A Phenomenology of Image Use in Science: Multistability and the Debate over Martian Gully Deposits

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Abstract
Insights from the phenomenological tradition of philosophy can be fruitfully applied to ongoing scientific investigations. In what follows, I review and refine a methodology I have developed for the application of concepts from the phenomenology of technology—concepts which articulate bodily and perceptual relations to technology—to a specific context of scientific practice: debate over the interpretation of laboratory images. As a guiding example, I introduce a case study of a contemporary debate over images of Mars which reveal evidence of fluid movement on the planet's surface in the last decade. Next, the framework of phenomenological concepts is applied to this example, and contrasts are made with the results of previous case studies. I conclude with reflections on the implications of this perspective for both the use of imaging technologies in scientific research specifically, and for the phenomenology of technology generally.

Keywords: Postphenomenology, hermeneutics, multistability, technological mediation, Mars, Mars Global Surveyor, Terra Sirenum, gully streaks, scientific imaging

Introduction

Philosophers of the phenomenological tradition work to describe human experience. A variety of thinkers have applied phenomenological insights to the study of human interaction with technology (recent examples include Verbeek, 2008; Ihde, 2009; Selinger, 2009; Rosenberger, 2009b). In what follows, I consider how these insights can be applied to the use of imaging technologies in scientific research. It is my contention that it can be useful for scientific debates over image interpretation to be conceived, at least at times, explicitly in terms of human interactions with complex technologies.

I begin with a review of a framework of phenomenological concepts I have developed through a series of papers (Rosenberger, 2008; Rosenberger, 2009a; Rosenberger, 2011). As a guiding example, I apply this framework to a case study original to this paper. It regards a contemporary debate in space science over the interpretation of images of the surface of Mars which reveal newly-formed streaks found within gully formations. The results of this study will be contrasted with those of previous studies also conducted through this framework of other scientific debates over images. Through the course of this essay I refine this framework in several ways, such as by evaluating it with respect to concerns raised in the hermeneutic tradition of philosophy, by articulating it in relation to the notion of underdetermination in the philosophy of science, and by considering its bearing upon contemporary accounts of "technological agency."

Human Experience and Scientific Images

In fields such as the philosophy of technology, science studies, and the history of science, insights from phenomenology have been used as tools for conceptualizing how scientists relate to the data produced by laboratory imaging technologies (e.g., Hasse, 2008; Heelan, 1983; Lynch, 1985;

Rasmussen, 1997; Staley, 2008; Rosenberger, 2011). A central voice in this theorizing has been Don Ihde (1997), and I expand on his work here.[1]

One way that Ihde and others conceive of human bodily relations to technology is through the concept of *mediation*. Under this conception, a technology comes between a user and the world, enacting transformations to the user's relationship to the world in the process; a technology, as a non-neutral mediating device, transforms a user's experience.[2]

Ihde distinguishes between two manners in which technological mediation occurs: what he calls "embodiment relations" and "hermeneutic relations" [1997, 95].[3] In an *embodiment relation* to technology, a user incorporates the device into her or his own bodily experience of the world. Ihde says, "These relations are ones in which the technology not only becomes maximally transparent, but which quasi-symbiotically becomes a kind of extended embodiment" (1997, 95). Consider the example of a butter knife, a device used to spread soft foods such as butter. While it is used, the experience of the knife itself fades into the background of awareness; a user accustomed to using the knife focuses more on what she or he is spreading—on proportioning the butter across the surface of a slice of toast—than on the experience of gripping the device. Janet Vertesi's anthropological studies of scientists' relations to the Mars Rovers provide an example of embodiment relations to complex computerized research technologies (2008). As a scientist that operates a Rover becomes deeply familiar with its use, she or he comes to embody the device in significant (if specific) ways that enable a mediated experience of the surface of Mars. Vertesi explains "The intensity of the embodied experience is such that team members regularly compare the experience of operating Rovers on Mars to simply 'being there'" (2008, 2528).

