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RESEARCH PAPER

Postphenomenology: Learning Cultural Perception in Science

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Abstract In this article I propose that a postphenomenological approach to science and technology can open new analytical understandings of how material artifacts, embodiment and social agency co-produce learned perceptions of objects. In particle physics, physicists work in huge groups of scientists from many cultural backgrounds. Communication to some extent depends on material hermeneutics of flowcharts, models and other visual presentations. As it appears in an examination of physicists' scrutiny of visual renderings of different parts of a detector, perceptions vary in relation to social and bodily experiences. Vision in physics has seemingly allowed an objective perception at a convenient distance of the body. This article challenges this view and proposes that the variations can be analysed as cultural at two echelons with the help of a postphenomenological approach combined with cultural psychological theory of artifacts. A third echelon presumably constitutes the phenomenological limit to culture in science. Even this last resort of subjectivity can be embraced by a postphenomenological approach. The process of culturalization in physics can be defined as a process of situating knowledge in a body whose continuous learning of micro-and macro perceptions makes scientific renderings unstable. Taken together postphenomenology, following the distinctions between body one and body two, and combined with cultural psychological learning theory, enables new insight into what constitutes culture in science.

Keywords Postphenomenology · Science and technology studies · Cultural psychology · Situated knowledge · Cultural learning processes

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Models, illustrations and diagrams serve, together with mathematical signs, as basic epistemological tools in science, making sight the most privileged of the senses (Jay 1988). A postphenomenological approach to unstable materiality and multi-stability in science is a pragmatic and in a deep sense empirical examination of "the things themselves" as their material constraints and conditions meets the human bodies which, while not transcendental subjects, are cultured. Images of what in a phenomenological sense was considered external are in the postphenomenological approach proposed by Don Ihde not reducible to representation or subjective experience. Bodies cannot be *transcendental*; they are *existential* and postphenomenology builds on this inheritance from Maurice Merleau-Ponty and contends that embodiment substitutes for subjectivity (Ihde 1993, p. 10). Perception is active. It is formed as bodies move in space, and materiality and perception are intertwined in the process. However, Merleau-Ponty did not go far enough, Ihde claims, because he did not include a pragmatic insight into how bodies are also cultured and gendered.[1] In a critical companion to Ihde's work, Selinger underlines that this emphasis on embodiment is philosophically significant (2006, p. 5). The claim also has wide implications for empirical studies of science. In the discussion of situated knowledges, Haraway, with reference to feminism, opts for a doctrine of embodied objectivity, which can be termed *situated knowledges* (1991, p. 188). This situatedness is countering claims of a static ahistoric "God's-eye-view" objectivity. Relativism is considered equally problematic by Haraway, as it is also a way of being nowhere while claiming to be everywhere equally. Only recognition of embodied partial perspectives promises objectivity. She uses her argument to plead for a radical multiplicity of local knowledges, and underlines that feminist embodiment is not connected to "fixed" locations in reified bodies, but rather with nodes, inflections and orientations. It has to do with communities, not individuals. Haraway never makes any precise definition of how to study situated knowledge empirically and leaves the reader with a rather abstract sense of what is meant by situated. Others have discussed situated knowledges as embedded in learning practical activities in communities of practices (cf. Lave and Wenger 1991; Brown et al. 1989). Empirical studies have concentrated on how generalized new group members learn to share knowledge of the community with more experienced practitioners. The perplexing thing about situated knowledge in these theories and empirical studies of communities is that knowledge is apparently embodied without a theory of how the body is relating to the community. This restricts studies of situated knowledge in empirical examinations of science and technology to the analysis of whole communities. In this sense, the problem raised by Haraway of the view from nowhere has not yet been solved.

With a postphenomenological approach to studies of science we can begin to grasp in more detail just how these situated knowledges develop as embodied

[1] Ihde (2003a) does acknowledge though that Merleau-Ponty in the posthumously printed *The Visible and the Invisible* shows deeper insights into what Ihde calls "macroperception," the hermeneutically meaningful perception which is culturally embedded.

perception where materiality and social interaction intertwine in culturally structured worlds. A recognition of the embodied situatedness of scientists' knowledge destroys the assumption, inherent in visualizing technologies, that the knowing subject in science is distanced from everybody and everything. Knowing subjects become knowing embodiments. For empirical studies of science, this means that the doctrine of objective representations can be countered with careful analysis of empirical data of how bodies come to know. This, I suggest, implies a focus on learning as well as a deeper understanding of the interrelation of spatiality, motility, and gendered bodies in a cultural context.

I propose we take Ihde's distinction between "body one" and "body two" (2002) as a starting point by combining body one and two with the discussion on micro- and macro perceptions (Ihde 1993). These approaches can furthermore be connected with a cultural psychological understanding of how we learn the meaning of artifacts. Together these frameworks make it possible to construct a model of how we learn situated knowledge, which constitutes an analytical split of cultural perception in science at three echelons: (a) the individual physicists' embodied perception of a material artifact in relation to bodily operations; (b) the embodied perception of a material artifact in relation to social interaction in communities; and finally (c) embodied perception as a cultural embodiment.

Postphenomenological Embodiment

It has been a perpetually returning problem in science and technology studies how to come to grips with the relation between science as a social and cultural practice, and the people who in everyday life through their bodily actions constitute the basic re-establishment of what can be called science. To fill this gap Ihde proposes a distinction between *body one* and *body two* (2002, p. xviii)—the lived sensuous and the cultured body.

