images to move people's emotions before they are consciously aware of it, and to frame the form that thought will take. Science thus plays a most significant role in policing theory formation in disciplines like visual communication that rely on assumptions about how the mind works.

It is also significant in theory formulation that the older emotional pathway, which allows raw emotions to connect with the thinking areas of the hemispheres, seems to be most deeply connected to both imaginations' metaphoric visualization and to creative thought itself. Again and again, for example, great creative minds explain their creative thought generation in terms of visual imagery and their reliance on mental images as springboards for extending their understanding well beyond the parameters of verbal language or logic.

Roger Shepard—artist, writer, and recipient of the National Medal of Science—has theorized that in thinking visually, we go beyond sense data and make automatic inferences, developed through evolution, to guide perceptions. How our "mind's eye" imagines the world both parallels our perception of the real world and illustrates an evolving internalization of implicit physical and mathematical knowledge (Shepard, 2001). Because of visual special effects, for example, we can illustrate and make concrete exactly how black holes appear to work, and illustrate abstract concepts as visible relationships through experientially oriented virtual simulations. Science not only requires visual imagery to explain its micro- and macro-worlds that lie beyond human visual experience, it also relies upon visualization as a creative process through which grand designs may be imagined.

This visualization process is creative both in the science learner and in the scientist as well. As the scientific genius Albert Einstein observed of his own mental images: "My particular ability does not lie in mathematical calculation, but rather in visualizing effects, possibilities and consequences" (Pinker, 1997, p. 285). Other scientists Pinker describes as thinking in images include Faraday and Maxwell, Kekulé, Watson and Crick. Cognitive psychologist Howard Gardner suggests that the creative mind works in images precisely because mental images allow us to understand one idea through another (1993, p. 365).

The union of Science and Image thus implies the use both of technological imagery to explore mind functioning, and of the mind's own pre-logical creative function in producing imagery that advances thought and makes imagination palpable and understandable.

The Power of Film

Immediately after its inception as a technological phenomenon to capture a passing moment (as with Lumière brothers' *Train Arriving at the Station* (1895)), film soon became a vehicle for stimulating the imagination and making the never-before-seen real in a perceptual sense (as with Georges Méliès' delightful *A Trip to the Moon* (1902), complete with disappearing imps, chorus girls, and comic scientists). Neurologist Semir Zeki observed that "artists are in some sense neurologists, studying the brain with techniques that are unique to them, but studying unknowingly the brain and its organization nevertheless" (1998, p. 10).

Yet some forward thinking early film theorists understood perfectly well that film had the ability to alter perception, and therefore affect thought and attitude in profound ways. They understood the link between image perception and mindset and used film technology to quite literally alter the mind of the audience.

The great Soviet film theorist and director Sergei Eisenstein (1949, p. 62), for example, believed that the ultimate application of film montage was in propaganda, “Step by step," he tells us,

> by a process of comparing each new image with the common denotation, power is accumulated behind a process that can be formally identified with that of logical deduction. . . [This] leads to the formal possibility of a kind of filmic reasoning. While the conventional film directs the emotions, this suggests an opportunity to encourage and direct whole thought processes as well.

The power to create and to direct thought, Eisenstein felt, lay in the dynamic energy of images juxtaposed in dominant counterpoint in time, space, line, place, volume and light. It was the perfect synthesis of philosophy, art and science–the ultimate integration:

> The projection of the dialectic system of things into the brain, into creating abstractly, into the process of thinking, yields: dialectic methods of thinking; dialectical materialism–PHILOSOPHY. The projection of the same system of things, while creating concretely, while giving form, yields: ART (ibid, 1949, p. 45).

In effect, in Eisenstein's view, film as art was able to create a perceptual argument for Marxist ideology and thus engage the viewer's emotion and direct his or her thought. Béla Balázs, one of the greatest film theorists, a director and scenarist who worked with Pabst and Riefenstahl, and an eminent teacher who worked with Eisenstein in the Soviet Film School in Moscow, also realized at once the power of film to influence the public mind and spoke eloquently of its potential:

> We all know and admit that film art has a greater influence on the minds of the general public than any other art. The official guardians of culture note the fact with a certain amount of regret and uneasiness. But too few of us are sufficiently alive to the dangers that are an inevitable consequence of this fact. Nor do we realize clearly enough that we must be better connoisseurs of the film it we are not to be as much at the mercy of perhaps the greatest intellectual and spiritual influence of our age as to some blind and irresistible elemental force. And unless we study its laws and possibilities very carefully, we shall not be able to control and direct this potentially greatest instrument of mass influence ever devised in the whole course of human history (1970, p.17).