In a *hermeneutic relation* to technology, in contrast, the user looks directly at the technology and interprets it (Ihde, 1997, 95). ("Hermeneutics" is the name for a tradition in philosophy which studies the nature of interpretation.) A hermeneutic relationship with technology has a reading-like quality; with the right interpretive knowledge and skill, a user gains a transformed access to the world by perceiving and interpreting the device's readout. For example, if a user knows how to "tell time," she or he gains access to the time of day by glancing down at her or his wristwatch. In many cases, this transformed access is granted in the form of a perceptual gestalt. Rather than looking at the numbers and hands and then putting them together to determine what they mean, the watch user perceives the time all at once. Similarly, a pilot looks out the windshield at a windsock along the runway and interprets it to read off the strength and direction of the wind. The meaning conveyed by the wind sock is experienced at a distance all at once in a perceptual gestalt.[4]

The next important concept is what Ihde calls *multistability* (1997, 171). This refers to a single technology's capacity to mediate human experience in more than one way. An individual technology can be taken up for a variety of purposes and can be fit into a variety of contexts. Yet, at the same time, there are limits to how an individual technology may be put to use; the materiality of the device ensures that only some relations will be experientially "stable." The butter knife, for example, can be used for a variety of tasks besides spreading butter on toast, such as for cutting, stabbing, stirring, etching, or even used as a makeshift flathead screwdriver. Yet at the same time it cannot be used to do simply anything.[5]

The use of images in science is primarily characterized by hermeneutic relations to technology. Ihde explains, "most image technology fits better into *hermeneutic* rather than *embodiment* relational schemes. That is to say, the perceptual focus is *upon* the display screen, *through which* there is a presumed reference" (1997, 96). An imaging technology transforms an otherwise imperceptible object of study into an image of that object which our human bodies are able to

perceive. In order to share a hermeneutic relation with an image, the user must possess certain knowledge and interpretive skills that enable the image to be perceived coherently. For example, for a medical practitioner to find meaning within an fMRI image of a brain, she or he must possess knowledge about the significance of the various colors mapped upon the brain-shaped readout. Insofar as this practitioner is accustomed to reading this kind of image, much of its meaning is perceived in a gestalt. The practitioner can then focus attention on the points of interest within the image. Ihde even claims that this "repeatable gestalt" quality of the experience of images is exactly what accounts for the importance of imaging in science (1997, 161).

As any mediating technology, an image in science is multistable. This occurs in terms of the image's capacity to be interpreted in multiple perceptually-stable ways. I have developed the notion of *hermeneutic strategies* to refer to the interpretive framework one brings to an image which makes possible a particular stability (Rosenberger, 2008; Rosenberger, 2009a; Rosenberger, 2011). Hermeneutic strategies involve several features, including the details of the particular scientific theory through which one reads the image. They also include the particular understanding of the imaging process that informs one's reading. In many cases of scientific practice, an object of study may only become available to human perception through the transformative actions of imaging technologies—as in the case of microscopic objects, interstellar objects, objects within a living body, etc. Through potentially multiple levels of mediation, an imaging technology gathers information about the otherwise invisible object of study and transforms it into an image, a form available to human perception. One's particular understanding (be it explicit or implicit) of how the object of study is transformed by the imaging technology is an important, yet easy-to-overlook, feature of hermeneutic strategies.

The hermeneutic strategy one brings to an image determines what features of the image's content stand forward in one's awareness as important, and which instead remain in the background. If one is accustomed to perceiving a particular kind of image through a particular hermeneutic strategy, much of the image's content is experienced in a perceptual gestalt *in the terms of that strategy*. For example, in a debate between two meteorologists over the predicted course of a storm system which appears in a satellite image, each interlocutor brings a different hermeneutic strategy to the discussion. This should not imply that each hermeneutic strategy enables an accurate apprehension of the object of study itself, in the same way that it should not imply that the rival meteorological predictions are both correct about when the storm will occur; the claim is simply that each hermeneutic strategy presents a perceptually-stable relation to the mediating technology—the image.

This phenomenology of multistable scientific images shares a special relationship with the notion of underdetermination in the philosophy of science: this account is dependent upon, but does not reduce to, the notion of underdetermination.[6] Underdetermination refers to the fact that a multiplicity of scientific theories can be made consistent with a particular set of data, and that a theory that first appears to be contradicted by certain data can be adjusted to be rendered consistent. Such adjustments can occur, for example, in terms of the background assumptions which undergird that theory, or in terms of ancillary claims of the theory (e.g., Quine, 1951; Duhem, 1954 [1914]; Lakatos, 1970; Harding, 1976; Laudin, 1990). This phenomenological account of imaging can be understood to apply to a specific subdomain of theory-underdetermining data in science: scientific images. Not only does the traditional notion of underdetermination apply to this subdomain, but additional factors and constraints emerge particular to image interpretation; issues of human bodily relations to technology are introduced by the fact that the data at issue take the form of readable material artifacts, i.e., images. An image in science remains an example of data which underdetermine theory, but in this subdomain such theories are at times constrained to those which enable a scientist (as a human being with

particular perceptual capabilities) to attain a stable perceptual relation. Where the notion of underdetermination describes the capacity of scientific *data* to be *accounted for* under multiple *theories*, the phenomenological framework outlined here describes the capacity of a scientific *image* to be *perceived* by scientists in terms of multiple *hermeneutic strategies*.