Body one stands for the motile, perceptual and emotive being-in-the-world we meet in Merleau-Ponty's work; body two is embodiment constructed in a cultural context including constructions of gender, age, etc. These bodies can be seen as bodies relating to and mediated by technology.

As Verbeek (2005) has noted: the technosciences are more than interpretations of reality; they act, even encroach, upon reality. This is in line with Haraway's notion of bodily apparatuses in which objects constitute an active part (Haraway 1991, p. 200). With the postphenomenological perspective, we can dive deeper into the constitution of the relation between object and embodiment. There is *always* perception (Ihde 1993, p. 87), but perception can be seen to follow the distinction between body one and body two. In *Technology and the Lifeworld (*1990) Ihde distinguishes between *micro-perception* (with an emphasis on bodily-sensory dimensions) and macro-perception (which emphasizes cultural-hermeneutic dimensions). These are not separate and discrete but interrelated; are parallel to body one and two as distinguished in *Bodies in Technology* (2002), and in practice are inseparable from each other. Body one can never be completely dissolved into body two, but is at the same time permeated with cultural signification.

Embodiment is *both* actional-perceptual and culturally endowed (Ihde 2003a, p. 14).[2]

The same is the case with micro- and macro-perceptions. Micro-perception is sensory, fundamental and reflexively to bodily position. Macro-perception is what *contexts* micro-perception and as contexts can vary it yields cultural diversity and thus gives way for an understanding of perception as polymorphic. Through this analytical distinction the expanded phenomenology of perception which links micro- and macro-dimensions can give clues to the shape of a polymorphic structure, which can be named "structured multistabilities" of perception (Ihde 1993, pp. 75–76). As an example of this structured multistability, Ihde mentions the diversities in reading positions and reflexively implied positions in literate cultures and those found in non-literate cultures.

In the discussion of visual hermeneutics, Ihde (2003b, c) furthermore operates with a weak programme in which instruments such as particle detectors simply mediate, in the sense that they provide a new access to phenomena. In the strong programme, the instrument is not neutral but becomes part of the construction of perception. There are bodies everywhere and thus also in technology (Ihde 2002), so the notion of body one and two also have implications for embodied perception in technology. In *Expanding Hermeneutics: Visualism in Science* (1999), Ihde proposes a material hermeneutics, which enables visual artifacts in science to be interpreted as a nonlinguistic analog to textual presence.

Technologies are in no way innocent, but simultaneously enhance and limit perceptions. Scientific material hermeneutics can, as other kinds of hermeneutics, be seen as a culturally structured positioned being-in-the-world. Here Ihde has distinguished between technologies which make new perceptions possible (glasses are an example, telescopes and microscopes others), and technologies which do not amplify or replicate the body's sensory abilities, but engage our interpretive aptitudes (Selinger 2006, p. 5). The latter are "text"-like and form an interrelation between the material composition of the artifact combined with the scientist's ability to perceive material signs as significant data and the scientist's knowledge of the technology in itself.[3] Whatever reality there is out there is co-constructed by the instruments, as Verbeek has put it (2003). Technology transforms our perceptions, but how we interact and create "stories" and debates about what we see also forms perceptions (see Rosenberger, forthcoming). Instruments are the means by which unspoken things "speak," and unseen things become "visible" (Ihde 2002), but as we have different embodied experiences with technology their visibilities are unstable in relation to bodily experiences. Scientific instruments can render the

[2] In Ihde's earlier work, *Technology and the Lifeworld* (1990), he makes a distinction between "microperception" and "macroperception." The first focuses upon the experienced active sensing and motile body; the latter upon the cultural-hermeneutic dimensions of embodiment. Later, in *Bodies in Technology* (2002) a parallel set of distinctions, "body one" and "body two," are introduced. For both distinctions, embodiment necessarily has both dimensions.

[3] Ihde has referred to these relations between body and technology as embodiment relations, hermeneutical relations and alterity relations. In relation to my discussion here I would like to underline that when we combine Ihde's postphenomenology with learning theory we find that (in Ihde's terms) hermeneutical and alterity relations are intertwined with embodiment relations through social relations, which is why I abstain from using these terms here.

invisible visible, but in this process technology forms perception and sets up limits for interpretive possibilities built in to the very materiality of technological artifacts. The question now is how the material hermeneutics, which in science are often visual hermeneutics of models, illustrations, and diagrams (which form representations of reality mediated by scientific instruments), can be argued to be culturally informed. I would like to go one step further into the mediation process and claim that not only the visual artifacts and the stories we tell, but the very processes, which constitute the meaning of artifacts in science and technology must include the individual embodied experience of cultural learning.

Clarke has criticized Ihde's sensory-motile and social-cultural body for actually *not* moving ahead of Merleau-Ponty in so far already Merleau-Ponty underlined that bodies are intersubjective and thus could account for the polymorphic cultural contextualization of technology. In that sense Merleau-Ponty and Ihde are compatible (Clarke 2003). I do not agree. The phenomenological body of Merleau-Ponty has the problem that it can only examine intersubjectivity, and thus culture, as a matter of putting oneself in the other's place *qua* having a body.[4] Shared hermeneutics cannot be accounted for, as Clarke claims, by "empathy" (2003, p. 6). With the distinction, yet intertwinement, of body one and body two with their matching micro- and macro perception I believe Ihde takes one huge step ahead of Merleau-Ponty, because it now becomes possible to ask: what, apart from an experiencing body, can account for the culturally shared material hermeneutics and situated knowledge of body two?

