A Neuroimage Is Worth a Thousand Transformations: The Deceptive Epistemic Value of Neuroimagery

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The enigma of the mind has enticed scientists, philosophers, and artists throughout history. Its universality binds us together, but its potential for plasticity enables an infinite range of human uniqueness. As an essential, defining component of human life, it is necessarily connected to all that life constitutes.

The introduction of magnetic resonance imaging (MRI) and the related functional magnetic resonance imaging (fMRI) in the latter part of the 1970s revolutionized the manner in which scientists investigate the structure and function of the brain. These neuroimaging techniques rely on the intrinsic spin of protons in water molecules and the differential signal resulting from atoms of different tissues and of oxygenated versus deoxygenated blood. MRI and fMRI can be performed on a live, conscious individual and have relatively good spatial and temporal resolution. In contrast, earlier investigational methods relied either on post-mortem analysis that divorced the brain from its in-vivo elegance, or rudimentary imaging techniques that could not provide three-dimensional perspective. The advent of MRI and fMRI heralded a new era of scientific intra-explorations of the mind with unprecedented detail and scope.

The popularity of neuroimaging is pervasive. Brain images are stamped across newspapers, journals, and television broadcasts. Matted on a black background and highlighted with pockets of color, they are ubiquitous: seducing us with secrets about the inner workings of our minds and the mysteries of our personhoods. The number of neuroimaging studies continues to balloon, with the number published in 2004 and 2005 alone matching those published between 1991 and 2001 (Illes, 2008).

There is little question why neuroimaging is such a popular topic: cognition sits focally in the vortex of humanity. As the masters of our own minds, we feel attracted to, and responsible for, insight about our brains. Understanding how we think adds invaluable richness and perspective to our everyday experiences; to the narrative of human history; to the cumulative trajectory of scientific discovery and progress; and to the values, beliefs, behaviors, and idiosyncrasies that make us uniquely human. Revelations about our cognitive processes necessarily have repercussions that radiate across all sectors of life as we know it; no wonder we are so intrigued.

The universal appeal and relevance of neuroimaging data has led to expedited communication of neuroscientific research—communication that often excludes the ambiguity and tenuousness inherent in any burgeoning discipline. Popular neuroscience is exported to an eager public without much discussion about the methodology behind experiments, resulting in a dramatic asymmetry in conceptual understanding between the scientists who conduct the experiments and the public to whom findings are communicated. Central to this miscommunication and false knowledge creation has been the use of neuroimages, which—through their likeness to photographs—imply familiarity, accessibility and inferential proximity that is not actually there. The images included with neuroscientific papers are neither mimetic nor revelatory like their photographic counterparts; instead, they are the finished products of a tremendously complicated series of data accumulation, processing, and interpretation. As a result of this enhanced impression that neuroimaging allows direct observation of the thinking brain, the public reception has been prone to overestimate the explanatory weight of the results of neuroimaging experiments (Huber, Kummer, & Huber, 2008).

The differential in knowledge between the neuroscientists and the public—the elite group of experts (what Ludwik Fleck has characterized as the esoteric circle) and the outer, exoteric circle of the wider community—results in a false representation of knowledge with the potential for gravely negative consequences. As the findings revealed by neuroscience thrust us into deeper dialogues about the ethics and politics of humanism, a misinformed public will be vastly unprepared for the nature of the discussion and its consequences.

To evaluate the deceptive nature of the neuroimage *per se*, one must first attempt to penetrate the esoteric circle responsible for its creation. The theoretical basis of magnetic resonance imaging is the assertion that atoms with odd-numbered atomic weights, such as hydrogen, have natural axes of rotation (Kalat, 2009). When an individual is placed in the MRI scanner, the hydrogen protons in the individual's brain become aligned with its strong magnetic field. The scanner then emits energy as radio waves, causing the protons to tilt; when this radio-wave energy is turned off, the protons return to their resting state, releasing the absorbed energy. The release of this energy is the magnetic resonance signal, which is the raw data exported by the scanner. An orchestra of sophisticated computer analyses decodes this data to render a structural image that reflects the density of tissue throughout the imaged brain (Kalat, 2009; Purves, 2007).

