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The Coding of Technical Images of Nanospace: Analogy, Disanalogy, and the Asymmetry of Worlds

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Abstract
This paper argues that intrinsically metaphorical leaps are required to interpret and utilize information acquired at the atomic scale. Accordingly, what we 'see' with our instruments in nanospace is both fundamentally like, and fundamentally unlike, nanospace itself; it involves both direct translation and also what Goodman termed "calculated category mistakes." Similarly, and again necessarily, what we 'do' in nanospace can be treated as only metaphorically akin to what we do in our comfortable mesoworld. These conclusions indicate that future developments in nanotechnology will rely, in part, on the creation of more sophisticated metaphorical codes linking our world to nanospace, and I propose some initial possibilities along these lines.

Keywords: Nanotechnology, Imaging, Phenomenology, Metaphor, Scale

Introduction

In this paper, I want to explore some features of images used in contemporary nanotechnology in order to establish a strategy for enhancing visualization practices toward particular achievable goals. I propose this approach in response to a particular species of 'nanohype' evident – or at least implicit – in such images. I am less interested in what we might call 'delusions of grandeur' or 'flights of fancy' in the domain of nanotechnology than with the pragmatics of scientific visualization strategies at this scale. The many, effectively fictional, depictions of nanotechnological prospects that have caught the recent attention of the public – such as miraculous blood-cleaning nanorobots and panacea-like medicines tailored to individual genetics or, on the negative side, the dangers of rampant 'grey goo' – are not my concern. Instead, I focus on a different sort of hype being generated in expert circles. These claims, associated with new scientific imaging traditions, encourage us to believe that recent instrumental advances constitute a truly deep shift in our understanding of, and access to, the atomic scale.

Much of the recent interest in such images has involved this sort of partisan enthusiasm, with vivid depictions suggesting possibilities for atomic-level engineering far beyond current practice. For example, through the circulation of synthetic instrumental images showing arrangements of a few dozen atoms on a carefully prepared surface, we are easily led to the false impression that engineers can now control atoms with the same ease that a child controls wooden blocks. Simultaneously, the supplementation of instrumental data with sophisticated routines for image manipulation has become standard practice in the field. Access to computer image enhancement, stemming from advances in speed and volume of information processing capacity, lends investigators great flexibility in image presentation. The bulk of this paper will inquire into implications of these developments with respect to contemporary nanotechnology, presenting a case for a realignment of practices with basic objectives that can serve both scientific and human ends.

Explicit claims that we have developed sophisticated technological inroads into the nanometer scale regime seem to depend on either (a) an instrumental interface that is information-rich or (b) an instrumental interface that is phenomenally-rich. The former sort of claim is often formulated in terms of our new ability to really 'see, understand and control' the atomic regime. In the latter, the claim is rather about our now being able to adopt a subjective perspective equivalent to 'being at the nanoscale.' The two are not mutually exclusive, but do represent independent instincts that I will analyze more fully below. Each is reflected in recent discussions of trends in nanoimaging in the scholarly literature. In response to these analyses, I contend that such practices have in fact done relatively little – given their potential – to enhance our understanding of atomic-scale phenomena. By analyzing these sorts of images in comparison to a set of specific technical ideals that they can reasonably aspire to achieve, I hope instead to promote modesty about current imaging trends as well as to indicate some avenues for improvement of them with respect to the informational and phenomenal desiderata just described. In pursuit of this goal, I will examine a different conception of image making geared toward the production of richer models of the atomic regime. I hope thereby to replace nanohype with a degree of 'nanohope' – the pragmatic possibilities of bringing the atomic and human scales into better contact.

This project will involve the consideration of images at a variety of interrelated levels: Not only individual physical ('actual') images [$Image_1$], but also individual mental images [$Image_2$] and mental image sets or frameworks as well [$Image_3$]. These last serve as a means for our interpretation of both kinds of individual image, and can also usefully be regarded as mental 'worlds' (or world analogs) insofar as they offer putatively comprehensive models of a physical domain (or actual 'world'). For example, I will use 'nanoworld' as a group term to indicate the phenomena of the nanometer scale taken as an ensemble. Our mental image of this nanoworld is not a single item but a developmental framework, akin to that constituting our 'normal' human world. These various dimensions of 'imaging' will emerge more clearly in the course of my discussion, but I will begin by posing a question about the relationships among these levels.

What can and do we expect to glean from interactions with this nanoworld given that imaging technologies are an inherent part of the process? As I will develop below, the use of images as media between human experience and phenomena is always a hybrid process involving different possible modes of interpretation. My question is thus at once semiotic, epistemological, and ontological in character. That is, considering together the three senses of image just discussed, explaining our mediated interactions with the nanoworld involves sign systems, knowledge processes, and structures of being. I will link these aspects of the problem by examining a variety of perspectives (cognitive psychological, aesthetic, pragmatist, and phenomenological) on images offered in the philosophical literature. Using this framework, I will argue that imaging codes can be made more sophisticated by mutually accommodating these various possible modes of interpretation more fully and more densely. In a 'scientific' mode, this equates to the transmission of information at a maximal efficiency. From another more common-sensical perspective, however, the goal is better construed as achieving fuller phenomenal contact between the subject and object of inquiry. To obtain these goals together most effectively, I propose that we can utilize a systematic imaging strategy that I will describe through the notion of a 'technical image' combining a scientific modality (in principle, readable by machine) and a manifest modality (in principle, always referred back to an existential agent).

I further suggest that closer attention to the encoding of images reveals, in the particular case of atomic scale phenomena, important and inextricable disanalogies with normal experience. This, I will argue, is a direct result of the metaphorical character of nanoscale images; images capable of conveying a rich functional representation of the atomic regime must do so by significantly reorienting our phenomenal expectations.

Metaphorical leaps are required to use and interpret atomic scale information because of fundamental disanalogies between the relevant ambient phenomena of that scale and those of our own. That is, the processes and structures that we wish to monitor and manipulate in the nanometer regime differ constitutively from those that we are familiar with through our various naked senses. Of course, differences of this sort are not unique to the atomic scale; certain reorientations of sensory expectation must occur with many phenomena that we access through technological instruments. Users of binocular optical microscopes, for example, must not only learn to physically refocus their eyes but must also deal with an unfamiliar combination of reflected and transmitted light in viewing samples. Thus, while some elements of vision enhanced by such a microscope remain analogous to our 'normal' experience (relative sizes and temporal simultaneity of the entire visual field, for example), others can differ substantially (the significance of color within the same object, and even apparent shape). Users of such instruments, as part of the process of developing expertise, must learn to accommodate these new phenomenal regularities in order either to understand what they are seeing or to work with the objects under observation. Depending on the instrumental situation, new tactile habits or other sensory-motor readjustments may be required. Such human-technological experiences create, in effect, circumscribed new worlds as supplements to our everyday one. As my development below will argue in detail, this process is a complex one involving multiple experiential modalities that mutually adjust to one another. In particular, accommodating a new instrumental interface into our experiential palette reorients both our formal theoretical expectations and our common-sensical ones at the same time.

These are obviously relative accommodations. Rarely are all of the components of our experience put into flux at once by a new instrumental interface with the world. But this is part of my point: What makes the nanometer scale a special case is precisely the degree to which the forces, structures, processes, and events of interest defy the expectations of the human-scale. This is not an absolute or unique barrier but it is an especially conspicuous issue for the case of nanotechnology. To see why this is the case, let us now turn to some specific analytical approaches to imaging.

The Technical Image

The central notion I will use in my exploration is that of the *technical image*. By a technical image, I mean an actual image that is systematically encoded. Thus, the technical image appears as an ideal type – an image, in my framework, is more or less technical depending on the degree to which its features are determined either by an established semiotic code or by singular discretionary choices. At the opposite end of the extreme from the technical image would be an entirely *non*-technical image whose features are the result only of individual decisions introduced by the image-maker. With a different flavor to the terminology, we might similarly describe the technical/non-technical axis as being one dividing the domesticated or disciplined from the wild or feral. The distinction in question, as the examples below are intended to indicate, is one between a domain of features exhibiting predictability and commonality on the one hand and one of discretionary, unbounded characteristics on the other. The systematic encodings of the technical domain lend themselves to the formulation of collective imaging traditions in two senses: (1) that of grouping images themselves collectively, as in atlas-like compendia or comprehensive image environments, and (2) that of organizing intersubjective knowledge communities around the image system.

This perspective is amplified by reference to Daston & Galison's recent treatment of modern traditions of imaging and objectivity (2007). In this work, they detail how a tradition of image formation by means of machines emerged in the nineteenth century formal sciences, and document the extent to which such instrumentally generated images still depend on superadded interpretive codes for their interpretation. Despite the pursuit of 'objectivity' that this historical tradition endorsed, the products of the enterprise thus instead epitomize a particular strategy of instrument-centered 'intersubjectivity' accomplished through complex technical codings. This observation shifts our attention from absolute distinctions between scientific and other images to the details of these coding practices themselves.

Since all images contain codes of one sort or another, a few familiar examples may help to indicate some initial distinctions in this regard. Take, for example, a black and white photograph. At a basic level, the photographic image encodes the position of spatial objects by recording optical contrasts. The patterning of black and white components actually recorded on film is systematically related to properties of the objects in the image field, and it is a replicable feature of the device. Thus, it represents a 'technical' encoding in my sense, at least at an idealized level of analysis. But we encounter complications in separating the technical aspects from other ones. First, the systematic relationship itself is a complex and usually unknown one involving many factors – properties of the film, exposure, lenses, and other camera parameters as well as external light conditions. Furthermore, the pattern encoded on film is rarely the image of direct interest in a photograph. Rather, we encounter the developed and printed translation of the camera's recording, introducing yet another level of variables, some perhaps systematic in character but others irreplicable and uncontrolled. Nonetheless, the interpretive frameworks we employ for photographic images obviously provide a sufficient level of intersubjectivity to allow for widely shared translations in many circumstances. To the extent that such images, in conjunction with our frameworks for use, can transmit unambiguous information content, their technical character remains a practical - and not merely an ideal – matter.

While machine-based strategies like photography are a common approach to introducing systematic encoding, my notion of a technical image also embraces features independent of instrumental recording media. Classical traditions of painting, for instance, also exhibit many systematic features. For one, as Patrick Heelan's classic analysis (1983) details, the use of linear perspective introduces a technical encoding of spatial relationships far different from the one the human eye itself perceives. Correspondingly, our ability to adapt to and intuitively interpret such features is indication of a flexible capacity for systematic mental imaging in ourselves. Technical interpretations, though, remain a special case of our readings of images: In some symbolist traditions, color takes on a technical significance in paintings in addition to its naturalistic or common-sensical one. Yet systematic encoding of meaning through color is effectively independent of the function of color in the visual depiction itself. That is, we can recognize a person depicted in such a painting without registering the technical role that the particular colors selected for that depiction might be meant to play. In effect, the technical interpretations exist as an elective subset of the general interpretations – a notion I will return to in later sections.

We observe also, from these examples, that systematic codings may be either open or closed in their parameters. In the sense I am using the term, closed translational systems are those employing a code that comprehensively maps a particular phenomenal space or dimension into an image. One example of such a system is the 'color wheel' familiar in contemporary computer software, allowing selection of a given tint for a virtual object. This wheel maps all available colors into a closed system of choices that, importantly, is also structured into a set of comprehensive relationships– a circular space of related individual options (or more precisely, given the independent axis of black-white options, a cylindrical or elliptical one). It is a good formal model for the notion of the technical image I am proposing, insofar as it exhibits not only systematic and finite encoding of a continuum but also a phenomenal relational structure that delimits and shapes what the system as a whole can be used to represent (at most three dimensional phenomena, with special relationships of similarity and difference dictated by the color structure, *etc.*). However, such systems are not the only ones that exhibit what I am calling 'technical' character. 'Open' translational systems need exhibit no such comprehensive coverage of a dimensional space, nor any such special relationships among individual components, yet they can still qualify as technical in my sense if they exhibit translational systematicity. For example, the iconography of maps or road signs is encoded in a systematic way (one-to-one correspondence between an icon and its referent-type). Yet, it need not cover a continuous phenomenal space of possibilities, nor need there be any particular relationship among icons (beyond such trivial qualities as being perceptually distinguishable). While there often are certain discretionary relationships in iconic codes – such as the use of related symbols for settlements of different sizes on a map – these are matters of associative convenience rather than functional necessity. That is, they are choices rather than the outcome of systematic constraints included in the form of the code itself.

These coding possibilities are evident in some familiar examples from cartography: The representation of shapes or locations of geographic features represent technical features of a typical map, as they are constrained by the characteristics of the chosen projection. Other mapmaking practices such as the coloring of adjacent nations in contrasting tones are non-technical as they are effectively subjective or arbitrary in character. But we should not confuse non-technical with non-practical, nor subjective with illogical here; there are plenty of practical and logical reasons for distinguishing nations by color on a map and also to use particular color combinations to do so. The important distinction here is whether the elements of the code stand in constrained relation to one another as a condition of the code's operation as a whole (technical) or whether these relationships are 'picked' without impacting the code overall (non-technical).

Many cartographic encodings blend these approaches, as with the representation of the population and political status of cities by a set of icons that fuse a systematic representation of size with discretionary markers for capitals or other special features. In practice, most images – even in natural scientific practice – combine features of both extremes as well. However, I will be arguing here for a greater attention to technical images as a particular domain where our imaging traditions could be enriched. Even if purely technical character is only an ideal when applied to actual images, technical structure can still be achieved in images as a matter of degree. Furthermore, I will argue that this is a beneficial approach. Thus, my intention here is admittedly normative and prescriptive, and I will value one set of imaging practices relative to other interacting ones on the basis of a number of specific criteria.

To clarify these commitments, it will be helpful to consider more fully some of the different sorts of images that would qualify as technical by this definition, as the class I am trying to describe covers a number of superficially disparate domains. The three salient kinds of technical image I will address here are: (1) *instrumental images* – phenomenal traces (visual or otherwise) that encode and record one or more properties of an object by means of an intervening machine; (2)

model or map images – representations of salient characteristics of an object or objects; and (3) *virtual reality [VR] or simulation images* – phenomenally-immersive presentations of the subject within an environment of objects. I do not regard these as clearly demarcated or mutually exclusive domains of images, but a separate consideration of these three types will reveal different implications of the perspective I am proposing.

The primary distinctions I wish to draw are one dividing the typical instrumental image from the typical map or VR image, and one dividing the VR image from the other two. In the former case, there is usually a distinction in terms of *richness of information content*, with most instruments operating along what we might call a single phenomenal 'channel' and most maps and VR simulations being 'multichannel' in character. That is, in a typical instrument for probing the nanometer scale – such as a scanning tunneling microscope – we are presented with a visual image that, no matter how synthetic it is in formulation, is conveyed to the user via a single unitary phenomenal coding scheme. An example of this is seen in the visual black-and-white contrast images in Figure 3 below: all of the information content in this image is contained in this B/W coding 'channel'. In a typical map image (such as the political-geographic type in Figure 1, discussed below), a multiplicity of overlapping codes are employed: one for land elevation, another for water depth, others for population centers, regions, *et cetera.* By utilizing multiple coding 'channels', the map image – and similarly, the virtual reality image – is capable of conveying more about its subject than would be possible by a single visual code. The richness of information content thus encapsulated can be quantified by reference to the complexity of the symbol system required to encode the image.

A different axis divides the VR simulation from the instrumental trace or map: a dimension of *richness of phenomenological access*. That is, the VR simulation attempts to place the observer into a constitutively interactive sensory milieu where the boundary between the image and the observer's environment disappears. While producing such a perceptual fusion may often entail an information-dense simulation medium (as described in the previous paragraph), the goal of perceptual acquaintance here is not congruent with achieving information-density. What is sought is instead a convincing alternative experience. As one example of a phenomenal 'virtual reality' not reliant on information-dense processes of re-coding, consider the zero gravity simulators used by the U.S. space program to train astronauts. This alternative reality is created by means of an aircraft flight path in which passengers temporarily experience weightlessness in controlled free-fall. This process provides a compelling and immersive phenomenal experience, but not one especially information-dense in nature. Of course, in formulating a virtual reality simulation of nanospace, we might think more in terms of an alternative visual experience, but here too the goal remains orthogonal to that of information density: However much information might be packed into a virtual 'nanoenvironment', the primary project remains creation of a qualitative apprehension of 'being there.' It is this quest for phenomenal richness that is at the heart of virtual reality projects. In more usual images, the image appears as part of the observer's environment and the sensory capacities of the observer are not experientially fused with the imaging device. As such, the images produced by instruments or constituting maps differ fundamentally in their intended purpose from those proffering a virtual reality experience.

The definition I have proposed for the technical image, the practical traction that I think the notion provides, emerges from a conception of these two kinds of richness – of information content and phenomenological access – as desiderata. In the domain of technical images, I contend, we have a strategy for enhancing both of these dimensions of our experience of phenomena. Nonetheless, I do not wish to characterize technical images as good images and others as bad or inferior. Nor do I want to equate the technical image solely with instrumental images used in contemporary natural science. Further, the technical image is not necessarily equivalent to the informationally-rich image or the phenomenally-rich image. However, I do want to maintain that images that are technical in my sense are capable of achieving particular pragmatic ends, including levels of phenomenological access to unobservable phenomena and levels of information density that other images do not provide. Technical images obtain these advantages by way of a coding scheme that accommodates systematic disanalogies and analogies within the image itself, translating into our own experience an information-rich depiction of nano-phenomena that is simultaneously compelling within a human perceptual framework.

Insofar as they are *images*, they exhibit general semiotic characteristics that I contend are best interpreted as a type of visual metaphor. Simply put, I suggest we consider images (in the context of this paper) as symbols for phenomena, and therefore potentially similar to or different from those phenomena across a partial range of qualities. I will thus begin my discussion by examining the notion of visual metaphor itself and the advantages provided by considering images – and nanoscale images in particular – in this light. Insofar as they are *technical* elements of images, in my terminology, these semiotic characteristics also take on a particular form. This form restricts the technical image to certain representative strategies, but provides it uniquely useful capacities as well.

To demonstrate this latter point, I will draw parallels between my conception of the technical image and some related epistemological and ontological distinctions stemming from the work of Wilfrid Sellars and Maurice Merleau-Ponty. With this conceptual apparatus in hand, I then turn my attention to some different basic types of images pertinent to contemporary nanoscale research. I use these to emphasize the positive potential of technical images to enhance, in two ways, our access to the regime of the very small. I then show how a focus on these capacities of the technical image meshes with two other analyses of nano-imaging by Don Ihde and Felice Frankel.

Visual Metaphor

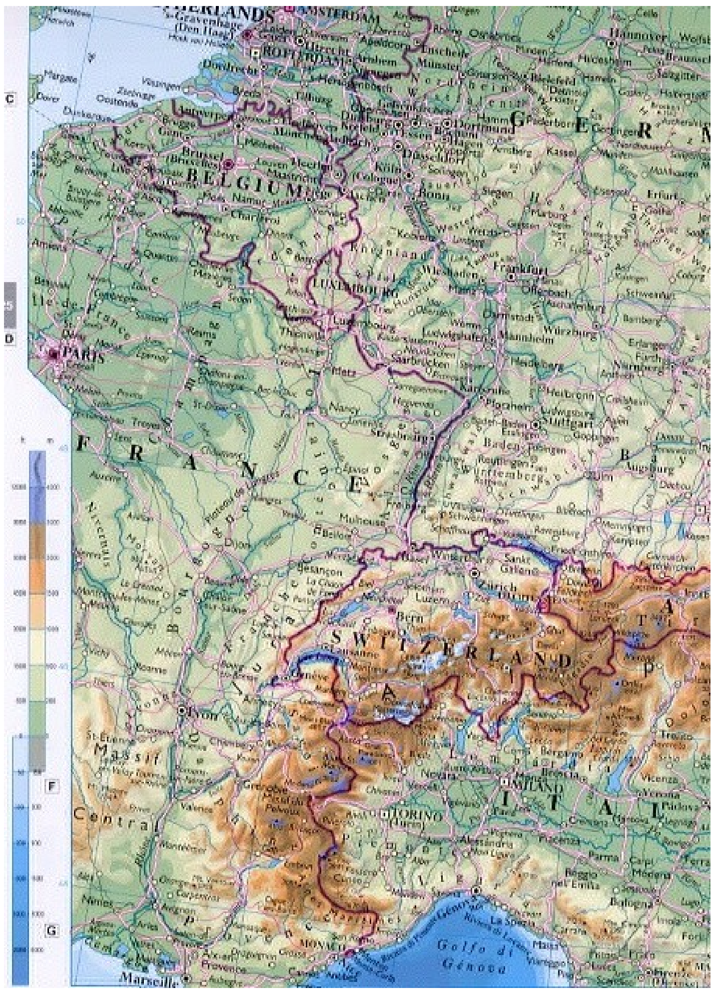
I have said that my notion of a technical image relies upon the degree of systematic encoding involved in the production of the image. What precise role, then, does a systematic encoding play in producing a particular relationship between the phenomena being imaged and the observer? My explication will proceed in two parts, the former positioning image-making as a species of visual metaphor and the latter (in the next section) examining images as potentially productive of new experiential worlds.

Discussions of visual metaphor have been most prominent in two domains of inquiry: art history and aesthetics (as in Goodman (1976), St.Clair (2000), and Carroll (1994)) and cognitive psychology (*e.g.*, Lakoff & Johnson (1980, 1999) and Seitz (1998)). However, I maintain that this is also a useful framework within which to consider imaging technologies. The above-cited review by Seitz examines different models of metaphor and concludes that the best approach to the semiotic role of metaphor is a cognitive, or symbol systems, perspective. Seitz suggests that such a view is compatible with the work of both Goodman and Lakoff & Johnson, but uses Goodman's *Languages of Art: An approach to a theory of symbols* (1976) as a primary reference point. This model understands metaphor as not exclusively or especially verbal, but rather a general process of "the transfer of properties across symbol systems." (Seitz, 1998) By means of such encoding processes, we establish an economy of analogies and disanalogies – what Goodman calls a set of "calculated category mistakes" – among different symbolic regimes.

For example, both the mesoworld and the nanoworld are known to us through mental frameworks or models (*Image*$_3$). Interactions between ourselves and those worlds is enabled by these mental frameworks, which are themselves constituted by symbol systems. But the nanoworld exists for us *only* through instruments, and principally through instrumental images (*Image*$_1$). In Seitz' terminology, these images are the medium for 'transfer of properties' between the nanoworld and the mesoworld. From Lakoff & Johnson's similar perspective, the nanoworld would instead be regarded the 'target domain' that we attempt through metaphor to understand. The 'source domain' from which we draw our metaphors, is the mesoworld. But since the actual images that serve as our medium are themselves phenomenal mesoworld entities, they intrinsically limit the potential for creation of productive analogies with the nanoworld. When coding images systematically by way of a scientific algorithm, we are also necessarily coding them within a particular perceptual framework for interpretation. Thus, in suggesting that we should regard the technical image from this perspective as one that is *systematically* encoded, I am marking out a special status for those images in which the use of visual metaphor is effectively predetermined by a schema of constraints on content. These constraints are productive ones in the sense that they provide an avenue for the creation of metaphorical bonds between not just individual images (*Image*$_1$ or *Image*$_2$ in my earlier development) but between entire contextual image frameworks (*Image*$_3$).

In the next section I will supplement this perspective with some additional notions about mental images and frameworks for their interpretation, but some initial observations that point toward these developments are possible now. The metaphorical links described above organize our experience into what might be called either 'experiential gestalts' or 'lifeworlds'. As already suggested by my use of 'nanoworld' and 'mesoworld,' these frameworks are ultimately local in their coverage and many can exist in our minds without need for coherence. It is this multiplicity of contexts that demands the creation of symbol systems for translation. But, returning to Goodman's descriptive phrase, only in some such worlds can the 'calculated' disanalogies involved between symbolic 'categories' properly be considered 'mistakes.' Some interpretive frameworks – including those we use to systematically encode images – depend constitutively on cross wiring of categories in this way and within such a domain such decisions are anything but mistaken. However, in frameworks of a different kind – those directly dependent on phenomenal expectations, for example – we do run the risk of mistaking source and target domains in the sense Goodman indicates. I will reconsider this distinction in my discussion of specific nano-imaging examples below.

Returning for now to the familiar regime of mapmaking, we observe that the content of a typical relief map in an atlas is effectively predetermined by means of the color, icon, and other codes described in the legend. Each of these symbols is functional within a larger system, with color typically coding both for elevation and for correlated phenomena such as terrain or ecology (blue for water, green for low-lying grassland, brown for hills, gray for mountains, *etc.*). These exemplify the salient characteristics of the technical image, which ideally would contain only



rigidly encoded information, with the basis for the coding (which we might also call $Image_3$) determined prior to formation of the particular image ($Image_1$). The technical features of the coding are also, importantly, adjusted to characteristics of the human perceptual system. For example, while the particular choices of tones used for elevation and depth can be informally correlated to environmental features (as just explained) they also, as a set, lie in a perceptual continuum. The land elevation colors – while muted – are arranged in a spectral order: not the canonical seven-fold 'ROYGBIV' spectrum running from Red to Violet, but one approximating an 'IVROYG' ordering from Indigo to Green in nine tonal increments. The remaining blue tones used for water are ordered by a black-white value component. Thus, the arrangements take advantage of a shared pre-formed perceptual coding of colors that allows for easy interpretation by analogy.

Figure 1: A typical cartographic representation of a region of central Europe, excerpted from the Oxford Atlas of the World, eleventh edition (2003).

Taken as a whole, this is an image that is both systematically like and systematically unlike the things it portrays. Furthermore, its coding scheme – shared and explicit throughout the atlas – provides a fairly comprehensive template for acquainting ourselves with and interpreting the entire set of images therein. It employs this ordering of already familiar perceptual categories (Lakoff and Johnson's 'source domain') to refer to another finite set of phenomena of interest (the 'target domain'). In a technical context, the visual metaphors that are introduced between target and source provide an avenue for effective translation. In this respect, it is the translational system itself – what I called above an 'economy of analogies and disanalogies' – that is of primary interest, directing our attention to matters like the arrangement of scalar continua and icon keys. Yet, the image also importantly participates in another interpretive context at the same time, one that demands that the map be 'like Europe' for us in a fundamentally different way. It is in this context where particular code choices such as mimicking grassland and mountain colors are generated – the decisions that render the map a compelling portrayal of its subject and lend it a degree of similarity to an aerial photograph of the same region. To distinguish these domains more clearly and relate them back to the two technical imaging desiderata I introduced in the previous section, I will now turn to some related concepts about images already available in the philosophy of science and technology.

The Technical Image & Philosophical Image Worlds

My development here will rely on a synthesis of pragmatic and phenomenological perspectives on images. I will begin by suggesting a way to understand my perspective on technical images within the 'stereoscopic' synthesis of manifest and scientific viewpoints proposed by Wilfrid Sellars. It will emerge that a central difference between my perspective and Sellars' is that between a discussion of literal images utilized in a social milieu and one of mental images employed in the individual mind. Nonetheless, I believe that Sellars' position amplifies my own by clarifying the relationship between systematically-constrained semiotic codes and the discretionary ones of day-to-day existence. To further develop this relationship, I will move from Sellars' system of image spaces to an interpretation of Merleau-Ponty explicated by Dreyfus and Todes (1962). This will shift the discussion into the domain of embodied phenomenological 'worlds', where I will suggest some consequences of my notion of a technical image for the extension of our lived experience into the domain of unobservables. This argument relies on the already established conception of images as a form of (primarily) visual metaphor, wherein levels of systematic analogy and disanalogy with our typical experience serve to delimit our phenomenological access to certain phenomena.

The distinction I propose between technical and non-technical images is first and foremost about actual physical images ($Image_1$). Nonetheless, it is importantly congruent with a mental image distinction drawn by Wilfrid Sellars in his seminal paper "Philosophy and the Scientific Image of Man" (1962). Therein, Sellars argues for an epistemology that preserves in "stereoscopic" perspective two ways of seeing the world. One, the manifest image, represents the 'common-sense' picture of the world we develop through the mediation of symbol systems in general. The other, scientific, image is an outgrowth of the manifest view that whittles down the contents of the world to a set of physical structures and properties that are systematically related to one another in a theoretical frame. A proper philosophical understanding of what our knowledge consists of must, Sellars contends, retain both perspectives in order to do justice to our experience. It is in the same spirit that I suggest we distinguish technical images – images that will, in Hacking's famous terms, allow us to "represent" and "intervene" in a technoscientific manner – from non-technical ones that provide us only a commonsensical and *ad hoc* depiction of phenomena. My intention is not to eliminate one sort of image-making tradition in favor of the other, but to identify the special characteristics of one with respect to the other and thereby to highlight the complementary nature of the two - in short, to consider the technical image, and the prospects for its enhancement, in 'stereoscopic' terms. These stakes will be more obvious when we introduce an explicit phenomenological element to the discussion. This will allow us more easily to make the leap from Sellars' mental images to the role of actual technical images in creating a mediated experience of theoretical phenomena.

While Sellars' immediate concern is to relate the formulation of scientific theories to our mental process at large, Maurice Merleau-Ponty's approach to images begins from a different standpoint. The latter's *Phenomenology of Perception* (1945/1962) addresses the problem of how technological artifacts such as images assist us in broadening our existential milieu. In this pursuit, he is insistent that we must regard the mental states discussed by Sellars as embodied phenomena instantiated through physical entities. Merleau-Ponty thus emphasizes, in a way Sellars does not, an explicit role for actual images (my $Image_1$) in his discussion of the human-world interface. Since for him both our own existential situation and the phenomena of the world are co-products of a relational process of development, actual image media and their phenomenal qualities are of crucial interest in establishing our orientation to the world.

Merleau-Ponty's attention to embodiment helps to link Sellars' model back to our earlier discussion of visual metaphor and its limitations. In particular, Sellars' exclusive focus on an idealized mental image domain does not, by itself, indicate clearly the systematic constraints that are imposed on coding systems by our existential status in the world. While Sellars and Merleau-Ponty are equally adamant that we regard our knowledge processes as mediated through acquired image frameworks ($Image_3$), the phenomenological perspective on imaging technologies presented by Merleau-Ponty strongly attaches constraints of physical constitution to the problem of mental framework development. This move could be interpreted as one from issues of knowledge systems to those of an emergent 'natural' ontology but the broader view proposed by Merleau-Ponty identifies these as inextricably connected. Given this relational state of affairs, a shift from epistemological to ontological concerns is best construed not as an absolute disjunction but as a difference in emphasis – from 'what we can *know*' to '*what* we can know.'

The complementarity of the Sellarsian and Merleau-Pontian approaches is further reflected in the similar analytical structures that they provide for distinguishing among image frameworks. In a paper explicating Merleau-Ponty's work, Dreyfus & Todes (1962) argue that we can understand him as proposing three distinct experiential 'world'-types characteristic of our distinctively embodied existence. These are: (1) a *pre-personal world*, (2) a *lifeworld*, and (3) a *scientific world*, each of which represents a particular interpretive mode. Despite important differences between Merleau-Ponty and Sellars with regard to the implications of these experience-structuring 'worlds', this framework can be understood as according with Sellars' model of stereoscopic manifest-scientific existence. This is especially the case when we note that Sellars' model is essentially tripartite as well, including what he terms an "original" image alongside the manifest and scientific ones he attends to in most detail.