Here I want to offer one suggestion, namely the process of learning as the intermediating link between bodies and macro-perceptions of artifacts.

Cultural Artifacts

A pervasive theory for analysis of the relation between human activity and material artifacts can be found in Cultural Historical Activity Theory (Vygotsky 1978; Leontiev 1981; Cole 1996; Engeström 1987; Cole and Engeström 1993; Cole et al. 1997; Chaiklin et al. 1999; Wertsch 1985), and the work on distributed cognition that grows from it (Hutchins 1995). These perspectives generally lack the phenomenological emphasis on the body, the *corps vecu*, and the phenomenology of perception as the primordial fundamental point of departure for our experiences with the world. What they can add to the postphenomenological is the social learning of intentionality and artifacts in cultural historical activity. In the phenomenological sense, bodies share the same *experiences* with material objects, and thus intersubjectivity is created through shared experience. When the perspective is cultural–historical, the meaning of artifacts must be *learned* first in social interaction and then internalized. Such a theory of learning has been provided by one of the "founding fathers," the psychologist Lev Semionovich Vygotsky.

[4] Clarke thus claims Merleau-Ponty is compatible with what Ihde names postphenomenology and refers to this quote from the *Phenomenology of Perception:* "to feel one's body is also to feel its aspect for the Other" (1962, p. 245).

He, with his colleagues, Leontiev and Luria, formed the first generation of such a cultural psychological framework. In the words of Vygotsky:

> Every function in the child's cultural development appears twice: First on the social level, and later on the psychological level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All higher functions originate as actual relations between human individuals (1978, p. 57).

Artifacts are not just material entities, they are also signs—and it is as signs (or pictures or pictograms) that they can be psychologically internalized. It follows that artifacts from the very outset are imbued with cultural meanings, which are learned and internalized *not* just in use, but also in *social* use. In this cultural psychological perspective, all artifacts are *artificial*—they are not grown out of soil or shaped by the winds.[5] They are created by human beings—and their creation is never accidental, but embedded in human activity. Artifacts are created with purposes. They are tools meant to fulfil a desire or requirement developed in a cultural group of people, who pass not only material artifacts but also their cultural meaning on to the next generations through a process of learning.

> [A]n artifact is an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action. By virtue of the changes wrought in the process of their creation and use, artifacts are simultaneously ideal (conceptual) and material. Artifacts are material objects, created in the process of goal directed human actions. They are ideal in that their material form has been shaped by their participation in the interactions of which they were previously a part and which they mediate in the present (Cole 1996, pp. 117–118).

As human beings learn and internalize the social meanings of artifacts in use, their creation and use are inseparable from the activity they are learned in. Vygotsky underlines that this internalization of abstract "tools" like language and other signs makes humans capable of reorganizing the visual-spatial field into an internalized field of attention. We are no longer, like animals, dependent on the actual physical field, which formerly guided behaviour. We guide our own behaviour as we in social interaction internalize social meaning and instead of being solely connected with the physical sight of artifacts, behaviour is guided by the "ideal" internalized sign meaning which makes us perceive artifacts with our "inner eyes." Socially constructed signs, rather than immediate visual perception of the environment, guide our actions (Vygotsky 1978).[6] Our mediated, "logicalized" memory, through

[5] There might be different positions on the nature/culture debate within the group of theorists working with cultural historical activity theory. I make no distinction between learning the cultural meaning of the Sycamore tree or the cultural meaning of a wooden chair. In other words in terms of learning the cultural meaning of artifacts no distinction can be made between "natural objects" and "cultural objects."

[6] In this framework there is no reference to the concept of intentionality, but it might be connected with the concept of motivated action in the cultural–historical framework. Though some of the early proponents actively dissociated themselves from transcendental phenomenology, in the new version of postphenomenology the views become compatible.

the use of signs, makes it possible to establish and find logical relations as an external activity. Signs can be words as well as external objects, as knots on a handkerchief or monuments that force us to remember (Vygotsky, p. 51).[7]

When the focus is on life-long learning in science these processes of incorporating and modifying material artifacts imbued with "ideal" sign meaning is ongoing and never-ending. Relating this approach to the discussions of Ihde's technologies, artifacts are created in historical contexts, which they mediate in the present. Ihde's notion of "technological intentionality," also discussed in Verbeek (2003), is in this context a learned intentionality and perception is not only situated but situated in an activity, which forms the way we look at artifacts (Goodwin and Goodwin 1998).

What we can add from the postphenomenological perspective is that not only does technology render objects visible, which were formerly invisible. Embodied knowledge is also open for an embodied hermeneutics of what is *not* visible in artifacts for particular situated bodies.