Functional magnetic resonance imaging (fMRI) is an extension of MRI's underlying technological basis in that it exploits the fact that oxygenated hemoglobin has a different magnetic resonance signal than the oxygen-depleted form of hemoglobin. Activated brain regions use more blood than relatively inactive areas, and therefore require greater local blood flow. Within seconds of a neural area being activated by a specific cognitive task, local microvasculature networks respond to the oxygen depletion by increasing blood flow to the active area. This results in a decrease in the concentration of oxygen-depleted hemoglobin from that area of the brain. Researchers use the differential magnetic resonance signal resulting from arterial blood flow to active areas in the brain—known as the blood oxygenation level dependent (BOLD) signal—to measure relative activity in various areas (Kalat, 2009; Purves, 2007). Again, highly advanced statistical software is required to create a 3-D brain image reflective of a temporally dynamic suite of MR signals. And, as would be expected, differential thresholds and controls placed during analysis render results that offer a variety of different interpretations and results.

Because the isolation of specific cognitive functions is contingent upon the quality of control conditions, neuroimaging data is highly sensitive to empirical design. Furthermore, the act of devising in-scanner tasks requires a nuanced but impeccably precise notion of whatever phenomenon is the target of interest; it is challenging to devise a task that can be realistically completed by participants lying motionless on their backs that nonetheless offers insight about the cognitive phenomena underlying aggressive behavior, empathy, or the influence of social cognition, among the many other points of contemporary neuroscientific curiosity. The very notion of investigating a complex human quality like "empathy" is further complicated by the necessity of unpacking the concept and sorting through fractal interpretations. Indeed, some have argued that it is futile to examine such loaded phenomena before the social sciences have come to a consensus about their definitions. Advocates of keeping neuroscience and the social science disciplines distinct argue that the use and investigation of terms borrowed from behavioral psychology, economics, and colloquial language only detracts from investigations of the intrinsic nervous system (Huber, Kummer, & Huber, 2008).

Neuroimaging entails specialized knowledge about nuclear physics, parametric statistics, and physiology, among other disciplines. Unparalleled complexity exists at almost every level of its functioning: the decision to use hemodynamic magnetic signaling as a proxy for brain activation; the specialized medical equipment needed to acquire a scan; the parameters necessary to elicit activation; the statistical thresholds needed to illuminate meaningful patterns; the list goes on and on. This complexity is exacerbated by the relative novelty of neuroimaging itself, which—relying on innovation and creativity to actualize its landscape—is plagued by widespread heterogeneity among the design and results of neuroscience laboratories (Illes, 2006). As a result of this complexity, every step of the neuroimaging process implicitly contains many opportunities for error (Huber, 2008), including the dissemination of results, for which there is still no set of shared standards or regulations: no Kuhnian paradigm.

The very act of communicating findings with a neuroimage or "brain mask"—something that suggests the self-contained and easy inferential character of a photograph—serves to literally mask the layers of complexity that have converged to create the neuroimage in the first place. The neuroimage is a "black box": a product of a set of commands so complex that only input and output are vested with meaning (Latour, 1987).

Latour (1987) stresses that analogous black boxes abound in science, and Fleck (1979) notes that gaps dividing the knowledge held by esoteric and exoteric circles are common. Indeed, attempting to communicate to the general public the extensive complexity underlying the production of knowledge in all disciplines of academia would be extraordinarily tedious, requiring indoctrination of sorts into cultures complete with their own vernacular and rituals. Communication of scientific findings cannot be fully comprehensive if it is to be feasible, especially with most scientific rhetoric already too dense to be widely accessible. To be usefully communicated to the public, scientific knowledge must be simplified so that it is lucid and apodictic (Fleck, 1979).