With this additional apparatus in hand, perhaps we can begin to comprehend the intimate connections advertised at the outset of this paper between various aspects of imaging. The common ground between the Sellarsian *original image-manifest image-scientific image* conception and the Merleau-Pontian *prepersonal world-lifeworld-scientific world* conception is, I take it, the following: In each level of the two systems, we can identify a particular modality of human experience encompassing semiotic, epistemological, and ontological concerns. Further, the qualitative character of these modalities is largely the same in both philosophical schemes. Mode I is a space of perceptual possibility constituting a transcendental limit on experience. That is, both Sellars' original image and Merleau-Ponty's prepersonal world are domains where the relationship of the subject to its environment is entirely unclear and waiting to be resolved by experience. This mode sets limits on what can be a sign for us, what we can know, and what we can take the world to consist of; it is an effective bound on what experience we can develop. Nonetheless, the sensory-motor potentialities with which we are endowed in this state can develop into Mode II by a process of categorization. Mode II, the manifest image or lifeworld state, is one in which the status of subjects and objects has been clarified and we exist in a richly phenomenal milieu stabilized by experience. Mode III, the scientific image world, is one populated not by phenomenal objects but by theoretical entities standing in constrained relation to one another. In other words, the scientific world is one bounded by postulated structures and properties regarded as underlying normal experience. While more phenomenally sparse than the Mode II world, it consequently provides instrumental advantage for us, allowing us to obtain what Merleau-Ponty calls "maximum grasp" on entities for purposes of intervention in our environment.

What do these models add to my discussion of the technical image? The progression from Mode I to Mode II to Mode III traces a focusing process in which we obtain leverage on the world by developing semiotic systems of representation and intervention. Images of various types play fundamental roles in this process. Furthermore, the three sorts of technical images I have identified address these modes differently and thus demonstrate different implications of valuing technical images. The Mode III 'scientific' world is one based on finite algorithmic characterizations of phenomena, especially as formulated quantitatively. The leverage provided by such characterizations is a direct result of this minimalistic and circumscribed framework (*Image*$_3$), not only because of its representational effectiveness but also because of its related capacity for enabling action. As Ian Hacking's (1983) account of representing and intervening reminds us, these two aspects of the scientific project are related facets of the same problem – attaining "maximum grasp" is simultaneously a matter of depiction of, and intrusion into, a phenomenal domain.

At first glance, this Mode III role might appear to cover the significance of the technical image as I have described it; if systematic encoding is the salient feature of such images, then the scientific modality, as just described, appears to provide a reasonable framework for their formulation and use. The model provided by Sellars, centered as it is on the mental domain, might accommodate this move. However, as my development up to this point has tried to indicate, the embodied situation detailed by Merleau-Ponty militates against such a tidy characterization. To obtain this kind of theoretical systematicity, we and our images must take part in actual phenomenal processes. In so doing, we encounter obstacles related to the other two, non-scientific, modalities. These help to indicate, in a way that Sellars' own discussion does not, definitive 'manifest' elements of the technical image that must be taken into account.

The Mode II domain of Sellars' 'manifest image' and Merleau-Ponty's 'lifeworld' is the framework within which the processes of visual metaphor actually operate within our embodied minds when interpreting an image. This domain is quite flexible in its capacities for structuring phenomena, especially when using instrumental supplements. We can simulate red-green color blindness using special lenses, and thereby also resystematize the significance of color. We can also superimpose instrumental images (such as infrared or ultraviolet 'night vision') onto our normal visual mode. Yet this flexibility has limits dictated by the Mode I domain. We cannot, for example, introduce a new color between yellow and orange in the spectrum (infinite gradations between them, yes; but a distinct new intermediate, no). Nor can we introduce a new spatial dimension into our visual field in the way we introduce an orthogonal component into an equation. As such, both Modes I and II are directly relevant to the analysis of even technical images of the kinds I am considering.

In the case of instrumental traces, the constraints placed upon a technical image are artifacts of the device itself. This is the classic sort of technological mediation described in innumerable sources from Heidegger's hammer onward; the device effectively serves as a surrogate subject for us, recording phenomena we might not otherwise observe. In essence, the instrumental image is a product of a metaphor machine, where the depiction makes manifest – introduces into our lifeworld – some phenomenon. In some sense, the metaphorical relations behind the image must be built into the device itself in order for it to function. In other words, instruments of this sort have embedded in them theoretical constructs. We might also say that the scientific instrument relies upon prior Mode III coding to produce phenomena to be interpreted in Mode II.

Maps, or models, differ from instrumental traces in that the process of depiction usually involves no physical instantiation of theory (no machine coded to produce the image) but rather discretionary action on the part of a subject. That is, the map is an artifact of someone working in Mode III to produce phenomena to be interpreted in Mode II. By contrast, the typical painting – unlike the map – is an artifact of someone working in Mode II to produce phenomena to be interpreted in Mode II.

Perhaps the most interesting case – that of the VR simulation – is one that aspires to create a kind of substitute Mode II existence. Like the typical instrument, the VR system relies again on Mode III type encodings, yet it must also serve the task of creating not just a depiction but an immersive experience as well. In so doing, I think, the VR simulation can run up against constraints not just from Mode III but also from Mode I. To see how this is the case, let us return to the notion of the technical image as one displaying systematic constraint by means of a metaphorical coding of analogies and disanalogies with our Mode II existence.

Consider the problem of translating a system of simple auditory tones into a system of simple color tints, or what I will call the 'sight-sound synaesthesia' problem. I will take as given both that perceptual relations as I characterize them require the pre-existence of particular developed mental models and that the relations being mapped only partially capture the phenomena in question. This case thus helps instantiate the reduction process described by Sellars in the shift from manifest to scientific perspective. The translation between sound and color is an incomplete one on both ends (hearing being far more than perception of simple tones and color sight far more than perception of simple tints). We can nonetheless, from a certain scientific standpoint, accurately model each of these phenomena – sound and color – as continua. Thus, a one-to-one mapping of a given range of tonal frequencies onto a given range of hues can easily be achieved. In fact, many different one-to-one mappings of this sort are possible. However, in the manifest view, both of the phenomena in question exist within particular associative structures and are experienced in this more complex relationship. I discussed this issue in detail above regarding the color wheel, or color cylinder, system. A similar model can be formulated for auditory tones, which are (or can be) perceptually related in harmonic cycles – a phenomenon missing from the space of color hues.

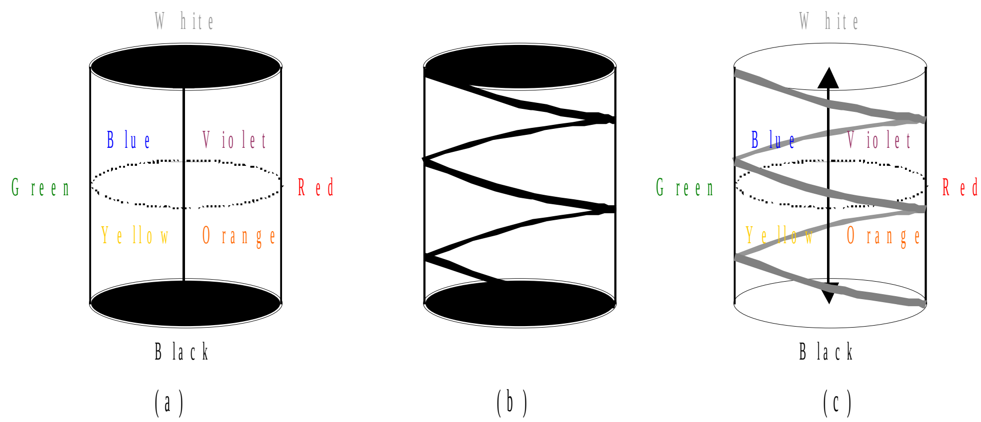


Figure 2: Disanalogous Structures of Perceptual Color and Tone: (a) schematic representation of color solid; (b) schematic representation of harmonic tone cycles with vertical distance between cycles indicating octave interval; (c) superposition of color and tone, showing incompleteness of mapping.

Just as we can utilize a cylindrical color structure (Figure 2(a)) to indicate perceptual relations contrast and resemblance among colors, we can utilize a cylindrical surface to map these tonal relations of sound: By representing the tones as a spiraling sequence around the surface of the cylinder (Figure 2(b)), we can capture the perceptual similarity of tones falling into harmonic-octave relationships as well as delineating a continuum of frequency. We can translate this more structured sequence into colors as well, but now only in a more constrained fashion if we wish to maintain the same content. For example, we might map this spiral onto the surface of the standard color cylinder already discussed (Figure 2(c)). Such a mapping would have the useful feature of indicating all tones in harmonic-octave relationships as similar in tint (*i.e.,* positioned at an identical radial angle on the cylinder) but different in black-white value (vertical location at a given radial angle). This translational scheme thus offers certain advantages over the simple mapping of continuum to continuum, but it also demonstrates a formal incongruity between sight and sound in systematic structure – a mapping of a phenomenon that is comprehensive (all possible tones fall on the spiral) onto one that is not (not all possible pure tints fall on the spiral). In other words, the denotative significance of a sign within one system is not congruent with that of one within the other. It is just this sort of disanalogy that provides a potential manifest limit on translation between disparate phenomena. The scientific 'model' can restrict itself to primary qualities, abstract codes and equations, and the like, but the scientific 'image' *qua image* – whether physical or mental – cannot. Even for mental images, this limitation appears for reasons described by Merleau-Ponty: Our mental images are embodied ones and depend on (Mode I) as a possibility space as well as on (Mode II) as an empirical existential lifeworld.

We interact with the technical image, as with any image, in a stereoscopic way, 'seeing double' through both scientific and manifest lenses. Scientifically, the image conveys a complex of data, as when a map allows us to 'see' the state of Germany by means of icons or codes that indicate elements of that technical construct, the German state. In a manifest mode, we also 'see' on the same map aspects of the common sense image of Germany the location: Its qualities of terrain, size, climate, etc. The two image modes are anything but exclusive, yet their practical implications for technical image interpretation are quite distinct. Through systematic encodings, a technical image provides an information medium that should, in a scientific modality, be entirely transparent: Within the corresponding coding framework, the technical image promises to offer unambiguous content with machine-readable objectivity. However, this systematic theoretical role necessarily depends on embodied instantiations. As a result, the more dense the technical coding, the more phenomenally rich the embodied image must correspondingly be. Furthermore, this image – to convey to us – must have a structure we can apprehend, but the phenomena it depicts need not be structured in this way.

Some Current Trends in the Analysis of Nanoimaging

With this perspective established, I will now consider the consequences of my notion of a technical image for several sorts of technical representations of nanospace – the domain of atomic-level phenomena now being explored in contemporary materials engineering. First, I will briefly suggest a symmetry between methods of modeling the entities of the nanoworld and those of our normal experience, insofar as their common object is to establish relevant physical regularities (and, correspondingly, operative constraints on image content). I will also examine some conclusions by two leading investigators of imaging in contemporary technology, Don Ihde and Felice Frankel, to see how they mesh with my own perspective.

So far, I have given only a brief sketch in principle of how the technical image fits into a pragmatic phenomenology of imaging technologies. Now, I will turn to the question of the relationship between imaging phenomena at the atomic scale and imaging on the more familiar 'meso' scale available to bodily perception. My approach here is indebted to the path described by Don Ihde's phenomenological program of instrumental realism, and I find many points of commonality with this work. Ihde's conception of technologies as mediating and extending our manifest world (Ihde, 1991), his criticism of visualism as a basis for rich phenomenal experience (Ihde, 1999), and the non-reductive ontology that characterizes his approach (Ihde, 2001) all resonate fully with my framework. Nonetheless, I am concerned that some of Ihde's recent work might be interpreted as suggesting a kind of symmetry among all scales of technical images.

Specifically, Ihde has recently stated his opinion that virtual reality simulations of the atomic or molecular scale can be regarded as fundamentally equivalent to virtual reality simulations of, for example, piloting an aircraft or viewing our galaxy from above (Ihde, 2003). However, the equivalence Ihde has in mind here is of a different category than the distinctions I am concerned with. Ihde's intention is to indicate that these various simulated spaces are all at present similarly inadequate as phenomenally immersive experiences. These comments are motivated by his commitment to an ontology encompassing an array of sensory modalities beyond the visual, to which I am sympathetic. However, I propose that this orientation has led Ihde to ignore certain details of embodied imagistic simulation that appear even within the visual domain itself. My insistence on difference has instead to do with the process of encoding involved in the creation of a technical image: A technical image is one that creates a functional coding of phenomena by means of visual (and perhaps other) metaphors. In the case of a virtual reality simulation, this encoding attempts to create an immersive environment. In order to refer to functional (or "instrumentally real") phenomena, the simulation must be technical in character. To be immersive, it must also be a multi-sensory image (not just a visual one), and it must create a phenomenologically convincing experience – the formation of a lifeworld.

Now, phenomena at the nanoscale are obviously observable (perceptually accessible) *only* in a metaphorical sense. Furthermore, the set of phenomena that are relevant at the nanoscale are fundamentally unlike those we perceive at the mesoscale. For example, nanoscale entities (as they are theoretically understood) are not fixed in space or time in the way we normally understand objects, nor as a consequence do they exhibit familiar characteristics such as solidity or texture. Quantum mechanical and quantum electrodynamic properties in particular are uncanny to us in our normal reference frame. Even such phenomena as electrostatic interactions are difficult for us to interpret by means of unaugmented sensory perception. Conversely, at the atomic scale, such familiar phenomena as light and sound have vastly different implications. Thus, a technical image of the nanoscale, constituted through the phenomenal variables of our mesoworld, will incorporate the same kinds of structural disanalogies we observed in the synaesthesia problem in the previous section. The incongruence that matters in this regard is between the nanoworld itself, as object or 'target' of imaging, and the Mode I mesoworld space of human perceptual possibility out of which both the manifest and scientific viewpoints emerge as dual 'sources' of image content. The more comprehensively we attempt to map between the two domains, the more metaphorical leaps of this sort will appear. Given this situation, the achievement of rich nanoscale virtual reality appears to be a tall order.

It thus seems to me that we have several options: (1) Perhaps we are simply stuck with a phenomenological limit on our access to the nanoworld. In this case, the bulk of disanalogies between the nano and meso scales would simply be too great to bridge and no compelling virtual experience of atoms would be possible. (2) Perhaps the best we can do is combine thin functional access to the nanoscale with a rich phenomenal fantasy. This, I think, is what happens in Ihde's equation of the flight simulator to the molecular simulator – the two may be equally convincing as experiences, but are disanalogous in that one closely models the actual experience while the other models something that does not exist. What we effectively have here is a model of nanospace, but not a virtual reality. (3) Perhaps rich phenomenal access to the nano world is possible, but if so it will involve disanalogies with normal experience powerful enough to create substantial incommensurabilty between the domains. In substituting a phenomenal coding capable of functionally representing nanoscale entities for our normal perceptual coding schemes, we would need to step out of one world and into another. This third option is the one I find most satisfying, although I admit the possibility that the first is correct. What I want to argue against (option 2) is the propagation of illusion as the opening of a new domain of phenomenal access.

Ihde's claim of equivalence across scales for virtual reality is, in effect, a tacit criticism of the phenomenal thinness of contemporary practices. The practical equivalence of simplistic single-channel visual simulations of very large, mid-sized, and very small phenomena indicates for him equivalent prospects in each putative virtual reality domain, by introducing more comprehensive modeling to capture relevant details better. But if the view I am forwarding is correct, this is the point where the equivalences end, as the scale regimes impose particular constraints on imagistic translation. On the issue of atomic-level virtual reality simulations, I thus emphasize – as a supplement to Ihde's perspective – an asymmetry between the nanoscale and the meso and macro scales. We are either stuck with a phenomenally thin picture of the nanoscale or we must admit a structural asymmetry introduced by our partial perspective as embodied human investigators (for more on the notion of partial perspective, see Haraway (1988)).

My criticism of Felice Frankel's promotion of a visual culture of science is similarly directed. In a recent contribution to *American Scientist*, the magazine of the Sigma Xi Scientific Research Society, Frankel interviews two prominent players in atomic-scale imaging – Don Eigler and Dominique Brodbent – and presents their depictions of a so-called 'quantum corral' as "icons" of current scientific practice. These images, which graced the covers of *Science* and *Physics Today*, are enhancements of an instrumental trace demonstrating the researchers' capacity to arrange iron atoms in a circle on a copper surface to create a contained pattern of electronic resonance inside. My analysis will proceed by a comparison of various views of the same quantum corral, arguing that the technical content of these images is effectively identical despite their differences in appearance. This will in turn provide an opportunity to consider how contemporary practices of nanoscale imaging approach the problem of providing both scientific and manifest access to their target domain. The images in question are shown in Figures 3, 4, and 5 below. The first of these is a gray-scale image in two parts, showing a rearrangement of atoms over time, from a initial disordered state in Figure 3(a) to an ordered one in 3(b). As a brief aside, we may note that this pairing emphasizes the connection between representing and intervening at this scale advertised in my earlier discussion of Hacking – the image pair shown in this figure not only *reflects* our ability to intervene among these atoms, but is itself a constitutive element of that intervention. However, the main distinctions I wish to emphasize are between the image in Figure 3(b) and those in Figures 4 and 5. These all represent the same physical configuration of atoms, but the latter two introduce elements of three-dimensional perspective and color that are missing from the black and white overhead view on which they are based.

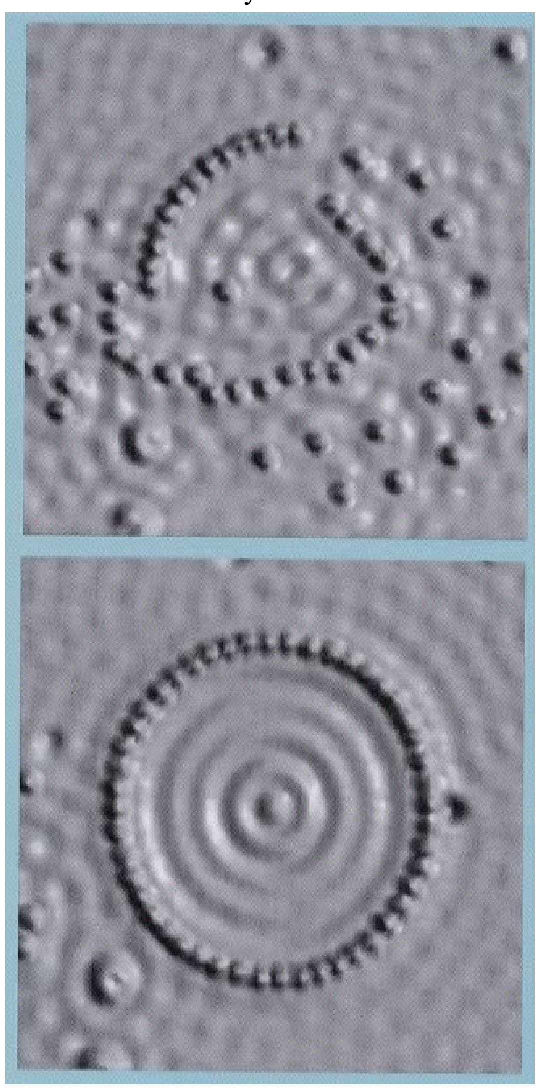


Figure 3: The 'gray corral' image showing the quantum barrier under, and after construction, using gray scale shading. From Frankel (2005).

Figure 4: The 'orange corral' image created by Don Eigler for the cover of *Science* magazine, as reproduced in Frankel (2005).

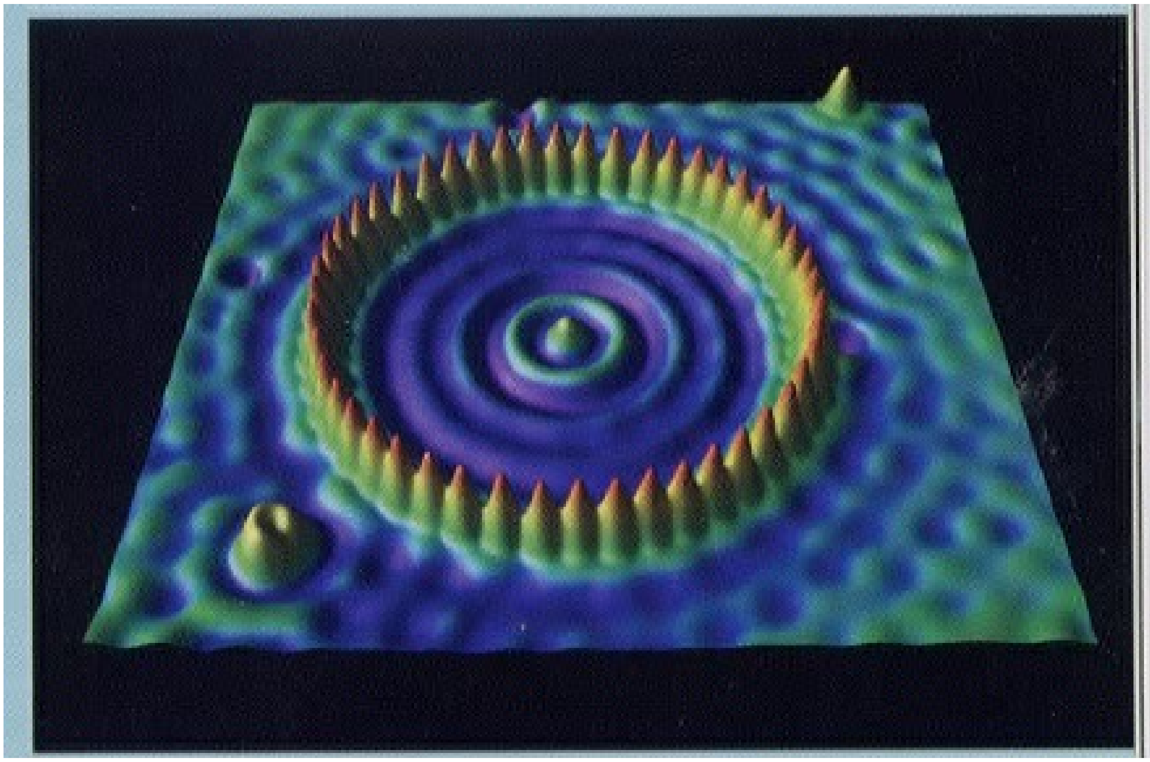


Figure 5: The 'blue corral' image created by Dominique Brodbent for the cover of *Physics Today*, as reproduced in Frankel (2005).

Eigler and Brodbent's products are compelling images, but for largely non-technical reasons. In fact, both researchers describe to Frankel quite vividly the discretionary choices they made to accentuate the phenomenal impact of the data they have imaged. Here are some typical quotes from Frankel's article, with the interviewee identified:

> Don Eigler: "I wanted to create an image with as dramatic a perspective as possible… I chose the colors, "lighting conditions" and point of view of the observer to suit the purpose of the moment."
> Don Eigler: "I began to apply paint. It was a matter of…searching for the combination of perspective, lighting, surface properties and color that communicated what I wanted to communicate."
> Don Eigler: "I wanted others to share in my sense of being an intimate observer of the atoms and the quantum states of the corral."
> Dominique Brodbent: "For the blue corral…the separation effect was achieved by coloring the surface by height, using a color map that assigns a single color to a particular height above ground. There are far fewer degrees off freedom to handle compared to the technique described above." (All quotes, Frankel (2005))

Clearly, too, Eigler and Brodbent are describing distinct practices of image enhancement. Eigler's strategy appears, in my terms, entirely non-technical (see Figure 4). No trace of systematicity is evident in his process; rather, he characterizes the image formation as a 'search.' His language – of choices, personal communicative desires, and the achievement of intimate acquaintance with the subject is distinctively geared towards a manifest, or Mode II, conception of the image. Furthermore, this conception is itself a fairly thin one; what Eigler describes as the experience of 'being an intimate observer' is precisely the sort of single-channel visual illusion discussed earlier in relation to Ihde's position on virtual reality images. As I will elaborate in my conclusion, this minimalistic conception of observation – what we might call the 'Maxwell's demon' perspective – is more appropriate to a Mode III scientific interpretation than to the purposes of phenomenal acquiantance that Eigler advertises.

Brodbent's approach, by contrast, appears to fit better with my conception of a technical image. However, we should note that the encoding of the blue corral described by Brodbent introduces a color scheme redundantly over an already existing topographic representation of height in black and white (see Figure 5). While we might observe that this superposition of color onto the 'terrain' assists the eye in directional orientation, it serves the primary purpose in this image of accentuating rather than adding information. As such, I contend, both Eigler and Brodbent's enhancements leave the technical content of the image unchanged, relative to the more sparse Figure 3(b). Here too, as with the nanoscale 'virtual reality' situation described above, we are in danger of substituting a compelling illusion for a richer depiction of the domain being imaged. And, of course, this is perfectly understandable when we recognize the purpose of Eigler and Brodbent's corrals as selling their research rather than putting us in a position to experience the nanoscale as such.

Still, we should not confuse rich access to the nanoscale with vivid representation of the nanoscale. Frankel's observations ignore the positive role of technical constraints in favor of an 'aesthetic' approach to image manipulation that does little justice to either the scientific or manifest potential of technical images. Frankel praises the manipulation of nanoscale images by workers like Eigler and Brodbent, as she sees in them parallels with longstanding practices of artistic depiction. On this basis, Frankel argues for a strengthened visual culture in science that will make the objects of the nanoworld more vivid to us. But is strengthened visual culture only a matter of vivid representation? No. It is also a matter of technological access. My objection is based on the premise that such approaches – which doubtlessly do enhance our experience of *the images themselves* – do little or nothing to enhance our experience of *nanoscale phenomena*, either from an informational or a phenomenal standpoint. Instead, images of the type Frankel discusses typically use false color, shading, and filters to highlight features already on display rather than to introduce new information. The result, I contend, is a characteristic 'thinness' of nanoimages both informationally and phenomenally. By contrast, an alternative attention to the technical features of nanoimages would push the visual culture toward richer and more functional mappings of nanospace.

Conclusions

We ask our images to provide certain things for us. Problems arise when we mistake what they have provided for something else – for example, 'familiarity' of an image with 'usefulness' of an image. The technical image, as I have defined it, lends itself to certain tasks. In particular, as I have tried to demonstrate, it is conducive to attaining dense transfer of information that is also phenomenally rich. As such, strategies of improvement for technical images must not only attend to theoretical systematicity of encoding but must also take seriously the problem of embodied translation between incommensurate manifest domains like the atomic scale and the human scale. What is demanded by advocates of nanoscale virtual reality and by Eigler's search for observational intimacy is not a disembodied and impotent seat among atomic phenomena but an experiential engagement with them. In other words, virtual nanospace reality asks us to be in a situation like the entities of that regime. The difference between the situation of a Maxwell's demon in nanospace and the situation of an atom in nanospace is one of embodied engagement in the latter case. Transferring our human embodiment down to the level of atoms thus means much more than the capacity to render that domain visually familiar.

Frankel's strategy, for example, succeeds only in a subdomain of the Mode II world: It provides vivid aesthetics to the image – a (largely false) feeling of familiarity and acquaintance – but without an actually rich experience of the relevant phenomena. This, I maintain, is an impoverished conception of what it means to participate in a manifest world. Even this pursuit of compelling illusions, though, indicates an important instinct evident in contemporary scientific work. Researchers at the nanoscale are clearly conscious of the value of Mode II 'lifeworld' engagement with their subject matter, especially when it comes to conveying these results to the lay public. What they appear to have failed to recognize, though, are the full technical implications of this desideratum in relation to 'scientific' ones. Engagement with the manifest, phenomenal world is not merely about vividness ("That's a striking red") or valence ("I love that shade of red"), but also contextual interpretation – the experiential relationship of phenomena, such as color contrasts or sonic harmonies (resemblances) in my synaesthesia example. The significance of an image emerges within a perceptual structure of such relationships, and these too are elements of our embodied Mode II worldview.

My argument, then, has essentially been about what we mean, and what we might mean, when we claim that we can now 'see' atoms or 'gain access to' the nanoscale. I want to hold claims of this sort to a fairly high standard. By deploying the notion of a technical image, I intend to indicate a pathway towards a richer use of phenomenological perspectives in technoscientific work. By focusing on the specific constraints required to encode functional properties of phenomena in images, I hope to encourage the development of a stronger tradition of imaging (like Frankel). I also believe, like Ihde, that such a tradition – to give us rich manifest experience of a lifeworld – must be one that transcends the limits of visual phenomena in favor of a more comprehensive semiotic positioning of the observer in a perceptual space. My criticisms have been directed at a seeming credulity about what a richer phenomenal experience consists of. On the one hand, Frankel appears to license the introduction of convincing but fantastic elements into images purporting to represent a novel space. On the other, Ihde's comprehensive skepticism about the state of the art in virtual reality may obscure important differences between imaging at different scales. By contrast, I want to advocate a strict standard – by analogy with cartography – for representation and intervention at the atomic scale, not merely as a corrective to nanohype but also to encourage the production of images that can better convey to us the pragmatic possibilities for us to incorporate aspects of the nanoworld into our perceptual frame. I also want to insist on ineliminable asymmetries between the nanoscale and our normal scale of perceptual experience. These can be understood as variations in the visually metaphorical character of representations of the two regimes.

I employ the notion of a 'technical image' to argue for an interpretation of instrumental imagery that relies less on concerns about truth or reality than about those of efficacy. Accompanying this perspective is a set of normative considerations that impose constraints on what a proper technological image should be. These include an understanding of images as semiotic systems capable of conveying claims, attention to interpretive flexibility and its limits in actual images, norms of minimalism and coherence associated with such images, and a contraposed norm that militates for maximal coupling between imaging codes and our perceptual capacities. In these terms, we can view the problem of imaging nanospace as reliant upon levels of constraint in visual codes, levels of phenomenal detail involved in such coding, and other related issues. In short, I hope to replace discussions of realism with discussions of efficacy, or of functionalism of structure and properties, in the domain of images.

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Gilbert Simondon and the Dual Nature of Technical Artifacts

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1. Philosophical reflection on technical artifacts: why read Simondon?

Philosophical interest in technical artifacts is a fairly recent matter. For a long time, philosophy of technology was more concerned with broad issues such as the influence of technology on society and culture. At such a high level of analysis, the influence of individual artifacts was out of sight, or at best an example for illustration. In the past decade or so, a more analytical approach emerged in the philosophy of technology, accompanied by an 'empirical turn' that stimulated an interest in reflection on more specific and concrete technological developments. In that context the analytical reflection on technical artifacts emerged. Well-known is Randall Diperts' book 'Artifacts, Art Works and Agency' for the way he distinguished natural objects, tools, instruments and artifacts[1]. Other contributions were made by Van Inwagen, Wiggins, and Lynne Rudder Baker[2]. Probably the most extensive effort in this realm was the "Dual Nature of Technical Artifacts" research program that was carried out at the Delft University of Technology in the Netherlands. This program aimed at developing an account for technical artifacts by describing them in two interconnected ways: on the one hand the artifact can be described in terms of its physical properties (its size, shape, weight, color, etc.) and on the other hand it can be described in terms of what it is meant for (its functional properties). The functional properties are relational (intentional) in nature, while the physical are not[3]. Both designers and users reason about artifacts by making connections between these two descriptions. One of the insights that this program produced was that designers not only create a new artifact, but also a use plan for it[4]. Elements of the concept of a use plan were present in earlier literature (such as the idea of a script in artifacts, as developed by Akrich and also Latour), but the use plan in the Dual Nature account is elaborated in terms of action theory. Users may follow the designer's use plan, or come up with their own use plan.