This framework of concepts can be applied to ongoing debates in science over the interpretation of images. I suggest that doing so has the potential to productively draw attention to the human perceptual and conceptual relations to the imaging technologies, and to the transformations they have rendered to the object of study, relevant to the debate. These transformations can be both what makes research on an otherwise imperceptible object of study possible, and at the same time what shapes a debate over image interpretation. This process of making explicit user relations to instrumentation has the potential to advance a scientific discussion by setting up critical contrasts between rival debate positions in terms of these bodily-instrumental issues.

I have developed this framework so far through two case studies of contemporary scientific debates. The first regards a disagreement in neurobiology over images of synaptic vesicles, the organelles within neurons responsible for neurotransmission (Rosenberger, 2009a; Rosenberger, 2011). I refer to this disagreement as *the synaptic vesicle debate*. Central to this debate is a technique called "quick-freezing" which freezes a nerve sample almost instantaneously. This enables the creation of images of synaptic vesicles frozen during the milliseconds in which they take part in neurotransmission. An issue I suggest to be crucial to the history of this ongoing discussion is a transformation of a *temporal* nature: the transformation of the process of neurotransmission into a single moment of that process (in the form of an image). This change at once makes visualization of the otherwise-too-fast-to-see synaptic vesicle action possible, and also constitutively informs the dispute over this action.

The second case study regards a debate in space science over images of the surface of Mars which reveal a landmass within a crater named Eberswalde which is interpreted to be the ancient remains of a river delta (Rosenberger, 2008). Researchers disagree about what kind of water flow must have existed in Martian history in order to have created this formation. That is, they disagree about whether it was indeed river-like, and about the duration over which it lasted. I refer to this disagreement as *the Eberswalde delta debate*. The images most central to this debate were created by the Mars Orbiter Camera aboard a craft called the Mars Global Surveyor. I suggest that a transformation pivotal to this debate is of a *morphological* nature. The change from the ranging topography of Mars to the flatly two-dimensional satellite image is one that underlies much of the discussion.

In the next section I instantiate the phenomenological concepts reviewed here with a further case study. Like the Eberswalde delta debate, it also deals with images of Mars gathered by the Mars Global Surveyor. In the conclusion of this paper I contrast the following study with the two summarized above.

The Martian Gully Deposit Debate

In November of 2006, researchers unexpectedly and permanently lost contact with the Mars Global Surveyor, a craft which had launched for Mars in 1996, and which had produced a catalogue of images of its surface at an unprecedented scale and resolution (Fig. 1). The debate I explore here concerns images produced by the Mars Orbiter Camera (MOC), an imaging device aboard the Mars Global Surveyor.

Figure 1. Artist's rendering of the now lost Mars Global Surveyor. Image Credit: NASA/JPL. This and the following figures can be found at http://www.photojournal.jpl.nasa.gov

The debate I consider below begins as part of another debate which also originates in MOC images. Images of Mars' surface reveal tens of thousands of gullies of an unknown though seemingly recent origin running down slopes into craters (Malin and Edgett, 2000). Upon their discovery, spirited debate ensued over how these gullies could have formed. Theories include ground water flow, melting snow, dry granular flow, and the flow of subsurface CO^2. In addition, darkly-toned streaks caused by superficial dust movement on the surface running down into gullies are abundant in such images, and are an example of a constantly changing feature of the Martian terrain (Schorghofer et al., 2007).

A major development in this research occurs when it is discovered that surprising changes have taken place on the Martian surface since the Mars Global Surveyor arrived; lightly-toned streaks have formed along gullies in two sites on the planet (Malin et al., 2008); that is, the lightly-toned streaks appearing in later images are absent from earlier images of the same locations. Unlike the always forming and changing darkly-toned streaks caused by dust movement, the few newly-formed lightly-toned streaks bring important potential implications; they raise the startling possibility that liquid water may have flowed briefly on Mars' surface during the time between the creation of the first and second images, creating the lightly-toned streaks in the process. For example, it was found that a lightly-toned streak had formed at a site named Terra Sirenum between the time it was first imaged in 2001 and later in 2005 (Figs. 2 & 3). If it is true that these streaks were created by contemporary water movement, then there are important implications for the issue of the potential for life on Mars; where there is water, there may be life (Sanderson, 2006).