But this "invisible hand of science" and the room it leaves for false impressions is especially pronounced in neuroscience, due to the imitative relationship of the neuroimage to the photograph. Unlike the phenomena that neuroimaging studies attempt to communicate (data that ends up remarkably inferentially distant from the images that are produced), the use of an image format connotes facility, familiarity, and accessibility. Like photographs, neuroimages seem to provide evidence about real, recognizable objects: visual truths even their own producers cannot refute (Huber, Kummer, & Huber, 2008).

This is because we award greater epistemic legitimacy to photographs than we do to most other visuals, including the most accurate of paintings and drawings (Roskies, 2008); and, as a result, we trust them more. Indeed, photographic images "have been typically granted an epistemic status almost as privileged as vision itself" (Roskies, 2008). Cohen and Meskin argue that photographs assert a sense of objective truth because they present information about the subject without including the bias of the perceiver of the subject; we can almost "see through" photographs to the objects they capture (2004).

But neuroimages are not mimetic like photographs, because "visual characteristics of brain activity are not faithfully replicated in the image" (Roskies, 2008). In fact, the raw data of neural activity is not visual at all. Nor are neuroimages revelatory in the same way as photographs. Neuroimages undergo a series of transformations that are hidden to the consumer of the visual image—that lie latent in Latour's "black box." Unlike interpreting a photograph, which is entirely self-referential, interpreting a neuroimage necessitates understanding the decisions made in constructing and analyzing the image. In this way, neuroimages are more like diagrams or schematics than they are like photographs, and, as such, do not deserve the status of the epistemic framework conferred by the latter.

The deceptive inferential proximity of neuroimages (resulting in the creation of an epistemic status that both functions above and obscures layers of complexity in neuroscientific experimental design and analysis) is an important contributing factor in the overestimation of the explanatory power of neuroimaging experiments. Neuroscience is widely appealing and fundamentally applicable. As the “lords of our tiny skull-sized kingdoms” (Wallace, 2005), we all have something invested in what neuroscience has to elucidate about the mind. Our curiosity about ourselves likely leads us to voraciously consume whatever scientific truths (or, potentially, misconceptions) the field of neuroscience has to offer. Interestingly, the weight we put on neuroscientific claims extends even beyond the field of neuroscience itself. Weisberg and colleagues found that naïve subjects, and even those with some college-level neuroscience or psychology training, rate scientific explanations as better when they include neuroimaging data, even when that data is explanatorily irrelevant (2008).

Of course, public interest in domains of science is inherently a good thing. No science exists independent of its social context; scientific process requires public interest for infrastructure, resources, and the dispersion of information, among other things. In fact, Latour has characterized science as a balance between social responsibility and the integrity of investigation: a “trade-off between the intensity of the drive to interest people ‘outside’ and the intensity of work to be done ‘inside’” (1987).

Because neuroscience is so widely popular and meaningful, it is especially important that its revelations be communicated accurately. The advances in imaging technology have also introduced a myriad of vastly important spiritual, ethical, and political considerations. Understandings of personhood, morals, and spirituality all will be informed by the secrets we unlock from our minds. If findings are communicated in a way that fails to depict the complexities of neuroscience, “civic discourse about its meaning will be impoverished” (Racine, Bar-Itlan, & Illes, 2005).

Yet, including every element of epistemic ambiguity, every detail of epistemic design, is an impossibility. Too much information poses just as much of a problem as too little information; an overabundance of detail will drown out the popular appeal of neuroscience that is crucial for its survival and its development. But we can begin by including some of the context of discovery in the communication of neuroscientific findings. We can illustrate data in contingency graphs instead of providing images that imply self-inclusive explanation. We may begin to better establish the amorphous, controversial territory upon which these battles for neuroscientific “truth” are being waged. If neuroscientists do so, they may find the public better prepared to discuss the relevance and role of neuroscientific findings in the various ethical dilemmas within which it has now found itself entangled: in use as evidence in the courtrooms, in providing biological bases for erecting the boundaries of diagnostic classifications, in serving as the basis for special educational interventions for students in schools, among other potent issues.

We need not open the black box, but we should expose its boundaries.

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