It may seem that the recent interest in analyzing the nature of technical artifacts was not preceded by any earlier efforts, but this is not the case. At least two philosophers can be mentioned as early philosophers of technology who wrote on technical artifacts: Gilbert Simondon (1924-1989) and Hendrik van Riessen (1911-2000)[5]. Simondon was a French philosopher, whose philosophy of technology is sometimes indicated as neo-aristotelian[6]. He studied at the Ecole Normale Supérieur and the Sorbonne University in Paris. As his main publication on technical artifacts, the book *Du Mode d'existence des objets techniques* (from now on to be abbreviated as *Du Mode*[7]) was never translated into English, it remained fairly unknown and is quoted only rarely. If ever it is quoted or discussed it is in the context of Continentally-oriented philosophy of technology. For instance, Andrew Feenberg referred to Simondon's work while discussing possible confusions between what he called primary and secondary instrumentalization[8]. There are a few publications that have Simondon's work as their primary focus. Paul Dumouchel presented a summary of Simondon's main ideas, as explicated in *Du Mode*[9]. Dumouchel, as Feenberg, seems to be more interested in the implication of Simondon's writings for our view on the impact of technology on society and culture than on his ideas about the development of technical artifacts. Simondon's work was also discussed in a paper by Henning Schmidgen[10]. Schmidgen's motive for reading

Simondon was primarily an interest in the history of science and technology more than an analytical-philosophical interest in technical artifacts. Finally I want to mention a paper by Adrian Mackenzie in which he discusses *Du Mode* in the context of a review of the social-constructivist approach to technology[11].

Simondon also features in the survey of important philosophers of technology that was published by the German Verein Deutsche Ingenieure (VDI) in 2000[12]. As could be expected, in French literature he is mentioned more frequently than in English literature, but here, too, there seems to be no publication that discussed his work in the context of a reflection on technical artifacts in the analytical manner, as we find it in the *Dual Nature* program that was mentioned earlier. If at all Simondon as an early philosopher of technology is revived in more recent publications in the philosophy of technology it is always in a Continentally-oriented article on the role of technology in society and culture. That is understandable, because Simondon himself wrote that his main purpose for writing *Du Mode* was to show that there is no conflict between technical artifacts and human culture[13]. Humans and technical artifacts belonged together and, as he phrased it, humans are the conductors in the world-orchestra of technical artifacts[14]. According to him a better understanding of the nature of technical artifacts could prevent people from being torn apart by fear and love for technology. In this respect he disagreed with other voices in that time, such as those of Jacques Ellul, who wrote his *La Technique ou l'enjou du siècle* in 1954, and Martin Heidegger, who published his *Frage nach der Technik* in the same year. Both philosophers emphasized the negative impacts of technology on society and culture, and although Simondon did not mention them, the Introduction of *Du Mode* can be seen as a response to their ideas, and thus it is understandable that we find references to *Du Mode* primarily in Continentally-oriented literature. In a way, the recent efforts to get a better understanding of technical artifacts thereby reflecting on concrete examples of technical artifacts (as promoted in the empirical turn in the philosophy of technology) can be seen as a similar attempt to move away from too general statements about technology that are not tested against real practice, and create a more balanced picture by carefully examining technology 'from inside'[15]. A confrontation of Simondon's ideas with the more recent insights as gained in analytically-oriented philosophical studies on technical artifacts, such as in the *Dual Nature* program, has not been published yet. That is the aim of this article. What I will do here is first present a summary of Simondon's main ideas about the nature of technical artifacts, thereby using the French text of *Du Mode*, and also the publications on Simondon I quoted earlier, but primarily by going back to the text of *Du Mode* itself, and then compare these ideas with the more recent insights as they have been developed in research like the *Dual Nature* program.

2. Concepts in Simondon's philosophy of technical artifacts

In the first place it is important to note that Simondon used the word 'objet' for indicating a process rather than a device or machine. He wrote: "the technical object is not this or that thing, given here and now, but that of which there is a genesis"[16]. So for him, the steam engine as a technical object is not what we usually call a technical artifact but a sequence of engine designs that displays a certain development[17]. Ontologically speaking, for him a technical object is not a material entity, but an event, or rather a sequence of events. At first sight this would mean that we have to be very careful in comparing his ideas with the *Dual Nature* approach, because in that approach the technical artifact is not a process, but a material entity. Simondon did discuss numerous examples of technical artifacts. As long as we are aware of the fact that he sees those artifacts primary as the outcomes of a process we can draw the comparison between his view on these artifacts and the *Dual Nature* view.

In *Du Mode* the term concretization features quite prominently. Here too, we have to be aware of the specific way in which Simondon used the term. Concretization is taking a step from abstract to concrete. That holds both for Simondon's way of using the term and for the common use. In common use this refers to the process of developing an artifact as one that starts with only abstract entities (theoretical concepts, a list of requirements and perhaps sketches) and ends with a concrete object (a prototype or a finished product). But for Simondon abstract and concrete have a different meaning. As his term 'objet' refers to a sequence of artifacts, also his term 'concretization' refers to this sequence, and not to the genesis of one artifact in this sequence, as in common use. He distinguished between craftsmanship (l'artisanat') as a primitive 'abstract' stage, and industry (l'industrie') as a 'concrete' stage[18]. In the stage of craftsmanship technical artifacts are still in an early process of their genesis (that is, earlier in the existence of the technical object-as-process), which can be seen from the fact that there is not yet a convergence or 'condensation'[19] of functions in the parts of the artifact. Each function is realized in a separate part. It is only later in the genesis that parts become multifunctional. Convergence is another important term in *Du Mode* and Simondon wrote that the real challenge in technology is to bring together functions in a structural unit (that is what he called 'convergence') rather than to find a compromise between conflicting requirements[20] We have to note that Simondon used the term 'structural unit' rather than 'part of a device'. This raises the question if his concept of convergence also applied to a bringing together of functions in the whole artifact (as we see it happen frequently today in our alarm clocks that are at the same time radio's; for this there is even a special term: hybrid products). That would explain why it is particularly in industry that we find more concretization, because then less products would be needed for more functions, and thus mass production becomes more worthwhile. In principle it is well possible that Simondon had this in mind, because already in the Introduction of *Du Mode*, he described three levels of entities: elements (parts of artifacts), individuals (artifacts) and ensembles (combinations of artifacts working together)[21]. The examples he used to illustrate the concept of concretization, though, all are at the level of elements (i.e., parts of artifacts).

Simondon's use of the terms 'abstract' and concrete' is by no means obvious and at certain points even clashes with the normal use of terms. Intuitively we would associate the term 'concrete' with the stage of craftsmanship because the use of abstract concepts seems to be more characteristic for the stage of industrialization. Here, again, we have to keep in mind that Simondon's focus is not on the artifact, but on the sequence of artifacts that constitute what he calls an 'objet'. The difference between concrete and abstract does not refer to a concrete artifact versus an abstract concept of the artifact-in-design, but to two stages in the sequence of artifacts. The stage of craftsmanship is a way of developing artifacts that is 'primitive'[22] in that there is a low level of sophistication in the way the functions of the artifact are realized in its parts. In the stage of industry functions are combined in parts in a more sophisticated way, and probably Simondon saw this as a crucial prerequisite for mass production as practiced in the industrial stage. Simondon does not elaborate on this assumption. This makes his terminology confusing, as now we tend to associate 'abstract' and 'concrete' with artifacts and not with the sequence of artifacts. This also obscures the meaning of the terms craftsmanship and industry, because for Simondon they do not sites or phases in the overall history of technology, but to approaches to artifact development. This confusion is enhanced by the fact that Simondon does not explicitly claim that concretization did not take place yet in the historical era of craftsmanship, but only emerged after the Industrial Revolution. Perhaps he would not even want to make that claim, because in principle the approach that he labels as 'industrial' could also have been practiced in the historical period before the Industrial Revolution. This would also explain why he does not need the 'individual' and 'ensemble' levels to illustrate his concept of 'concretization'.

In *Du Mode*, Simondon elaborates in detail a couple of examples in order to illustrate his claim that convergence was the key issue in the genesis of these artifacts. I will describe one of them here: the penthode. This amplifying electronic tube was invented in 1926 by Bernard D.H. Tellegen. Tellegen at that time was a scientist in the Philips Natuurkundig Laboratorium (Philips Physics Laboratory[23]). Simondon described this invention as a step in the genesis of amplifier tubes that started with the triode[24]. In the triode there are still separate parts for different functions: the cathode is for producing electrons, the anode is for capturing them, and there is a grid for regulating the electron flow from cathode to anode. The triode's functioning was hampered by the capacity between anode and grid, which could easily result in an undesired auto-oscillation of the current in the tube. To fix this problem, another grid was added to the design, between anode and grid, and this functioned as an electrostatic insulation. But because of the potential between the anode and this extra grid, and between the extra grid and the original control grid, the extra grid also functioned both as an extra control grid for the anode and as an anode for the original control grid, thus strongly enhancing the amplifying function of the tube (up to 200 times amplification in stead of 30-50 times). So the extra grid functioned both as a solution for the original problem and as an enhancement of the overall function of the tube. This is typical for what Simondon called concretization. This new tube, called the tetrode, had a new problem: now electrons hitting the anode caused secondary emission of new electrons at the anode, which electrons caused other electrons coming from the control grid to be turned back. Tellegen solved this new problem by putting an additional grid between the insulating grid and the anode. By giving it a negative potential (approximately the same as the cathode) the electrons approaching the anode were no longer hampered by secondary emission at the anode. But this additional grid also could be used as an additional control grid. So again functions were combined in an element of the device. By positioning the bars in the additional grid in the electrical 'shadow' of the bars in the original control grid, the secondary emission is reduced (so not only the effect of secondary emission is dealt with, but also the emission itself). Furthermore, the variation in capacity between the cathode and the control grid becomes very small, which suppresses practically every frequency shift when the tube is used in a wave generator circuit. The additional grid is what Simondon called 'over-determined'. Over-determination is the natural effect of concretization. When an element serves more than one function, both functions determine that element. Simondon used the example of the penthode to illustrate how in each step of concretization new conflicts may emerge, but in a next step those will be solved and further convergence of functions in elements will take place. The penthode is a product that was developed in what we normally call an industrial context (the Philips company). The fact that Simondon uses this example to illustrate his concept of concretization clearly indicates that in his terminology the early stage of concretization (craftsmanship) can take place in the context of what in normal use of the term is called 'industry', while in Simondon's use of the term 'industry' it means the later stage of concretization.

In a previous publication, I derived a simple taxonomy of technological knowledge, based on the Dual Nature approach. I distinguished three different types of technological (artifact-related) knowledge, namely knowledge of the physical nature, knowledge of the functional nature, and knowledge of the relationships between the physical and the functional nature[25]. Simondon in *Du Mode* also pays substantial attention to technological knowledge in relationship to technical artifacts. It is the main focus of one of the three parts of this book (Part II on 'Humans and the Technical Object'). In that Part he discusses the genesis of technical artifacts as the object of human knowledge. As for the stages in the genesis of technical artifacts, here too, he differentiates between two types: the knowledge stage of childhood and the stage of adulthood[26]. Knowledge of artifacts in the stage of childhood is intuitive, without an insight into the explanation of the functioning, and focused on working with the artifacts in practice. In the stage of adulthood such knowledge is rational, based on theoretical insight into the functioning of the artifact, and focused on reflections that are more universal than just related to this single artifact. A person with childhood knowledge of artifacts – an artisan – does not really master the artifact but is bound to the rules for usage as learnt in his/her education. A person with adulthood knowledge, though, - an engineer - has freedom to adapt the artifact or its use according to his/her own needs[27]. According to Simondon, there is place for both. The difference between the two types of people has consequences for their education. Childhood knowledge will be transferred in different ways than adulthood knowledge[28].

In the third Part of *Du Mode*, Simondon used the term ‘magic’ for the phase in which humans only had childhood knowledge of artifacts. In that phase they saw the artifact as a whole and they did not yet differentiate between the purpose of the artifact and the way this purpose is realized in matter. This is what the coming of ‘technicity’ caused to start. Technicity means that humans realized that there are different ways of reaching purposes through artifacts. From then on reflections on purposes and reflections on the way these can be reached through artifacts also became the domain for different human endeavors. In religion, humans reflect particularly on purposes, while in technology the material realization forms the focus of reflection[29]. Simondon claimed that this also has consequences for the nature of reasoning in religion and in technology. Religious thinking according to him is more deductive. It starts with certain convictions about purposes in life and from those deduces what is needed to realize those. In technology thinking is more inductive, Simondon claimed. It starts with reflecting on concrete artifact and by induction tries to gain more general insights about how purposes can be reached through artifacts[30].

It is interesting to note that Simondon considered natural objects to be the best examples of concretization. According to him the convergence of functions as a fit between physical realization and functional requirements in structural units is optimal in natural objects. Although Simondon nowhere specifies this, we must assume that ‘natural object’ in his terminology is restricted to those objects in nature to which we apply the concept of ‘function’. In the more contemporary debate on the concept of function this happens only in living objects[31]. We speak, for instance, of the ‘function’ of the heart. Also the implicit evolutionary notion behind Simondon’s claim that natural objects are a sort of final outcome of a concretization process suggests that ‘natural object’ for him means ‘biological object’, and not minerals or atoms. On the other opposite of the spectrum, where there is not yet any fit between physical aspects and functions in structural units, is the scientific representation of the artifact-in-design[32]. According to Simondon the result of this is that the behavior of natural objects can be predicted more reliably than the behavior of technical objects[33]. The more concretization progresses, the more the technical object becomes like a natural object. To illustrate this Simondon discussed artificially grown plants. Compared to natural plants they have a less effective integration of functions in structures. Artificially cultivated plants have lost the natural ability to survive in cold circumstances (they have become dependant on the greenhouse), and in some cases they have also lost the ability to bear fruit and create a next generation. Concretization would then be the manipulation of such plants in order to make them resemble more and more the natural plant with its abilities to survive and multiply on its own[34]. This is a fairly speculative example, in particular when we realize that nowadays there is much effort to manipulate flowers in such a way that they seem to have an even better integration of functions than natural plants. This is one of the places in *Du Mode* where one gets the impression that Simondon's ideas have been derived from a priori views on reality rather than from reflections on empirical data.

This aspect of context dependence brings us to another concept in Simondon's philosophy of artifacts, namely that of hypertely[35]. In a situation of hypertely the artifact is fully dependant on its environment. It can only function at the interface of two worlds: the world of its own internal (technical) requirements and the external, social (or 'geographic', in Simondon's terms) world in which it is used. To illustrate this, Simondon used the example of the engine in an electric locomotive. On the one hand, it needs to be adapted to the external world in order to obtain its energy, and on the other hand it needs to be adapted to the train that needs its output energy. This is typically the case for what Simondon called 'elements'. These can only function in a larger whole (an artifact, or an 'individual' in Simondon's terminology). This notion strongly reminds of what H.A. Simon wrote in 1969: according to him an artifact functions as a kind of 'interface' between an 'inner' environment, the substance and internal organization of the artifact, and an 'outer' environment, the surrounding in which it operates[36]. The study of this is what Simon calls the 'sciences of the artificial' and here, too, we see an analogy with Simondon's writings, in which we also find the claim that there is such a science[37]. Simondon claims also that in the case of an individual the artifact can function by itself, but there is still a certain dependency from its environment. A windmill is a fully functional device, but it needs the wind to function. The highest degree of context-independence is found in 'ensembles', which are able to create their own necessary circumstances[38]. In any case, the artifact functions on the interface of its internal milieu (with its own conditions) and the external milieu (with its conditions). Simondon uses the term 'evolution' in his discussion of the concept of hypertely. Thereby he does not refer to the Darwinian concept of evolution, but there seem to be implicit references to the Darwinian idea of adaptation to the environment in the way he explains hypertely in technical objects.

Simondon saw a certain pattern in the way elements, individuals and ensembles develop. According to him, first an element develops into an individual and then the individual develops into an ensemble. At a certain moment, in the ensemble a new element may emerge. This element then also can be the beginning of a whole new ensemble. This can be illustrated by the steam engine (the element) that grew out to a steam locomotive and then into a whole transportation system based on steam technology. At a certain moment in this ensemble, the steam engine was first replaced by an electric engine, which became the beginning of a whole new transportation system, based on electric energy. This is what Simondon called the 'saw-tooth' pattern in technological developments.

3. Comparison with the Dual Nature insights

In the first place, it should be remarked that it is too much to call Simondon an analytically-oriented philosopher of technology. There is too much speculation and too little argumentation in his works to justify that. Simondon mostly uses examples to support his claims and there are only few instances where we find solid argumentation to show that the claims have a broader status than just for those examples. Yet, his ideas are sufficiently original to make them worthwhile for further consideration by confronting them with what has been found in the *Dual Nature* approach of technical artifacts. Maybe the Dual Nature findings can be used as the missing argumentative support for Simondon's ideas, or his ideas can lead to an extension of the Dual Nature findings.

In the first place we can note that Simondon already realized that for a full account of technical artifacts it is not enough to discuss either the physical or the functional nature. Simondon phrased this as follows. In the Introduction of *Du Mode*, he criticizes earlier visions on artifacts that regard them either as material constructions ('assemblages de matière') or as filled with intentions ('animés d'intentions') [39]. Simondon claimed that by combining both aspects in one account, a view on technical artifacts results that helps people understand the artifacts around them and accept them as useful parts of their environment. Simondon did not provide any arguments for this, and in that respect the *Dual Nature* program was necessary to come up with such arguments and thus give a more solid foundation to what Simondon brought forward as an intuitive claim. Kroes and Meijers have argued that a description of any artifact is incomplete and ambiguous if it has only one of the two natures[40]. A screwdriver, for instance, can not be adequately described only as 'a device with which one can turn screws', because there are many other devices imaginable to do that, so that someone could develop a wrong image of a screwdriver if that image is based only on the description of the functional nature. The same ambiguity arises when only a physical nature description is provided to define a screwdriver. The same long stick can be used to open a tin can, and therefore a wrong image of the artifact could result from such a limited description. The technical artifact can only be defined unambiguously when both the physical and the functional nature are described. In a good design there is a fit between these two natures. According to Simondon this fit is not optimal, but improves when the process of concretization progresses. He claims that the artifact is always between a natural object (where the fit is optimal) and a scientific representation of the artifact where there is no fit yet. We have already remarked that this claim is a questionable one.

In the second place, Simondon's ontology of artifacts meets the same criteria that have been developed in the Dual Nature program for any ontology of artifacts. Houkes and Meijers have described two main criteria for this: underdetermination (the ontology should accommodate the fact that an artifact can be used for different functions and a function can be realized through different artifacts) and realizability (the ontology should accommodate the fact that a function can be realized through any artifact, and an artifact can not be ascribed any function)[41]. They have shown that some existing ontologies, such as the one developed by Lynne Rudder Baker, do not (yet) meet these criteria. Let us now examine if Simondon's ontology of artifacts passes this test. I would like to propose that this is the case indeed. Simondon has explicitly claimed that each technical artifact is not fully determined. Only natural objects have a perfect fit between parts and functions. Technical artifacts are always somewhere in between a scientific representation in which the link between function and material realization is totally undetermined yet, and a natural object for which the determination is complete. This fits with Houkes' and Meijers' underdetermination criterion. At the same time, Simondon described the process of concretization as one that has a certain necessity, because in the variation of possible next step in the evolution of an object, there are always 'right' and 'wrong' next steps, of which only the right ones will lead to continuation of the development process (just like in biological evolution only the strongest beings will survive, and not just any possible variation). This makes Simondon's ontology fit the realizability constraints criterion.

In the third place, we can observe that both Simondon and the Dual Nature program seek analogies between biology and technology. The way this analogy is analyzed shows an important difference between Simondon's analogy and the one developed in the Dual Nature program. Simondon compares the process of the becoming of an object (object meaning not an individual artifact, but the whole line of development as a sequence of artifacts in which the level of concretization constantly increases) with the evolutionary process through which living creatures have emerged. The analogy led him to his claim that not all variation in an artifact will survive but only the one for which the level of concretization is higher than its predecessor's. In

Simondon's ontology, the object is not an artifact, but an event, or a series of events. His ontology is a dynamic one. In the Dual Nature ontology, it is the duality of natures that defines the being of an artifact. This is a static ontology. Here the analogy with biology is in the concept of functions and the way they are ascribed to physical entities. Vermaas and Houkes have shown that this analogy breaks down in the case of novel artifacts that do not have clear predecessors. In such cases evolutionary (etiological) accounts of artifact functions do not meet reasonable criteria for technical artifact function accounts[42]. The question is, though, if such artifacts exist at all. Simondon's ontology suggests, but without sound argumentation, that this is not the case. There may be elements coming into being in ensembles that form the start of a new development, but even in that case the new element always has some resemblance with the artifact that was used for the same function previously. The diode, for instance, according to Simondon, was a relatively new element because of its asymmetry, and thus the beginning of a new evolutionary line of artifacts, but it can also be seen as a next step in the search for amplifying devices[43]. Neither Simondon nor the Dual Nature program seem to have sound arguments for determining whether or not artifacts necessarily have a predecessor or can be so new that all comparison with previous artifacts does not give any reasonable explanation for its design. A better source of arguments to determine that are such concepts as 'technological trajectories', 'normal technology' and 'revolutionary technology'[44]. These seek to analyze the development artifacts as part of a broader social development. In Simondon's approach and in the Dual Nature approach all arguments for determining whether or not there is a predecessor must be derived from the artifact itself, while in the technological trajectory or normal versus revolutionary approaches such arguments can also be derived from the social context.

The fourth point of comparison I want to discuss is the relation between the physical and the functional nature (in the terminology of the Dual Nature account). The Dual Nature program has shown that both the designer and the user take into account that relation. In that program this has been conceptualized in what is called the use plan. This use plan is an action theoretical account for the way users reason about how to use the artifact, and how the designer, when designing the artifact, puts himself or herself in the role of a prospective user. Here it is the Dual Nature program that is dynamic, whereas Simondon's account is more static. Simondon discussed the relation between physical and functional nature in terms of a fit between a set of functions and a set of parts, whereby the level of sophistication of the artifact (or as Simondon called it, the level of concretization) is defined by the extent to which a minimum of parts can realize all the desired functions. The latter account provides a specific criterion for assessing the quality of the design: the fewer parts needed for all functions, the better. One can pose the question what advantage that gives. But for those who are acquainted with current ideas about quality in design, as elaborated in Total Quality Management tools, there is an immediate resemblance with the desire to reduce the number of parts in a device that forms the basis of several of such tools (for instance, this is clearly the case for Value Analysis and Design for Assembly[45]). Obviously, contemporary design practice seems to justify Simondon's appreciation of a reduction of the number of parts. But the TQM literature seems to fail in producing sound arguments for using part reduction as a general guideline no less than Simondon's book *Du Mode*. Although current practice offers an empirical support for Simondon's claim, giving such an important role to part reduction as the basis for the appreciation of the fit between physical and function al nature remains fairly speculative. The Dual Nature account does not seem to provide such a specific criterion and this is more on the safer side. The disadvantage of that is that the outcomes of such an account may be less inspiring for designers than Simondon's account.

In the fifth place, I want to compare the ways Simondon and the Dual Nature program discuss knowledge. Thereby I will use my own taxonomy of three knowledge types, as derived from the Dual Nature account (knowledge of the physical nature of a technical artifact, knowledge of its functional nature, and knowledge of the relationship between the physical and the functional natures) for comparison with Simondon's taxonomy of two knowledge types (childhood and adulthood knowledge). Simondon's description of childhood knowledge (the knowledge of the artisan) suggests that it mainly contains what I have called knowledge of the functional nature of a technical artifact. Someone having only childhood knowledge knows what an artifact is for, but does not have an understanding of its composition (or broader: its physical nature) neither of why that composition (physical nature) makes it work. Adulthood knowledge (the knowledge of an engineer) then means also having an understanding of the latter two aspects of the artifact. This, however, is too simple to do justice to what Simondon means to say. Simondon would probably not deny that one need not be an engineer to know that a long object can be used to enlarge force (use as a lever). This would be knowledge of the relationship between the physical and the functional nature of that object (which, in my first, naïve analysis would be only in adulthood knowledge and not in the artisan's childhood knowledge). Yet, there one can still differentiate between childhood knowledge and adulthood knowledge here. The adulthood knowledge only recognizes the potential of the long object of serving as a force enhancer, but cannot explain why the object can do that. The engineer, though, with adulthood knowledge can explain that and is even able to calculate how much output force will be generated by a certain input force given the geometry of the situation. The difference between childhood knowledge and adulthood knowledge, therefore, is not the absence of relationship knowledge in the childhood knowledge and its presence in adulthood knowledge, but a difference within that category of knowledge. Apparently there is a childhood version of relationship knowledge and an adulthood version. That obviously raises the question if the other two knowledge types in the taxonomy that was derived from the 'Dual Nature' account also have childhood and adulthood versions. Indeed, it seems possible to make that distinction for the remaining two types, physical nature knowledge and functional nature knowledge. An artisan's knowledge of the physical nature will be limited to the observable and practical aspects of the physical nature, such as size, weight and type of material. The engineer's knowledge will go beyond that and also comprise theoretical aspects of the physical nature, such as the energy band structure in the semi-conducting material. That can make quite a difference. An artisan seeing a transistor for the first time can develop knowledge of certain aspects of its physical nature (it is very tiny and mainly made of silicon), but it will not help the artisan much in using it. The engineer, also seeing it for the first time, will be able to predict that the material in the transistor can be used to amplify an electric current. In a similar way one can distinguish a childhood and an adulthood version of functional nature knowledge. An artisan studying an oscilloscope for the first time could recognize that its steering plates can be used to direct the electron beam to any desired point at the screen, but (s)he will be left wondering what this function might be any good for. The engineer, though, with a deeper understanding of the functioning of horizontal and vertical steering of the beam could predict that the oscilloscope can serve as a means to display an electrical signal. So Simondon's differentiation between childhood and adulthood knowledge can be translated into certain differences within each of the three knowledge types that have been derived from the Dual Nature account of technical artifacts.

Finally, we can observe that the concept of hypertely and the series of element, individual and ensemble is absent in the Dual Nature approach. This approach analyzed artifacts only at the level of individuals, that is, artifacts that can function independently. There is now, however, a new research program that succeeded the Dual Nature program that focuses on sociotechnical systems.

In this program it is exactly those two issues that are dealt with: the fact that artifacts are parts of systems and that these systems operate on the cutting edge of technology and society (the concept of hypertely). It will be interesting to see how this new program will compare with Simondon's approach, once its first results will be published.

4. Conclusions

This article has suggested that it is interesting to go back to earlier philosophers of technology, such as Simondon, who published ideas that were not yet followed up because they were too analytically-oriented to be recognized as interesting in an era in which the overall approach in the philosophy of technology was still Continentally-dominated. Those ideas got lost in the history of philosophy of technology, but now can be re-valued in the context of a more analytically-oriented philosophy of technology. There exists some 'analytic philosophy of technology' avant-la-lettre, be it with a less developed argumentation, but still it is worthwhile to trace it back and see how it might contribute to our current interests.

My analysis shows that as far as analytical rigor is concerned, the Dual Nature account technical artifacts should be preferred over Simondon's more speculative account. Simondon has some very specific claims that in *Du Mode* are supported by various examples, but there are few places only where sound argumentation is presented to elevate the level of generalization. On the other hand, the specificity of Simondon's somewhat more daring claims make it interesting as a source of inspiration, and maybe a more in-depth analysis of Simondon's claims will allow for the development of the argumentation that is missing in *Du Mode*. The fact that Simondon's account does bear resemblance to the Dual Nature account and seems to fulfill the criteria for an ontology of technical artifacts may make that a worthwhile effort.

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1 Dipert 1993

2 References can be found in Houkes and Meijers 2006.

3 Techne 6:2 (Winter 2002) was a special issue dedicated to this program. It was supervised by Peter A. Kroes and Anthonie W.M. Meijers at the Delft University of Technology, the Netherlands. It was carried out by two post doc researchers (Wybo N. Houkes and Pieter E. Vermaas) and two Ph.D. students (Marcel Scheele and Jeroen de Ridder).

4 Kroes and Meijers 2006

5 The latter was a follower of the Dutch philosopher Herman Dooyeweerd, who developed a philosophy that is generally indicated as ‘reformational philosophy’ because of its religious background. Van Riessen was an electrical engineer by training. In 1949 he received his Ph.D. in a thesis in which he first described the views of various philosophical schools on technology. The second part of his thesis analyses technical artifacts and engineering design in terms of Dooyeweerd’s conceptual framework. This framework is based on the notions that reality is complex because it can be described in terms of different aspects (e.g., the physical, the economical, the juridical and the aspect of belief or trust) that can not be reduced to one another, and the regularities or ‘laws’ that we see in the various aspects. See also de Vries 2005. Van Riessen’s work was also discussed extensive by Carl Mitcham in the First Van Riessen Memorial Lecture; see www.aspecten.org/HvRML/LezingHvRML_1.html.

6 For instance, in the Wikipedia encyclopedia on the Internet; see: en.wikipedia.org/wiki/Gilbert_Simondon. Simondon studied at the Ecole Normale Supérieure en Sorbonne from 1944 onward. The reason for this is probably the way Simondon wrote about forms and content. He saw an analogy between humans and artifact in that both are a combination of form (associated by Simondon with such terms as function, thinking, actuality) and content (associated with realization, potentiality, and life). For Simondon this analogy explains why humans are capable of inventing artifacts (*Du Mode*, p. 60). It can be questioned, though, if the fact that Simondon used these terms justifies calling him a neo-aristotelian philosopher, because this use of the terms ‘form’ and ‘content’ is different from Aristotle’s.

[7] In this article I will quote from the 1989 edition: Gilbert Simondon, *Du Mode d'existence des objets techniques*. Paris: Aubier. The original edition was published in 1958. *Du Mode* was originally the 'thèse complémentaire' for his doctoral thesis titled *L'individu à la lumière des notions de forme et d'information*, of which the first volume came out in 1964 and the second in 1989.

[8] Feenberg 2000

[9] Paul Dumouchel 1995

[10] Henning Schmidgen 2004

[11] Mackenzie 2005; There is also a dissertation on Simondon by Vincent Bontems, published in 2004, but it remained unpublished; I was not able to consult it for this publication.

[12] Hubig, Huning and Ropohl 2000

[13] *Du Mode*, p. 10.

[14] *Du Mode*, p. 11.

[15] Kroes and Meijers 2000

[16] *Du Mode*, p. 20 (my translation).

[17] In this article I will use the term 'technical object' to indicate Simondon's 'objet techniques' and the term 'technical artifact' for the material entity, in the same way the *Dual Nature* program uses that term.

[18] *Du Mode*, p. 24. It is interesting to note that the difference between craftsmanship and industry also plays an important role in the writings of the other early analytical philosopher of technology I mentioned, namely Hendrik van Riessen. For Van Riessen, though, the difference lies primarily in the fact that the influence of science on technology transferred the characteristic of universality to technology, which resulted in uniformity of products in the industrial approach rather than unique products in the craftsmanship approach. This is clearly different from the way Simondon differentiates between the two approaches or stages. Van Riessen explains the difference from the perspective of production and quantity, while Simondon uses the perspective of design and quality.

[19] The latter term is used on p. 34 in *Du Mode*.

[20] *Du Mode*, p. 22. This is an interesting view, because in most literature reconciling conflicting demands is seen as the core of design problem. Apparently, for Simondon there is a more important challenge.

[21] *Du Mode*, p. 15. Probably the term 'ensemble' can be seen as an equivalent of the term 'system'.

[22] *Du Mode*, p. 24.

[23] A full history of this industrial laboratory, including more details about Tellegen and his penthode, can be found in Vries 2005. See p. 39 and 40 for the penthode, which in the pre-WWII period was one of the most important patents for the Philips company as this device became a standard for amplification of signals for communication worldwide. Tellegen and his penthode are also described in Blanken 2003. Blanken is the director of the Philips Company Archives.

[24] His account can be found in *Du Mode*, pp 27-34.

[25] Vries 2003

[26] Simondon uses the terms 'minorité' and 'majorité' in French for this (*Du Mode*, p. 85). These are not to be confused with 'minority' and 'majority' in English.

