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Technological Materiality
Beyond the Dualist Paradigm

Susanne Küchler

WEARABLE COMPUTING, and smart fabric in more general terms, are already, and certainly will be for some time, the subject matter of jokes. This is partly because a pair of boxer short that dials the number of the emergency services, or a coat that changes colour depending on your blood pressure, is potentially hilarious or at the very least 'unsettling'.

Yet, as in all jokes, the laugh comes only when you 'see' a synthesis of opposites, as here between mind and matter, which draws attention to a potentially new way of perceiving the world. Smart fabric is, in this sense, *serious fun*. Serious, because what it demonstrates is an environment that is both material *and* informational, with the environment being internal to the material; and funny, because it touches a raw nerve in a society that believes its working relations to be a matter of its own choosing, not least because it is dominating matter through machinery.

Imagine a rope that emits a sound if there's a chance it will break (McQuaid, 2005: 20). Or an airplane skin riddled with fibre optic nerves, ready to detect structural flaws that might predict catastrophic failure. A little more familiar may be the prospect of wearable electronics developed for communication, entertainment, health and safety that are integrated into clothing and into textiles covering all areas in our built environment. Such innovations are the work of a multidisciplinary group of scientists who are engineering intelligence into materials whose composite and membrane-like quality is one of the most distinctive characteristics of design in the 21st century, where a concern over form has given way to one over informed materials. The goal of their research into smart or intelligent materials and structures is to animate the inanimate world by endowing it with more and more of the attributes of living things (Amato, 1992).

This new field of research that weds high-tech sensors and responsive elements with traditional structural and additive materials is blurring the

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seams between mechanism and material. Smart materials research has had its own journal since the early 1990s (the *Journal of Intelligent Material Systems and Structures*), and has included in its community not just chemists, physicists, biologists, material scientists, computer scientists, but also, among many other technical disciplines, textile specialists as well as practising artists. With such a huge array of disciplines involved, it is not surprising that any literature on the subject has so far been directed only to experts in the various fields; because the materiality of fibre and the structure of fabric is playing an increasing role in animating the material world, textiles experts have more recently begun to add to this highly technical literature with papers on 'polymer gel actuators' or 'the mechanical properties of fibre Bragg gratings' (Braddock Clarke and O'Mahony, 2005; Clemens et al., 2003; Dry, 1993; Edwards and Vigo, 2001; Hartmann et al., 2000; Holme, 2000; McQuaid, 2005; Meoli and May-Plumlee, 2002; Tao, 2001; Van Laerhoven and Cakmakci, 2000).

I hope to break out of this inward-looking discourse by presenting and analysing this material in ways that will make it accessible to social scientists; for what smart textiles show up is the need for theory in the social and historical sciences not to dwell too long on recovering 'things' that we have long rendered invisible, but to move on to ask questions about the kinds of materials that carry the socio-technical image within which we come, sometimes belatedly, to recognize ourselves (Brown, 2003; Latour, 1996a, 1996b). Smart textiles, in other words, raise the challenge set out so well by Bruno Latour: that is, to move beyond the axis of duality implicit in much of social theory, which supports the assumption that there is an absolute difference between the immaterial and the material constitution of culture and society, as the notion of materiality on which we have begun to rest an alternative theory of subject/object complementarities, one grounded on the pragmatics of mediation, is itself changing in front of us (Miller, 2005: 1–4; Thrift, 2005).

As an anthropologist I see the implications of technological materiality for social science theory and method as follows. First, central to much social science research up to now has been the idea that society can be studied by observing the *processes* whereby persons make mere objects their own – *processes* we have come to call 'consumption', involving the selection, manipulation and transformation of objects or of parts of objects. Any mere object thus appropriated has been seen as a ready source for social scientists intent on reconstructing how a society remakes itself over time. In fact, this model of consumption is deeply rooted in the 19th-century notion of objectification, which defined as a process of mediation the translation of a mere object into a 'sticky' object, which comes to stand in or substitutes for a person, solidifying thereby forms of attachment that can be described as the brick and mortar of social analysis. Current research into material innovation, however, has led to the ability to accommodate the individuation process at the production stage of the manufacturing process already. Nineteenth-century models that separate production and consumption therefore

have to be reviewed, with the consequence that theory and method in this area have to be reassessed. A direct consequence for social science is that it now has to locate social processes at the stage of *material innovation* in ways that will bring notions of social relations into dialogue with the creative transformation of materials.