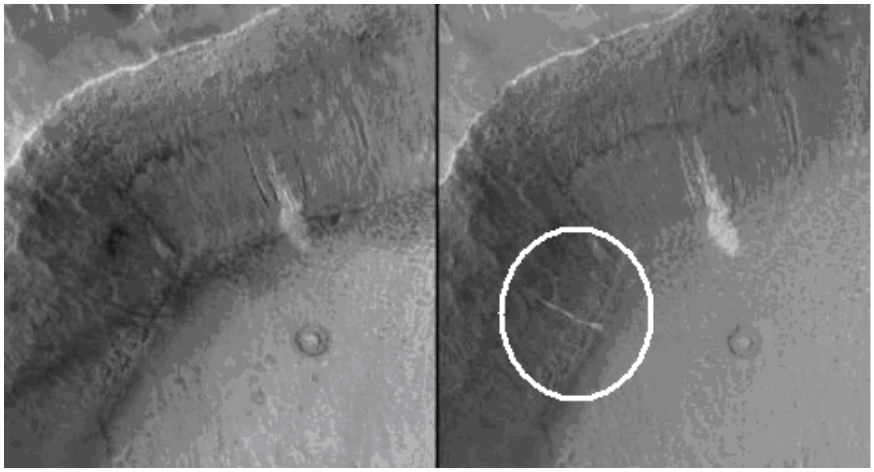

Figure 2. The image on the left was taken of the Terra Sirenum crater in 2001, and the image on the right in 2005. Notice the lightly-toned streak (circled) appears only in the 2005 image. Image Credit: NASA/JPL/Malin Space Science Systems, circle added by author.

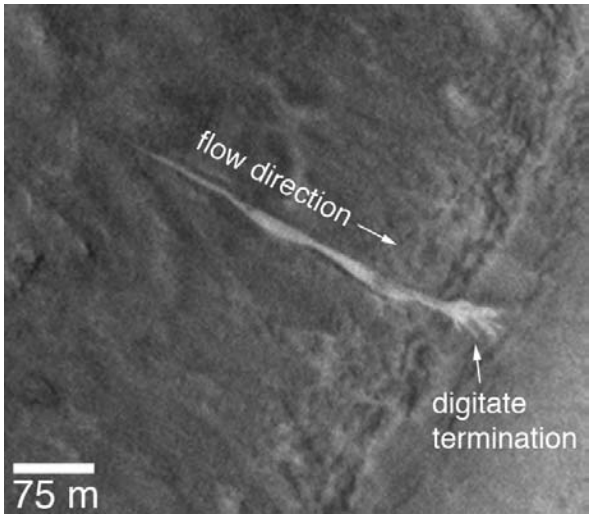

Figure 3. A closer view of the of the lightly-toned slope streak in Fig. 2. Image Credit: NASA/JPL/Malin Space Science Systems.

Many hold that the lightly-toned gully streaks were created by the emergence of liquid ground water, or at least debris wet with water or brine (Malin et al., 2006; Chevier and Altheide, 2008; Kochel and Trop, 2008). However, rival theories have emerged, such as the claim that the lightly-toned streaks were formed by dry granular flows (McEwan et al., 2007; Pelletier et al., 2008), or by the flow of debris coated in frost (Hugenholtz, 2008).[7] I refer to this disagreement as *the Martian gully deposit debate*.

Insofar as these MOC images can be perceived in terms of multiple accounts of the formation of the lightly-toned gully streaks, they can be understood as examples of multistable readable technologies. Each stable perceptual relation to these images is made possible by a different hermeneutic strategy. The hermeneutic strategies here are each constituted by a rival scientific theory which claims to account for the lightly-toned gully streak phenomena.[8] This includes each

theory's explanation of the images' content, but also their accounts of other related non-imaged data from further instruments, of physical and computer simulations, and of comparisons with terrestrial geography. In addition, I suggest that each hermeneutic strategy, implicitly or explicitly, includes some account of the actions of the imaging technologies which have created the images at issue. This feature of these hermeneutic strategies is explored further in the next section.

Mediation and The Mars Global Surveyor

The Mars Global Surveyor together with the MOC mediate scientists' experiences of the surface of Mars. Though the Martian landscape is not available to unaided human bodily perception here on Earth, these devices enable Mars to be perceived in the form of images. To do so, imaging technologies must render a number of transformations to the Martian surface; Mars itself differs in important ways from these images.