[27] Later in *Du Mode*, on p. 251, Simondon admits that users, too, can have such knowledge, which enables them to use the artifact in ways that differ from what the designer had in mind.

[28] Although Simondon did not use these terms, probably what he refers to is the difference between vocational and general education. Still today the difference between the two is the content of much debate.

[29] *Du Mode*, p. 157.

[30] *Du Mode*, p. 233/4.

[31] See, for instance, the collection of essays in Ariew, Commins, and Perlman (eds.) 2002.

[32] In Simondon's terminology, this representation is abstract in a double sense: it is not yet materialized, but also is does not show the convergence of functions that defines concreteness in Simondon's use of that term.

[33] *Du Mode*, p. 35.

[34] *Du Mode*, p. 47.

[35] *Du Mode*, p. 56.

[36] Simon 1969

[37] Simondon uses the name 'mécanologie' for that science.

[38] This distinction strongly reminds of one made by Simondon's contemporary philosopher of technology, Van Riessen. He defined two situations: one in which the device loses its meaning outside the environment in which it normally functions (e.g., the sledge of a lathe, which can only be used in such a lathe) , and one in which the device can be taken out of that environment and be put in a different environment where it can also function, though

maybe in a slightly different way (e.g. a gear which can be used in a clock but also in other devices). The first situation is called a ‘part-whole relationship’, and the second situation is called an ‘enkapsis’. Van Riessen took both terms from Dooyeweerd and applied them to technical artifacts.

[39] *Du Monde*, p. 10 and 11.

[40] Kroes and Meijers 2006

[41] Houkes and Meijers 2006

[42] Vermaas and Houkes 2003

[43] *Du Mode*, p. 40.

[44] Constant 1980

[45] See, for instance, Fox 1993 and Boothroyd, Dewhurst and Knight 1994.

On Amnesia and Knowing-How

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Abstract
In this paper, I argue that Stanley and Williamson's 2001 account of knowledge-how as a species of knowledge-that is wrong. They argue that a claim such as "Hannah knows how to ride a bicycle" is true if and only if Hannah has some relevant knowledge-that. I challenge their claim by considering the case of a famous amnesic patient named Henry M. who is capable of acquiring and retaining new knowledge-how but who is incapable of acquiring and retaining new knowledge-that. In the first two sections of the paper, I introduce the topic of knowledge-how and give a brief overview of Stanley and Williamson's position. In the third and fourth sections, I discuss the case of Henry M. and explain why it is plausible to describe him as someone who can retain new knowledge-how but not new knowledge-that. In the final sections of the paper, I argue that Henry M.'s case does indeed provide a counterexample to Stanley and Williamson's analysis of knowing-how as a species of knowing-that, and I consider and respond to possible objections to my argument.

I. Introduction

Philosophers sometimes distinguish between two kinds of knowledge: knowledge-that and knowledge-how. Knowledge-that is sometimes referred to as propositional knowledge, declarative knowledge or factual knowledge. Paradigmatic instances of knowledge-that include: (a) knowing that Albany is the capital of New York; (b) knowing that 2 + 2 = 4; and (c) knowing that the Romans had an elaborate system of aqueducts. Knowledge-how, on the other hand, is generally associated with abilities or skills. Knowledge-how is sometimes referred to as applied knowledge, practical knowledge, procedural knowledge or simply know-how. Typical examples of knowing-how include: (d) knowing how to ride a bicycle; (e) knowing how to speak a language; and (f) knowing how to fix the plumbing.

Philosophers have devoted most of their epistemological attention to studying and analyzing knowledge-that (hereafter KT), and significantly less time and effort in consideration of knowledge-how (hereafter KH). The attention that has been paid to KH can, for the most part, be traced back to Gilbert Ryle's 1949 book *The Concept of Mind*.[1] There (and in other writings[2]) Ryle defends the view that KT and KH are, in fact, distinct kinds of knowledge. He perceives this view as being in opposition to philosophical orthodoxy, which held (or so claimed Ryle) that KH is reducible to (or is a kind of, or species of[3]) KT. Ryle gave a number of arguments criticizing this orthodoxy, most notably the argument that this position leads to problems involving infinite regresses.

More recently, the subject has received a flurry of attention stemming from a 2001 article by Jason Stanley and Timothy Williamson in the *Journal of Philosophy* entitled "Knowing How".[4] In that paper, Stanley and Williamson argue against the claim that "there is a fundamental distinction between knowledge-how and knowledge-that." On their view, Ryle, "was wrong to deny that 'knowledge-how cannot be defined in terms of knowledge that' (1971, p. 215)." Stanley and Williamson conclude that, "(k)nowledge-how is simply a species of knowledge-that."[5]

This conclusion rests on claims (which I will briefly describe below) about the syntactic structure and semantic properties of KH and KT ascriptions. Unsurprisingly, critics of Stanley and Williamson have challenged the linguistic claims upon which their argument depends.[6] However, I would suggest that a more straightforward way to raise doubts about Stanley and Williamson's conclusion is to present a counterexample(s). That is, if there are cases in which it can be shown that an agent possesses KH but does not possess the relevant KT, it would seem that Stanley and Williamson's account would be shown to be false. Such cases do, in fact, exist.

In what follows, I will describe one such case. First, though, in Section II, I will summarize Stanley and Williamson's argument for the conclusion that KH is a species of KT, and summarize their account of KH. Then, in Section III, I present the history of a man called Henry M. who, after brain surgery, lost the ability to retain new propositional knowledge. In Section IV, I provide evidence that Henry nevertheless possesses the ability to acquire and retain new KH. In Section V, I revisit Stanley and Williamson's account of KH as a species of KT and argue that Henry M. is indeed a counterexample. Finally, in Section VI, I consider and respond to some potential objections to my argument.

II. Stanley and Williamson on Knowing-How and Knowing-That

As noted above, Stanley and Williamson argue that knowing-how (KH) is a species of knowing-that (KT). They make their case by first undermining Ryle's claim that views such as theirs, which deny the claim that KH and KT are distinct, necessarily have regress problems. They note, however, that not all critiques of views such as theirs rely on regress-type objections. Others who, like Ryle, have defended the view that KH and KT are distinct have done so by arguing that examination of KH ascriptions and KT ascriptions reveals fundamental differences between the two kinds of knowledge.[7] For example, consider the following sentences:

(i) John knows how to ride a bicycle.
(ii) John knows that Albany is the capital of New York.

The two sentences have a surface similarity, with "John" as the subject and "knows" as the verb. However, as William Bechtel and Adele Abrahamsen point out, "…the expression 'knowing that' requires completion by a proposition, whereas the expression 'knowing how' is completed by an infinitive (e.g. 'to ride') specifying an activity."[8] According to this argument, this linguistic difference is meant to indicate a substantive difference between the two kinds of knowledge.

Stanley and Williamson, on the other hand, argue that this linguistic difference is superficial, and that a deeper look at the structure of such knowledge ascriptions reveals (according to "recent syntactic theory") that, "to say that someone knows how to F is always to ascribe to them knowledge-that."[9] More specifically, according to Stanley and Williamson, a claim such as "Hannah knows how to ride a bicycle":

> …is true relative to a context *c* if and only if, there is some contextually relevant way *w* such that Hannah stands in the knowledge-that relation to the Russellian proposition that *w* is a way for Hannah to ride a bicycle, and Hannah entertains this proposition under a practical mode of presentation.[10]

Simplifying things a bit, we can summarize Stanley and Williamson's account of KH ascriptions as follows:

> The sentence "Hannah *knows how* to ride a bicycle" is true if and only if Hannah *knows that* such-and-such is a way for her to ride a bicycle, and she knows this under a practical mode of presentation.

This last clause about knowing the proposition "under a practical mode of presentation" is meant to distinguish cases such as the following:

(a) Sue has read lots of books about riding a bicycle and has studied the methods involved in riding a bicycle, but she has never actually ridden a bicycle.
(b) John has much experience riding a bicycle and has been doing so for years.

In both cases, we could say that the subject knows that such-and-such is a way to ride a bicycle, but only in case (b) would we characterize this as knowledge under a practical mode of presentation (and thus, only in case (b) would we properly characterize the subject as knowing how to ride a bicycle).[11]

So, Stanley and Williamson argue from the linguistic structure of the various kinds of knowledge ascriptions to the conclusion that KH is a species of KT. And according to Stanley and Williamson's analysis, a claim ascribing KH to some agent is true if and only if that agent has propositional knowledge of a certain sort. Thus, if some agent acquires and possesses some bit of KH she can thereby be said to have acquired a bit of KT. In what follows, I attempt to challenge their analysis by describing a man who is capable of acquiring bits of KH but who cannot acquire the relevant bits of KT.

III. The Strange Case of Henry M.

In 1953, a 27-year-old man referred to as Henry M.[12] underwent a "fractional lobotomy",[13] a procedure intended to reduce the severity and frequency of his epileptic seizures. The surgery consisted of removing parts of Henry's medial temporal lobes[14] – including his hippocampus – a procedure that was experimental, but had been successful in reducing seizures in other patients. With respect to the seizures, the surgery was a (relative) success.[15] However, the surgery also had a "striking and totally unexpected behavioural result: a grave loss of recent memory…"[16] That is, while Henry could remember much of his life (and the things he knew) before entering the hospital for surgery, he was unable to remember recent, post-surgery events, or people that he had recently met (such as the hospital staff).

Henry's amnesia is not the typical form of that condition – the kind that (along with long-lost twins and alien abductions) often comes to the rescue of struggling soap opera writers. In that familiar version of amnesia, one is unable to recall events from before the trauma, though is in most other ways normal. That kind of amnesia is called *retrograde amnesia*, which means (to put it a bit crudely) that old memories are gone, but new ones can be formed.

By contrast, Henry has a form of amnesia that is quite different in that he retains memories from before the traumatic event but cannot form new memories of things that have happened since the surgery. Or at least, he cannot *retain* new memories for more than a few minutes at a time (that is, he cannot shift short-term memories into his long-term memory). This form of amnesia is called *anterograde amnesia*, which involves (again, crudely put) the ability to retain old memories but the inability to retain new ones.[17]

When it became apparent that Henry's amnesia was not a short-term result of the surgery, Dr. William Scoville (Henry's surgeon), and his colleagues began to perform tests in an attempt to determine the severity of Henry's condition. He and his colleagues wanted to know:

> …whether [Henry] was severely impaired regardless of the kind of memory test (free recall, cued recall, yes/no recognition, multiple-choice recognition, learning to criterion); regardless of the kind of stimulus material (words, digits, paragraphs, pseudowords, faces, shapes, clicks, tones, tunes, sounds, mazes, public events, personal events); and regardless of the sensory modality through which information was presented (vision, audition, somatosensory system, olfaction).
>
> The answer to these questions, on the basis of decades of experiments, is 'yes': his impairment is not only severe, but also pervasive.[18]

Henry retained his capacity for short-term memory – i.e. he could remember new information for short periods of time (seconds or minutes) given a suitable environment and a certain level of attentiveness. He also retained much knowledge acquired before the surgery – knowledge of his parents' names, for example, as well as knowledge of word meanings, knowledge of how to speak and write English, and knowledge of how to walk and control his body. Additionally, Henry has retained general reasoning abilities (his scores on general intelligence tests are comparable to others of the same age and background and have been consistent both before and after the surgery[19]), language abilities, and social abilities.

What Henry lost was the ability to retain new memories, or at least new memories of a certain kind. Specifically, the damage done to Henry impaired his ability to retain "declarative memories". Declarative memories come in two main forms: episodic memories and semantic memories. Episodic memories, as the name suggests, are memories of particular episodes – i.e. events associated with a particular time and place – for example, remembering that one had eggs for breakfast yesterday; or remembering the night of one's senior prom; or remembering the moment one's child was born; or remembering the day that President Kennedy was assassinated. Semantic memory involves the ability to retain and recall general facts about the world (including, as the name suggests, the meanings of words). So, remembering that "software" refers to computer programs would be an example of a semantic memory, as would remembering that Paris is the capital of France, and that fire requires fuel, heat and oxygen.[20]

Further study of Henry has been done over the years since his surgery (quite a lot of it, actually[21]), and it has continued to reveal that "even with thousands of repetitions, he is unable to learn new facts. His doctors must reintroduce themselves each morning, and [Henry] is never sure where he is for very long".[22] Suzanne Corkin, a neuroscientist who has studied Henry extensively for decades, finds his condition basically unchanged. In a 2002 article, she wrote that Henry's condition "manifests as deficient acquisition of episodic knowledge (memory for events that have a specific spatial and temporal context) and of semantic knowledge (general knowledge about the world, including new word meanings)."[23]

It seems fair to describe Henry as being unable to acquire and retain new propositional knowledge, or KT. The sorts of things that he cannot remember and learn (or learn and retain for very long) are propositional in nature. He cannot remember that his doctors' names are such-and-such, or that he is now older than 27, or that such-and-such person is President, etc. These are paradigm cases of KT.[24]

IV. Henry and Procedural Knowledge

A number of years after Henry's surgery, as doctors and scientists continued to study the range of his memory loss, researchers discovered a "kind of memory task that [Henry] can perform normally: skill learning."[25] That is, Henry can acquire what neuroscientists call "procedural knowledge". As Corkin reports:

> The dissociation in H.M. between the acquisition of declarative memory and other kinds of learning was initially shown for motor learning. The first experimental demonstration of preserved learning in amnesia was [neurologist Brenda] Milner's report that H.M.'s time and error scores decreased within and across three days of training on a mirror-tracing task. H.M. was asked to draw a line between two adjacent outlines of a star-shaped pattern, but he could see only his hand, the pencil and the star reflected in a mirror (with left and right hand reversed). Although no control data were reported, he showed clear skill learning, in marked contrast to the absence of declarative memory for any details of the testing sessions, or even a feeling of familiarity. Subsequent studies…showed that his initial performance on motor learning tasks was inferior to those of control participants, but that he could still show consistent improvement over several consecutive days of testing, and that he could retain that non-declarative knowledge for as long as a year. These results indicate that acquisition and retention of a visuomotor skill rely on substrates beyond the MTL [medial temporal lobe] region.[26]

To be clear, with regard to the mirror-drawing task, Henry did not remember having learned the task, or having done the task before (when asked, he would report each time that he had never tried it before – or that he did not remember doing so). And yet with each new practice session, his performance continued to improve (though not generally as quickly as non-amnesic patients). He acquired the skill despite having no memory of having done so. Henry knew how to do the mirror-drawing task (and he got consistently better at it with practice), but did not know that he knew how, or that such-and-such was a way of doing the task.

The mirror-drawing experiments were performed on Henry in 1959, which was six years after his surgery. Later, in 1962, further tests of skill-learning were performed and it was discovered that "while unable to learn the correct sequence of turns in a 10-choice tactual maze, Henry gradually reduced his time scores over 80 trials." Corkin noted that "on the basis of these two findings, it was hypothesized that other motor skills could also be acquired by patients with bilateral lesions of the medial temporal structures." [27] Corkin set out to explore this hypothesis and constructed further tests of Henry's abilities with respect to motor-learning tasks, many of which required placing a stylus on a moving target. She found that, although Henry's scores on such procedures were lower than those of the control group:

> On the two tasks which involved learning over several days (Rotary Pursuit and Bimanual Tracking), H.M.'s performance improved from session to session and from day to day. Similarly, his tapping scores after a 40-min rest interval were superior to those recorded before it.

Corkin concluded that these results provided "additional support to the notion that the medial temporal-lobe structures are not necessary for the acquisition of motor skill." [28]

Henry has, over the years, demonstrated similar abilities with respect to other skill-learning tasks – for example, the Tower of Hanoi puzzle, which involves shifting ordered stacks of donut rings from one pole to another according to certain rules.[29] Additionally, Henry's results have been repeated with other amnesics similar to Henry as well as in animal experiments involving creatures with hippocampal-system damage similar to Henry's. Additionally, brain scientists Neal J. Cohen and Howard Eichenbaum, who have pioneered much of this research, note that neuropsychologists have found a double dissociation between skill learning and [propositional] recall and recognition which provides "strong evidence for claiming a distinction between the cognitive processes or systems mediating the dissociated categories of performance."[30]

Based on this sort of evidence, it seems fair to describe Henry as having the ability to acquire and retain knowledge-how, or KH. The sorts of things that he can acquire (and retain over time) are memories of how to perform new skills and abilities. He can remember how to do puzzles, perform tasks and follow procedures. These are paradigm cases of KH.

V. Stanley and Williamson's Account Revisited

The evidence cited above supports the claim that Henry can acquire and retain KH but is incapable of acquiring and retaining KT. Now, recall that according to Stanley and Williamson, a claim such as "Hannah knows how to ride a bicycle" amounts to:

> The sentence "Hannah *knows how* to ride a bicycle" is true if and only if Hannah *knows that* such-and-such is a way for her to ride a bicycle, and she knows this under a practical mode of presentation (this is my simplified version of their account from page 4 above).

Applying this analysis to Henry, we would get something like:

> The sentence "Henry knows how to perform the Rotary Pursuit Task" is true if and only if Henry knows that such-and-such is a way for him to perform the Rotary Pursuit Task, and he knows this under a practical mode of presentation.

However, given what we know about Henry, we can now see that this analysis cannot be correct. For Henry *does* know how to perform the Rotary Pursuit Task but he *does not* know that such-and-such is a way for him to perform the Rotary Pursuit Task.[31] Thus the left side of the above biconditional is true (since Henry knows how to do the task) while the right side is false (since Henry does not know that such-and-such is a way to do the task). Therefore, the biconditional is false and the analysis fails. This conclusion does not depend on an analysis of Stanley and Williamson's inchoate notion of a "way" or a "practical mode of presentation". Rather it follows directly from facts about Henry's condition along with standard interpretations and paradigmatic examples of the concepts involved.

VI. Objections and Responses

There are, of course, a number of ways to challenge the argument that I have given above. The most likely objections, I suspect, will involve arguing that either (1) Henry does, in fact, have KT, or (2) Henry lacks KH. In what follows I consider and respond to both sorts of objections.

I expect that those sympathetic to Stanley and Williamson's view will simply insist on the claim that Henry does, in fact, have some propositional knowledge with respect to the Rotary Pursuit Task (or whatever the example of KH might be). But on what basis could such a claim be made? Henry retains no memory of performing the task from one instance to the next and if later he is asked questions about the task or about how to do it, he will not be able to answer them. If asked whether he has ever performed the task before, he will respond negatively. So again, given our ordinary conception of propositional knowledge, it seems odd to say that Henry knows that such-and-such is a way for him to perform the Rotary Pursuit Task.

Now it might also be true that a normal person who knows how to perform the task might lack the ability to describe how it is done (due to poor descriptive abilities, for example). This would not preclude us from claiming that she nevertheless had propositional knowledge with respect to the task. But Henry is importantly different from such a person. Henry does not merely lack the ability *to describe* how the task is performed; he lacks any memory of having performed it. More fundamentally, he lacks the ability to retain such memories for any length of time. Thus, when faced with the task on a new day, Henry will not assent to claims such as "you have successfully performed this task before" or "such-and-such is a way (for you) to perform the task". It seems fair to say that Henry retains *no beliefs whatsoever* about how the task is performed from one time to the next, and so cannot thereby be said to have propositional knowledge about it.[32]

It might be argued that Henry does have beliefs about the task, but that they are tacit, or implicit, or in some other way outside the purview of his consciousness. Just as, for example, many people hold the tacit belief that the number of people in the room at a given time is less than a million, even though they might not explicitly entertain such a belief, perhaps Henry holds beliefs about the Rotary Pursuit Task that are not explicit. In other words, perhaps Henry's problem is one of access – that is, he *has* beliefs about the Rotary Pursuit Task, but he cannot get at them, or call them to consciousness.

However, this seems unlikely, based both on the empirical data and on our traditional conception of tacit/implicit beliefs. With respect to the empirical data, the most mature neuroscientific theories posit that the hippocampus is necessary for retaining propositional attitudes – not just for accessing them.[33]

With respect to the traditional conception of tacit/implicit beliefs, on most accounts of such beliefs if the belief is made explicit, the person who holds the belief (upon sufficient consideration) will assent to it. Henry, however, will not assent to such claims. He will, in fact, deny at least some of them (e.g. he will deny that he has ever encountered this task before). Additionally, some other characteristics that are sometimes assigned to tacit beliefs – e.g. that they are inferentially connected to other beliefs (desires, etc.) – do not seem to apply to Henry either. Nothing Henry does or says (other than doing the task itself) implies that he has beliefs about the way to perform the task. It might be asserted that from the fact that Henry can perform the task that he *must* thereby have beliefs about it. But this assertion begs the question at hand. Are there reasons for assigning beliefs to Henry that are not question-begging? Well, there are a number of different philosophical views about what beliefs are, exactly, but it is difficult to see how Henry could be said to have the relevant beliefs on any of these views. It is simply implausible to call something a 'belief' when it is completely inaccessible, beyond conscious recognition and unconnected to other propositional attitudes that Henry has.[34]

It might be argued (by those sympathetic to Stanley and Williamson's position) that Henry has propositional knowledge based on linguistic evidence. The argument might go as follows: (a) we can ascribe KH to Henry regarding, for example, the Rotary Pursuit Task; (b) linguistic analysis tells us that to ascribe KH to Henry with respect to the Rotary Pursuit Task is to ascribe KT to Henry with respect to the Rotary Pursuit Task (under a practical mode of presentation); (c) therefore, Henry *has* propositional knowledge and is thus not a counterexample to Stanley and Williamson's analysis.

In response, I would argue as follows. While I would certainly agree with premise (a), and for the sake of argument, will grant Stanley and Williamson premise (b), it does not seem that the conclusion necessarily follows. That is because the premises are about our ordinary concepts and our use of language (which are the domain of linguistic analysis) while the conclusion is about actual states of Henry's brain (which is, to some degree, the domain of neuroscientists doing empirical research). The case of Henry is (in part) meant to demonstrate that caution should be used in making this type of inference – from premises about the linguistic properties of knowledge ascriptions to a conclusion about what possessing knowledge actually consists in. Or put another way, if Stanley and Williamson are correct, what are we to say about the work done by the scientists who have been studying Henry (and others like him) for the past half-century? Such scientists have generated and confirmed numerous hypotheses and theories about the neurological substrates of various mental phenomena, including knowledge, beliefs and memories. I would argue that their work has led to significant progress concerning our understanding of the nature of knowledge, and that it should not necessarily be dismissed if it clashes with the linguistic analysis of knowledge-ascriptions.

Stanley and Williamson might reply that what such scientists have indeed made significant progress, but that what they were *really* investigating was not whether Henry possessed KH or KT (or both, or neither), but rather whether Henry had propositional knowledge *under a practical mode of presentation*. Even aside from problems with Stanley and Williamson's notion of practical modes of presentation,[35] this response is unsatisfactory. That is because as noted above, current scientific theories based on recent neurological findings shed doubt on the possibility that Henry is capable of retaining propositional attitudes in general. We need not agree with such theories to see that they, and the evidence they are based on, are relevant to the debate about KH and KT. Stanley and Williamson's analysis, however, calls into question the relevance of such data.

In his article "Against Intellectualism", Alva Noë makes a similar point in response to Stanley and Williamson. Noë asks:

> Why should linguistic analysis be regarded as dispositive in matters like this? Is it not a home truth of analytic philosophy that grammar can mislead? What does the grammar have to do with what we are talking about or thinking about or studying when we study practical knowledge?[36]

And:

> …Stanley and Williamson's investigation is in some ways methodologically backward. It is a mark of philosophical progress that we can now see that neither linguistic analysis nor cultivated intuitions are the key to understanding the nature of the mind.[37]

So while linguistic evidence is certainly of interest, and relevant to questions related to KH and KT, it is not the only sort of evidence that should to be taken into account. The kind of evidence that has come to light through the study of Henry M. (and others like him) – empirical evidence that has arisen via the scientific study of the brain – is certainly something that philosophers with an interest in this topic need to consider.

I do not, then, believe that there are good arguments for the claim that Henry does, in fact, possess KT regarding the various skills and abilities that he possesses. What, though, of the other form of objection to my conclusion – i.e. the claim that Henry does not actually possess KH? There are at least two reasons that someone might make such a claim. First, it might be argued that all knowledge has a propositional component and therefore, if Henry's "knowledge-how" lacks such a component, it is not truly knowledge. Put another way, it might be said that Henry does not, in fact, have KH because he does not possess knowledge at all. So, one might claim that since Henry lacks any explicit propositional knowledge of the Rotary Pursuit Task, or conscious ability to formulate strategies for performing the task, or memories about how he performed the task, then it cannot be claimed that Henry has knowledge of the puzzle. Rather, he only possesses an ability or skill which, by itself, is not knowledge. In short, such a claim challenges the view that KH – if it merely consists of the performance of abilities or skills and lacks any propositional characteristics – should be considered a kind of knowledge at all. This objection amounts to an embrace of what Ryle called "the intellectualist legend" and what Noë refers to as "intellectualism".

However, such a challenge begs important questions. Those who claim that Henry has knowledge of some sort would presumably not deny any of the above claims (that he lacks explicit propositional knowledge, etc.) and yet could still insist that he *knows* how to perform this task. They might make this claim based, most importantly, on the fact that Henry *can* in fact perform this task and that his performance on the task improves with time and practice. That implies that his success is not merely accidental or lucky. Additionally, Henry's brain and body are involved in this activity, and they change and adapt in response to repeated exposures to it. Henry is not simply demonstrating instinctual behavior or autonomic responses to stimuli. He *learns* how to perform the task, and in doing so, learns something about how to navigate the world (or, at least, a small part of it). It is difficult to see why this should not be described as acquiring knowledge – unless one begins with the assumption that all knowledge is propositional in nature.[38]

Finally, one might accept that there is such a thing as KH and that it has a non-propositional nature and yet still argue that Henry does not possess KH. One might argue for this conclusion by claiming that Henry's behavior simply does not meet the standards required to qualify as KH. This objection assumes that such standards have been established, which is debatable. Nevertheless, there have been a few proposals put forward about the criteria one must meet to possess KH and according to all of these proposals (the ones that I am aware of) Henry does, in fact, qualify as acquiring KH. For example, Henry has the ability to perform the task and it can be said of Henry that he is disposed to perform the task under the appropriate circumstances. Similarly, Henry succeeds at performing the task, his success is non-accidental, and if he tries to perform the task under the appropriate circumstances, he succeeds.[39]

VII. Conclusion

Henry M. (and others like him) provide a compelling reason to reject Stanley and Williamson's account of KH as a kind of KT. On Stanley and Williamson's account, possession of KH implies possession of a corresponding bit of KT. Henry M's condition shows, however, that possession of KH is possible in the absence of the ability to acquire (and/or retain) KT. So Stanley and Williamson's account appears to be wrong.

Perhaps more importantly the case of Henry M. (and all the work, research and theorizing that has sprung from it), has potentially profound implications for epistemological questions about the relation between theoretical scientific knowledge and technological knowledge. In-depth consideration of such implications is beyond the scope of this essay. However, it should be noted that if it is indeed the case that KH and KT are distinct kinds of knowledge, with distinct neural substrates, then it might also be the case that epistemological theories and ideas that have been developed using theoretical scientific knowledge as a model could be counterproductive as tools for analyzing technological knowledge.[40]

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Endnotes

[1] Ryle, Gilbert 1949. See especially Chapter 2.

[2] Especially Ryle 1946.

[3] These positions are not all the same, though Ryle tends to bunch them together. Stanley and Williamson's position (discussed below) is that KH is a species of KT but that it is not reducible to KT. I will focus on their particular position throughout the paper unless otherwise noted.

[4] Stanley and Williamson 2001.

[5] Stanley and Williamson 2001, pg. 411. Citations are from the *Journal of Philosophy* version of the paper (see fn 4 above). There is also a version of the paper online at: http://www.rci.rutgers.edu/%7Ejasoncs/JPHIL.pdf. The Ryle reference in the quote cited is to Ryle's "Knowing How and Knowing That" (see fn 2 above).

[6] Including: Koethe 2002, Schiffer 2002, Rumfitt 2003, and Noë 2005.

[7] For example, David Carr in his articles "The Logic of Knowing How and Ability", *Mind*, 88 (1979): 394-409, and "Knowledge in Practice", *American Philosophical Quarterly*, 18 (1981): 53-61. Also Bechtel, W. and Abrahamsen, A. 1991. *Connectionism and the Mind: An Introduction to Parallel Processing in Networks*, Oxford: Basil Blackwell.

[8] Bechtel and Abrahamsen 1991, pg. 151.

[9] Stanley and Williamson 2001, pg. 426. The reference to recent syntactic theory is on pg. 417.

[10] Stanley and Williamson 2001, pg. 430.

[11] Stanley and Williamson argue for the existence of practical modes of presentation by invoking the analogy of first-person modes of presentation. For criticism of this aspect of Stanley and Williamson's analysis, see Noë 2005, pp. 287-88.

[12] Henry M. is sometimes referred to as "H.M." or "Mr. M.". I collected general information on Henry M., his condition, his surgery, etc. from a number of different sources ranging from his surgeon, Dr. William Scoville's, 1957 article (co-authored by Brenda Milner), in which he first published information on Henry M., entitled "Loss of Recent Memory After Bilateral Hippocampal Lesions" in the *Journal of Neurology, Neurosurgery and Psychiatry* (JNNP), vol. 20, pp. 11-21; to a biographical book about Henry by Philip J. Hilts called *Memory's Ghost: The Nature of Memory and the Strange Tale of Mr. M.* Touchstone. 1996. Additionally, Suzanne Corkin, a cognitive scientist at MIT, has worked with, and written about, Henry extensively and a number of her articles are cited below.

[13] Scoville and Milner's terminology

[14] The brain has two medial temporal lobes, one in each hemisphere. If you put your hands on each of your temples, the medial temporal lobes would be underneath them. The temporal lobes are today associated with (among other things) memory and language skills, though their function was more mysterious when Henry underwent his surgical procedure.

[15] Henry went from having severe seizures almost daily before the surgery to having two or fewer a year after the surgery. See Corkin 2002.

[16] Scoville and Milner 1957, pp. 13-14.

[17] The main character in the 2000 film *Memento* suffered from this form of amnesia.

[18] Corkin 2002, pg. 153.

[19] Corkin 2002, pg. 153-4. See also, Hilts 1996, pg. 116.

[20] There are some exceptions to the above claims (see Corkin 2002 for some discussion). Henry can acquire bits and pieces of new semantic knowledge – for example he can sometimes identify names of people that have become well-known since his surgery if given parts of the name or descriptions. Such exceptions are sometimes attributed to minor remnants of Henry's hippocampus that survived the surgery, or to other parts of the brain (retained by Henry) that might be partially responsible for certain kinds of memories. The exceptions are rare, however, and for the most part Henry has been unable to new episodic or semantic memories since his surgery.

[21] Corkin, a cognitive scientist at MIT, estimates that over 100 investigators have poked and prodded H.M. since his condition arose in 1953. See Corkin 2002, pg. 153.

[22] Schaffhausen "The Day His World Stood Still."

[23] Corkin 2002, pg. 153.

[24] I address the possibility that Henry has KT but that it is beyond conscious access, or that he is merely incapable of verbal expression of such knowledge, in Section VI below.