One might think that the theory of this art would naturally be regarded as the most important field for present–day art theory. No one would deny today that the art of the motion picture is *the* popular art of our century––unfortunately not in the sense that it is the product of popular spirit but the other way round, in the sense that the mentality of the people, and particularly of the urban population, is to a great extent the product of this art, an art that is at the same time a vast industry. Thus the question of educating the public to a better, more critical appreciation of

> films is the question . . . of the mental health of . . . nations. Nevertheless, too few of us have yet realized how dangerously and irresponsibly we have failed to promote such a better understanding of film art (ibid, p. 17).

While both Balázs and Eisenstein may seem to overstate the power of film in influencing an audience, it is well to remember that current scientific technology has confirmed the rather uncomfortable assertion that emotion guides thought rather than the reverse.

And although the good intentions of film directors and producers is often used to excuse the negative social effects of film imitation, in terms of perception, the intentions of the producer of the image is ultimately irrelevant in relation to the visual message itself. Neurological effects occur in viewers whether they are intended or not. Because neurologically, continually stimulating groups of brain cells makes them more sensitive and easier to activate (Carter, 1999), repeated neural firings with the same thematic or emotional content increase the likelihood of attitudinal and behavioral change toward conformity with the normal visual image. Like traumatic exposure, this realization has profound implications in terms of habitual media use and recurrent patterns of attitude and behavior within media, especially in interactive media such as video games.

Chief among neuroscience's contributions to the understanding of the power of the visual image to produce like states of mind and action in viewers is the detected presence of mirror neurons (mns) in the brain. What Social Theory research has revealed, neuroscience has deepened and broadened, establishing neurological research as the baseline for understanding human emotion, thought, action, and even social identity, primarily through a neurological process described as "intentional attunement" enabled by mirror neurons (Gallese & Migone, 2005).

Described as perhaps the most important finding of the last decade in neuroscience (Ramachandran, 2000), the discovery of mirror neurons has paved the way for understanding such diverse phenomena as the evolution of language (Rizzolatti & Arbib, 1998), emotional empathy in interpersonal communication, and personal social identity and coherence (Gallese, 2003). By establishing imitation as the chief means by which we learn, mirror neurons may ultimately prove to be the simplest and most direct route to understanding and addressing social behavior (Iacoboni et al., 1999; Gallese, 2000; 2001; 2003a, b, c; 2004; Gallese et al., 2004; Gallese & Migone, 2005).

The implications of mirror neuron functioning first became apparent when it was observed that in the Macaque monkey brain, a class of premotor neurons discharged not only when the monkey grasped objects, but also when it observed others executing similar actions. (Gallese et al., 1996; Rizzolatti et al., 1996a; Rizzolatti et al., 2001; Gallese et al., 2002). The same brain cells fired when the monkey watched humans or other monkeys bring peanuts to their mouths as when the monkey itself brought a peanut to its own mouth.

Concluding that mirror neurons could be the basis of a direct form of action understanding (Gallese et al., 1996; Rizzolatti et al., 1996a; Gallese 2000, 2001, 2003a, b, 2004; Gallese et al., 2004; Rizzolatti et al., 2001; Rizzolatti & Craighero 2004), researchers went on to find that mirror neurons could also be activated even when a major part of the action was hidden from view, or when sound alone suggested an action. (Umiltà et al., 2001; Kohler et al., 2002). When the monkey broke open a peanut or heard someone break a peanut, the same cells fired. In addition to being observed in primates, mirror neurons have also been observed in humans, and even in some birds. In humans, they have been found in Broca's area, premotor and the parietal areas of the brain Rizzolatti et al., 2001; Gallese 2003a; Rizzolatti & Craighero, 2004; Gallese et al., 2004).

Because the same cells have been found to function similarly in humans, whatever a person sees another doing may be experienced not simply vicariously through the imagination as a secondary process, but directly through a neurologically specific one. This means that, in the words of primary researcher Vittorio Gallese,

> to perceive an action is equivalent to internally simulating it. This enables the observer to use her/his own resources to experientially penetrate the world of the other by means of a direct, automatic, and unconscious process of simulation (Gallese & Migone, 2005).

The virtual world of visual media, it seems, has as direct an influence on individual thought and attitude as actual experience.

Neurologically, without our consciously realizing it, emotional learning occurs that pre-frames attitudes, thinking, and behavior. Emotional templates serve as a basis for perceptual anticipation of the future, and although reason and emotion both play crucial and inseparable roles in perception, at various times, emotion can and does function at the expense of reason. Whether we select out specific movies because they resonate with felt needs and realities, or we make media choices based on cultural norms, it is important to realize that the emotional learning that goes with media experience is both unconscious and peculiarly indelible.

Neurological researchers today believe that mirror neurons are intimately and intricately involved in all of the complex behaviors that allow us to learn and adapt quickly within our social environment. Utilizing the mirror neurons system, we learn the most effective ways to achieve desired ends, and even to select what ends *are* desirable. Mirror neurons allow us to become attuned to culture and to other human beings in very specific ways, for better or for worse. In light of this research, a great deal of what has been trusted as reliable theory in the “soft” social sciences must be reconsidered and corrected.