Second, the shift of processes of individuation to the production phase has gone hand in hand with the shift from an object-centred society to a knowledge-based society. Anthropologists looking at objects from the point of view of how they are individuated, in processes that range from shopping to the interior decoration of our homes, have tended to place knowledge technology in a secondary position, making it dependent upon processes of consumption (Kidders, 1981). As the making and distributing of knowledge is now, however, happening prior to the consumption phase, or even undercutting this phase entirely, it is materials that are made into the carriers of knowledge, capable of impacting on us directly in an open-ended sensory manner. It is, in fact, *materials* that form networks of integrated artefacts, linking as membrane-like surfaces what we once thought of as discrete objects. Such a technological materiality, which operates outside of the depth ontology we usually associate with things, is not open to the clarity of a social science method that places knowledge technologies within a framework of consumption. What we need is a new method, one that recognizes not just the role of objects in the production and appropriation of knowledge technology, but that takes the next step to study empirically the future-directed, transformative potential of materials within which technology is embedded, as the stuff available to rethink the history of modernity.

Where the modernist project has asserted a fabricated world that had nothing of the characteristics of society and politics, yet which built the body politic all the more effectively because it seemed completely estranged from society, the technological materiality that can be studied empirically today challenges the dualist definition of humanity on which science has relied for long (Latour, 1994: 58; Uberoi, 2002). Beyond what Latour called the 'boring alternation of humans to non-humans, and back' pursued by studies of technology and society, there is now a 'real' space, not one of imagination alone, in which we can observe the swapping of properties of mind and of matter without having to start from a priori definitions of humanity (Latour, 1994: 54; Rouse, 2002). Yet I fear that more is at stake than the chance to construct a new non-dualist axis for social theory, which tries to do justice to the idea that objects do *do* something other than laundering the socialness of the forces that we project onto them (Gell, 1998; Latour, 1996a: 236). For smart materials show up a technological materiality beyond the concept of the object altogether, however fluid this conception may be. What this materiality does, or is thought capable of doing, and how couched within it is another history of modernity, is the principal subject I address in this article.

A Short Survey of Smart Materials

The future, as suggested by some, is shaped far more by practical inventions that subtly alter the infrastructure of life than by paradigm shifts in scientific knowledge (Hansen, 2000; Latour, 1992). A prime example is the steam engine, the invention of which gave rise to *material* and *ontological* transformations, and resulted in the first industrial revolution (Serres, 1982: 56). However, the steam engine's revolutionary impact went well beyond the shaping of new habits, ways of life and notions of synchronic time. In fact, what we may wish to describe as the modernity inextricably linked to the steam-driven machine, is defined by the increasing *autonomy* of the technological (Hansen, 2000: 59) – an autonomy it is now arguably losing as the technological is becoming overt and *tangibly* present in materials.

The material embeddings of technology have possibly never before been so defined by their location, nor have they been so overt and problematic and anxiety-ridden – from the side of the consumer *and* the producer – as at the beginning of the new technological revolution, following the industrial and the cybernetic one, into which we are undoubtedly moving today. This 'third industrial revolution', as it is sometimes now referred to, is not only defined by the ubiquitous role of software, but also by what has recently been called the materiality of '*screeness*' in which the technical rises to the surface and becomes the exterior (Thrift, 2005). Such a materiality of exteriorized interiority has been compared to an interactive and constantly unfolding and expanding second skin (an idea expressed by architects such as Neil Denari, whose buildings emulate continuous surfaces that wrap around the world like a ribbon with exchangeable inner and outer spaces). Screeness, in other words, takes the form of a kind of horizontal or spatial network of interlocking artifacts that not only become indistinguishable as they are enveloped by one and the same surface, but may also soon morph into each other – an idea of transmission that replaces prior *prototypical modes of transmission* that were bound to a notion of a vertical and temporal series of distinct categories of things by transformative capacities of materials whose constitution affects how they interrelate with other materials (Thévenot, 1994).