Of course one of the most significant transformations is one of distance; the far away planet is brought to us here on Earth for our inspection. Also, we are presented with a particular bird's-eye perspective of the surface, one which we would not be able to attain in an unaided way even if we were on Mars. Instead of the colors one would see were one standing on Mars, the MOC images contain only blacks, whites, and grays. In addition, the version of Mars we receive in the form of MOC images has been reduced to two dimensions, that is, a two-dimensional image. It has been segmented from its context and has been framed by a page or screen. The MOC images themselves have a rhombus-like shape, and are combined together into mosaics. The images that are used are squared-off portions of the larger mosaics.

But the transformation I would like to focus on here is the change to the temporality of Martian gully dynamics. Through the imaging process, the ongoing happenings of the Martian surface are transformed into a single instant of those happenings. Each image presents only an individual moment of Martian history. Despite these constraints, researchers have developed effective strategies for investigation; the discovery of the recent formation of lightly-toned gully streaks was made by contrasting images created at different times. I suggest, however, that the effects of this transformation continue to deeply influence the hermeneutic strategies of the Martian gully deposit debate.

On the one hand, the tactic of contrasting images taken at different times is what enabled the discovery of the recent changes to the Martian surface in the first place. On the other hand, this procedure leaves these images open to interpretation in specific ways. For example, the speed and nature of whatever flow had created the lightly-toned streak in Figure 3 remains a matter of speculation. Each theory of the origins of the lightly-toned gully streaks implicitly contains an account of what a streak's formation must have looked like as it was happening. Also, this transformation is of relevance to the question of what substance currently composes the streak, and thus what accounts for its "light" tone. For example, though the Martian surface may be inhospitable to ice and liquid water, it remains possible that the streak is at times replenished by groundwater, i.e., that it was not formed by an isolated event (Williams et al., 2007).

Conceiving of these images explicitly in terms of human relations to technology draws out the particular transformations the MOC has rendered to the surface of Mars in the process of making it available for perception. The particularities of these transformations impose (explicit or implicit) demands upon the hermeneutic strategies on offer for these images. This can be formulated in terms of a suggested direction for further thought in this discussion. Rival theories could be contrasted generally in terms of their relationships to these transformations. Also, in

particular they could be contrasted in terms of the temporal transformation identified above. It can be asked what different flow scenarios could have possibly occurred in the non-imaged duration between the creation of the two images. How fast was the flow? What did it look like as it was happening? Were there multiple flows? The rival theories could be evaluated in terms of how fragile or robust they are with regard to these various possible scenarios.

Discussion

I have argued that applying the phenomenological framework outlined above to a scientific debate over image interpretation has the potential to productively highlight relevant human bodily relations to instrumentation. As an instructive example, I have instantiated this framework with the details of the Martian gully deposit debate. Considering these images explicitly in terms of their status as multistable mediating technologies prompts exploration of the ways in which the particular transformations rendered by imaging technologies inform this debate. The particular ways that Mars has been transformed in order to make it available for human bodily perception are themselves factors which deeply influence the discussion.

A revealing contrast can be drawn between this and the two case studies reviewed in the first section: the synaptic vesicle debate, and the Eberswalde delta debate. An issue highlighted above as important for the Martian gully deposit debate is how "temporal" transformations inform the debate's rival hermeneutic strategies. Interestingly, on this specific issue, the Martian gully deposit debate shares more in common with the synaptic vesicle debate—the neurobiological case study—than it does with the other Mars case study, the Eberswalde delta debate. Both the Martian gully deposit debate and the synaptic vesicle debate are crucially informed by the fact that imaging technologies, in the process of making an otherwise imperceptible phenomenon perceivable, transform that phenomenon into images of single isolated moments. In both of these otherwise quite different examples of scientific research, the discussions crucially involve filling in the blanks that exist in the un-imaged temporal moments.

The identification of these connections across disparate bodies of scientific research suggests a project for further thought for those working on the analysis of image use in science. It is possible to use this phenomenological framework for identifying potentially useful new classifications of practices of image interpretation.

Ihde has made some first steps toward charting such categories, stating, "If the dramatic appearance of relative distance (space) was the forefront fascination with Galileo's telescope, one might by contrast note that it is the dramatic appearance of a transformation of *time* which photography brought to scientific attention" (1997, 164).

Yet this distinction between spatial and temporal transformations is in my view only a beginning. For example, the temporal transformation common to the synaptic vesicle debate and the Martian gully deposit debate is one in which a *process* is changed into *single moments* of that process. Of course other kinds of temporal transformations are possible, such as video accelerated to display the slow turning of a sunflower, or decelerated to display the rapid fluttering of humming bird wings. Thus one task for this classificatory project is to identify the various kinds of temporal transformations important to imaging work.