According to neuroscientist Antonio Damasio, “images [i.e., mental patterns created through the senses] allow us to choose among repertoires of previously available patterns of action and [to] optimize the delivery of the chosen action” (1999, p. 24). Because the neurological maps that we use to navigate reality are drawn from the repetition of patterns of action provided by both direct experience and visual media, the parameters of our behavioral choices are determined by both equally, using the same underlying neural mechanisms and mirror neurons.

Now sharing its power with other visual influences such as television and videogames, film still remains the premiere art form, its power enhanced rather than diminished by the pervasiveness of other forms of visual language. Because of this, Balázs's warning about educating the public to a better, more critical appreciation of films as a question of the mental health of nations has become even more significant, and the study of film as communication more, not less, vital in understanding and controlling "this potentially greatest instrument of mass influence ever devised in the whole course of human history." The basis of this study, as Eisenstein himself understood, is science. Without science, we cannot understand our visual world.

Visual Communication and Science

Science is therefore a crucial component of all visual communication theory. Conversely, visual communication is also indispensable to science.
Brains, it seems, were built to process visual images with great speed and to respond to them with alacrity. But they did not evolve to process written verbal symbols in the same way. "Brains were not built to read," Gazzaniga told us,

> Reading is a recent invention of human culture. That is why many people have trouble with the process and why modern brain imaging studies show that the brain areas involved with reading move around a bit. Our brains have no place dedicated to this new invention" (1998, p. 6).

Visual information, however, leaks easily across the hemispheres through the limbic system and is unconsciously learned. This realization should put emotional processing of visual messages at the forefront of all visual communication research; it should also place visual communication as a priority in communicating scientific research to the public. Reading is essential to scientific research, but the chief means of disseminating knowledge and creating enlightened long term attitudes in the *public* mind cannot be through scientific literature. The science seems fairly clear: to reach the public mind, the easiest way is through the visual media. Like it or not, visual media governs a great deal of what occurs in the public mind, and attitudes about science are no exception. It may, in fact, be fair to say that the majority of what passes for information about science has been learned through watching *CSI*, *Oprah*, and a variety of major network morning shows. Attitudes toward scientific research, on the other hand, are often formed through the stories heard in church, and these stories are especially important to the future of science.

Research from the long-term Cultural Indicators Project initiated in 1973 at the University of Pennsylvania, for example, bears this out, and may show science the way to counteract false knowledge. Cultivation Analysis Theory, which crystallized from the project, has concentrated on the storytelling function of media, and focused on the developing patterns of attitude that neurological researchers have found to be the basis of unconscious emotional learning:

> We live in terms of the stories we tell—stories about what things exist, stories about how things work, and stories about what to do—and television tells them all through news, drama, and advertising to almost everybody most of the time (Gerbner Gross, Jackson-Beck, Jeffries-Fox & Signorelli, 1978, p. 178; 1980).

Since in reality there is no more important or fascinating story to tell than that of science, it seems essential that scientists themselves begin to see the importance of visual storytelling in educating the public mind, and to actively use visual media as a means to establish an awareness in the scientific classroom of what things exist and can exist, and to tell real stories about how things work and how they will evolve. Clearly the public has an appetite for science, but predominantly commercial interests have filled the vacuum, mostly with fantasy or inanity.

Some suggestions made by collaborating scientists and visual researchers (SIGGRAPH Eurographics Colloquium on Visual Learning in Science and Engineering) for developing visual thinking within the discipline have included: urging scientists to find ways to articulate and interpret the nuances of visual worlds, to work toward better collaboration across disciplines. Additionally, it is recommended that all science and engineering students have some exposure to creating visualizations; that any science program should begin with a firm grounding in visual theory and practice from an intuitive and experiential perspective. Pedagogically, because lecture alone is the least effective way of reaching the whole learning being, learning should be structured so as to engage as many of the senses as possible and allow students to explore, engage in, and visually complete the meaning of scientific concepts.

Conclusion

A quarter of a century ago, Roger Sperry, in his Nobel lecture, saw a confluence between science and the humanities which has truly yet to be realized,

> Where there used to be a chasm and irreconcilable conflict between the scientific and the traditional humanistic views of man and the world, we now perceive a continuum. A unifying new interpretative framework emerges with far reaching impact not only for science but for those ultimate value-belief guidelines by which mankind has tried to live and find meaning" (Sperry, 1981).

There is no simple way to counter resistance toward science as a foundation for thought in the humanities; or to convert scientists to visual ways of thinking; or to inspire some to leave the laboratory for the studio. But seminars like this one make a start.

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