[25] Schaffhausen "The Day His World Stood Still", pp. 3-4
[26] Corkin 2002, pg. 154
[27] Corkin 1968.
[28] Ibid, pg. 257.
[29] Though attempts to reproduce H.M.'s mastery of the Tower of Hanoi Puzzle have met with mixed results. See Xu and Corkin 2001.
[30] Cohen and Eichenbaum 1993.
[31] For purposes of simplicity, I am ignoring complications involving Henry's short-term memory. That is, there may be short periods of time, right after Henry has completed the Rotary Pursuit Task, in which Henry can be said both to know how to perform the Rotary Pursuit Task and to know that such-and-such is a way to do the task (under a practical mode of presentation). However, after this short-term propositional memory fades (a few minutes later), Henry retains the knowledge of how to do the task but does not retain the knowledge that such-and-such is a way to do the task (under a practical mode of presentation).
[32] I am assuming a justified, true belief account of propositional knowledge (with perhaps something added to account for Gettier challenges). Henry's condition would be even more problematic for an internalist account of justification since Henry's lack of declarative memories would seem to imply that even if he could be said to have beliefs, his beliefs would likely lack justification.
[33] See, for example, Cohen and Eichenbaum 1993. Throughout the book, they theorize that procedural memory/knowledge uses "fundamentally different" kinds of representations from those used in declarative memory/knowledge (e.g. pg. 49 and Chapter 3). The upshot is that amnesics such as Henry cannot store and/or access the kinds of representations necessary for propositional knowledge and/or belief.
[34] Even in the case of subconscious beliefs of the sort Freud argued for, it is possible to bring them to conscious awareness over time via therapy. This is not the case with Henry.
[35] See Noë 2005, pp. 287-88.
[36] Noë 2005, pg. 286
[37] Ibid, pg. 290. Noë makes this point by invoking the example of non-human animals, which Stanley and Williamson discuss when considering objections to their view. Noë points out that "whether or not [dogs] can grasp propositions is an open question, one that is debated in cognitive science" (289). It is not something that can be settled by analysis of knowledge ascriptions.
[38] This is a topic/debate that has received surprisingly little attention among philosophers. Definitions of, and characterizations of, knowledge tend to consider only propositional knowledge (see, for example, *The Cambridge Dictionary of Philosophy*, and most other philosophical reference works). As such, when it comes to the question "what is knowledge?", the focus is on the justified, true belief account of propositional knowledge. There is not much philosophical discussion of what knowledge *simpliciter* might be, though Linda Alcoff and Vrinda Dalmiya consider the question in their 1993 article "Are Old Wives' Tales Justified."
[39] I am not endorsing these various accounts of knowledge-how, which I borrow from writings of Ryle and Katherine Hawley, among others. I am, rather, making the point that on those accounts of KH that have been given, Henry seems to qualify as possessing KH. See Ryle 1946 and 1949, and Hawley's 2003.
[40] This assumes that KH is more central to technological knowledge than theoretical scientific knowledge and that KT is more central to theoretical scientific knowledge than to technological knowledge. I don't argue for this point here, though I think it is true. Note that I am not making a straightforward identification between KH and technology, or between KT and theory. Both sorts of knowledge no doubt combine in complex ways at higher levels.

An Ontology of Technology: Artefacts, Relations and Functions

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Abstract
Ontology tends to be held in deep suspicion by many currently engaged in the study of technology. The aim of this paper is to suggest an ontology of technology that will be both acceptable to ontology's critics and useful for those engaged with technology. By drawing upon recent developments in social ontology and extending these into the technological realm it is possible to sustain a conception of technology that is not only irreducibly social but able to give due weight to those features that distinguish technical objects from other artefacts. These distinctions, however, require talk of different kinds of causal powers and different types of activity aimed at harnessing such powers. Such discussions are largely absent in recent technological debates, but turn out to be significant both for ongoing technology research and for the recasting of some more traditional debates within the philosophy of technology

Keywords: Ontology, Philosophy of Technology, Critical Realism, Artefacts, Functions

1. Introduction[1]

It is fair to say that the term technology is used to refer to very different kinds of things. Material objects (some, but not all, of which have been transformed by human doings), practical knowledge and knowledge embodied in things (often material objects but not always), particular practices, even social institutions are all regularly considered to be types of technology. At the very least, this state of affairs has the unfortunate consequence that many heated debates about technology, and its relationship to the social world, are complicated by the fact that different authors are actually arguing about different things.

Not only is there a general failure to reach consensus about the meaning of the term technology, but there is often little attempt made to establish a meaning of technology at all. Indeed, many argue that technology may be seen as the archetypal black-box category of social science. Perhaps the most obvious example of this can be found in the discipline of Economics, where technology is simply anything that is important in constraining the feasible combinations of certain inputs to produce certain outputs. Once knowledge of different shaped production functions is to be had, no further knowledge of technology itself is sought. It might also be argued that, until fairly recently at least, even within the philosophy of technology there has been some degree of black-boxing of technology as a result of focusing upon the social consequences of technology rather than on the nature of technology itself. However, a variety of more recent contributions have attempted to reorient the study of technology towards describing the nature of technology prior to addressing its likely effects. It is with this in mind that, for example, Mitcham argues for a bridging of the gap between what he terms engineering philosophy of technology (concerned with what technology is) and humanities philosophy of technology (concerned with the social consequences of technology) (Mitcham 1994). A similar point is made by Pitt who pleads for a movement away from putting social criticism before a study of technology itself (Pitt 2000).

Kroes and Meijers go so far as to discern an empirical turn in the philosophy of technology (Kroes and Meijers 2000: 20). However, the focus on empirically adequate descriptions of technology and engineering practices (their meaning of an empirical turn) need not of course actually generate a general definition of 'technology'. And indeed much of the constructivist literature of technology in recent years, which can be understood as exemplifying the move that Kroes and Meijers identify, has rarely gone beyond a concern with specific technologies; attempts to provide definitions of 'technology' being generally accepted as either pointless or dangerous (usually betraying essentialist tendencies).[2] This is unfortunate in that the very literature that has had most to contribute to our understanding of the social dimensions of technology, has tended to shy away from any general statements about the social dimension of technology. Thus there is consensus about the fact that technology is irreducibly social, but little precision concerning the ways in which technology in general is social or of what implications follow from different conceptions of the social.

The aim of this paper is to give an explicitly ontological account of technology that focuses upon the social dimension of technology. It is worth pointing out from the outset, however, that such a focus upon ontology should in no way be seen as an attempt to give an account of technology that is 'out of history' or *a priori* in any sense.[3] More specifically, whilst the form of ontology I wish to pursue here (which might be termed accommodative ontology) is in keeping with ontology traditionally conceived of in that it is concerned with the most fundamental or basic constituents of the (social) world, history enters into the account explicitly in at least the two following senses. First, the account draws upon and develops currently prominent accounts of social ontology - thus starting with a particular, historically transient account that is nevertheless aimed at illuminating or conceptualising the most fundamental categories of relevance to technology. Secondly, some attempt is made throughout to compare, contrast and where possible accommodate existing conceptions of technology – their insights, preoccupations etc.[4]

In short, then, the idea is to move towards a conception of technology by iterating between 'extending existing ontologies' and 'accommodating substantive preoccupations'. Some distinctions will be of a more conventional nature than others. For example, in developing an account of technology it turns out that conceptualising the general category 'artefact' is relatively straightforward from the state of existing ontological theorising, but making the finer distinction between types of artefact (which are needed to distinguish technical objects from other artefacts) requires more conventional criteria. Specifically, I shall attempt to extend the best account I know of social ontology to a focus upon the general processes through which artefacts (understood broadly) come to be. Starting from the observation that technical objects, like all material artefacts, have a dual constitution – i.e. not only are they made up of objects that are material but that are irreducibly social too – the aim is to give an account of social activity that engages with objects of this dual nature. Alternatively put, the task is to spell out the ways in which this dual nature depends upon social activity.[5]

The third section of this paper provides quite different kinds of arguments to arrive at a more substantive definition of technology. Whereas the aim in the second section is to give an account of the artefactual world, such an account is as relevant to art and food as technology. Finer distinctions are then required to talk of any of the special features that technology might have. Thus I shall try to make further distinctions based upon the types of causal power that can be considered to be essential to different kinds of objects. In order to do this I inevitably have to deal with the problem of distinguishing and/or relating social relations and functions. The argument made is that although technical objects are irreducibly relational, social relations are not *essential* for their causal powers, an aspect of technical objects that distinguishes them from social objects. I then argue that the facet of technology that function is often used to express, is rather better conceptualised in very general terms as a concern with the extension of human capabilities. Various advantages that follow from this conception of technology are then drawn out.

2. A transformational conception of technical activity and a relational conception of material artefacts.

The social ontology[6] I wish to draw upon is that developed within a string of related accounts that have come to be known under the heading of Critical Realism.[7] More specifically, I wish to focus upon the particular conception of social activity that has been developed in these accounts (namely the Transformation Model of Social Activity or TMSA). So doing has two main advantages. First, it makes it possible to avoid problems that recur throughout the social sciences but are particularly dogged in technology studies: how to clarify the constitutively 'social' character of technology insisted upon by social constructivists without reducing technology to simply a social phenomenon (where its material basis or physical structure effectively count for little of nothing in an account of what technology is); and secondly how to give space to traditional concerns of the philosophy of technology such as technology's 'out of control-ness', without resorting to any form of determinism. Technical objects simply cannot be understood other than in terms of the various activities involved in their design, production or use. Thus the model of social activity I shall start with is not only a model for technical *activity* but also an integral part of the account of what technical *objects* are.

The basic features of the TMSA have been presented in different ways, notably as a corrective to existing voluntaristic or reificatory accounts of social structure or as a transcendental argument from the existence of generalised features of experience of the social world, such as routinised practices.[8] Either way, the main point that arises is that social structure exists only in and through the activity of human agents, even though it is not reducible to such activity. Put another way, against individualistic or voluntaristic accounts of social structure, structure pre-exists and is a necessary condition for all intentional agency, whilst, against reificatory accounts, structure only exists in virtue of the activity it governs. Thus if social structure always pre-exists actual behaviour this does not mean that individuals create structure in any sense but that it is actively reproduced or transformed. Similarly, if it is something that only exists in virtue of human activity, there is no sense in which it is outside of or external to human activity. However, neither are structure and agency simply moments in the same process – they are different kinds of thing. And it is this transformational nature of the connection between the two (interestingly, for my purposes, often conveyed by the Aristotelian metaphor of the sculpting artist fashioning a product out of the material and with the tools available) that lies at the heart of the TMSA. The resulting emphasis, then, is upon transformation.

Society, conceived of as the sum of the relations between agents is the ever present condition and continually reproduced outcome of social activity. Society acts as both an enabling and constraining influence on behaviour as well as, more constitutively, as a socialising force, thus impacting on how individuals react to the structural constraints and enablements they face. But as structure is only ever reproduced or transformed through human action, where such structure endures, its continuity as much as its change is a significant object of analysis. As such, social change is inherently non-deterministic. To capture this aspect of structure, following Giddens, the term 'duality of structure' is often used. Similarly, it should be clear that although action reproduces certain structural forms, this will typically not be the intention of this activity. Thus, my speaking English is not intended to reproduce the grammar of the language, although it does generally do so. Following Bhaskar, the 'duality of practice' is used to capture this dual aspect of action. Such conceptions of duality come together in what Bhaskar has termed the position-practice system: a set of mediating concepts used to refer to the 'slots' in the social structure into which acting subjects must slip in order to reproduce it (see Bhaskar 1989: 40-41). Thus agents occupy relationally articulated positions with rights, responsibilities, duties, obligations etc., that are reproduced by a variety of practices including the incumbent's fulfilment of those rights, responsibilities etc.

Let me draw out one more aspect of this account before we can return to a discussion of technology. Specifically, the TMSA can also be seen, as set within an argument for a qualified or critical naturalism[9], as an attempt to elaborate how the social and natural worlds differ. Ultimately, the differences between the natural and social world hinge upon the fact that the latter depends on us in a way that the former does not. Gravity would still be here tomorrow even if human societies disappeared over night, but the high-way code would not. For example, both (gravity and the high-way code) are necessary parts of a causal explanation of why a car stops at a traffic light. Both gravity and the high-way code are best understood as causal mechanisms[10], but they have different *modes* of existence. The high-way code is an emergent feature of human interaction – without such interaction the highway code could not exist.

Both natural and social science are understood to involve a focus upon causal mechanisms that are not reducible to events or states of affairs (see Harré 1970, Harré and Secord 1972, Harré and Madden 1975). Science, on these accounts is not restricted to such forms of inference as induction or deduction, which only concern movements from particular to general statements or vice versa *at the level of events*, but with forms of inference that lead from the observation or experience of events and states of affairs (e.g. falling apples) to the underlying structures and mechanisms that could give rise to them (gravity, curved space, or whatever). The difference between the two kinds of science then rests on the differences between the kinds of structures or mechanisms that feature in the respective (social/natural) domains. For present purposes the important differences can be thought about from the perspective of what must be the case for (successful and replicable) experiment to have the status it does in the natural sciences but not in the social sciences. In natural science, it would seem, closures are possible to achieve. Thus it must be the case that some mechanisms or sets of mechanisms have a sufficiently consistent internal structure to behave the same way under the same circumstances. Additionally, such structures or mechanisms must be isolatable from other disturbing or countervailing factors. Such possibilities rarely exist in the social world.

A major point of the TMSA is that social structures only exist in virtue of the activity they constrain or enable. Thus social structures depend, for their existence on the activities of agents and the conception agents have of such structures. As such social structures will not tend to endure across time and space in the same way that natural mechanisms do. Such differences (or ontological limits to naturalism) can be summarised as the relatively greater activity-concept-time-space dependence of social structures (see Bhaskar 1989: 37-54, 174-9). The major epistemological limit is that whereas the differentiability of natural mechanisms means that the natural world may well be characterised very usefully in terms of closed systems,[11] this is unlikely to be the case for much of the social world. It is important to point out, however, that this does not amount to saying that the social world is open and the natural world is closed. Both the natural and the social world are open, the differences between them lie in the possibilities that exist for the manner, and likely success, of strategies designed to close off particular regions of either the social or natural world.

For those familiar with critical realism at least, this much should be familiar if not uncontentious. But how is any of the account given so far of relevance to a conception of technology? The relevance comes technology's dependence upon social activity. The TMSA above is an attempt to draw out the main features of human agent's relationship with social structure through the medium of social activity. The focus is on the domain of social relations. However, such activity can be viewed under another aspect – as technical activity. Technical activity, at a very general level, is like all human activity in that people act intentionally, in conditions not of their own choosing but transforming the materials to hand, etc. But here a distinction can be made between technical objects, which serve as the condition and consequence of technical activity, and technical subjects, those human agents engaged in technical activity. As with the TMSA, these can be combined to provide a transformational model of *technical* activity (or TMTA, see Lawson 2007a).

Here the technical subject and object are, similarly, not reducible to or derivable from each other, they are different kinds of things, even though both are, in some sense, the condition and consequence of each other. As with social structure in the TMSA, the state of technological development both enables and constrains human activity. The idea that technology enables, or simply is, the control of nature is pervasive, at least since Bacon. But as new technological objects enable different sets of human actions to take place, this will always set new constraints, e.g. solar power enables cheap/sustainable electricity but is best located in sunny places, laptops make it possible to work in the library, but only near electricity points, etc. But the idea of constraint can be understood more systemically too. For example, Hughes focuses on the fact that technical objects are not used, and do not exist, in isolation – people use or deal with systems of technical objects. At any point in time there will be a weakest link in this technological systems that effectively acts to constrain the working of the whole (Hughes refers to these as reverse salients – Hughes (1983)). These constraints then act to give directionality to future technical activity. Constraints, as with the TMSA, are much more than any (metaphorical) fixed cage.

It is particularly important for present purposes, however, to point out that technical objects do not simply constrain or enable particular human behaviour – but have some effect on the nature of the human actor also. Of course, this is a recurrent theme in the study of technology, whether in Veblen's account of the machine process, or Heidegger's comparison of craftsmanship and new technology, or the Amish Bishops' decisions about which technology to 'endorse', the question that recurs is 'what does using this technology make us become'? The term socialisation, which features in the TMSA, should no doubt be replaced by something like technologization, but the idea is the same – technical objects (like social structure) do more than constrain or enable. They have a role in shaping the capabilities and competences of those engaged with some technology (a point that is returned to below).

As with the conception of social activity sketched out in the TMSA, technical activity can be understood in terms of transformation and reproduction (this time of technical objects), rather than creation from nothing. And indeed there are some clear advantages to thinking of technical activity this way. Viewing technical activity as transformational, as with social activity, affords a way between voluntarism and determinism. For example it makes it possible to accommodate the insights of those such as Ayres, who argued strongly against the idea of the heroic, lonely inventor creating technology in isolation and rather stress the importance of sequence or path dependence, etc. (Ayres 1961). As noted, a condition of invention or developments in technology is the state of technology itself. Thus as Ayres observed, similar patents are often filed more or less simultaneously in different places, light bulbs are unlikely to be developed before the invention of electricity, and so on. And indeed the kind of conception underlying Ayres' contributions, much like others considered to be technological determinists, such as Heilbronner (1967), seem to be making the simple point that some things cannot be developed without others being developed first. That is, they are talking about necessary rather than sufficient conditions. In which case a focus on design as transformational captures what is essential to the argument in a fundamentally non-deterministic manner. In other words, talk of constraining, enabling or socialising no more requires (or reduces to) a form of determinism in the TMTA than it does in the TMSA.

It is equally important however, to point out that transformation in the TMTA does not play the same role that it does in the TMSA. And indeed the limits to the analogy are particularly important for the account of how technology differs from other material objects, as I shall argue later. First, there is much in design that cannot be transformed at all. I am referring here simply to the fact that technical objects are constituted by natural as well as social mechanisms. For example, gravity is not something that human beings can change, but something that must be drawn upon or used. The importance of this will depend on the kind of artefact in question. Both a pendulum clock and a book are subject to gravity, but although a book may be very difficult to use in the absence of gravity, for the pendulum clock gravity is essential to its way of working. The designer is thus *harnessing* the powers of existing mechanisms in the design and not transforming them in any sense (see Pickering 1995). Secondly, we tend to see technical objects as 'designed' or 'engineered' on the one hand, and then simply 'used' on the other. Neither action seems to be a form of transformation or reproduction in the senses used above. For example, when we acquire a new CD player we read the instruction manual, which tells us who designed this particular player, what it is for and how it is to be used. Typically, we then use it in line with the designer's intentions. This is clearly different from, say, our use of language or our reproduction and transformation of social relations. If the role that transformation plays in technical action differs from the role it plays in specifically social action, then so too does the role of reproduction. For example, it is hard to believe that we reproduce a hammer by knocking in nails *in the same way* that we reproduce language by speaking.

Technical activity is typically divided up into the stages of design or construction on the one hand, and use on the other.[12] The design stage involves primarily a process of separating off various properties of existing things (artefacts or naturally occurring objects or mechanisms) and recombining them into objects with particular capacities or powers. Use is primarily concerned with identifying objects with particular capacities and powers and inserting (or enrolling) them into particular networks of social and technical interdependencies. The distinctions I have in mind here are essentially those developed by Feenberg in his Instrumentalization Theory (see especially Feenberg 2000, 2002). In order for an object to be open to technical control, it must first be split off from its original environment, then simplified so that certain aspects, that can be functionalized in terms of some goal, can shine through. But for a device to actually function some degree of re-contextualisation needs to be undertaken. This involves insertion within a system of working devices, and within particular social networks of use, as well as some measure of compensation for the simplifications undertaken, that embed the device ethically and aesthetically in particular contexts of use (Feenberg 2002).

It is not simply the case, however, that design is uniquely associated with isolation and use with reconnection. Rather, design and use involve both isolation and reconnection. But the kinds of isolation and connection involved at each end of the spectrum (design to use) do have different characteristics. At the design stage things are perhaps clearer. Particular functional capacities of things or mechanisms are isolated and (atomistically) reassembled in line with some prior criteria or functional requirements. Use, however, provides a more complex example of the isolation and reconnection moments, and centrally hinges on the relational aspect of technical objects. It is true that the form and content of the hammer would not disappear tomorrow if human societies ceased to exist (as say language would). But the hammer, in the eventuality of human societies ceasing to exist, would actually cease to be a hammer; because part of what a hammer is, exists only in relation to those using it. It is only by being used that a collection of wood and nails, or a tree trunk in the forest, become tables. In fact, use involves enrolment in two kinds of (analytically separable) networks, i.e., social and technical networks. For the telephone to work it must be connected to a telephone network, to an electricity supply, etc. But without human societies it is not a telephone at all. However, such relations are not simply concerned with the object's function. When I use my mobile on the train I am certainly reproducing the relation of this object to users in general as 'a communicating device', but I am also reproducing or transforming rules of politeness, etc., depending upon where I use it (in a mobile-free carriage?) and how (by speaking loudly?)

Technical objects are perhaps best conceptualised using similar 'mediating' concepts to those described above as a position-practice system. Such objects 'slot' into social and technical networks of relations, practices and other devices. They have positions in the same sense as human agents occupying social positions, but the practices that reproduce their sociality are undertaken by their users. The objects themselves contribute powers, the harnessing of which is a primary goal of technical activity. In this sense, we might talk of a position-power system for technical objects, in contrast to (but alongside) a position-practice system for human agents.

Viewed in this way, the TMSA has some role to play as a model for the kind of relation between technical object and subject, but it is also part of the relation itself. Alternatively put, the social activity that the TMSA is designed to capture is actually part of technical activity. It is the social relations of the TMSA that are reproduced and transformed in technical activity, as well as being enabling and constraining of that activity. However, technical activity is about more than simply reproducing or transforming social relations. The causal properties of material objects are harnessed and put to work in a process of isolation and reconnection that stretches across the activities of design and use.

By focussing upon technical activity in this way it is possible now to pinpoint the ways in which technical objects may be understood to be social. By social I mean here only those things that depend on us in some way. The first sense in which technical objects are social derives from the design process in which technical objects take a particular form. How different natural mechanisms, existing artefacts, etc., are brought together reflects the values, desires, intentions, etc., of those designers and all the groups that have had some say in the nature of the design, which then become concretized in the very structure of the technical object. Such values, etc., can then be understood to be exerting a continuing influence over technical activity both via the kinds of enablements and constraints noted above but also via the codes of operation built into and mediating their use.[13] This is of course, where the social constructivist approaches to technology have made such a strong contribution to the study of technology in recent years. How particular designs and formulations are settled upon is clearly a very social affair. However, as is brought out so well in the work of Marx, it is not just values, intentions, etc., that become concretized in this way, but social relations themselves. This is both because, as is brought out in the TMSA, the existing state of social relations are condition as well as consequence of social, including technical, action and because, as constructivists ably demonstrate, so much technology takes the form it does because of the way that disputes between different groups are settled. Thus the very structure of technical objects is irreducibly social.

This sense in which technical objects are social is worthy of note. To say that values, intentions and even social relations become concretized in this way is to talk of essentially social things becoming material. As such, given the relative concept-space-time independence of material things, there is a relative endurability and travel that is possible for those otherwise precarious aspects of the social world. Thus, and this seems to be centrally important for an understanding of the nature of technology, technology is the site in which the social achieves a *different mode of existence through its embodiment in material things*.

The second sense in which technical objects are social is the relational sense. Use involves the insertion or enrolment of technical objects into social and technical networks, which, in so doing, reproduces or transforms a variety of social relations along the way. Alternatively put, the duality of practice is as relevant for technical activity as it is for social activity. Indeed it is more relevant, in that the duality here captures not only the 'thin' sense in which action has unintended consequences, but the 'thick' sense in which in which action to do one kind of thing (technical) achieves another kind of thing (social).

Underlining, and differentiating, these two senses in which technical objects are irreducibly social thus emphasises the importance of transformation and reproduction as types of technical activity. But they have a more qualified role to play in the TMTA. This is because material artefacts have a mode of existence (as material objects) which is not *simply* reliant upon their transformation or reproduction through human activity. Transformation and reproduction, at the very least, need to be supplemented by the important moments of isolation and reconnection. And indeed it seems to be in terms of the latter that much of the changing nature of technology is best understood. For example, it is possible to characterise skills-based, tool-using technical activity in terms of the almost simultaneous acts of isolation and reconnection. Ingold's example of the weaver (used by Ingold to demonstrate that making is not necessarily a simple process of human beings putting some explicit plan or design in to action) could as easily be used to show that in certain contexts the necessary processes of isolation and recombination often do take place together – even tacitly (see Ingold 2000: Chpt 18).

Mass production, in contrast, can be understood in terms of an explicit and even institutionalised separation between processes of design and use, and also between isolation and recombination. Design or research departments often become quite disconnected from the details of how their (primarily isolative) research will be used by other designers (i.e. recombined with other technical objects into useful things), which are in turn disconnected in more far reaching ways from those who may actually use the objects produced (contextualising or embedding these objects in particular social and technical networks). Focusing upon the separation of moments in this way makes it possible to highlight different stages of technical activity (i.e. along the range between design and use). Where full or clear isolation is possible, recombination will tend to be more atomistic (which seems more likely at the design stage) whereas given the internal relatedness of the social networks in which technical objects are combined in use, the form of recombination will tend to be more organic.

To take stock briefly, drawing upon the TMSA I have attempted to give an account of social action that is engaged with material things, and of how these material things must be understood as socially as well as materially constituted. More specifically, I have argued that artefacts are irreducibly social in two distinct senses, both structurally and relationally. First, they are social in that the form they take is effectively a concretization of past values, actions, social relations, etc. Thus to understand why they take the form they do, requires a consideration of human actions of various kinds. The second sense in which artefacts are to be understood as social is the relational sense. Thus some account needs to be taken of the relations in which the artefact stands to people, institutions, etc. This was captured above in that technical action is conceptualised as both reproduction as well as transformation, and by noting that both dimensions of social activity (central to the TMSA and the TMTA respectively) are both in play simultaneously.

It was also noted that such technical activity can be viewed as having two moments – of isolation and of reconnection. And that the scope for separation of these moments would depend both on the nature of the artefacts involved and the institutional circumstances in which such activity takes place.

This broad account possesses a variety of advantages over existing conceptions, not least in being able to accommodate dominant ideas about path dependence, lock-in, out-of-controlness and so forth, without encouraging any form of determinism. But the discussion provided so far does not really provide us with a definition of technology as such. By focusing upon the domain of artefacts, where the social and material come together, I have thus far only been able to suggest broad features that seem relevant to a range of different artefacts. So far, nothing has been said that would help us distinguish between different kinds of artefacts (including art, toys, food, etc.) that traditionally have been contrasted with technology. Indeed nothing has been said that might distinguish material artefacts such as technology from other phenomena, usually understood as social, which also can be understood as the material results of human doings (such as social institutions). However, such distinctions lie at the heart of (or have motivated) much of the literature that deals with the nature of technology.

3. Function and technical objects

How, then, are technical objects to be distinguished from other artefacts? One obvious strategy is to invoke a concept that I have largely ignored so far, i.e., function. It seems undeniable that all artefacts are made or used for a purpose, and so have a *function* of some kind. Is it possible to distinguish a particular kind of function, a technical function, which all technical objects have, thus making it possible to distinguish such objects from other kinds of artefacts? For example Rathje and Schiffer (1982) distinguish technofunctions from socio and ideofunctions.[14] But as their account demonstrates, the problem is that such distinctions do not actually help us distinguish between different kinds of objects at all. Different functions, rather, refer to different properties of artefacts, so that any particular artefact could have all of these functions in different contexts. For example, a throne may have the technofunction of allowing someone to be seated, it may also have the sociofunction of communicating who is the king, conveying status, privilege etc., and it may also have the ideofunction of symbolising authority, monarchy etc. Thus given that it does seem plausible that artefacts have technical, social and ideological (as well as aesthetic, moral, political, etc.), dimensions, we at best have a typology in which many things can be viewed as technology under some description.

A further problem, for the attempt to distinguish different kinds of artefacts in terms of their functions, is that this does not, even in some partial sense, tell us anything about what some artefact must be like or what qualities it must possess to have a technical function and so count as a technical object (even if only under some description). If I were to use a famous sculpture to hang my clothes upon, I would be giving it a technofunction, but this does not really help me assess whether I am using the object incorrectly or whether I might be right or wrong in thinking that some object is indeed a technical object or not. By itself this distinction does not enable us to identify what it is about technical objects that make them different from other kinds of artefacts, and might make us correct to ascribe a technofunction to it. For those such as Schiffer, it is enough simply to say that everything is technology, viewed under some aspect (Schiffer 1992).

More recently, Searle has invoked the idea of function in order to distinguish a range of different entities (especially see Searle 1995). Searle's concern is to ensure that these different kinds of entity fit with his basic ontology of elementary particles and forces. He seems to suggest that there is a more or less continuous line from molecules to marriage, with both technical and social objects situated somewhere along the way. A conception of function is central to his account of how such objects fit in to this 'elementary' ontology. Searle distinguishes intrinsic features of things (such as mass, chemical composition etc) from those features that are observer relative. Whereas the former are easily grounded in Searle's basic ontology, the latter are more problematic (Searle 1995:14). However, it turns out that observer relative features can be accommodated indirectly, via Searle's conception of function. Although, for Searle, functions are pretty much the same in the social or biological worlds (i.e. they are observer relative), he distinguishes three different kinds of function assignment. Agentive functions refer to the use to which we intentionally put objects such as screwdrivers or televisions. Non-agentive assignments are made to biological functions such as pumping blood around the body – these do not serve some practical purpose but refer to naturally occurring objects. Lastly, status functions are a subset of agentive functions in which the object is taken to represent, symbolise or stand for something else. Both a screwdriver and a £5 note have agentive functions but one is a technical object whereas one is a social object. This distinction is based on the idea that for a technical object there is a strong link between function and physical structure, whereas for the latter there is not (which seems to involve the idea that all things used as money do not have a common physical structure). Put another way, the causal properties of the former depend upon its intrinsic structure whereas the causal power of the latter, to exist, depend on collective recognition that the object symbolises or stands for something in particular. As such, social objects have deontic powers (see Searle 2005) which the former, technical objects, do not have.

Putting the argument in these terms serves to highlight that it is actually the idea of causal powers, rather than that of function[15], that is doing the work here (at least in distinguishing technical from social objects). Indeed, whether an object is technical or social, in this sense, seems to depend upon the kind of causal powers that are most essential to it, that is on its intrinsic, physical or material properties rather than its (social) relationality.[16]

It is not, however, that the physical realisation of social artefacts is arbitrary (as Searle seems to suggest (see Meijers 2000:90). To take the usual example of money, even if money is actually not an artefact at all but a social relation, it is not at all clear that its physical realisation is in any sense arbitrary. Money could not be made up from water, or any other non-scarce resource, etc (see also Palmer for a discussion of this in relation to Searle 2003). Rather than arbitrariness, the point at stake here is the relative importance of the different kinds of causal powers it has. Thus, in effect, it seems important to look at whether some causal power is essential to something being the kind of thing that it is, and whether this power is intrinsic to it (grounded in its material form or content) or relational. This is not, however, the same as arguing that technical and social objects can be distinguished on the basis that technical objects have material effects and social objects have social effects, as other critics of Searle such as Miller propose (Miller 2005). The distinction does not follow from actual functions and actual uses (since artefacts, as Schiffer et al. point out, can in actuality have multiple functions and multiple uses), rather it hinges on different *kinds* of causal powers and different *kinds* of uses. To pursue this further, it is helpful to briefly consider the example of two particular artefacts, namely passports and photocopiers.

What do we know about the causal powers of passports? Clearly they are artefacts in the sense discussed in the previous section, they have material contents, social forms and relations of use. They are made up of complex plastics, paper etc. They are light to carry, difficult to reproduce, resemble their bearer etc. But they are more than any of these things and in fact what they essentially are is more than any of these things. The main causal power of a passport becomes obvious to anyone who has forgotten to take it to the airport to leave the country. The power of the passport to enable its bearer to travel between countries is inherently relational in character. It depends upon a whole network of (social) relations between the bearer and the passport, between the bearer and the airport staff, between the bearer and his or her own nation state, between the nation states that the bearer is trying to travel between and so forth. These relations depend themselves, as noted above, on a whole network of positioned-practices.