A number of theorists pursued this idea of an emerging spatial, inter-artifactual modality by pointing out the associated emergence of a 'post-social' regime of knowledge in which social relations and, most importantly, knowledge processes are taken over by objects – a notion that projects the idea of a sociality that once existed without objects but which now needs to be extended through 'sociological imagination and vocabulary' so as to encompass objects (Knorr Cetina, 1997: 2). Others, like Bruno Latour, have shown that what has taken the place of regimes of knowledge had in fact existed all the while in a kind of parallel universe of forward-looking experimentation, in university and other laboratories, each with its own specific culture and links to industry (Latour and Woolgar, 1979). Whichever argument we follow in our attempt to get closer to grasping the difference that 'screeness' will make to an ontology, it should be clear that

it forces us to reconcile material *capacities*, now turned inside out, which are *not* domesticated, and thus are *not* readily possessed by corporate institutions in the same way as earlier machine generated-prototypes were (Halbert, 2005; Latour, 2001; Tenner, 1996).

There are at present at least two competing strands of technical innovation that are noteworthy in emulating such material capacities. The first is driven by electro-engineering, which has seized on the availability of smaller, cheaper and more powerful electronic components, as well as of wireless communication, to develop soft-switching solutions that make computing not only ultra-portable and immediate, but also independent of any kind of container, as it is embedded in the form of carbon-coated fibres into generalized cloth surfaces that can take the form of clothing, wallpaper, furniture coverings, architectural structures and, of course, screens (Mitchell, 2005: 61–5). The second mode of innovation is driven by chemistry or materials science that creates new fibrous materials, so-called composites that are capable of responding to light and heat so as to conduct information rapidly across a range of surfaces that interact with each other without the need of external support (Barry, 2005).

While collaborations between engineering and chemistry are not out of the question, both in fact envision responsive materials as working in substantially different ways. Engineering conceives of architectures of networking membranes that create ever more expansive environments by literally colonizing new artefacts and attaching them to the network. Chemistry conceives of the environment residing within the material itself and perceives networking to be a process of transformation from the inside out via a process of envelopment. The tensions between these approaches are palpable, with chemistry presently having the upper hand, as currently engineering solutions to the problems of making materials connect with each other are widely considered to have fallen behind visions of what is desired within local contexts.

What we are faced with is thus an abundance of technological solutions that strive towards connecting, bringing together and solidifying immaterial streams of information in a material medium. That such engineered materials do more than reveal to us, through a kind of retro-projection, the social labour and its multiple animations in the lifeless body of the fetishized object, is apparent in the stories of Kautschuk – the generic term for a variety of elastic polymer as found in rubber and plastic – and of cellulose, which, independently of each other have shaped the mobility and material versatility characteristic of modern life in ways that we now take for granted (Antonelli, 1995; Haynes, 1953; Meikle, 1995).

But what *are* these materials produced by laboratory science today for the transport of the whole gamut of what we consider immaterial, from information to emotion (Deleuze and Guattari, 1988; Lash, 2002); and how do these material embeddings of a technology of knowledge begin to matter as much as, or even more, than the information they help to transmit? Revealingly, in a world so obsessed with possessing things visually, there are very

few good images of smart fabrics around. Those that do exist usually depict subjects in motion or are close-ups of certain features. This curtailing of distance indicates that what we are presented with is already individuated and that in order to 'see' it correctly, we have to wear it – like a displayed consumer item which has been touched and must be sold, smart fabric proceeds to undercut the surveillance of the market in presenting itself as 'in use' and 'in circulation'.

Admittedly, as promised second skins the practical inventions that were to have reshaped our lives are clearly still in the future – we know of them more through buzzwords such as 'wearable computing' than through actual products, although some have already hit the market. These include *intelligent running shoes*, with cushioning that automatically and continuously adjusts itself; *sunglasses which double as an MP3 player*; *an iPod-ready coat*, which allows you to adjust it with controls on the outside of the sleeves; a *chip-embedded watch*, which replaces the traditional ski-lift pass; *a line of underwear* that monitors heart rates, body temperature and insulin levels, and calls an ambulance if rates reach a dangerous level (Philips expects these products to be widely available in 2007); a '*thermogenerator*', designed by Germany's Infineon Technologies, which measures the difference between body temperature and the temperature of the garment and adjusts the perforation of the fabric; and a *'joy' dress*, dreamed up by an Italian designer, Alexandra Fede, which massages you as you wear it.