A second task is to identify the various kinds of spatial transformations that can inform debates over images. For example, I have suggested that the transformation crucial to the Eberswalde delta debate can referred to as "morphological"; in this case the shape of the object of study is changed from the full dimensionality of the Martian landscape into an image with only two

dimensions. Other spatial-type transformations are important to scientific research. For example, a telescope transforms the distance between a user and an object of study. A microscope transforms an object's size. A project for those working on the phenomenology of imaging is to flesh out this taxonomy of technological transformations in their temporal-type forms, spatial-type forms, and whatever others can be identified.

It may be possible to raise an objection to Ihde's use of the term "hermeneutic relations" to refer to interpretive relations to readable technologies. Addressing this potential objection is helpful for illustrating the relevance of this account of scientific debates over images to more general issues in the philosophy of technology. "Hermeneutics" is a philosophical tradition concerned with language translation and the interpretation of text (e.g., Gadamer, 1960; Taylor, 1971; Ricoeur, 1976; Habermas, 1983). Ihde borrows the term largely to highlight the ways that certain technological relations occur in a way similar to reading text: similarities such as the fact that the use of a readable technology (such as a thermometer) involves looking directly at and interpreting it; that one must "know how to read" the technology before the relation can occur; and that if this knowledge is possessed then much of the meaning is conveyed in a perceptual gestalt. Despite these similarities between reading text and "reading" certain technologies, it is possible to object that the relations between humans and technologies never involve the issues of primary concern to those who study philosophical hermeneutics.

Specifically, the tradition of hermeneutics strives to understand how communication and language translation occurs between different *people*—people with potentially different intentions and language forms. As Charles Taylor explains, "In a text or text-analogue… we are trying to make explicit the meaning expressed, and this means expressed by or for a subject or subjects. The notion of expression refers us to that of a subject" (1971, 5). The potential objection to Ihde's use of the term hermeneutics to describe relations to readable technologies such as a thermometer would point out that a readable technology does not possess intentions toward communication like the way human interlocutors do. A user cannot misinterpret what the thermometer intends to convey, or what its readout means to the thermometer itself, since the thermometer does not possess intentions toward communication. The potential objection claims that since a readable technology neither possesses intentions toward communication nor participates in a language tradition, the relation between a human and this device is in no way "hermeneutic."

However, there are issues central to contemporary philosophy of technology which complicate this potential objection. A theme in much work in the field regards the conceptualization of how technologies at once play a role in determining the effects of human-technology relations, and how at the same time technologies remain instruments that humans use for intended effects. This issue is sometimes referred to as technology's "non-neutrality." Albert Borgmann summarizes, "if there is one thing that the significant philosophers of technology agree on, it is this: Contemporary culture is pervasively technological, and technology is non neutral" (2007, 10).[9] I conclude this paper by considering two ways that technological non-neutrality has been theorized (the notion of multistabilty, and notions of technological agency) and their implications for future work on hermeneutic relations to technology.

One attempt to conceptualize technological non-neutrality is through the notion of multistability central to the above study. Ihde has long defended an account of the multistability of human perception generally, a claim he has articulated mainly through the exploration of the experience of visual illusions. However, when Ihde advances the notion that human relations to technology are multistable, he largely focuses on embodiment relations. The work of this paper makes a step to fill in this gap. With my series of studies of scientific imaging, I offer concrete examples of

relations to multistable technologies that occur in terms of hermeneutic relations.[10] While the thermometer may retain a single dominant way to be read, the reading of a hotly contested image in science presents multiple interpretive possibilities at several levels, at once calling together the rival scientific theories of image content, the transformative processes of the imaging technologies, the material specificity of the images themselves, and the individual relationships between the theories and the technologies. In this way, the relation shared by a user and a readable technology such as an image is more than simply an interaction between an intention-possessing human and an inert artifact with an unambiguous and determinate message. Instead, the user finds her or himself interacting with an artifact with the potential to convey multiple meanings to different users, and yet also at the same time to constrain that potential to certain stabilities by virtue of its material specificity.

The second complication to this potential objection regards philosophical accounts of human-technology relations which cede a level of agency to technology itself (e.g., Ihde, 1990; Callon and Law, 1995; Latour, 1994; Verbeek, 2005; Verbeek, 2008). These thinkers attempt to articulate the role that technologies play in the overall activity of human-technology relations. They hold, in various ways, that a device possesses a kind of agency, and that the technology itself takes part in the process of directing the relation. These perspectives approach the notion of agency not in terms of something possessed by an individual human, but in terms of the agency of the overall relationship between several participants—including both humans and technologies.