As different materials come and go and some technologies for identification become obsolete, it is the relational properties of the passport that are relatively more enduring. This is not to say that the material content of the passport is arbitrary or that the form that a passport can take is arbitrary but that both are relatively inessential to its causal powers.

Let us now consider a photocopier. Perhaps the most striking feature of a photocopier is its constitutional complexity and functional simplicity. An enormous amount of different parts all come together to do one fairly obvious thing. Paper is put in one end and it is returned, with a copy, at the other. There may come a time when archaeologists are uncovering the remains of this civilisation and working out what all our artefacts are for. A passport may be subject to several interpretations, the photocopier (if one survives intact) will not. It should be pretty clear what a photocopier is for. What is more, it really does not depend, as did the passport, for its causal powers on social relations of any kind. Of course, to be ‘functional’ it must be used by people who know how to use it. And it can always be used for other things (it could acquire a different system function – e.g. it could be sat on). But such factors are inessential to the causal powers of the photocopier viewed overall. I am suggesting then that the photocopier is an archetypal technical object because its causal powers arise most directly from its physical structure. Its relationality, unlike for the passport, are inessential to its causal powers.[17]

From the discussion of function above, we have a conception of certain artefacts that are best understood relationally but for which the essential causal powers are not relational, i.e., where their essential causal powers are intrinsic. In this case, a focus upon relations seems better equipped than a focus on function for distinguishing technical objects. But does this mean that function is irrelevant to a conception of technology more generally? Certainly, reference to function may be required in pointing out particular uses of particular technical objects in particular contexts? And it is also clear that functional requirements have made some impact upon how the artefact is structured. But those functional requirements as well as the enrolment in some system of use relate to particular, transitory, actions of use. Can we not simply do away with the idea of function and say, rather, that technology is always 'used' in some way or another? However, eating (such material artefacts as food) or playing (with such artefacts as toys) involves 'use' in this broad sense and would seem to require that food and toys be considered as technology? To avoid this, and to distinguish technology more clearly, it would seem that we have to re-introduce some role for the idea of function. If so, I believe the most helpful way to re-introduce the idea of function is at what might be termed the meta level. Specifically, the problems above make it clear how specific functions cannot be simply classified so as to demarcate technical objects. But all technical objects, I want to suggest have a very general function – to extend human capabilities. This one function seems to both distinguish technical artefacts from other artefacts (such as sculptures, toys, food, etc.), and be in keeping with many of the motivations for distinguishing technology in the first place (see Lawson 2007c). Let me briefly elaborate.

Our experience of technology is that, when using it, more is possible (be it good or bad, constraining or enabling). This seems to account for much of the pull or attraction of new technologies that technological determinists have felt the need to address themselves to. But there is no need for deterministic interpretations. The point, rather, is that technical activity, as noted above, harnesses the intrinsic causal powers of material objects for the purpose not of aesthetics, or consumption (directly) but to extend human capabilities. The use of the word extension here is intended to capture various features of the process involved[18]. It is not simply that new possibilities are atomistically 'added on'. What is involved in being human may substantially change in the process of technical activity. Not only does the technical subject change in the sense noted above of technologization, i.e. where using different technologies gives rise to different aspirations, competences etc., but also in accommodating new technologies into our everyday ways of doing things our sense of our own place in our world changes (Merleau-Ponty's sense) as well as physiologically, as Cyborgs, (in Haraway's sense). Extension of human capabilities transforms what it is to be human.

Moreover the use of the word extension is also intended to capture what seems to be fundamental to actor network accounts (and in keeping with the ideas of secondary instrumentalization noted above), that our use of, or engagement with, technical artefacts involves the enrolment of objects (and subjects) into an array of different kinds of networks. The extension of human capabilities comes about through a complicated mix of physical use, relational positioning, etc., in which material artefacts are harnessed to create more (real) possibilities. In this light, the difference between technical objects and toys is illuminating. Toys, it might be argued, perform a role in *developing* capabilities or skills. But they can then be taken away and the skill or capability persists (this, indeed, is the point). Technical objects extend capabilities, at least in part, by their positional enrolment in systems of use – if they are removed the capability is removed too (at least until a replacement is found).T[19]

It is now possible to advance a two part definition of technology. I am suggesting that technical activity is best conceptualised as activity undertaken to harness the intrinsic powers of material artefacts in order to extend human capabilities. As such, technology refers to the material objects that are the (material) conditions and results of this (technical) activity. Although technology can then be taken to refer to the sum of technical objects, the irreducibly social nature (structure and relationality) of these objects also requires an account of technical activity to give a complete account of the nature of technical objects. The term *harnessing* is an attempt to capture the transformational character of technical activity, including its isolating and reconnecting moments, at different stages (from design though to use) whilst conveying that we do not construct or design those causal powers which lie at the heart of or motivate much of technical activity (in Pickering's sense). Whether we wish to see these powers in terms of non-human actors, or different kinds of causal mechanism, the point is that they are made use of via a process of isolation and recombination, and that this harnessing will involve quite different characteristics, skills, etc., at different stages of technical activity. The focus upon *intrinsic* powers of material objects is intended to capture the distinction between technical and social objects as reconstructed from the discussion of Searle's work. Lastly the idea of *extending* human capabilities is intended to capture the kind of use to which technical objects are put, in contrast to direct consumption, play, etc. Perhaps the main point to note at this stage is that capabilities are realised in social and technical networks, via the enrolment of technical objects, what Feenberg terms secondary instrumentalization (Feenberg 2000). In this case, the moments of isolation and reconnection gain further significance for a general understanding of technology and technical activity.

A variety of advantages follow from adopting the above conception of technology. First, it sits comfortably with the general idea of historically adequate or accommodative ontology suggested at the outset. There would seem to exist a clear set of referents that require naming and theorising in some way or another, irrespective of whether the term technology is most appropriate for the job. And at the same time clear links have been established to the relevance of this conception of technology to a variety of issues and debates within the technology literature. Indeed, although space does not permit development of this point, I would argue that not only does this account of technology refer to and incorporate insights from the existing literature but it actually solves or recasts various tensions or dilemmas within the literature (see also Lawson 2007a).

Secondly, it proves possible to distinguish different kinds of artefacts. Although there are clearly borderline cases, and many artefacts that have a technical dimension or aspect, there are also grounds for distinguishing general features of these without being committed to the thesis that all objects are one kind or another.

Thirdly, the definition is able to incorporate a range of theories that are apparently at odds with each other. On the conception of technology advanced above, technology needs to be understood relationally and processually. More specifically, technology can be thought of most generally in terms of a process whereby, in the production of useful things, ideas, values and social relations become concretized in material artefacts in such ways as to have important implications for social life. Many of the differing conceptions of technology that currently exist result in part from this tendency to focus on just one or other aspect of the process, e.g. on the technical artefact, technical activity, technical knowledge or the process of concretization (Mitcham 1994, Winner 1977). Contrasting disciplinary approaches to the study of technology can also be seen to focus on one aspect or another of this process. For example, philosophers of technology (e.g. Heidegger, Ellul, Mumford, Borgmann) have tended to focus on *implications* – especially, on the degree to which technology's growing role in everyday life is responsible for the more dystopian features of modernity. In contrast, the more constructivist sociologists and historians of technology (e.g. Pinch, Bijker, Collins, Latour) have been more concerned with the *form* aspect of the process. i.e with *concretization.* More specifically, they have been concerned with documenting both how particular technologies come into being through a process of social negotiation, conflict resolution, etc., and which ideas, values and social relations become concretized in particular artefacts (see Lawson 2007d). The above account cannot only situate rival accounts, but go some way to combining their strengths, perhaps the most important example being that of the philosophy of technology and social constructivism. At this level of analysis the arguments made are not very different from those of Feenberg's Instrumentalization Theory.[20]

Lastly, it is possible to accommodate extremely different perceptions of being with (or using) technology ranging from a preoccupation of designers and beta testers with the intrinsic causal powers or material objects and on the other hand of extending human capabilities, especially by the insertion of objects into networks of use. Alternatively put, it can accommodate and/or ground an interest or competence in quite different aspects of the technical process. For example an interest in the causal powers of material objects may require certain kinds of skills, especially those most appropriate to closed systems (see Lawson 2007a); whereas the extension of human capabilities involves those skills most concerned with 'fit' or the enrolling of objects into networks of use, social relationality, etc. This may well go some way to explaining the observed different experiences of technology, of the relative security or comfortableness of some (e.g. those on the autism spectrum) with the more technical dimensions, etc.

4. Concluding remarks

The aim of this paper has been to provide an explicitly ontological account of technology. More specifically, recent developments within social ontology have been drawn upon to clarify exactly how, in what ways and to what extent, technology is a social phenomenon. The strategy used has been set at a very high level of generality: to give an account of material artefacts set within an account of social activity; to distinguish particular kinds of artefacts – technical objects – in terms of the importance of intrinsic causal powers and the activity oriented to utilising these powers for use. Specifically, I have tried to argue for a conception of technology as the material conditions and consequences of those activities most essentially engaged in harnessing the intrinsic causal powers of material artefacts in order to extend human capabilities. Each of the terms in this definition requires further unpacking (see Lawson 2007a, 2007b, 2007c). But the intention has been to discuss each to a degree that is sufficient to indicate the kinds of advantages that follow from this kind of accommodative ontological exercise.

At the very least, this conception clearly straddles the natural and social world in ways that seem sustainable. By focusing upon the nature of material objects that are irreducibly relational (without their relationality being essential to their causal powers), our view of technology is cast back squarely, although only partially and certainly not reductively, to the importance of the material component of technology and the importance of closed systems, and the isolative moment in artefactual activity. It becomes easy to understand why those such as Heidegger supposed that the essential aspect of technology is its isolative moment. And it becomes clear why those who focus on the reality of living with, and of using, technology (notably social constructivists) tend to focus on the more reconnective aspect of artefactual activity (see Lawson 2007a). In many respects, the most challenging requirement for a conception of technology at present, is the ability to combine both these moments. It is hoped that the account provided here ably meets this challenge.

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Endnotes

[1] I would like to thank Vinca Bigo, Andrew Feenberg, Tony Lawson, Jochen Runde, members of the Cambridge Social Ontology Group and an anonymous referee for helpful comments on an earlier version of this paper.

[2] A typical example is given by Fellows in the introduction to a book of collected essays in the philosophy of technology: “the contributors to this volume do not concern themselves with the essentialist exercise of defining technology; they more or less take it for granted that the reader is familiar with a variety of technologies, such as Information Technology and proceeds from there” (Fellows 1995:1).

[3] The idea that ontology is somehow in opposition to history, although difficult to imagine, does seem to have been encouraged by certain traditions in philosophical thought (see Latsis et al 2006).

[4] Of course, such a project involves judgments concerning which accounts are to be accommodated. But it seems to me that there can be no general strategy about this, each reference or accommodation needs to be weighted *en route* and presumably will have resonance or be useful for the reader to the extent that *appropriate* accommodations are attempted.

[5] It does seem to be widely accepted that whatever technology is, it does combine the material and the social – straddling both the social and natural worlds. But even where this is accepted there seems to be a reluctance to attempt to distinguish the social and material dimensions (e.g. Pickering 1995), or to elaborate exactly what is meant by social in this context (e.g. Kroes 2006) .

[6] It might be more correct to say that I am drawing upon a philosophical, as opposed to scientific, ontology of social phenomena (see Bhaskar 1989). For current purposes, however, the main point is that I am drawing on a relatively established account of the nature of social reality that focuses upon general properties of social phenomena but has not featured, to my knowledge, in discussions of the nature of technology (although see Lawson 2007a and Faulkner and Runde 2007).

[7] For those unfamiliar with such accounts a useful introduction is provided in Archer et al (1998).

[8] For the a statement of the former see Bhaskar 1989 and Archer et al. 1998; and for a statement of the latter see Lawson 1997, 2003.

[9] It is clearly impossible here to do justice to the complexities of the arguments involved. For a detailed account see (Bhaskar 1989; Lawson 2003; Collier 1994).

[10] See especially Bhaskar (1978).

[11] It is also important to point out that the use of open and closed system here does not exactly correspond to that in systems theory drawing upon the work of von Bertalanffy and others. Closed systems within the critical realist literature refer to systems where one (set of) causal mechanisms are so isolated that they always respond the same way under the same circumstances. For a recent discussion of these ideas see Bigo (2006).

[12] See for example Mitcham (1994). Although intermediate stages clearly exist (e.g. the craft worker amending the design of his or her tools in practice to suit the job at hand), such hybrids can easily be understood as combinations of design and use.

[13] Thus the use of technical objects is prescribed not only by the social relations implicated in an object’s ‘position’, but by the rules of use literally built into the object itself. For an expansion of these ideas and their implications, see Feenberg’s discussion of technical codes (e.g. see Feenberg 2002: 20-21).

[14] The latter two kinds are forms of symbolic function. Drawing on earlier work by Binford (1962), Rathje and Schiffer suggest that sociofunctions are concerned with the communication of information about social phenomena, making what they term social facts 'explicit without words'. Examples might be insignia or uniforms, which identify the specific roles of positions such as butcher, doctor, etc. An ideofunction is concerned with a very broad conception of ideology, and refers to that function that symbolises or encodes general values, or ideas. An example might be prayer books which serve to symbolise faith or belief. In contrast to these kinds of function, a technofunction is viewed as strictly utilitarian, relating to such functions as storage, transport, alteration of materials etc (see also Schiffer 1992:9-12).

[15] Although there is little space to pursue these issues here, it is often argued that the term function, in any case, does far too much work in Searle's account. Not only are different conceptions of function conflated (e.g. proper functions (Millikan 1984) and system functions (Cummins 1975), but the term function is used to capture things that are not easily understood as functions at all (in particular anything non-physical). Moreover the usual understandings of function in relation to technology are more at odds with the social content Searle is concerned with – i.e. function is typically counterposed to meaning and incorporation within the lifeworld, thus functionalization refers to a process in which aesthetics, meaning, etc., are systematically stripped away from the relaions in which we stand to different objects. Whether or not this leads to serious problems for Searle's account is not a matter of importance for current purposes (although see Kroes 2003 and Meijers 2000 for interesting discussions). But it does reinforce the gain to be had from recasting these arguments in terms other than that of function.

[16] Now, I am wary that any mention of the word essential sends signals that many will find both problematic and unnecessary. Given this, it should be stressed from the start that such talk of 'essential' in this context is not referring to timeless properties, but properties that can change but are, at any point, responsible for a thing being the kind of thing that it is. In effect, it is doing little more than accepting the implications of the fact that for things to have causal powers at all they must be structured. If things are structured, there would seem to be no reason why all features of some thing will be equally important (or unimportant) at some points in time. To accept this and to inquire into which properties are more enduring or important would seem to be nothing short of an enquiry into what is essential. In this case, technical objects are simply those objects whose causal powers do not crucially depend upon the relations in which they stand.

[17] Stating things in this way requires at least one qualification at this point. Given that I am not suggesting a clear dividing line between essential and inessential, I am not suggesting a clear dividing line between technical and social objects. There are going to be all kinds of borderline cases and blurring of these distinctions. If that is how the world is, however, then so be it. But it does seem to me that this makes it possible to talk of general characteristics of those kinds of things which are essentially more of one type than another. And this is all that is required to talk of technology as a general category.

[18] The term 'extension' has of course a distinct history in the philosophy of technology literature (see for example Brey 2000). Although it is not possible to pursue this here, the conception of extension I have in mind, whilst inspired by some of these accounts, differs in that it is not so much 'faculties' that are extended but what it is that human beings are capable of, and that such extension is a process of enrollment (see Lawson 2007a).

[19] To attempt to distinguish technical objects in this way does need further qualification however, in terms of the kind of definition is being advanced. Clearly this is more of a taxonomic than causal-explanatory aspect of technology's definition, of importance in distinguishing different kinds of material artefacts. But it does have some plausibility in both explaining the preoccupation (in some of the philosophy of technology literature) with such ideas as control and efficiency whilst (in the context of the fuller understanding of material artefacts as social in the senses noted above) being able to locate why such ideas are likely to be only part (and often a small part) of the story.

[20] The differences that are likely to follow are those that relate to the importance of ontological differences between the natural and social world that would appear to be central to an explicit ontological account of the nature of technology. Again, there is little scope for developing these points other than to signal the working out of a dynamic of technology based upon the greater isolatability of causal mechanisms in the natural world as opposed to the social world, and so the different nature of the isolative and reconnective moments of technical activity at the design and use ends of the range of technical activity.

Working with Substance: Actor-Network Theory and the Modal Weight of the Material

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Introduction

How should we think of the material world? How to conceive of nature, objects, technology, bodies – the 'stuff' of social life? This is a question which the social sciences have become increasingly comfortable tackling. And none have tackled it with quite the same wide-eyed enthusiasm as those theorists working on what became known (to Anglo-American users) as actor-network theory.[1] The originality and charisma of those writings has made that enthusiasm quite contagious, and as a consequence ANT's picture of the material has permeated much contemporary sociological thinking which concerns itself with science, technology, organization, or some blend of the three. In many ways this is a good thing. ANT has shown that ontology can be successfully liberated from scientists and professional philosophers (whose accounts can be inaccessibly technical or bafflingly obscure) and explored through sensitive empirical inquiries. It has pointed to ways in which questions about materiality can be made amenable to sociological analysis. But the type of ontology which ANT has elaborated can often appear as much a child of its intellectual climate as an outcome of such empirical research. That is to say, ANT's ontology has a distinctly late 20th century flavor, characterized by a commitment to relational-holism, which, I believe, fails to capture fully much of what is significant about the material world. It is my intention to lay out, despite the heterogeneous nature of the perspective, the ontological assumptions which link most 'ANT and after' thinking. With that picture clear I then want to elaborate another materiality practiced by industrial designers which, I believe, could be a powerful internalist counter-weight to ANT's heavy handed, and often unexamined, relationality.

ANT's Materiality

A great deal of contemporary qualitative sociology and social theory is underwritten by some degree of relational-holism. Certainly ANT is not alone in taking its lead from the processual-holistic philosophies of the past hundred or so years: the line of thought that re-emerged with Nietzsche, Bergson, Alexander, Whitehead, Heidegger, and the more speculative writings of the American pragmatists (Dusek, 2006:208-9). But it is in ANT work, perhaps more than anywhere else, that such thinking has been taken to its full sociological conclusions.[2]

In as much as it is relevant for our present purposes we can think of ANT's relational-holism as a series of interrelated ways of thinking about the material world:

> *An ontological holism*. Particular entities are thought of as the consequences of, and as characterized by, some wider fabric of relations.
>
> *A nominalism or localism*. As a consequence of the relationality of entities similarities (or differences) between particular things or happenings rest, *ex post*, upon facts external to those things or happenings.

A constructivism. As such nominalism undercuts identity a language of 'making' must be privileged over a language of 'finding'.

The Material is Relational

The first of these characterizations is stated clearly by Law (1999:3): "Actor network theory is a ruthless application of *semiotics*. It tells that entities take their form and acquire their attributes as a result of their relations with other entities. In this scheme of things entities have no inherent qualities." Particulars are established relationally in a sense roughly analogous to some loose version of Saussure's semiology. They are network effects.[3] ANT then could be thought of as a variety of "bundle" theory (Heil, 2003:108-9). Particulars can appear individual enough, but that individuation and isolation can quickly give way to a distributed network of 'outside' elements. The distinction is similar to the one that Heidegger drew between the 'ontic' and 'ontological'. To say that an object is a 'network effect' is to say that, properly viewed, it reveals itself as a bundled knot of others. This was, of course, the origin of the term 'actor-network'. It denotes the tension between centered and distributed particulars, between an atomic and holistic ontology, between deworlding and world. The only real reason why it should not be called 'particular-network' or 'individual-network' theory is that as a *sociology* its interest has tended to be in 'actors' – actors who, even in their autonomy, show themselves to be "actor-worlds" (Callon, 1999:185; Callon, 1986). An actor (or rather any individual thing), for ANT, is constituted by its relations to every other relevant entity (its world).

And it is with such a conception of particulars that ANT is able to perform some its more intriguing analytic moves. For instance such bundle-thinking enables analysts to sidestep the content-context distinction (and so, at times, that between nature and society). Aramis was not, for Latour (1996), an entity which failed because the context in which it was situated became hostile. Rather those things which might be called context folded together to constitute it, and as those relations withdrew, Aramis 'died'. Law's Portuguese carracks (1986; 1987) provide another canonical ANT example, being as much politics, mathematics, ocean and wind as wood and sails. Again, de Laet and Mol's (2000) Zimbabwe bush-pump study depicts an entity at once small enough to load into the boot of a car and again as large as the Zimbabwe nation itself, as new relations are explicated. What seemed – to the more ontic observer – a bounded individual object which moves with integrity through different environments, now appears 'fluid'. It *contains* its environment (Ibid:252,262) and so as that changes, so does the pump. Because such entities are the effects of relations – because they are characterized by those others to which they relate – there is no need to speak of a context or an 'outside'. They already 'are' everything which is relevant to them.

Similarly such thinking breaks down the distinction between perceiving subjects and objects perceived. Pasteur's encounter with the lactic-acid ferment (Latour, 1999a:113-44) was not characterized by a 'phenomenon' in which human reason came into a corresponding relation with an indifferent thing-in-itself. Rather, employing Whitehead's formulation (Whitehead, 1929; Latour, 2005b; Stengers, 2002), it was a 'concrescence' – an 'event' in which all entities relevant to the encounter were modified. A similar, less complex, example is offered by Latour (2004b) is his re-reading of Teil's (1998) account of perfume industry-training. The notion of articulate or inarticulate propositions (as opposed to true or false statements – another loose borrowing from Whitehead) is employed here to suggest a more or less fluid infra-emergence of characteristics: “acquiring a body is thus a progressive enterprise that produces at once a sensory medium *and* a sensitive world” (Latour, 2004b:207). Primary qualities and intrinsic properties are pushed aside in the interests of mutually elaborated compositions. It is in relations that odors and noses emerge – are articulated – and Latour is quick to emphasize that this is an ontological, not a linguistic, affair.

The Different, the Same and the Local

So ANT’s objects (and subjects) are relational entities. They are ‘things’ in Heidegger’s (1971a, 1971b) sense (gatherings), rather than ‘objects’.[4] A Portuguese carrack on land is not the same object once it is in the Atlantic Ocean, which itself is altered by the presence of the ship. A more or less radical nominalism follows on from this. The kernel of such a view is offered up by Nietzsche (1996:22) who speaks of “the error... that there are identical things (but in fact nothing is identical with anything else)... The assumption of plurality always presupposes the existence of something that occurs more than once: but... here already we are fabricating beings, unities which do not exist”. In a world in process, populated by completely relational entities without intrinsicality or essence, it would be illogical to make the jump from similarity to identity (Nietzsche, 2001:112-3) – to talk of various particulars, events, or causes, as being the ‘same’. This formulation is reaffirmed explicitly by Latour (1988b:162): “nothing is, by itself, the same as or different from anything else. In other words, everything happens only once, and at one place... If there are identities... they have been constructed at great expense”. In other words, because there is nothing intrinsically characteristic of any particular – they are characterized only in terms of their relations with others – there are no extra-relational grounds for two particulars comparison. And so there can be no presumption of identity between DNA in 1900 and DNA in 2000, between an anthrax bacillus in Pasteur’s laboratory and one in a sheep’s intestine, or between a bush-pump in the boot of my car and one that I have subsequently unloaded and installed in a town-square. These entities are all constituted in different networks of relations and so are themselves different. In as much as we can speak of similarity this is a consequence of some costly co-ordinating work: “if it sometimes appears that there are singular objects and singular subjects then, somehow or other, object positions and subject positions have overlapped and been linked” (Law, 2002a:36).

So we have a nominalism in which identity is discarded in the face of a processual relationality. Sameness and difference do not reside in the nature of things. In as much as they exist they are staged *ex post*. And it is as a consequence of this logic that one of ANT’s most strident criticisms of the claims of science emerges: its ‘experimental localism’ (Guala, 2003). Because if everything happens only once and in one place – if no two objects or events can ever be considered identical – then the claims of (particularly the physical) sciences to have uncovered universal laws of nature are dubious. These laws generally prescribe robust probabilistic or deterministic regularities in events, generalized from carefully staged experiments. But both regularities and generalizations are problematic for the kind of nominalism to which ANT is committed. Regularities presume stable identities to things and events, and generalizations presume that such identities can move relatively unmolested from context to context. Latour’s approach to this problem is to describe regularities and generalizations as the carefully crafted outcomes of networks which, extended painstakingly from local spot to local spot, replicate as much as possible the original local relations from where the story began. Pasteur established the ‘universal’ validity of his anti-anthrax vaccine by extending his local laboratory out into the field

(Latour, 1983, 1988a:90-3). Universals are not, in this view, discoveries as much as constructions. They are painstakingly built ‘empires’ (Latour, 1988c:162) – extensions of local relations from setting to setting.

The Material is Made

So for ANT the material is relational, without intrinsic properties. And so there are no *a priori* identities. If we can speak of sameness, repetition, or regularity then these have been constructed at cost through the local extension of networks of relations. The next aspect of ANT’s conception of the material – a more general privileging of construction over discovery – follows on logically from this. Now it seems at times that ANT (in particular the latter Latour), like Rorty (1996), wishes to present an enterprise in which the distinction between ‘finding’ and ‘making’ is discarded. We should not be labeling everything as constructed, and nothing as discovered, as that would be to emphasize the very distinction which we would like to supersede. Indeed at times Latour seems to be suggesting that creation and discovery are simply the contrasting effects of two differing narrative strategies (Kennedy, 2002:26-7). The ‘making’ narrative happens to offer a number of useful analytic benefits (Latour, 1999a:113-73) over that of ‘finding’ (we no longer have to distinguish between belief and knowledge or history and ontology, and the work of science is better brought into view).

However, given what we have already know of ANT’s ontology such a neutral ‘contrasting narratives’ line is untenable. There is simply no coherent sense in which we could ever say, given such a commitment to relational materiality, that Pasteur *discovered* microbes. As we have already seen, an entity with which humans have no relations is not the same entity once humans encounter it. The world ANT describes is one in flux in which every new encounter creates. To talk of discovery would be to posit an ‘external relation’ in Russell's sense – it would be to suggest that the relation between an object and its discoverer is ‘external’ to both, requiring us to accept that the identity of both remained unchanged by that relation (Johansson, 2004:112). But as we have seen there is no notion more antithetical to ANT’s ontology. And so discovery is an impossibility. When Latour (1999a:146) suggests that “we should be able to say that not only the microbes-for-us-humans changed in the 1850’s, but also the microbes-for-themselves. Their encounter with Pasteur changed them as well”, this is *not* a convenient methodological choice as much as a theoretical necessity (in much the same way that we are forced to say that Newton did not uncover regularities in the world as much as set off a fevered extension of Newtonian relations *across* the world). In as much as ANT is based upon a relational-holistic ontology, begetting a radical nominalism, it is forced – to some important extent – to always privilege making over finding in its accounts.

And it is here, hinted at earlier, that ANT’s ‘multiple ontologies’ emerge. There is no self-sufficient relation-neutral object ‘out there’ with which we could relate without altering it. To believe otherwise would be to engage in the ‘perspectivalism’ which Law (2002a:35) contrasts to ANT’s ‘semiotics’. From ANT’s semiotic point of view these engagements (representations, accounts, tests...) *perform whole new objects*. Such engagements must, as we have seen, be constructive rather than uncovering. And so the more we engage with an entity, in a sense, the more we multiply it:

> Perspectivalism solves the problem of multiplicity or difference by reconciling or explaining different views or perspectives because it says that they are looking at a single object from several points of view. Semiotics says that different objects are

> being produced, and then asks how, if at all, they are connected together in order to create a single object. (Law, 2002a:35)

Mol's (2002) study of the diagnosis and treatment of atherosclerosis works through this idea at some length. Throughout the hospital there are many atheroscleroses. This is not a cute metaphor pointing towards various approaches to, or perspectives on, a singular atherosclerosis, a single patient, or a single body. This would be to think in terms of stable identities, external relations and discovery. Rather they are various objects "enacted" (Ibid:32-33) in practices.[5] They are enacted in complexes of local relations, traveling as far as those relations can sustain them. As new complexes come together so too are new atheroscleroses articulated.

And so we have in ANT a picture of the material which is thoroughly relational. Material particulars are established completely through internal relations. So identity gives way to a processual nominalism, and the nature of entities becomes a matter of after-the-fact negotiations. Consequently all engagements create something anew. A radical constructivism is necessitated. Although painted in very broad strokes – and in some shades foreign to the original texts – we have here a basic picture of the materiality which ANT trades in as a means of better understanding the work of science, engineering and organization. What I want to do now is to present another materiality: a theory implicit in the practice, and explicit in the accounts, of senior industrial design students.[6]

Designing with Materials and Bodies

Discussing ANT, I have been talking about materiality in a more or less abstract sense. But when designing it seems that such a mass material is given. What becomes crucial is material in its countable form: the varied, but specific, substances from which objects can be made. For instance, Nicolas has spent the better part of a year designing a chair.[7] A number of chair-sketches are pinned up around his workspace, and to one side there is a fairly imposing mound of 1x1 polystyrene chair-models (we'll get to these latter). At the time he was also working on a more time consuming prototype mold. But the first thing he wanted to show me was a novel material which, for reasons of intellectual property, I will call material *z* (*figure 1*). The bulk of the chair will be made from *z*, and it seemed clear that *z* was the most interesting aspect of the design. For a start it is a politically and economically interesting material – it is recycled from waste sourced from economies in need of innovative exports. But more importantly for our present discussion Nicolas found *z* to be an interesting material from which to produce a chair. The material, where flat, has a certain degree of flexibility. Where it curves it gains a certain rigidity. This spectrum of flat to curved – flexible to rigid – surfaces is exploited throughout the design. (And to be clear, what Nicolas has exploited is not that spectrum in general – the fact of that relationship which is common to many materials – but rather the range specific to *z*.)

FIGURE 1:Foreground: A test sample of novel material 'Z'. Background: One of the models which this material has informed.

Inari is also building a chair, incorporating an unusual material (*y*). Her project began, unconventionally, with a range of materials which were matched up to a range of different design concepts. Eventually material *y*, as a component in a piece of public furniture, suggested itself as the most promising combination. This early planning, and the more specific process of designing the chair, followed an arc in which *y* was increasingly scrutinized.

> Inari: I narrowed it down to like, five top materials. And then for each of those five materials I mapped out their material characteristics. Um, like whether they’re durable, or UV resistant, brittle, or that sort of thing [...] By, um, experimenting with the material – which is [*y]*, and at the moment they bind it together and use it as matting, but I was trying to do more complicated shapes and things and see what it could do [...] You’ve sort of got a little idea of what it could do and how you could use it. And so then you go and test that and, you either prove that that works, or doesn’t work. And sometimes you sort of find out other things which you just didn’t expect, along the way, which is the best part really.[8]

Y ended up being, in terms of mass, a fairly small part of Inari’s design (compared, for instance, with Nicolas’s use of *z*). But *y*’s strength and flexibility, and its profitable application to wood, is in another sense a huge part of the design:

> Inari: I identified the most promising ways that I could use [*y*] to really improve public furniture in different ways. And that was really using it kind of- like a hinge so that it could flex and recline as you sat on it. And that sort of thing as well... the whole aesthetic thing. And then, so, I was basing the form around that [...] The [*y*] is only a very small part of it, like it – it sort of – it allows it to do everything that I wanted the [*y*] to do.