Embodying Physicists' Knowledge

I base my argument on my own extensive fieldwork in the culture of physics, beginning with my own enrollment as a physics student at the Niels Bohr Institute for physics in 1996. Here I, as an anthropologist, followed a group of physics students as they, as newcomers, gradually learned to share the situated knowledge of more experienced practitioners in physics (Hasse 2001, 2002a, b, c). This first study was followed by a second study in which I, for several years, interviewed and followed a group of scientists in their daily work. As part of this study, I spent 4 months in an Italian experimental physics institute, sharing an office and everyday life with a group of experimental particle physicists. Part of the time, I also participated in joint meetings at CERN in Switzerland, where physicists from more than 34 countries around the world met to work on and discuss the progress of building a particle detector. In this project, ATLAS, the physicists construct the detector to find new particles important for confirmation of their theories of how mass is constructed through particle collisions in a particle collider. The ATLAS experiment is built up around a complicated many-layered detector, with the purpose of "catching" the formation and decaying of particles in collisions taking place in a large 27 km tunnel lined with magnets forming a circle, which runs under France and Switzerland.

In a sort of quasi-experiment, I took around a hundred pictures during my fieldwork among the Italian physicists of some of the artifacts of importance for their work in experimental physics. The pictures were of white boards with their scribblings, notice boards, laboratory equipment and the particular instruments they worked with in Italy, which were to be connected with the detector in Switzerland. Some pictures were of particle events produced in computer simulations and constructed from events, in which particles collide in detectors and are visually

[7] As for monuments, as houses, Vygotsky mentions that the very essence of civilization can be seen as building monuments on purpose so as not to forget.

reconstructed by computer technology. Some of the pictures are photographs taken by me of hands-on parts of the experiment (tubes, wires, measurement instrument); others are flowcharts, models or actual visualizations of particles used by the physicists themselves in their own work.

I then selected 15 pictures from different areas of work and showed these to ten physicists who lived and worked outside of Italy—of whom all but one worked with the ATLAS experiments (together with more than 2,000 other physicists). They came from four other countries. Some of the physicists have worked for a long time directly with the practice illustrated by the pictures, others have worked for briefer periods, and others again work on different aspects of the experiment. Finally, I showed the same pictures to two groups of academics with no background in physics to get an impression of the boundaries of the situated knowledges of physicists.

A standard phenomenological practice begins with objects (or noematic domains) and through the rigorous use of *variation*, ascends towards the juncture of micro–macro perception interstices (Ihde 1993, p. 75). How does a variational centred practice of phenomenology operate? Bodily perception has *structure* but that very structure yields a polymorphy to perception. It is multistable (1993, p. 70). In Ihde's case, the familiar Necker cube becomes an insect resting on a hole with the legs spread out (1993, p. 76).

In my quasi-experiments, I do not follow standard phenomenological practice, but use the variations in the way physicists, presented with photographs of the material experimental objects, describe the objects they are supposed to share knowledge about in their everyday life as physicists. It is from these descriptions that I unfold an argument on the interaction of *body one* and *body two* and connect this perspective to learning in science education as well as scientific practice.

I have never myself visited the actual detector, though I have been standing above the tunnel where it is placed. I have seen many pictures of it and the shafts and tunnels around it and my reading is now connected to my embodied learned knowledge of particle detectors before and now. My own reading of the ATLAS detector is of course as limited as my own situated knowledge about particle physics—but it is also a prerequisite for this analysis of the physicists' embodied knowledge. Though I can argue that physicists have different partial perspectives on the barrel shape of the detector, they can question my partial view of particle detectors. Even so, I can build an argument around what I have learned in terms of material hermeneutics in physics.

The postphenomenological perspective points to the fact that there is *always* perception, but it is a particular structured perception, which fixes its object in privileged cultural ways. This practice is never explicit but implicitly taught and followed. It is, in Ihde's example of literacy, a way of "being-in-the-world" within a culture, which might differ from practice in other cultures (1993, p. 86). In my discussion, I build from this argument and claim that artifacts are multistable as cultural perceptions because learning organizes cultural knowledge about what is to be expected in the perceived world.

Physicists' reactions to the pictures showed diversity in their material hermeneutic of signs along many lines—for example between younger and older physicists having different cultural–historical histories of working with particle detectors.[8] One such difference was found in the material hermeneutics of a picture that depicts a so-called "event." This is the discovery of the W particle in the UA1 detector at CERN from the October to December 1982 run of the proton-antiproton collider, producing a high transverse energy electron. The particle is produced back-to-back with "missing energy," indicative of the emission of an invisible neutrino. This is explained to me in Italy by an older physicist, who himself participated in UA1. I became aware of this well known project because some of the older established physicists referred to it—and they all knew or knew about the Italian Carlo Rubbia, who received the Nobel Prize for his discovery of the W and the Z particles in 1984 together with Simon van der Meer, for the work he had done as head of the UA1Collaboration. I presented this picture to the non-Italian physicists to find out, from their hermeneutics, what signs they had learned to share with their Italian colleagues—and if their perceptions could be argued to come from shared learning experiences in the project.

To give an impression of what the black and white picture looks like, we can use the descriptions of the non-physicists who were shown the picture and described it as a fountain sprinkling drops to both sides from a horizontal hose in the middle of the picture. On both sides, two luminous transverse and somewhat blurred beams cut the "hose." Non-professionals with no practical experience of working with collider experiments perceive the signs in the picture as showers of water, a fountain, pieces of art, and they praise the picture for its aesthetic qualities.