Bruno Latour, for example, articulates these ideas from the perspective of actor-network theory, describing agency in terms of the collective action of various "actants" enrolled within a "network." He says, "These examples of actor-actant symmetry force us to abandon the subject-object dichotomy, a distinction that prevents understanding of techniques and even of societies. It is neither people nor guns that kill. Responsibility for action must be shared among the various actants" (Latour, 1994, 34).[11] Similarly, Peter-Paul Verbeek, building from Ihde's phenomenology, claims that both the user and the technology should be understood as agents which together "co-shape" their relationship. In his view, "When human beings use an object, there arises a 'technologically mediated intentionality,' a relation between human beings and the world mediated by a technological artifact" (Verbeek, 2005, 116). I suggest that these perspectives complicate the potential objection raised above by challenging any assumption that the notions of agency and intentionality apply exclusively to humans. The issue of the hermeneutic dimensions of human relationships to readable technologies is one ripe for further thought since it involves consideration of the kind of agency that human-technology relations possess.

By raising and addressing this potential objection, I mean to highlight the value and the limits of the term "hermeneutic relations" for referring to human interactions with readable technologies. It is clearly not simply the case that classical issues in the study of philosophical hermeneutics directly apply to such human-technology relations. However, with contemporary work in the philosophy of technology concerned with the best way to conceptualize the non-neutrality of technology, there is room for further thought on the hermeneutic dimensions of these relations.

I hope that the above has made clear that it is crucial for future work on scientific imaging to engage with the multistability of hermeneutic relations. As theorizing on the "co-shaping" of "networks" of humans and technologies advances, two issues must remain in the forefront of discussion. First, it is important that material agency is not addressed at the expense of human agency; scientific images do not by themselves determine how they should be interpreted. Second, it is equally important that the agency of users (individual or networks of users) is not addressed at the expense of material agency; scientific images play more than a merely

instrumental role in the practices of interpretation. Retaining an understanding of images as multistable, as open to a limited number of coherent hermeneutic strategies, preserves their agential-though-not-deterministic role in discussions over their interpretation.

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Endnotes

1. This essay, as other work on the phenomenology of imaging in science, contributes to the larger body of analysis of scientific imaging in the fields of science studies, the philosophy of science, and the philosophy of technology. Recent works on this topic include (e.g., Oaks, 2000; Mitchell, 2001; Beaulieu, 2002; Landecker, 2002; Latour and Weibel, 2002; Dumit, 2004; Forss, 2005; Joyce, 2005; Pitt, 2005; Prasad, 2005; Daston and Galison, 2007; Vertesi, 2007; Engström and Selinger, 2009).

2. A number of perspectives in the philosophy of technology and related fields utilize the notion of mediation (e.g., Latour, 1993; Latour, 1994; Bolter and Grusin, 2000; Bødker and Anderson, 2005; Kockelkoren, 2007).

   Here I expand on the conception of technological mediation developed within the emerging school of thought called "postphenomenology" (e.g., Verbeek, 2005; Ihde, 2009; Rosenberger, 2009a; Selinger, 2009; see also the 2008, 31(1) issue of the journal *Human Studies* on this topic). The postphenomenological perspective builds on traditional work in phenomenology and applies it to the study of human experience of technology. Postphenomenology shares ontological commitments with the pragmatist philosophical tradition, and often utilizes or expands ideas developed through Ihde's body of thought. (For critical analyses of postphenomenology's relation to pragmatism see Mitcham, 2007; Hickman, 2008). The framework for conceptualizing debates over scientific images which I advance here is an example of an application and expansion of postphenomenology.

3. Embodiment and hermeneutic relations are not the only two types that Ihde has identified. For example, he uses the term "alterity relations" to refer instances in which the user interacts with the technology in a way similar to how she or he would interact with other people, for example the use of ATMs (Ihde, 1990, 97). "Background relations" refer to the relationship a user shares with technologies that for the most part exist as part of the user's surrounding environment, such as a running refrigerator (Ihde, 1990, 109). More recently, Peter-Paul Verbeek has expanded on this list, for example attempting to articulate relations that involve technologies implanted into the human body (2008).