How then do these designs, and these designers, 'do materiality'? Firstly they focus in on *specific* materials: they engage with them *in their specificity*. *Z* and *y* are decisive influences upon the objects which will emerge from these processes, in that the way these materials behave is incorporated into the design. A strong understanding of materials will always be important for designers ("When in doubt, Make it stout, Out of things you know about" (Ullman, 1992:199)), but the students use of *novel* materials bring this relationship better into focus. There isn't the tacit understanding of these materials, and they have not been rendered simple and predictable via handbooks (eg. Budinski, 1979; Lesko, 1999). For Nicolas and Inari the design process is one in which these materials must be tested repeatedly. There is a back and forth between concept and material: conceivable objects must be related back to these materials, which may, in the end, preclude their existence. In other words, as *z* is better understood, the range of good *z*-made chairs is altered. The differences between *z* and everything else, or between *y* and everything else, become points of difference in the objects into which they are incorporated. (In some modest sense we could even think of them as formal causes – Nicolas's chair will take some form, rather than some other, in some strong measure as a consequence of *z*.) For instance there is a sharp dipped curve between the seat's pan and its back which exploits *z*'s flexibility. It is aesthetically pleasing and ergonomically sound, but most crucially it is a z-*ish curve*. In encounters with the material a select range of specifically *z*-ish chairs present themselves, and this curved device was amongst them. As these materials are scrutinized a specific range of objects are delineated.

Designing with Bodies

Este is working on a three-wheeled cycle. Much of his work has been in the form of sketching and the production of small scale-models ("for aesthetics"). And the aesthetics are certainly coming along nicely. The cycle, on paper, is all sleek lines and fast curves. But at this point in his design process he seems to have regressed somewhat, because he is spending most of his time working with a fairly ugly, angular, wooden frame (*figure 2*). He explains that this is an 'ergo-rig'. With it he is able to conduct various experiments in which people are able to 'ride' his cycle. The ergo-rig allows Este to discover how bodies interact with his cycle, and to alter his design accordingly. Primarily he is interested in establishing the degrees to which the structure of the cycle should be adjustable, and where such variables should lie (the variables "that make a difference"). The first part of this problem is the easier – there is anthropometic survey data and standard degrees of accommodation.[9]

The second problem – establishing what parts of the structure should vary – is more complex. But with the ergo-rig he is able to trial various movable parts with a wide range of bodies. As mock users ride the rig he can see what parts need to be adjusted, what parts need to be adjustable, to what degree, and where. Through this "structural evidence" a number of important moving parts in his cycle's frame will emerge.

Nicolas has also been engaged in ergonomic testing. He has made a number of seat-backs and separate seat-pans out of polystyrene (*figure 2*), and has tested various combinations against various bodies. Such tests are only really indicative (his material – *z* – will behave differently to the polystyrene) but still serve to suggest certain lengths, certain curves, certain depths... and of course to preclude others. Again we see a movement in which the designer engages in a more or less experimental relation with the material world – with singular materials, with the means by which they are assembled, with bodies – and through this engagement a specific range of design possibilities are raised and another set discarded.

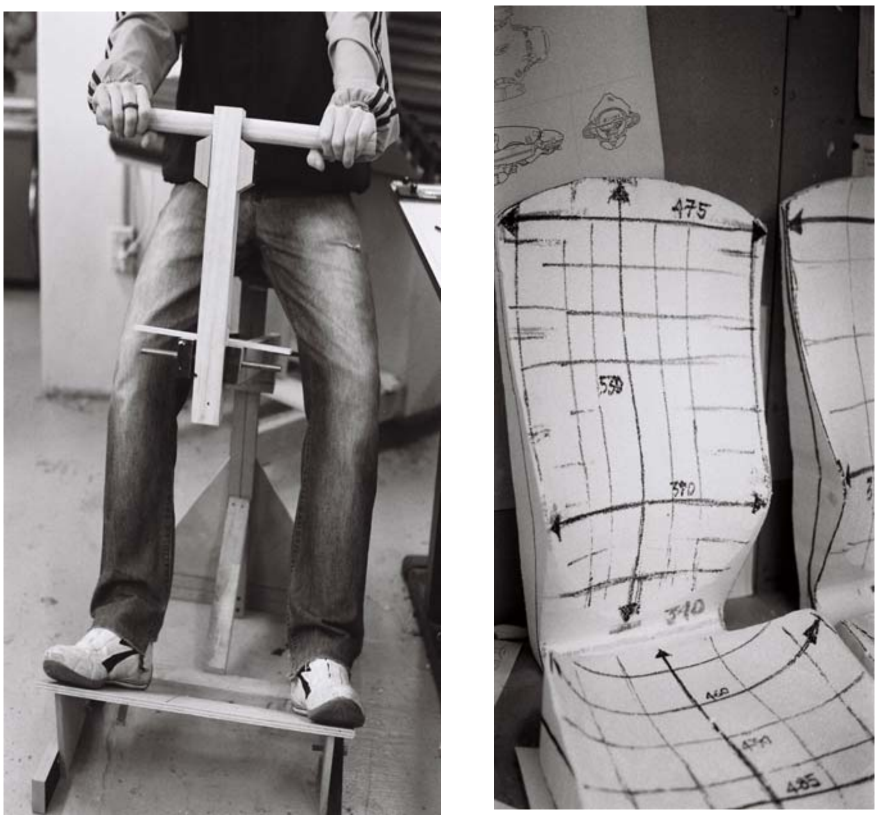

FIGURE 2: Left: Este's 'ergo-rig'. Right: Polystyrene ergonomics mock-ups with interchangeable seat-pans and backs.

The Realism Inherent in Design Practice

There has been a fairly repetitive theme in these snippets of the design process. They have all pointed to situations where specific knowledges are acquired and incorporated into the production of an object. Often through direct experimentation (but also, on occasion, through the testimony of experts) an increasing understanding of materials and bodies are produced, and so the emerging product is better understood in turn. More importantly the examples I have offered center around material entities, and suggest a movement in which, as knowledge about these material entities increases, design freedom is lost. There is a seemingly limitless expanse of curves and angles which could be deployed in the seat-pan of a chair. But after experimenting with *z* – after learning how it bends and curves, how it contorts before various weights, to various degrees, when molded into certain angles – Nicolas found himself dealing with a much narrower range. Este was uncertain as to where to place adjustable parts on his cycle – he had ideas of course, but too many. But after fifty people had sat in his ergo-rig his options had decreased down to a manageable few. The movement I am pointing to is depicted in *figure 3*.[10]

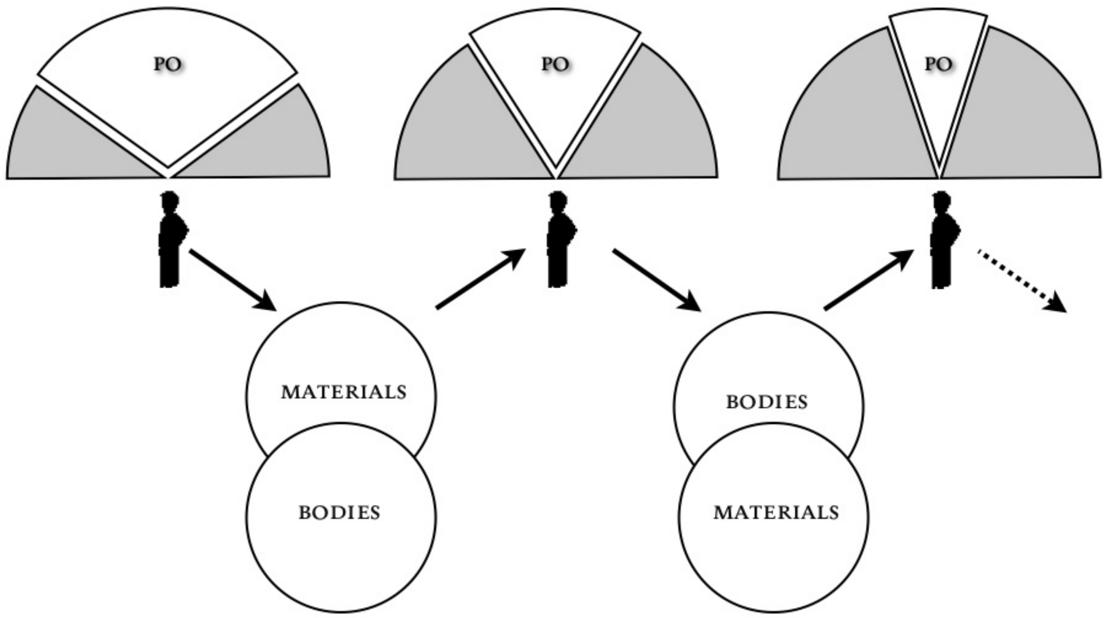

FIGURE 3: As the designer engages with the material, the horizon of possible objects (PO) narrows.

And what is so instructive about this movement, this closing off of the possible, is how thoroughly realist it is – how at odds it is with ANT's relation-processual ontology. There were relations of course: relations among, say, Nicolas, a vice and a sample of z; among Este, a user and his ergo-rig. But these relations were accepted as very much external. They did not reconstitute those particulars, they reconstituted the design. Of course the final product is being constructed, but the means of its fabrication, the character of the materials which would constitute it, or the bodies of those who would use it, are not. The designers' relations with these entities were ones characterized by *sincerity* (Harman, 2002:238-243; Levinas 1988); a sincerity which grants the particular a being; which takes it as "real to the extent that it is in its own right" (Zubirir, 2003:40). Indeed the arc of *figure 3* is completely underwritten by a materiality quite divergent from that in which ANT trades.

Inari picks up a large piece of *y* and considers its possible application as a flexible hinge between sections of a bench. As her tests progress, it becomes apparent that when supporting certain weights, at certain angles, *y* fails. And so in line with the movement I have been describing in *figure 3*, these experimental encounters now leave Inari with a narrower range of possible objects (certain bench-back weights are now precluded, certain strains on the *y* component will be avoided...). The material (*y*) becomes in some sense *explanatory* of some possible-benches' failure, in as much as facts about *y* explain why one cannot make these particular benches. It is apprehended, analytically speaking, as the feature characteristic of some set of possible worlds in which a certain bench-back weight is unfeasible. And the second we are capable of speaking in this manner (or rather – as the designers do – *acting* in this manner), we have left behind the sort of ontological holism to which ANT is committed. For an entity to be a feature characteristic of some happening across a number of possible worlds requires us to imagine that particular (a clump of Inari's novel material) maintaining its identity across those differing worlds (which is, of course, just another term for differing contexts or networks) *and furthermore* to imagine it as carrying the same qualities, attributes, or properties (the ones which ruin the bench) too. *Exactly how sincerely we should approach an entity – how free it is from the sinewy rhizomal* réseaux *(Latour, 2005a:129), how much of its behavior inheres to it in its own right – is demonstrated in such unassuming experiments*. ANT's pseudo-Saussurean anti-essentialism and its nominalism fail to capture the practical metaphysics elaborated in such a testing regime.

Again, when bodies and polystyrene seat components are repeatedly related, and their respective fits acknowledged and incorporated into an emerging design, the experience is one of – in the long view – *making* a chair. But locally it is very much an act of *finding* out about both. A body confronted by eight seat-pan mock-ups is the same body on each. The mock-ups too, must maintain their identity through collusions with different bodies. Various combinations of the two (bodies and chair-parts) are in no way seen as multiplying. We may say different things about different combinations, but this is very much *perspectivalism* – we are creating new *sentences* about the *same* thing ("*this* one is much more comfortable... have you tried it with *that* back?"). If this were not so the entire ergonomic experiment would collapse. It relies on the integrity of the chairs and the bodies and on their steady covariance, predicated on their capacity to move unchanged through various iterated combinations. Certainly when one precludes the possibility of designs *a, b* and *c* by setting aside unpopular seat-back eight, one does so in the sincere belief that it is not somehow changing in its trip from a co-worker's back to a rejects pile on a nearby bench. *The mock-up is rejected as what it is in its own right. We reject its intrinsic qualities because of their failure to play well with the equally robust properties of this or that body.* Contra ANT there is no construction or multiplication of entities here. We are *finding* out about chairs, bodies and their interactions. While there *is* a proliferation of articulate propositions regarding backs and seats and legs and such, for the ergonomic experiment (or, say, for a perfume training session) to work this must be a linguistic affair grounded in a more or less indifferent context-independent range of entities.[11]

And what this general practice of exploration and discovery grants material particulars, as a necessity, is being. Something like what Harman (2002) misleadingly calls 'tool-being'.[12] What tool-being designates is a substance: not one predicated on a billiard-ball metaphysics, but on a recessive 'subterranean' nature which recedes from all relations. For Harman Heidegger's *vorhandenheit* (presence-at-hand), designates all relations; from those of a detached human perceiving a broken hammer, through to the brute causality of raindrops hitting a tin rooftop. *Zuhandenheit* (readiness-to-hand), although traditionally read as a specifically human mode of engagement with a certain class of objects (tools), becomes a term designating a crucial dimension of *all* entities: their reserved, singular, hidden being. It designates a life for material things beyond the networks of relations in which they are implicated. What makes tool-being so necessary for a practice of discovery is that, without depths untouched by relations, little would be gained by subjecting the material to such trials. For example, imagine if Nicolas was to take a sheet of *z*, and lock it into a vice. If we take ANT's relational holism seriously, we would have to think of this piece of *z* as being exhaustively characterized by the relations in which it is currently embedded. In other words it would be without inherent qualities, reducible to its present encounter with vice, air, designer etc. But then, let us imagine that as part of his tests he begins to saw at the sheet with a hacksaw. It begins to tear, giving way to the blade. Something is now happening to the sheet of *z* which has never happened before – it is cut down the middle. Now what is crucial here is that it is not the relations in which *z* is embroiled which are cut – we are not sawing through the negative semiotic imprint of vice and air and Nicolas etc... This is clear because we are achieving something with the saw which those other entities could not. We are cutting *z*, not *z* as previously encountered by vice, air, sunlight etc. For the new relation with the hacksaw to be able to elicit a novel response from *z* relies on *z* holding something of itself in reserve from the entities to which it previously related. (This formulation is adapted from an example of Harman's (2002:230).) *In other words, for change or novelty to occur at all – for a mode of discovery to be possible – entities must have secrets (like z's sawability) held in reserve from whatever networks of relations they might find themselves in from moment to moment.* Or as Heil (2003:109) puts it: "Imagine a world consisting of exclusively of particulars whose nature is exhausted by relations these bear to other particulars... Would such a world differ from a world consisting of a static, empty space?".

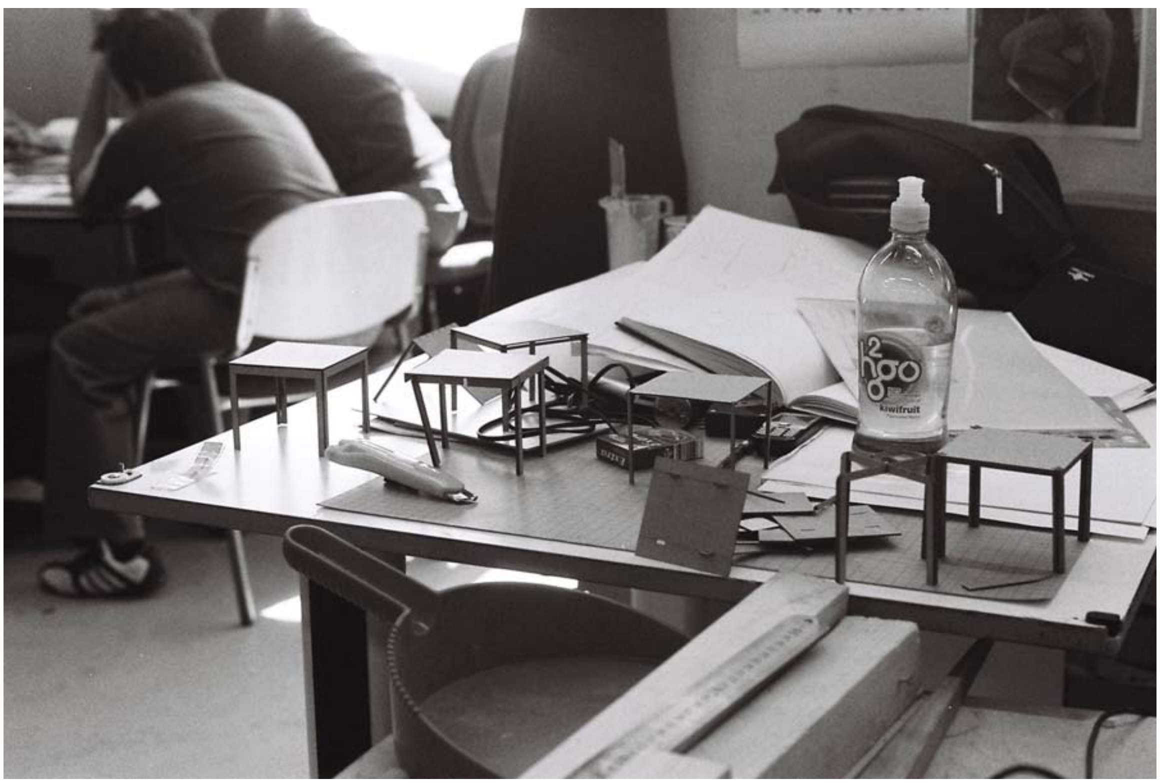

FIGURE 4: Chris's table of 1:10 scale models.

Designing with Substance

All of this comes together in the way these designers use physical models or mock-ups in relation to sketches and computer aided designs. Chris is designing a table with special compartments.[13]

His table is littered with fairly flimsy 1:10 scale models (*figure 4*). These have been very useful so far, providing a relatively quick and easy means of trialing broad ideas about structure. They allow Chris to cut broad swathes through the thicket of possible tables:

> Chris: Well I started with just an idea at first; and this was a way of developing it really. You find out what can't work, what will work, really quickly. So down the track I'll know... that yip, so that joint will do well... in the whole situation.

These small prototypes have a specific and important role in the design, as do sketches and computer models. But there are, by all admissions, dimensions of the emerging table which they do not capture. They tap some of the dimensions of the recessive substance of the table, but not enough:

> Chris: You can't know that to know... what you're gonna have in there until you, before you do a proper detailed [model] [...] It's so much better to do it in a full size... scale model because it represents things better... and more accurately [...] like a realistic sort of view. Like it is cool to do little representational models but- because yeah it is quite easy to get it built up on the computer and then get it made up by a machine. But yeah... it's still much better to get it done up on a full scale. And plus so, it's just more realistic really. Because you get real materials.

To really understand his table will require a 'more realistic' view. That sort of view is provided by touching actual materials, manufactured as they actually will be, at actual scale, with an actual body. *To really understand requires sincerity and substance*. Jon and Taira lament at length the gap between the offerings of a sketched or computer-modeled design and those of a substantial prototype. The problem that keeps appearing is that of a discrepancy between the object as conceived as a bundle of co-ordinates and angles – a seemingly contingent assemblage of idealized elements – and the substance which will eventually confront them:

> Jon: Well that's one thing that helps with actually making it real- like that backpack that I made actually looked completely different on the computer to how it looked in real life.
>
> Taira: Well materials the big thing! You can't draw or render materials. You don't know what they are.
>
> Jon: You can-
>
> Taira: And like oh! And the other big thing is like you can, you can make a shape, and you can render it on the computer as metal, but that doesn't mean you can make it in metal. And you can, you can do whatever you like on the computer but it doesn't- it can't be real [...] You're loosing the reality of the process.
>
> Jon: Materials are more than just aesthetic, materials are like - if your trying to combine two pieces of metal-
>
> Taira: -well some metals, the further away on the periodic table they are, the um, worse they react with each other. So you can't necessarily, put two pieces of metal

> together... because they'll start, well one will just eat the other away. But that- that wont happen on the computer.

FIGURE 5: As the designer engages with the material, the horizon of possible objects (PO) narrows.

(The process they are referring to is Galvanic corrosion, and it demonstrates well the point made earlier. If a cathodic metal begins gnawing away at a more anodic counterpart it is *the metal itself* which is corroded, not the metal as previously delineated by some network. That is, the potential for corrosion is one facet of the being which it held in reserve from its previous uncorrosive relations.) I ask them to elaborate on the backpack example. Jon rummages through some boxes before bringing out a prototype (*figure 5*):

> Taira: See that backpack, well you could draw, you can draw that a million times, as much as you want, but you're never gonna really know what it's like to go over a body, what the straps gonna look like. You can [deduce] what they're gonna look like, but you never know what it's gonna feel like on your skin.
>
> Jon: -how the pockets are gonna work.
>
> Taira: You don't know that until you make it. And once you've made it you can go back to your computer model and change it. Or you can go back to your drawings and alter it.

INTERVIEWER: That's been coming up a lot in these - the ergonomics thing, the testing for ergo-

Jon: Well that's like- because we deal with- but it goes beyond just the ergonomics in the sense that it fits nicely, or it's comfortable because-

Taira: It's detail.

Jon: Yeah it's about the way that two different-

Taira: I mean you can draw what materials look like but you can't draw that, Solidworks that [indicates a webbed material under backpack's strap]. I mean you can draw a zipper on the bag, but a drawing of a zipper is gonna look completely different to how a zipper is gonna be put into the bag and...

Jon: How it's hidden or if it's not hidden.

Taira: And just like... what it's like to use the zipper.

These designers' encounters with more substantive incarnations of their designs seem to present, if not a 'shock of the real', then certainly a 'surprise of substance'. It is arguable that more experienced designers will not have such experiences as often – their deeper implicit knowledge of materials and bodies may prevent them from making design choices which run up against the stubbornness of substance. But being able to avoid conflicts with such a stubbornness makes it no less stubborn. What we have here is very much a practice predicated on the experience of the *realness* of the material world: on its insistence on a certain range possibilities at the expense of another. These designers are 'doing' a *realistic* materiality which, suitably elaborated, we can think of in terms of:

A reservedness. Individual entities, although they relate with others in interesting ways, do so 'in their own right'. That is, some of their nature is held in reserve from whatever relations they may be embroiled in at this or that time. They are not exhausted by networks.

A discretion. As a consequence of this individual entities are discrete. They can never be swallowed up by their contexts because their reserved inherent qualities mark them out as separate.

A sincerity. A further consequence of their reservedness is that encounters with such particulars are characterised by discovery. Reshuffling our relations with entities does not multiply or alter them as much as it taps into new sections of their reserved nature. And so a language of finding is most appropriate to such encounters.

An independence. Because of their reservedness objects need not be predicated on effects. They can be granted a life outside syntagms of human action.

A weight. I think most crucially for social theory, these designers throw into stark relief the capacity of the material to distinguishing between the possible and the

> impossible. In other words, material entities allows certain happenings and preclude others.

Recovering Substance

At the beginning of this paper I suggested that the radical holism of ANT's ontology is in part a consequence of the intellectual climate in which it was born. As Harman (2002:230) puts it, intellectuals in recent decades "have gotten very much into the habit of poking holes in all remaining versions of the old substance-concept, and measuring their own critical liberation by the extent to which they are able to do so". Faced with the twin perceived threats of, on the one hand, a naive scientific materialism content to reduce the material world to a deterministic collection of dead particles, and on the other, an equally naive sociology of science and technology trading in a world of centered disembodied subjects who talk, look, agree and believe, but never get their hands dirty; it is not difficult to see the utility of ANT's ontological project. But as Harman (2002:184) notes, these are ideas "once but no longer liberating. It is an idea that fights the *last* war instead of the next one". Now that such relational thinking has succeeded at complicating those various chunks of social and material stuff, which once looked so commonsensical and necessary, it is time to start taking stock of what has been lost in such a venture. The point is not to be reactionary, but to acknowledge that only part of a story has been told. Reinventing our ability to talk about the *substantive dimensions* of entities is, I believe, the next important project for an ontologically minded social theory.

That is to say, a sociology of science and technology requires an understanding of the material world which is at least as rich and complex as that employed by those they study. And the angle from which *these designers* approach that world, with its realism and its respect for substance, deserves a place in such an understanding. We need to take these dimensions of the material as seriously as these students do if our accounts are to have the same ring of sincerity. It needs to be felt in such accounts that the material world has a resistance and a reticence which can never be fully muted by the contingencies of our local practices and network building enterprises. The material weighs in decisively. It is not a mere bundle of relations whose reshuffling is constrained only be our ingenuity. Or rather, such a relational perspective taps into only one aspect of the material world. The 'deep' and 'heavy' material which we have focused on needs recognition.

Exactly how this might proceed is something of an open question. One path towards achieving this would be to recognize the movement in *figure 3* as a more generic moment in material life. That is, just as the designers practiced a material which constrained their range of design choices, we all experience the material world *as possessing modal weight.* Material things serve to designate the possible, grounding some actions and precluding others. They help to establish and delineate the range of possible worlds to which we have access at any one time.

Now in a way this is a notion not too far removed from ANT's early concerns. When Callon and Latour, in a key founding statement (1981:286-287), attempt to define an 'actor' they designate:

> Any element which bends space around itself, makes other elements depends upon itself and translates their will into a language of its own [...] Instead of swarms of

> possibilities, we [now] find lines of force, obligatory passage points, directions and deductions.

This definition overlaps fairly well with the notion of modal weight. It is just another way of saying that, in as much as an entity is real – existing in its own right – it will show itself as a feature characteristic of worlds in which certain events occur. The entity will demonstrate a modal weight which causes relative possible worlds to apprehend it as necessary. Equally it will foreclose access to other possible worlds. To the degree that we actually engage with that entity, we will be unable to take certain paths. Although the language is perhaps a little more 'analytic', this is very much in keeping with ANT's 'sociology of translation'.

The crucial *difference* is that I believe such modal weight – such 'bending of space' – is an *epiphenomenon of substance*. It is what resides in the reserved underbelly of entities, not in their relations with one another. When Law (2002b:92) says that "in ANT the possibilities of the world are constrained, but contingently so" I find this just a little too easy, a little too light.[14] The weight is there but it is not located. The sincerity is absent, and we still have an image of lines of force which require only local networks and practices for their existence.[15] Gibson's (1979) affordance fares much better on this point.[16] Although employed to describe relations (between organisms and the world) affordances are still viewed as more a less *inherent qualities of entities*. Even if a particular affordance is never articulated in practice it never the less exists as a potential (Keil, 1999:5). Here the modal weight – the lines of force and bending of space – is properly located beneath local relations, in the internal relation-independent substance of things. Objects are granted the capacity to set "the limits to what is corporeally possible [without determining] the particular actions which humans may engage in" (Urry, 2000:204).

Whatever analytic device is chosen, recovering substance from the wreckage of the 'last war' is a worthwhile project. And doing so in a manner which keeps hold of what is still 'liberating' in ANT's approach to social theory is a necessary one.[17] Whether this involves some adaptation of affordance, a sterner notion of translation, more of my tedious possible-worlds talk, or some completely new contrivance, I am certain that the result will be accounts in the Actor-Network tradition which better capture the interesting, recalcitrant, 'full-blooded' contours of the world.

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Endnotes

1 I use 'ANT' here very broadly to designate a whole raft of work across a variety of 'ologies' – including those works which would consider themselves 'after' ANT. It is of the nature of the perspective that it is difficult to pin down (Law, 1999; Latour, 1999b), but I think it would be silly to argue from this that there is nothing there at all. What I am designating here is the range of ideas elaborated by the founding authors and texts which, no matter how far thinkers might have traveled from this or that acronym, remain central to the perspective.

2 It is often difficult, however, to establish whether such thinking represents beliefs about what the world is like, or useful relatively world-neutral methodological prescriptions. This is a distinction which ANT might try to avoid, as it raises troublesome questions of correspondence; but it is also one which Latour has made repeatedly in his most recent major work: "Surely you'd agree that drawing with a pencil is not the same thing as drawing the shape of a pencil." (Latour, 2005a:142). The risk is that given this lack of clarity I may appear to be stamping my foot because the letter 'B' doesn't 'buzz'. In what follows I intend to do my best to avoid this by hearing out whichever angle seems the most charitable. And as my own claim is both methodological and ontological – I intend to argue not so much that ANT's account of materiality is simply wrong, but rather that its heavy-handed holism is muting other interesting dimensions of objects – I think I can successfully sidestep this problem.

3 Law has riffed on this theme at some length (Law, 1999, 2000, 2002b; Mol & Law, 1994; Law & Mol, 1995, 2001; Law & Singleton, 2000) bringing his notion of multiple spatialities into the mix.

4 This '*Gegenstände-Dinge*' opposition has become increasingly popular in ANT writings (Latour & Weibel, 2005, Latour, 2004a).

5 Mol (Ibid:41-2) contrasts the term 'enact' with 'perform', 'construct', and 'make'. However, I am using them all as synonyms in this paper. I don't believe the difference in connotation is as great as she suggests. In any case it is certainly not large enough to confuse my fairly brief summary of ANT ideas.

6 This research is based on observations and interviews conducted in 2006 with twelve industrial design students from Victoria University of Wellington's School of Architecture and Design, and Massey University's Institute of Design for Industry and Environment. Students participated in unstructured interviews conducted at their work-spaces, where they discussed their projects. The research was conducted with ethical approval from Victoria University's Human Ethics Committee, with the assistance of staff from the relevant institutions.

7 Names have been changed in the interests of privacy.

8 In the interests of accessibility I have adopted a very simplified method of transcription for the designers' interview data. Brackets indicate corrections or commentary. Bracketed full-stops indicate points where dialogue has been edited. All other punctuation can be treated as in the main text.

9 From the 97.5 percentile male to the 2.5 percentile female is a common spread, although probably too much for this particular design.

10 Now to anyone familiar with the design process this will seem a desperately impoverished account. Aesthetic concerns have been largely ignored, as have problems of marketing, user-studies, documentation... My description is certainly shallow when compared with the complex accounts produced by designers themselves in their reports and theses. And it could well be argued that what I have described differs little from the 'in-house' notion of 'design space' (Bessant, 1983) - the differentiation of the "feasible and infeasible" given a certain range of constraints (Arora et al., 1997:8-9). As for the latter, whilst what I am describing is similar to the notion of design space I have avoided using that term because what I am getting at here is a more limited concept – I am interested in such a 'space' only in as much as it is narrowed by the material world. The more expansive design space concept can have a very technical usage in testing and optimization literature (ie. Lilja & Yi, 2006; van der Linden, 2005; Haftka et al., 1998), conflates more factors than I wish to deal with, and as such can be explored as more negotiable than the closing I am describing (ie. Sharrock & Anderson, 1996). And so too the possible charge that the design-space concept is less characterized by constraint than that which I am presenting (especially for more experienced designers who, through their greater tacit knowledge, work in a less "discovery driven" (Stankiewicz, 2002:39) manner) can be left aside. Even when the material world is experienced as presenting design opportunities as opposed to closing off options it remains a closing in as

much as the material suggests this design rather than that. And in any case there is, as Constant (1999:330-1) notes, still a major asymmetry between the feasible and unfeasible: that something is possible in no way means it will be done; that it is impossible means that it certainly will not. The former charge – that my account is an impoverished description of the design process – I am happy to concede. My intention is not to tell designers how they work, or to contribute concepts to a theory of design. My intention is to abstract from the work of these designers a lesson about materiality.

11 If not there would be no way of judging the sensitivity of the covariation between them (which is what the notion of articulate propositions boils down to) – how could a proposition be judged inarticulate if there are no pre-existing distinctions to be missed?

12 The term has nothing to do with tools except that the notion is elaborated through a re-reading of Heidegger's 'tool analysis' (Heidegger, 1962).

13 Again, intellectual property prevents a more detailed description.

14 The same 'light way out' can be seen in May's interpretation of Deleuze: "rather than take Deleuze's (periodic) tack of positing Being as difference, I suggest that we can have all the ontological differences we need if we are more austere in our ontology. Instead of seeking Being itself and requiring of it that it contain all the differences that we would like to see instantiated in our world, we can turn directly to the practices in which people are engaged. Practices are a rich source of ontological posits; differences abound in different practices. Thus, by jettisoning the project of a philosophical ontology, we open the way to the kinds of ontological differences Deleuze commends to us." (May, 1997:18).