Multistable Perceptions

Where non-professionals' situated knowledge makes them miss the mark (of particles) completely, physicists and especially particle physicists fare much better. What puzzles the younger physicists, though, is that the actual pictures are turned the "wrong" way in relation to today's visualization of particle events. In the following "I" stands for the interviewer and "A" for a young physicist, Amelia, "G" for an experienced physicist, Georg, and "E" for a rather experienced younger physicist, Elly. They all come from countries outside of Italy and work in the ATLAS project together with their Italian colleagues.

I: Interviewer
A: Amelia
(Event nr 2958 1279. 99579. Picture of UA1, W particle, hanging on Mazzonis display board. Photo taken 16/11–2002 by CH)
I: Can you tell me what this is?
A: Yes, this is an event. Yes but is this … this is not ATLAS, is it?
I: No, it is not ATLAS.
A: No! It is something very old—I do not know what kind of old, though …
I: You can see it is old?

[8] There is also a gender dimension to these reactions but it will go too far to discuss this here.

A: Yes, because they have … first of all … it is strange, because in ATLAS it would look different—like a more vertical show …

Amelia mentions that the picture must be old. This might be due to the black and white quality and the somewhat blurred appearance. However, she sees what is not there—she sees that the figure is pictured lengthwise, and implicitly compares the horizontal version with the vertical version she usually works with in ATLAS.

I: When you say it's an event, what do you mean?
A: Well, yes, we have had some kind of a collision here. I think … Because it looks rather central. Therefore, we have had a collision, where something happened, only I do not know what … I do not know which experiment it is … However, it is *not* a bubble chamber. It is a collider experiment, but which I do not know.

Contrary to the non-professionals to whom I have shown this picture, Amelia can recognize this as a particle collision. This intelligibility demands knowledge of collisions, particles and their qualities and how they are visualized in the particular detector version—for example that traces are made in collisions and that the shower sprinkles are movements of particles. She is also capable of comparing it with another physical space, which it cannot be because its physical shape would be different.

I: It is from UA1.
A: Yes. Oh, it's the W? So this is the inner calorimeter? No, I would never have guessed that.

Amelia can make very qualified guesses, but there are limits to how close to the event actually shown on the picture her situated knowledge can get her.

My experiment is not only an exploration of visual hermeneutics, but also of the importance of how mattering matter differs in perceptions when people have gone through different learning processes connected to particular practices. Amelia works every day with the vertical computer pictures of events and she can use this situated knowledge in her material hermeneutics, but she cannot "see" this particular detector for her inner eye as a familiar room to move about in—as she can when she talks about her "own" event.

This picture is, as Ihde (2003b) has discussed in relation to other scientific visualizations obtained through technological instruments, not an eyeball vision. Though it looks isomorphic it is a transformation of data from a particle collision transformed into a perceivable gestalt through instruments to let invisible things speak by making them visible. However, these invisible particles visualized in pictures like these are only visible to some in relation to practical embodied internalization of the social meaning of signs. A lot of Amelia's situated knowledge is knowledge that belongs to the epistemic culture of particle physicists and comes with the artifact or pictures of artifacts (themselves being a kind of second order artifacts). The material hermeneutics cannot just be explained by internalization of social meaning of the "ideal" aspect of artifacts like detectors, as we shall see in the next example.

G: Georg
(Event nr 2958 1279. 99579. Picture of UA1, W particle, hanging on Mazzonis display board. Photo taken 16/11-2002 by CH)
I: Can you see what this is?
G: Yes, that must be traces from the anti-proton-proton collider and that is either from UA1 or maybe from UA5.

Contrary to the other physicists, when I show this picture he answers without a doubt. When he expresses doubt it is at a completely different level of analysis than the other respondents. His doubts are embedded and situated deeper in the materiality of the actual detector shown on the picture.

G: … from the streamer chamber. It's probably the streamer chamber, but I am not sure.

Pictures from a streamer chamber are photographed via transparent electrodes, which result in pictures of particle tracks rather like bubble chamber photographs. Georg, as Amelia, can see that the picture is not from a bubble chamber, but he can see further that it might be from a streamer chamber; but when he is told that his other hunch, UA1, was the right one, he immediately perceives the whole of the detector for his inner eye.

I: It is UA1 so what do all the small …?
G: Yes! These are the traces. When it is UA1, then there are strings in this direction, that is, perpendicularly on the paper and then there is a signal in the string lying there … So the traces, the electrical particles, they have passed through the gas and have knocked loose the electrons. Then they have drifted towards the nearest string, so that is why they go along the trace, that is the signal.

Georg perceives the whole (invisible in the picture) detector with strings (which are not in the actual picture).

We do not have bodies, we are bodies. This lesson learned from a phenomenological perspective has wider implications than has yet been explored in empirical sciences. As the postphenomenological perspective underlines: situated knowledge forms our hermeneutic possibilities for interpreting a picture like the UA1 event, because interpretation implies our own embodiment. Our bodies, including their limits and contingencies, are reflexively implied in this process. What our bodies can perceive can be seen analytically from this perspective in a double perspective: body one and body two. As body two Georg and Amelia share a certain kind of epistemic cultural learning. They are both understanding that this is about particle collisions of a particular kind, and Amelia's associations to bubble chambers are not completely off the track (sic!), as this detector was known as the first "electronic bubble chamber" and the reconstruction software was done by ex-bubble chamber track reconstructors (Denegri 2007). They are Western physicists and read the pictures from the same reading position as all Westerners. They are also learners in a physics culture, which has taught them to perceive the signs of particles where non-professionals see fountains.