The body, as we can see, is being used as a surface on which to assemble inter-artefactual and systemic networks that work *on*, as well as *off* the body, in so far as the same fabrics can cover anything from walls to furniture and beyond. People in the industry are eloquent concerning the new significance of clothing as a second skin, which must be mobile, additive and adaptable. As Wolf Hartmann of the Institute for Innovation and Environment in Bochum has said: 'we have known that clothing had a language and have researched it for some time, but no one thought of realizing its technical potential' (Hartmann et al., 2000: 30; see also Barthes, 2006). The concepts driving such innovations that are at once material and technical include *wearable and affective computing*, which not only stores and transmits information but also picks up and impacts on emotions (mostly from engineering); *ambient intelligence*, which is embedded in the material environment in terms of an ever-present and attentive 'intelligent' interactive mode potentially capable of independent learning and increasing complexity (mostly driven by chemistry); or *augmented reality*, a form of broadened awareness through the permanent availability of virtual information (both).

The products designed at the beginning of the 21st century must clearly be likened to the first mainframe generation of computers, which filled entire rooms and which were slow and cumbersome by comparison with today's computing. And yet it is estimated that collaborations between opto-electronics, nanotechnology, micro-electronics and CTI-technology,

together with the textile industry, will very soon go beyond the present 'smart' stage of materials which act as sensors and actuators, to produce 'clever' materials capable of learning and adapting to different environments and material interactions. The next step in these collaborations will be to create 'intelligent' materials which can process information and deliver feedback in an interactive manner while networking any number of other materials; the final step will be to create materials with the highest form of 'intelligence'; that is, the ability of a material to take a decision based on moral considerations and feelings.

While different and competitive in their orientation, one can still generalize about the laboratories' striving to embed computation into everyday things in that they are all devoted to making things that are *inter-relational, forming huge complex systems of sensate things that (eventually) really learn*. Intentions originally outlined by MIT when its first lab, entitled 'Things that Think', opened in 1995, are shared today across a wide spectrum of labs. These are, to develop:

- sophisticated sensing devices and coordinated architectures that augment, animate and coordinate networks of things;
- seamless interfaces that bridge digital, physical and human needs for creative expression and design;
- an understanding of context and affect that can make things *think* at a much deeper level.

While different factions in the field of materials science and electronic engineering quibble about methodologies and the specific implications that different material solutions to the practical problems of an additive, mobile and material system of communication will bring, they generally agree on one thing. As it stands, they are fairly sure that a *technical sense* – left to the iterative, and thus repetitive, devices of machines and the bodily *habitus* of man ever since the first industrial revolution – will play as profound a role in the third industrial revolution as it did in the first two, yet it will be a role *played out* in a manner quite different from, though with consequences every bit as drastic as the transformation brought about by steam power that heralded the age of modernity. It is not just that communication is showing a material face in this new technology, which would arguably not be new at all, but merely point up something we should have taken note of all along (Gumpert and Pfeiffer, 1995; Latour, 1990). Instead, the technological materiality of smart fabrics radically changes how we conceive of communication; couched in the fibrous threads of reactive materials are potentials of transformation, heralding a new sensitivity as to how creativity is governed, and novel constraints of complementarity, replacing notions of connectivity and reshaping conventional network-based models. As they are made to work in a space beyond mediation, what is social in these high-tech membranes is a question that will occupy social science for some time to come (Gershenfeld, 1999; Ihde, 1974; Tenner, 1996).

Many of the ideas about what this new inhabiting of technology materiality is going to do come to the fore in an associated technological development known as *rapid prototyping* (RP). Coupled with *rapid manufacturing* (RM), rapid prototyping is beginning to follow the lead given by smart fabrics in creating things that are individuated from the start. In fact, RP and RM promise to transform the notion of work and attendant social relations, just as CAD (computer-aided design) drawing and micro-level design are making rapid inroads into the automated knowledge-based generation of design, producing seamless garments or fabrics from powdered compounds that can be manufactured both fully assembled and with variable weave anywhere in the world (Castle Island, 2007; Hopkinson et al., 2005). Interestingly, patented in rapid prototyping is not the software, but the powdered compound, and it is likewise at the level of the compound that safety issues are thought to be at stake.

The essential character of Rapid prototyping technology is an *additive* mode of *fabrication*, bonding materials layer by layer to form objects, quite in contrast to mechanical processes of fabrication such as milling or turning, in which objects are formed through repetitive action by removing material to create a shape which can then be further reduced into the stuff of cultural memory. We may imagine RP to be a new invention, though in fact it isn't – it was merely forgotten, solely present in the vanguard of art and laboratory practice. RP can actually be traced to at least two areas of 19th-century technology: topography and photosculpture.