15 I have same problem when considering Latour's experimental localism. Science's regularities, generalizations, and universality are seen as the consequence of extended networks of technical relations, but if substance has the modal weight I suggest then this may not be the case. If the substance of entities can restrict our access to possible worlds 'in its own right' then laws of nature may be more or less necessary, and the practices and networks in which they appear more or less contingent. In other words, the substance of the world may establish a 'nomological modality' (Divers, 2002:4) – a constraint on what is possible which no changes to networks or practices can defy. And if this is the case the generalisation of Newton's laws begins to look very different from the exporting of cheeses (Latour, 1988b:227). That is, there are many different actually-possible worlds in which we ship cheeses, or do not ship cheeses. And there may be many in which we demonstrate laws of nature via costly local networks of instruments and expertise (or choose not to). But, in this view, there may still be *none* in which we actually act counter to those laws. If we accept that the material weighs in decisively, restricting what is possible, then we have to admit the possibility that it is exactly such restrictions which the scientist's 'laws of nature' capture. And if that is the case then they require no networks to travel.

16 Gibson, a psychologist, offered affordance as a means of coupling perception and action in accounts of an organisms engagements with the 'outside' world. Certain material entities, in this view, suggest certain responses, with the affording world, perceiving mind, and acting body "conjoined into a single dynamic unit... things in the world exist as... collections of features that 'afford' (or support) some specific response" (Baber & Barber, 2003:54). It has gained some sociological currency, and is sometimes invoked as a counterweight to ANT-style accounts of human-technology relations. See for instance Hutchby (2001); or compare Lupton's (1999) and Dant's (2004) accounts of driving.

17 And there is still much liberating in ANT's approach. Unlike many realist caricatures and criticisms of ANT, mine is done with affection.

Disclosing Visions of Technology

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Review of *In Search of an Integrative Vision for Technology*, Sytse Strijbos and Andrew Basden (eds.), Dordrecht: Springer Publishers, 2006, 310 p. Hardcover, ISBN: 0-387-32150-0 (series: Contemporary Systems Thinking), $109.00.

Since 1995, a group of scholars from different nationalities and disciplines has come together every year to discuss normative and interdisciplinary issues regarding science, technology, and their social roles and impact. Members of the group share an interest in systems theory and normative reflection, and are inspired by the work of Herman Dooyeweerd, a Dutch philosopher in the Calvinist tradition. The group founded the *Centre for Philosophy, Technology, and Social Systems* (CPTS). Recently, several members of this center published the book *In Search of an Integrative Vision for Technology: Interdisciplinary Studies in Information Systems*, edited by Sytse Strijbos and Andrew Basden.

In Search of an Integrative Vision for Technology embodies a new voice in the philosophy of technology. It contains an interesting collection of articles, which each address a specific aspect of the 'systemic' interaction between technologies and society. The ambition of the book is to develop an 'integrative vision for technology'. By this, the authors mean a vision which does analyze technology "as such", but only in "the normative context of human and societal aspects". The book employs concepts from both systems theory and the philosophy of Dooyeweerd to analyze and evaluate the relations between technologies and their social context, and at some places it argues from an explicitly (Protestant-) Christian point of view.

The book is built around a conceptual framework, elaborated by Strijbos and Basden in the introduction to the book. The framework distinguishes five key elements needed to understand the relations between technology and society. First of all, the authors discern *basic technologies* (1). With the help of these technologies, *technological artifacts* (2) can be constructed. As soon as these artifacts are used, *sociotechnical systems* (3) come into being: complex relations between artifacts and users, which act as an infrastructure that fundamentally alters our lives. These sociotechnical systems come about when technological artifacts get a place in *human practices* (4). In their elaboration of this notion of practice, Strijbos and Basden make a Dooyeweerdian distinction between the *qualifying* aspects of a practice on the one hand, relating to 'what' the practice is and what makes it different from other practices, and its *founding* aspects on the other, relating to 'how' a specific practice is done and gets shape in specific ways. These 'founding' aspects form the point of contact with technological artifacts: at this point, where sociotechnical systems arise, human practices are co-shaped by technological artifacts, while artifacts in their turn get meaning in the context of these practices. The fifth element in the framework is formed by what the authors call *directional perspectives* (5), by which they indicate "a spiritual perspective that guides the way in which people work out the 'structure' of a practice – spiritual motivation, ethical attitudes, ethos, worldviews and other things that deeply influence the more visible aspects of human practice".

The structure of the book follows this conceptual framework. The first part of the book concerns "Artifacts and their development". All chapters in this section aim to contribute to a better understanding of the process of developing artifacts for human use, with a focus on information technology. They contain reflections on aspects of knowledge representation in information technology (Basden); the concept of 'qualifying function' (Bergvall-Kåreborn); the elicitation of interdisciplinary knowledge (Winfield and Basden); and on Checkland's Soft Systems Methodology (Mirijamdotter and Bergvall-Kåreborn). Part two of the book analyses how and to what extent information technologies can be seen as socio-technical systems. It contains chapters on the systems character of modern technology (Strijbos), on the cultural desire for unlimited communication (Van der Stoep), and on the cultural influence of communication technologies (Van der Stoep). The third section of the book focuses on how technologies influence human practices. Its chapters deal with the ways in which various systems approaches can inform evaluations of human practices (Vlug and Van der Lei); with unexpected and adverse impacts of the use of information systems (Eriksson); and with developing a framework to understand practices of technology use (Basden).

The fourth section of *In Search of an Integrative Vision for Technology* concerns the 'directional perspectives' that form the fifth element in the conceptual framework. One chapter in this section elaborates a new field of 'systems ethics', expanding systems theory into the domain of ethics (Strijbos); the second chapter examines how various approaches within systems thinking ("hard", "soft", "critical", and "multimodal") rest upon different world views and religious foundations (Eriksson); and the third chapter in this section develops the idea of "disclosive systems thinking" and the normative principles behind it (Strijbos). After these four sections, the book contains a fifth section with two critical reflections (by Midgley and Mitcham) on the perspectives developed in the book, mainly focusing on the strengths and weaknesses of the conceptual framework organizing the book.

Also for readers who, like me, do not have their home base in systems theory and neither in neo-Kantian systems like Dooyeweerd's, *In Search of an Integrative Vision for Technology* is an intriguing book, since it develops an original elaboration of intuitions were also elaborated in a radically different form in Science and Technology Studies and in the Philosophy of Technology. The idea that technology and society are inextricably connected, e.g., is widespread in the field, but Strijbos's and Basden's book conceptualizes this relation in a new way, which deserves critical attention. Moreover, ethical reflection is an integral constituent of the 'CPTS model' – as the authors call the conceptual model guiding the book – and this makes the model very timely in light of current discussions about ways to fill the normative gap in STS and the philosophy of technology, which has been criticized by many scholars already.

In order to explore what exactly can be the potential contribution of the book to current discussions in the philosophy of technology, I will discuss two aspects of the conceptual model, one ontological, the other ethical. First, I will discuss how *In Search of an Integrative Vision for Technology* analyzes the relationships between technology and society and how this analysis relates to other positions in the field. Second, I will discuss the ethical approach of the book and its possible contribution to the ethics of technology. For both lines of inquiry, I will use an exemplary technology to which I will apply the CPTS model in order to investigate its strengths and weaknesses. This example will be the technology of obstetrical ultrasound.

When analyzing obstetrical ultrasound with the help of the CPTS model, the five levels of the model are directly helpful to distinguish many relevant aspects of this technology. At the level of *basic technologies*, there are the technologies of ultrasound radiation, detection, and translation into a visible image. The *artifact* here is the ultrasound scanner itself, and the *sociotechnical systems* are the medical systems in the hospital, which involve interactions between the building, electricity, expertise of doctors and nurses, procedures, devices, et cetera. The *human practices* around obstetrical ultrasound are the medical practices of doctors and nurses, and the practice of expecting a child and dealing with the questions and responsibilities connected to that. The level of *directional perspectives*, to conclude, concerns ethical questions about how to deal with ultrasound in medical practice and how to deal with the results of antenatal diagnostics when expecting a child.

The CPTS model, therefore, is able to conceptualize both the specificities of the technology, the social context in which it will find its place, and their points of intersection. Yet, it remains the question if this specific conceptualization of the interaction between technology and society is able to cover all relevant aspects of technology's social roles. In Philosophy of Technology and in Science and Technology Studies, many scholars have analyzed these relations between technology and society, but unfortunately *In Search of an Integrative Vision for Technology* hardly discusses these positions. Such a discussion would have been interesting, since major differences exist between the approaches.

Characteristic for the CPTS approach is that it stresses the *interaction* between technology and society, whereas many current approaches in STS and the philosophy of technology focus on their *mutual shaping* or *co-constitution*. Within the CPTS approach, technology helps to shape what is called the 'direction' of human practices (the 'how' of practices, or their 'founding function'), but not their 'structure' (the 'what' of practices, or their 'founding' function). The nature of practices is considered to have already been determined before technologies come to play a role in them; technologies can only affect how these practices get shape in specific circumstances, not what they *are*. This implies that important implications of the technology of obstetrical ultrasound might fall out of the scope of the CPTS model. For this technology actually constitutes the practice of expecting a child and dealing with pregnancy *anew*, rather than merely giving a new direction to the already existing practice.

The introduction of ultrasound has radically changed what it means to expect a child. Ultrasound fundamentally shapes our experiences and interpretations of the unborn child and of what it means to be pregnant. By isolating the fetus from the female body, for instance, it creates a new ontological status for the unborn child, as if it had an existence apart from the woman in whose body he or she is growing. Moreover, because of its ability to make diseases visible, ultrasound places the unborn child in a medical context, thus translating pregnancy into a medical process, the fetus into a possible patient, and – as a result – congenital defects into preventable forms of suffering. Ultrasound therefore plays an important mediating role in the experience of being pregnant and in moral decisions about the life of the unborn child. This role is ambivalent: on the one hand, it enhances the bond between parents and unborn child, which makes it more difficult for them to choose to have an abortion in case the child suffers from a serious disease; on the other hand, the very possibility to make predictions about the health condition of the unborn child may invite people to terminate the pregnancy if the child is likely to suffer from a serious disease. What is not ambivalent here, however, is the fact that pregnancy has changed into a process of *choice*.

Ultrasound has therefore radically changed the practice of being pregnant and dealing with the uncertainties and responsibilities connected to that. It did not simply give a new direction to what already happened, but it reshaped the practice of being pregnant in such a way that new categories are needed to understand it. This implies that an adequate conceptualization of the relations between technology and society should take their interwoven character more into account than the CPTS model does. Rather than starting from the idea that there is a set of practices which all have a different *a priori* structure, it might be necessary to show how these practices themselves are actually *constituted* by technologies. And for this purpose, Dooyeweerds neo-Kantian framework – however relevant – might be too limited to fully grasp the social and cultural roles of technology. For this reason, the book would have benefited from more discussion with other positions in the field.

What distinguishes the CPTS model in a positive sense from many other approaches in the field, however, is its integration of ethical reflection in its conceptualization of technology. Because technology is inextricably linked to human practices, these practices and technology's role in them need 'guidance' in a moral sense, as the authors of *In Search of an Integrative Vision for Technology* explain. Especially Sytse Strijbos' article on Disclosive Systems Thinking offers a systematic elaboration of an ethical framework that is able to address the relations between technology and society as elaborated in the CPTS model. Elaborating Dooyeweerd's analysis of the various aspects of reality and their "intrisinsic normativity", Strijbos argues that technologies might form an obstacle for such norms to be realized, and that ethical reflection on technology needs to be directed at making room for their realization.

Yet, again, the example of ultrasound shows that there are limitations to this approach as well. First of all, the idea of intrinsic normativity becomes problematic when taking into account the constitutive role of technology in the relations between humans and reality. What the relevant aspects of reality are, and what their 'intrinsic' normativities are, is always co-shaped by the specific relations human beings have with reality, and by the mediating role of technologies in these relations. Moreover, by placing the 'directional perspectives' exclusively in the domain of society, guiding human practices in which technologies can play a role, the CPTS model cannot account for the moral dimension inherent in technological artifacts. As the example of ultrasound shows, not only human practices, but also technological artifacts can embody morality. This is not to say that technological artifacts are able to make moral decisions themselves, but because of the pervasive and mediating role of technology in our culture ethical reflection and moral decision-making are simply not exclusively human in nature anymore. Moral decisions about abortion get shape on the basis of specific interpretations and representations of the fetus, which are fundamentally mediated by technological devices. When locating 'directional perspectives' only in the domain of society, therefore, an important 'locus' of contemporary morality remains out of sight.

This has serious implications for the quality of moral decision-making in the practice of engineering and technology design – where the 'directional perspectives' of the CPTS model have their primary relevance. If the ethics of technology is to be more than pulling the emergency brake when a technological development is found to be morally unacceptable, we need to take the moral dimension of artifacts seriously. Only in this way we can morally evaluate not only human behavior, but also technological artifacts, and deal with this 'material morality' in a responsible way. *In Search of an Integrative Vision for Technology* is right and praiseworthy in its integration of normative reflection in its approach to technology, and it offers an interesting and rich analysis of the various aspects of the relations between technology and society. But the too radical separation between technology and society behind the CPTS model conceals aspects of both technology and society that need to be addressed for an adequate understanding and evaluation of our technological culture.

Seeing the World through Technology and Art

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Review of *Mediated Vision*, Petran Kockelkoren (ed.), Rotterdam: Veenman Publishers and ArtEZ Press, 2007. ISBN: 978-90-8690-105-0, in Dutch: 978-90-8690-088-6, Online: http://www.aias-artdesign.org/mediatedvision/

Mediated Vision, edited by Petran Kockelkoren, is a collection of articles and art exhibitions that each explores the effects that technology has upon the ways humans experience the world. After a review of the collection as a whole, I return in a final section to two of the articles, those written by Don Ihde and Peter-Paul Verbeek, to provide them further contextualization and commentary. Verbeek's piece, I suggest, represents an important next step in a specific line of criticism of Ihde's work.

With *Mediated Vision*, Kockelkoren has made the rare accomplishment of assembling a collection that taken together amounts to more that the sum of its individual contributions. The articles and works of art are quite diverse, but are related to one another in that each explores aspects of human vision mediated by technology. The essays are written by philosophers and art historians such as Don Ihde, Thomas Y. Levin, Peter Sonderen, Robert Zwijnenberg, Peter-Paul Verbeek, and Kockelkoren himself. The artists featured include Annie Cattrell, Felix Hess, Wouter Hooijmans, Esther Polak, The Realists (Jan Wierda and Carel Lanters), Gerco De Ruijter, Frank Sciarone, and Jeroen van Westen.

Mediated Vision is structured to be an inviting read. Every page is colorful, and (as necessitated by the theme) there are interesting images throughout. The articles are short in length, each getting across specific insights rather than fully-developed theses. Thus the book has a resonance more like a symposium than a collection of separate works. Each page of an article is framed by a colorful backdrop of pictures of technologies or computer-produced images. The chapters of *Mediated Vision* alternate between articles and short exhibitions of artwork. Each art presentation includes an introduction by Kockelkoren and a few pages of representative images of the artist's work. And several of the articles respond to the works of the artists included. The interspersing of artistic and textual contributions is effective; the sum total of the contributions creates a context of insight and creativity that amplifies the ideas of each individual entry.

Both those working on theory regarding technological mediation (philosophers of technology, art historians, etc.), and also artists interested in these themes, will find *Mediated Vision* to be an approachable collection. Since the articles are concise, the art exhibitions come with introductions, and Kockelkoren has included a set of short biographies of the philosophers and artists mentioned throughout the book, anyone interested in the topics explored in this volume should be able to comfortably pick it up. In the next section, I summarize the articles and artwork presentations.

Essays and Artwork

Don Ihde and Peter-Paul Verbeek both approach issues of technology from the perspective of a tradition of philosophy called phenomenology. Phenomenologists explore philosophical questions from the starting point of human bodily experience of the world. For thinkers such as Ihde and Verbeek, a technology is investigated in terms of the way an individual's experience of the world is altered or enhanced through its use. In Ihde's article, "Art Precedes Science, Or Did The *Camera Obscura* Invent Modern Science?," he investigates the ways that technological developments lead scientific research along particular directions, and also how technology leads the directions of our greater epistemological discourse. Ihde follows the use of a device called the camera obscura (a gadget that works like a pinhole camera but can be the size of a room) from its use by Renaissance artists to its development into optical devices in science, and then to the advancement of these tools into present day imaging techniques. As well, Ihde explores the way that the camera obscura has been used as a central metaphor by modern epistemologists, helping to articulate the conception of the division between subject and object, and also the notion that the mind can be thought of as a theatre where representations of the world are experienced (Phenomenologists like Ihde oppose these sorts of modern conceptions of the mind).

Peter-Paul Verbeek's piece, "Beyond the Human Eye: Technological Mediation and Posthuman Visions," expands upon the vocabulary Ihde has offered for understanding technological mediation. In so doing, Verbeek lays out a useful new classification of approaches toward understanding the way images mediate our experience of the world. Verbeek offers three categories: modern visions, postmodern visions, and posthuman visions. "Modern visions" are experiences which presume that an image can provide an objective relation to reality, reinforcing an idea of the autonomy of the viewer and of the world (e.g. a painting that realistically conveys its subject matter). "Postmodern visions" instead emphasize the need for the viewer to interpret what he or she sees, such as a highly technical image from medicine or scientific research (e.g. CT or MRI). In contrast, "posthuman visions" are those that emphasize the "intentionality" of the mediating technology itself, such as works of art that present aspects of the world that would be impossible to view without specific mediation. Verbeek offers the creations of artists such as Wouter Hooijmans, Esther Polak, and The Realists (all contributors to this volume, reviewed below) as examples of postmodern visions. In the next section, I return to Verbeek and Ihde's contributions to consider the contrast between them in greater detail.

Robert Zwijnenberg's article, "From Mirror to Screen: Mediating My Own Body," consists of a series of reflections regarding the experience of an image of oneself as perceived through different mediating technologies. Zwijnenberg contrasts two technologies that allow us to perceive our own bodies: Leonardo de Vinci's thought experiment of the mirror room, and Mona Hatoum's contemporary video art installation *Corps étranger*. In a small sketch, de Vinci devises a person-sized booth whose interior walls are comprised of six mirrors. A person standing inside the mirror room would receive a view of many sides of him or herself at once, as in the case of department store dressing rooms equipped with several mirrors. Zwijnenberg suggests that de Vinci's thought experiment can be understood to raise issues regarding the nature of technological mediation, and regarding the corporeal manner in which an experimenter interacts with his or her own instruments. *Corps étranger* expands upon these themes. In this installation, a viewer enters a small cylindrical room in which plays video and audio of the interior surfaces of the artist's body captured by medical technologies. Reflecting upon the contrast between these examples, Swijnenberg argues that the difference between mirrors and screens in terms of the mediating role they play in our experience is an inessential one.

In a particularly entertaining entry entitled “Surveillance and the Ludic Reappropriation of Public Space,” Thomas Y. Levin reviews a number of attempts by artists to comment upon the pervasive presence of surveillance technologies in society. The projects he reviews are creative and fun examples of performance art, often making a public spectacle of otherwise unseen surveillance equipment. Artists such as Denis Beaubois and others create video installations of themselves holding signs up to cameras, challenging the conventions of being watched, and changing the awareness of passersby. Levin concludes with some reflections regarding the nature of surveillance with the advent of facial recognition technology and thus the certainty (rather than just the possibility) that there is nobody on the other end of the lens to read one’s protest signs.

Of the essays included in this collection, Peter Sonderen’s “The Sublime: A Matter of Time” has the least connection to the theme of technological mediation. Instead, Sonderen reflects upon the temporal aspects of our experience of the sublime, building upon the philosophy of Edmund Burke (and of Immanuel Kant). Burke has provided a sophisticated account of how the experience of something sublime brings about feelings of pain and danger, and causes effects such as astonishment and reverence. Sonderen investigates how artwork can cause this experience and comments upon its temporal nature. Not an art historian myself, I would be interested to see a critical examination of the way that Sonderen so deeply and explicitly understands the sublime to be connected to modernity, representation, and the autonomous moral subject.

Just before coming upon the final essay of *Mediated Vision*, Petran Kokelkoren’s “The Artists as Researcher,” I had worried that the collection as a whole put too exclusive an emphasis upon the ways our perception is mediated by fine art and by scientific instrumentation. Kockelkoren considers a wider scope of technologies, including those of popular culture. As a jumping off point, he reviews Walter Benjamin’s influential essay “The Work of Art in the Age of Mechanical Reproduction” (Benjamin, 1969 [1936]). Benjamin considers the consequences of technologies of mass production such as film and photography for our conceptions of artwork and artistic genius. In Kockelkoren’s perspective, though the piece is typically regarded as a conservative and pessimistic view of technology, Benjamin should be read differently; Benjamin’s work investigates the novel ways that people relate to the world in this new era of technological mediation.

Kockelkoren claims that our senses become conditioned by the technologies that mediate our experience. This conditioning has changed as technology has evolved. As a guiding example, he reviews Erwin Panofsky’s controversial history of the shift from the perceptual habits of the Middle Ages to those of the Renaissance, claiming “People perceived in a different way in the Middle Ages, as the composition of their painting shows, in which distance was suggested by vertical stacking” (Kockelkoren, 2007, 133). This regime of perception changed with the “central perspective” of Renaissance art and the philosophical investigations of the autonomous subject position in the works of René Descartes and others.[1] Another example of a historical change in perceptual regime comes from Schivelbusch’s account of the experience of riders of early trains (Schivelbusch, 1986). The view from a moving train presented a novel perceptual sensation. One’s position on the moving train had to be actively incorporated into the way one perceived the environment, a difficult experience for some at the time. Kockelkoren writes, “What happened in this transition was that a Renaissance conditioning, namely the freezing of the image through the application of central perspective, clashed with the gaze of the moving subject” (2007, 135). This understanding of the history of changing technologies and changing perceptual regimes opens up a space for artists to make special contributions. In Kockelkoren's view, artists play (and have always played) a number of crucial roles in a society's ever-changing perceptual disciplining. These roles can be understood as a sort of "artistic research."

Kockelkoren attempts to articulate this kind of research by identifying a number of ways artists investigate changing technologies and shifting perceptual regimes. Through the review of many Dutch artists (including several contributors here), he identifies five types of artistic research. First, there is "recursion," or the use of art to contest the dominant perceptual paradigm, opening up space for potential alternatives. "Remediation" refers to attempts to revisit and reopen controversies of previous paradigms. The transformation of information perceivable by one sense into something perceivable by another (e.g. visual to audio), he calls "conversion." "Translation" is his term for an artist's attempt to introduce the technologies of experts to the lay public. And lastly, the use of art to create new relationships to the environment he calls "reorientation." Kockelkoren's list is not meant to be a comprehensive account, but a sketch of what it can mean for artists to engage in research on technological mediation.

Though each art installation in this book receives only a few pages, their inclusion is effective. These short sections provide nice introductions to the sorts of works each artist creates. It is difficult to express the impact of the art pieces in writing here, so I will simply summarize the contributions to convey the overall flavor. The work of Annie Cattrell includes glass sculptures of inner parts of our bodies, such as the lungs, and even the parts of our brains in use while our different senses operate. Artistic duo "The Realists," Jan Wierda and Carel Lanters, use stereoscopic photography to create 3-dimensional experiences. The book includes sets of images which, with training, a reader can use to produce these effects. The work of Esther Polak included here regards images of convoluted lines created by mapping people's everyday routines with GPS tracking devices. There are also photos of Frank Sciarone's public art pieces, whose size create unusual visual gestalts. Felix Hess's work on the conversion of things typically experienced through one of our senses into something sensible with another (e.g. air movements into sound) is represented through photos of his installations and machines. Gerco de Ruijter's work featured here consists of bird's-eye-view photography captured by fixing cameras to kites. The work of Jeroen van Westen investigates the way natural landscapes exist among the influences and effects of human communities. And Wouter Hooijmans' photography of natural scenes explores the effects of extremely long exposure times.

One criticism to register of the total entries into this volume is that there is not enough engagement with both artistic projects and philosophical works that make politically-charged investigations into the topic of technologically mediated visual experience. I have in mind philosophical and artistic work that explicitly reveals and critically analyzes the ways that specific conventions of technological mediation support oppressive institutions and unjust practices in our society. Just a few examples of culturally critical projects on these topics include the work of Rosalind Pollack Petchesky, Michael Dumit, Susan Bordo, Valerie Hartouni, and Donna Haraway (e.g. Petchesky, 1987; Hartouni, 1996; Bordo, 1997; Dumit, 1999; Haraway, 2007). These sorts of issues do not receive adequate attention in this volume. Levin's piece comes closest, reflecting upon the efforts of artists to make unnoticed surveillance technologies more apparent. I do not mean to imply that every article, collection, or monograph on the issue of mediation and imaging technologies must spend time considering issues of politics, justice, and oppression; academic research productively takes up a narrow focus upon its different objects of study. But several of the pieces in this collection claim to offer wide histories of imaging technologies, novel classifications, philosophical reflection upon our conceptions of selfhood, and reflection upon the roles of artists. With these expansive themes addressed, the two topics of the politics of imaging technologies and the potential for political resistance in artwork are important holes in the general impression that emerges from *Mediated Vision*.

Postphenomenology and Posthumanity

As a final set of reflections, I would like to further contextualize Ihde and Verbeek's entries into this volume. Both philosophers are figures in an emerging perspective in the philosophy of technology called "postphenomenology" (e.g. Ihde, 1993; Ihde, 2003; Verbeek, 2005; Ihde, forthcoming; Rosenberger, forthcoming; Selinger, forthcoming).[3] This developing school of thought includes a focus upon the technologies that mediate human experience of the world, an effort to amalgamate the philosophical traditions of phenomenology and pragmatism, and an emphasis on concrete case studies. Those working from this perspective generally utilize Ihde's insights as starting points. But Verbeek, while advancing the postphenomenological view, has also offered a specific critique of Ihde's work along the way.

With his recent book *What Things Do: Philosophical Reflections on Technology, Agency, and Design*, Verbeek has positioned himself as a rising star within the field of philosophy of technology (2005). Declaring commitment to the postphenomenological perspective, the book thus also becomes an important touchstone for this emerging school. But, interestingly, Verbeek presents his version of postphenomenology as more radical than Ihde's. He explains, "it is necessary to hone Ihde's analysis on one point. For the way in which he speaks about technological mediation seems at times to lapse once again back into the subject-object schema that it is precisely the phenomenological ambition to overcome" (Verbeek, 2005, 129). A greater emphasis, in Verbeek's view, needs to be placed upon the ways that humans themselves are transformed by the process of technological mediation. "Mediation," he says, "does not take place *between* a subject and an object, but rather *coshapes* subjectivity and objectivity" (Verbeek, 2005, 130).

But how much do Ihde and Verbeek's positions in fact differ? In his review of *What Things Do* here in *Techné*, Evan Selinger comes to Ihde's defense (2005). He suggests that Verbeek makes too much of some of the language Ihde uses when making points about technological mediation. Selinger agrees that it is important to study the topic of the transformations of humans through their experience of technology use, but does not view Verbeek's position to be significantly different than Ihde's in terms of content or emphasis.

I suggest that Verbeek's critique of Ihde is further advanced through his piece in *Mediated Vision*. As well, Ihde's article itself can be seen to show how close he and Verbeek's positions in fact remain.

Ihde's piece, taken alone, can be interpreted to provide support to Selinger's defense. By suggesting that the advance of particular technologies has played a significant role in the development of scientific research, and also in the development of Western conceptions of epistemology, Ihde reveals the intimate ways that technologies deeply inform our actions and perceptions. Laboratory technologies, for example, do not only change the world so that we can perceive it, they also influence the directions scientific research travels, and they impact our very conceptions of ourselves, of truth, and of the nature of knowledge.

But Verbeek's piece here can be read as providing further tools for distinguishing his own more radical understanding of technology's "coshaping" capacity. His claim, for example, that certain relations to technology are best understood in terms of "posthumanity" represents a direction for thinking about what a more radical view of postphenomenology could look like. This raises specific questions: as in Selinger's defense above, we can ask whether the posthuman account Verbeek provides indeed offers something different from Ihde's view. We can also question whether the categories Verbeek creates are themselves coherent and useful.

In my view, Verbeek succeeds in pointing toward the direction of a more radical postphenomenology, but he does not offer a clear distinction between Ihde's postmodern claims and his own posthuman observations (and, to be fair, this is more than can be reasonably expected from a short article). With the notion of the "posthuman vision," Verbeek attempts to articulate a certain form of relating to the intentionalities of technologies. He explains, "Rather than putting these intentionalities in the service of human relations to the world—as in what Don Ihde calls 'hermeneutic relations,' where technologies provide representations of reality that need to be interpreted by humans in order to constitute a 'perception'—they [posthuman visions] explore technological intentionalities as relevant *in themselves*" (Verbeek, 2007, 49).

There are two problems with the notion of posthuman visions as offered here. First, since Verbeek uses only examples from fine art to articulate this concept, it is unclear whether posthuman visions refer exclusively to specific attempts to disrupt conventional conceptions of human subjectivity, or if they instead also refer to visions occurring pervasively throughout our everyday interactions with technologies. And second, the notion of posthuman vision is not as clearly independent from that of postmodern vision as Verbeek implies.

The definition which Verbeek has provided for his notion of post human vision, and articulated with examples from fine art, appears applicable to instances of more familiar technologies. A fast-forwarded film of a turning sunflower, a slow-motion film of a vehicle crash test, or satellite pictures of one's home may all qualify as posthuman visions. But more, the very examples which Verbeek uses to describe postmodern visions also in some ways resemble posthuman ones, and vice versa. On the one side, the medical imaging technologies Verbeek offers as examples of postmodern visions (since such scans require human interpretation) all contain their own "intentionalities" in the way of posthuman visions; one sort of scan may reveal dense internal features, another may reveal blood flow, another the burning of glucose. On the other side, the examples Verbeek offers in his definition of posthuman vision themselves require a bit of hermeneutic instruction to be appropriately viewed. For instance, one viewing Hooijman's sustained exposures or Polak's GPS drawings for the first time may require some information about what one is looking at before one is able to experience the significance of the intentionalities of the mediating technologies at work.

Importantly, these criticisms do not, in my view, amount to a critical blow to Verbeek's concept of posthuman vision. The observations that the definition of posthuman vision applies to many everyday examples, and that it shares essential overlapping points with postmodern notions, simply provide important qualifications. With the introduction of posthuman vocabulary into discourse on the phenomenology of technology, Verbeek successfully provides a new direction for further emphasizing and articulating the capacity for technology to change and guide human perception.

In Summary

While this review can relay some of the claims and ideas of the entries in *Mediated Vision*, it cannot capture the experience of the combined written and visual pieces of this collection. Each individual entry here stands fine alone, but the total sum of this collection results in an engaging, approachable, and thought-provoking experience. *Mediated Vision* impressively accomplishes the task of inspiring new ideas within its readers.

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Endnotes

1 Panofsky's views appear in (Panofsky (1991) [1927]). Kockelkoren complicates Panofsky's story with review of Jonathan Crary's work which suggests that views of subjectivity in the Renaissance were influenced in a variety of ways by a number of technologies, including the kaleidoscope, stereoscope, and especially the camera obscura (Crary 1992).

2 An expanded version of this history of perceptual regimes occurs in Kockelkoren's *Technology: Art, Fairground and Theatre* (2003).

3 See also a forthcoming issue of the journal *Human Studies* on the topic of postphenomenology. Contributors include Cathrine Hasse, Don Ihde, Evan Selinger, Peter-Paul Verbeek, and myself.