Close up this postphenomenological analysis, which refuses to reduce body one to body two, gives analytical tools for refined distinctions. Georg and Amelia do not perceive the event in exactly the same way—and the difference is that Georg's situated knowledge is much more embedded in the materiality shown in the picture. Where Amelia uses qualified guesswork, Georg can use his own embodied knowledge of how the detector UA1 and UA5 actually was physically built up. He can "see" much more in depth invisible stuff in the picture than Amelia and can make the distinction between the streamer of UA5 and UA1's drift chamber. Once he recognizes UA1 the whole detector appears: the central tracker is a 5.8 m long, 2.3 m diameter drift chamber with 6,176 sensitive wires organized in horizontal and vertical planes. Georg's material hermeneutics are closer to the actual visual appearance of the material UA1 detector represented as the horizontal hose and the vertical beams.

In the next example the physicist also has problems identifying the event because she cannot read her situated knowledge of the physical detector space into the picture.

> E: Elly. She has given up finding out what it is and I explain to her.
> (Event nr 2958 1279. 99579. Picture of UA1, W particle, hanging on Mazzonis display board. Photo taken 16/11-2002 by CH)
> I: It was one of the events from UA1—probably the W …
> E: Well, OK. I think it would have been easier to see, if you looked at a vertical show. In any case, across not lengthwise. Like this, you can become confused by all these piffts [the dots]. But all this is not interesting, it's just the residue. Therefore, if you had had it in this direction [across]—now this is of course too nice, but in any case …
> I: Yes like we usually see it in ATLAS [where particles are shown cross-section wise rather than lengthwise as in UA1].
> E: Yes, so you can have a better overview over what actually triggered this event.

Perceiving the Invisible

In Italy, Denmark, the Netherlands, and the UK physicists participated in the historical project UA1 in the 1980s. Today some of the physicists I show the pictures to have themselves worked with Rubbia both on the Italian and the international side of the project. In this material, it is obvious that those physicists, like Georg, who worked at the same time as Rubbia immediately form a hermeneutic pattern of the dots on the picture. Whereas the young people have not learned what the older physicists have learned through physical presence in UA1—so they are guessing from their shared knowledge about physics and experiments internalized in social use of the next generation of detector artifacts.

Georg can see all the invisible parts of the detector—the strings and the gas—and he is not at all confused by its lack of a cross section of the detector. Those who actually worked with the experiment, like Georg, not only recognize the experiment, but the very construction of it. He "sees" these slashes as walls, which he explicitly underlines in the interview: "These are the walls, because it consists of different detectors—so to be able to separate them, you see …" He, in a basic phenomenological sense, "sees" what is invisible. The mind is inherently embodied. The embodied mind is connected to learning in culturally situated practice and this practice informs not only what is perceived, but also what *can* be perceived.

In the words of Merleau-Ponty, Georg's perceptual life is subtended by an "intentional arc," which projects round about his past, future, his human setting, and physical, ideological and moral situation (1962, p. 136). It is the diversity in the body one micro-perceptual arc, which makes his, Amelia's, and Elly's perceptions of the "same" object multistable. At the level of body two multistability is achieved through a comparison between the structured perceptions of particle physicists. At the upper echelon, all Western people have learned to read text and pictures from a particular perspective and thus culturally share the position of perception.

What Elly, Georg, and Amelia share, is a learned knowledge about particle physics, in the standard model. They know what leptons are, and how they must look—and they share the situated knowledge that visualizations of particles in ATLAS are shown as cross sections of the barrel vault of the detector. They do not share a situated knowledge about the UA1 experiment being horizontally exposed. They have not all learned to work with UA1 and therefore they do not share a perception of the walls and the drift towards strings in experiment shown in the picture.

The physicist Barad is right when she claims that she wants "to encourage doubt about [the] presumption that representations (that is, their meaning or content) are more accessible to us than the things they supposedly represent" (2003). The meaning of socially constructed artifacts cannot be taken for granted.

The main point in my analysis here of these three interviews is that multistability in perceptions can be explained by differences in experiences of learning and that these learning processes run along two lines: (a) through your own body movements and physical interaction with artifacts in space, or (b) through social designation of meaning in the Vygotskian internalization process. Georg could have shown the picture himself to Amelia, explained the picture to her, and thereby made her internalize a material hermeneutic closer to the actual artifact. He himself, as a more experienced practitioner, is in no need of such explanations as learned by co-producing the UA1 site. The process of learning through social designation and learning through bodywork in practical activity can take place simultaneously, but does not necessarily do so. In any case, both learning processes become embodied as internalized cultural perceptions. Following a distinction made by Vygotsky in his discussion of psychology of art, the question of professional identities is not so much one of the difference of individual versus social, but the difference between collective and social (1978, p. 17). Even the most physical embodiments of detectors are socially constructed in cultural–historical activities, but the way physicists perceive these social products are not coinciding. Therefore, perception is not based solely upon a collective situated knowledge. A social situated knowledge can only to some extent be shared. To that extent such epistemologies can be called a collective material hermeneutics.