4. It is important to keep in mind that the classical texts of phenomenology receive the criticism that they do not adequately take issues of gender and race into their accounts of bodily experience (e.g., Young, 1990; Bordo, 1997; Fisher, 2000). Ihde's work has also been criticized for inattention to such issues (Selinger, 2003; Eason, 2003; Scharff, 2006). In terms of Ihde's corpus, this is a complicated criticism. Ihde does address issues of gender, race, and cultural difference in terms of the way humans experience technology, but often this analysis comes in a separate section from his work on the specifics of the bodily experience of technological mediation. For example, in *Bodies in Technology*, he separates his comments regarding cultural difference into a separate structural domain called "Body 2" (Ihde, 2002). His analyses in this regard can be interpreted in two ways. They can be seen as a positive contribution to conversations about gender, race, and culture in the phenomenology of technology since these issues are actively addressed (rather than ignored as was often the case in classical phenomenology), and since Ihde insists that the domains of Body 1 and Body 2 are inextricable. However, since Ihde treats these issues separately from his more central investigations into the experience of technology, his work can also be seen as part of the problem since it threatens to systematically separate these sorts of issues from the discussion of bodily experience of technology.

5. The concept of multistability shares overlap with related ideas in the field of science studies, such as actor-network theory's (ANT) notions of "programs and antiprograms" (e.g., Latour, 1993; Latour, 1994; Latour, 1999) and the social construction of technology's (SCOT) notion of "interpretive flexability" (e.g., Pinch and Bijker, 1997; Bijker, 1995). These notions are used to articulate the ways that the materiality of artifacts does not by itself determine how technologies are designed or how they advance. There is a temptation to take all of these notions to be essentially saying the same thing. For example, Verbeek equates the notions of multistability and interpretive flexibility in the following quote: "the existence of multistability—a product's "interpretive flexibility" as Bijker calls it (Bijker, 1995, 20)—need not hamper designers in explicitly trying to anticipate the mediating role of products in their use context" (2005, 217). I sympathize with projects that attempt to amalgamate postphenomenology and perspectives from science studies such as ANT and SCOT for the purpose of incorporating the advantages of each (e.g., Smith, 2003; Verbeek, 2005; Selinger, 2009).

However, I resist the claim that the notion of multistability reduces to the notions that already appear in these science studies frameworks, i.e., that all of these notions are saying the same thing.

In my view, the notion of multistability's explanatory value stems from its ability to at once point to a technology's potential to maintain multiple relations with users, and at the same time to constrain these possibilities—by virtue of its materiality—to limited stabilities. Neither the notion of "programs/antiprograms," nor "interpretive flexability" (and for that matter, other related concepts from social theory), provide the same descriptive advantage on this point. I also remain open to the possibility that these concepts retain their own advantages not circumscribed by the notion of multistability.

6. Within discussions in the philosophy of science, the precise definition and implications of underdetermination are of course subject to much complex disagreement. With these comments in this paragraph here on underdetermination in its relation to the phenomenology of scientific images, I mean only to address a confusion I have encountered. Namely, it has been suggested that my account of image interpretation reduces to the notion of underdetermination. It does not. And here I hope to have clarified why.

7. As Nadine Barlow summarizes in her textbook on cutting-edge research on the surface of Mars, the consensus regarding the lightly-toned streaks in the Centauri Montes region is that, "Although the deposit might have been a dust avalanche, water flow is the preferred interpretation" (2008, 214).

8. While the different theories of the Martian gully deposit debate can be understood to make up different hermeneutic strategies for the MOC images, it may also be possible to interpret these images—as mediating, readable technologies—through an entirely different context. Such a context would be independent of the instrumental and theoretical context of the study of Mars. (Perhaps one in which the images are perceived in terms of their artistic or some other value).

9. This theme pervades several recent collections in the field (e.g., Achterhuis, 2001a; Ihde and Selinger, 2003; Olsen and Selinger, 2007). As Hans Achterhuis puts it, "The new philosophers of technology saw, on the one hand, that the development of technology is accompanied by a transformation of society, but on the other hand that the process of technological development is determined by socio-cultural factors" (2001b, 6).

10. Ihde's central examples of the multistability of vision have been visual illusions such as Necker Cubes and the duck/rabbit. A recent review of his *Postphenomenology and Technoscience* (Ihde, 2009) makes the specific criticism that the multistability of visual illusions is not the same as the multistability of human-technology relations (Cerbone, 2009). I believe my work here makes significant steps toward addressing this criticism.

    Rather than only visual illusions, here I present actual examples of readable technologies to which users maintain multistable relations. This fleshes out similarities and differences between technologies which can be embodied in multiple ways and those which can be read in multiple ways.

11. The move to apply notions of agency to collectives of humans and artifacts is one which has been met with controversy within the field of science studies. See for example the "epistemological chicken" debates between Harry Collins, Steven Yearley, Steve Woolgar, Michel Callon, and Bruno Latour (appearing in the collection Pickering, 1992).