What the analysis shows from a postphenomenological perspective is that body one and two cannot be conflated, as predicted by Ihde. In addition, even more importantly: this approach makes it possible to make distinctions and introduce light and shade into the sometimes rather brutally demarcated line between social and individual knowledge. From a certain perspective, all knowledge is culturally situated and all material hermeneutics are cultured. Particle detectors belong to very specific cultural activities found in very particular historical situations, which are cultured precisely because they are not commonly shared, though taken for granted by the people who have their being-in-the-world in detector physics. All these material artifacts are socially constructed, but people have internalized their social meaning differently according to proximity of distance from their actual production in a meaningful activity.

Situated Knowledge Revisited

Galison notes in *Image and Logic* (1997) that in "the old debate" between logical positivists (e.g., the Vienna Circle) and anti-positivists (e.g., Thomas Kuhn and Mary Hesse), observation is the use of senses to gain knowledge. Against this, we find the Platonic view that knowledge is already present in the mind or shaped through categories present in the mind. Both views share, according to Galison, an interest in perception and thus psychology—but for different reasons. Positivism sees perception in experiment as what holds up science. Anti-positivists, such as Kuhn and later Harry Collins, Barry Barnes, and Andrew Pickering, all opt for theory-ladenness (see also Rosenberger, forthcoming). This makes science seem to be caught between paradigms. Paradigm is thus the unit of analysis. However, is there really *a* physics culture and *a* physics paradigm?

Galison argues we should drop "block relativism" and rather acknowledge that there is not one but many cultures in physics, which are intercalated not coinciding (Galison 1997, pp. 12–14). Different scientific cultures are also different perceptual cultures and, as noted by Knorr-Cetina, different epistemic cultures (1991, 1999). These studies deal with science at a rather general level and do not probe into the psychological processes behind the scientists' perception of artifacts. Science and technology studies rarely look into the *scientists*' cultural perception. Culture or paradigms are the defined unit of analysis, but not what creates paradigms and cultural epistemology in relation to scientists. When we demarcate a "culture," we need a deeper almost existential understanding of the mechanisms behind everyday cultural perception in science (Traweek 1988; Watson-Verran and Turnbull 1995; Latour 1986, 1987; Latour and Woolgar 1986; Lynch 1982, 1985, 1988; Lynch and Woolgar 1988). A general theory of how we learn cultural perception of material artifacts might be helpful in this respect.

It is not enough to give an account of one's own partial perspective, as a particle physicist's differs from those of engineers or describe what made one interested in particle physics in the first place or even how one believes your gender plays a part in your partial perspective. Embodied knowledge is of another kind. In this case where we start with the embodied perspective, not "gender," "class," or "political stance," we can acknowledge that some perspectives are more partial than others. This acknowledgement of course does not tell us anything about the "truthfulness" of the claimed particles in the picture, but it does tell us something of the actual detector invisibly present in the picture.

Using a postphenomenological approach enables deeper understandings of what constitutes the partiality of situated knowledge. Postphenomenology preserves the very structure of science and technology as multistable whereas claims for objective hermeneutics depend on the physical situatedness of the body.

The objectivity of representations has long been under attack in STS as well as by some feminists (Harding 1993; Haraway 1991). They have argued that the more reflexive the knower can be about his or her own subjective knowledge the stronger the objectivity. Representationalist epistemology, as noted by Ihde, has the problem of needing some kind of guarantee of external reality, and this "external reality" is often seen as "nature." In a postphenomenological perspective objects become multistable and new questions can be asked in line with the problematization of representationalism. Visual hermeneutics are from this perspective not a subjective reading of an external representation, but a lived embodied experience forming perceptions of the material worlds. Situated knowledge is about the partial perspective of a knowing subject and how for example gender situates the subject and provides a partial perspective. In Ihde's postphenomenology "situated knowledge" is about the partial perspective of a knowing body—or in the words of Lock, an embodied mind. This perspectivally situated knowledge is tied not only to a partial perspective, but also to a body whose knowledge is and has been situated in space and time. This body of matter is also the body that matters (to paraphrase Lock 1997, p. 269). It is *res extensa* combined with *res cogitans* combined with *res faber socialis*.

In their material hermeneutics, the three physicists all have the knowledge they draw on tied to an embodied practical knowledge of particle detectors as barrel shaped. This space is invisible to non-professionals, who cannot see the picture as embedded in a barrel.

Even though my research project covers differences in perceptions in relation to national cultures, gendered perspectives, and age, what I find is that the single factor making changes in physicists' material hermeneutics is their past-lived bodies-in-action embodying a material world learned through activity, which situates their knowledge in particular ways.

The three physicists have different embodied experiences with how the barrel shaped detectors form pictures of events. Because of this embodied experience, Amelia rules out the bubble chamber. All of these physicists have visited the actual detector site and know what the actual physical space of detectors look like. Amelia and Elly are used to pictures, which give a frontal look into the barrel. No strings are visible, only the particle tracks. Georg has been used to move around in another detector space in his inner eye, because he has participated in UA1 where the barrel was cut up lengthwise in photographs. When they "read" the picture of the event, they use their embodied knowledge of how barrels look to move in invisible space around the event. However, it disturbs the situated knowledge of Amelia and Elly that the picture of the barrel is cut lengthwise.

Georg is not distracted by this disturbance and moves deeper into invisible space. He can see strings, but he also sees the invisible rear ends and walls that remain invisible to Amelia and Elly. Partial perspectives are not equally partial. Some are more partial than others are. In relation to the distance from the actual physical detector space, the non-professionals and even the physicist who is not a particle physicist have the least situated knowledge of the actual physical presence of the detector barrel. They are not even able to perceive the picture as a three dimensional barrel shaped space. Amelia and Elly both perceive it as some kind of space, but cannot immediately place their own bodies in the invisible space as it "turns the wrong way." Georg can walk into the space with ease and his knowledge is firmly embodied in the physical space of the detector. The fine-tuned postphenomenological analysis reveals that there are limits to social internalization and the particularity of situated knowledges. Some situated knowledges are closer to the actual activity of constructing artifacts than others.

Conclusion

Doing away with Cartesian epistemology and metaphysics makes it possible to understand materiality in new controversial ways as both mediated by the social culture, unruly and multistable, and yet embodied. When embodiment replaces subject in a postphenomenological approach there are no subjects detached from objects in science, but transformations of human bodies with transformations of mattering matter. Through an analysis of Danish and Italian scientists' material hermeneutic of pictures as relating to more or less recognisable artifacts from their situated perspective in relation to a particle experiment, ATLAS, I argue, stressing the postphenomenological approach to situated knowledge, that the scientists express multistability in perceptions, because learning in their situated practice creates slightly differently embodied perceptions. What I find is that the single most important factor making changes in physicists' material hermeneutics is their past-lived bodies-in-action embodying a material world learned through activity. It is their embodied experience of being in the world, which can explain their perception as cultural –in the sense that *qua* their body two learning they have learned to perceive the object in a similar way compared to non-professionals.

While Georg, Amelia, and Elly can all reflect, their embodied perspective only appears when they are contrasted with each other and the non-professionals. What in a phenomenological sense was considered external is in the postphenomenological approach not reducible to representation or subjective experience. Intersubjectivity is not reducible to having bodies. The postphenomenological approach to science and technology enables new understandings of relations between materialism, embodiment and learning in practice while creating unruly and multistable objects. Materiality changes with perception. Perception changes with embodied learning of artifacts. The very structure of technologies is multistable, with respect to uses and to cultural embeddedness in the activities producing artifacts. When learned experiences differ, so do material hermeneutics. In these processes boundaries expand and close as imaging equipment translates invisible things into visible. All knowledge possible for us implies our own situated embodiment of knowledge. The postphenomenological approach explores how bodies, including their limits and contingencies, are reflexively implied in this process.

What we call culture is an analytical distinction to be questioned in different ways. At the uppermost level, we find that physicists share a habitus preferring an overhead reading position, in common with many other Westerners.

From this postphenomenological perspective, we can speak of a collective situated cultural knowledge of how to read a text or a picture. These are structured multistabilities at the upper cultural echelon, where we find the collectively learned privileged "elevated" perspective within literate cultures, which differ from those of non-literate cultures (Ihde 1993, p. 79). At the next cultural echelon, we can say that the physicists in comparison to non-professionals share cultural body two macro-perceptions in the sense that they all can perceive the invisible space of a barrel and particles in the picture. This they have learned as a cultural embodied knowledge of experimental particle physicists who have seen the actual detector placed in the tunnel under CERN.[9] Nevertheless, their body one, as predicted by Ihde, does not conflate with their body two because their embodied experiences differ from each other as the individual physicist's embodied perception of a material artifact in relation to bodily operations. This does not create individual idiosyncratic perceptions, as all perceptions are simultaneously micro- and macro-perceptions.

Georg's embodied knowledge and thus his body one micro-perceptions are closer to the actual barrel invisibly wrapped around the picture. Does this mean culture stops at this echelon? No, because even though body one and two do not conflate, body one is moving in a cultural context. Bodily materiality also relates to another materiality—*technology*, as Ihde says. Whether the barrel is shaped round or square, it is a cultural artifact produced by men and women in cultural historical ever-changeable and changing activities. Therefore, body knowledges are simultaneously situated and cultured. There is no bare or isolated micro-perception except in its field of a hermeneutic or macro-perceptual surrounding; nor may macro-perception have any focus without its fulfillment in micro-perceptual (bodily-sensory) experience (Ihde 1993, p. 75).

This study presents a new complexity into the discussion of situated knowledges. The focus on embodied knowledge demands an external perspective to be called forward and reflected upon. Otherwise, our embodied knowledges remain self-evident. This external perspective can be obtained through a postphenomenological method of variation across bodies, nationalities, gender and experience (rather than actual age, though this might conflate).[10] Embodied situated knowledge in this case

[9] Some young experimental physicists might not have actually visited the crypt, but they have seen the photographs of the barrel, and the workers working in the shaft, which can also give them an embodied sense of shape and size.

[10] Though there is no space for an analysis of variation of gendered perspectives here, it can be noted that it is not accidental that Georg is both the most experienced learner, has the most situated perspective, and is a male. Female physicists are most often younger, less experienced, and thus have lesser chance of a more situated knowledge.

concerns representations of "nature," i.e. manmade objects like detectors, but *ceteris peribus* in light of this argument a visual hermeneutic of any "natural" object imbued with social meaning would be equally dependent on embodied learning. Even so the previous social construction is not conflating body one and body two. Some situated knowledges are closer to the actual activities producing cultural artifacts and thus become more physically embedded situated knowledges than others did. The realm of "a view from everywhere and thus nowhere," i.e. relativism, is broken along with the "god's-eye-view." In this sense, postphenomenology can be seen as a new methodology for scientists in research and development as well a perspective to be considered by researchers in science.

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