Topographical relief maps were invented by Blanther in 1892; his layering method consisted of impressing topographical contour lines on a series of wax plates, cutting the wax along the contour lines, and then stacking and smoothing the wax sections. This produced a surface of positive and negative forms which when printed created a raised relief map (Beaman, 1997). *Photosculpture* also arose in the 19th century from attempts to create exact three-dimensional replicas of objects, including human forms (Gall, 1997). In 1860 François Willème achieved the best realization of this technique (which was further developed by others in 1904 and 1924), using an additive process of a photography in the round, cardboard mounting and photosensitive gelatine, which expands when mixed with water, to transpose the three-dimensional image into object form. In fact, additive fabrication technologies have been increasingly present in the 20th century: in stereolithography, which works by changing liquids into solids through the application of light; in the extrusion of thermoplastics, also known as fused deposition modelling; and in the stacking of web material in laminated object manufacturing.

So what is new about RP technology today if not the technique, which is basically a development of its 19th-century forebear? The answer lies in the fact that, beneath the seemingly innocuous and familiar phrasing (of making prototyping more 'rapid') lies a profound difference of effect: RP does *not* result in a prototype which can be serially reproduced in manufacture, *nor* does it produce a simulacrum by giving shape to an idea or a

thing which exists already. What happens in RP is that the material transformation, which defines the technique, becomes an intrinsic property of the materiality of the product. Each and every product of RP is *new*, made to measure and to material specifications that are unique, and, in so far as it is 'new', it is different and distinct from anything that came before or will come after. Today's development of RP, in other words, offers unlimited freedom of production and the possibility of unleashing a new era of mass customized design.

The central idea of RP thus creates visions of a decentralized production, with individuated things being created through desktop printing from a powdered compound anywhere in the world. This decentralized mode is reflected in the localized architectures created by smart fabrics that equally are without centre, as the clothing that we may use to activate another artefact, for example, the door of a car, is just one element in a circuit that may connect the most disparate items in a built environment. Chemistry is perhaps even more explicit about the nature of the new perception that may be called for as it creates a vision of the world in which the environment is no longer outside but inside the materials that envelop us in additive layers like an onion.

Irrespective of what it will do to our perception, the new technical sense has other surprises in store which designers anticipate as they work on creating new material solutions to responsive artifacts. As we begin to encounter materials with self-cleaning or conductive qualities, or even a material that interacts with other materials in such as way as to change its own make-up, an industry thriving on obsolescence, devoted to repairing technical function is turned upside down almost overnight. While chemistry envisions doing away with servicing materials altogether, those working on wearable computing using electro-technology point to the need to 'free' wearables from personal traits (in fact destroying connections) in order to enable them to be moved into, and repositioned in, new sensory architectures. The dismantling of an interconnected architecture of computing may become as significant, or even more so, than setting it up.

From an anthropological perspective, it is fascinating to see that the processes of individuation which take place at production, and which may give us clues about the social relations that may become a manifest part of such architectures, also extend to the phase beyond use, when architectures are disassembled. The material transformations that will go hand in hand with such processes of recycling may become key sites for social analysis, displacing anthropology's present concern with primary consumption. At the same time, technicians are aware of increasing pollution in a material environment that is suffused with intensely personal traits and immaterial spirit stuff alike; already, special coatings of fabrics have been created that screen out radiation and other pollutants by absorbing it into the material.

Such new services, which handle and control material complementarity, also signal a profound shift in the attitude toward complexity of function that has long stood for a certain state of cultural development. What Lyotard

(1991) has called 'complexification' in the technical realm, arguably has had its day, and a new goal of '*simplicity*' will inform material invention in the years to come, with surprising effects on the mind that is to inhabit this stronger, faster, lighter, safer and smarter second skin.

In fact, much innovation at present is simply concerned with getting the material interfacing of artefacts to work. As such, networking relies heavily on creating artificial systems capable of memory and of unlimited attention, the work of materials science and of electro-engineering has developed in a symbiotic relation with the science of cognitive technology. As the inter-artefactual networking transports our own mind beyond its bodily confines, how this networking is materially realized in aggregate systems will thus undoubtedly impact on the way we conceive of issues of power and control. At the same time, the ideas that groups of researchers bring to designing materials that interact with each other are beyond existing ideological framings of power relations, in that these ideas are never abstract, but are always concretely phrased in relation to the *potential* that is inherent in the materials that are used for building interdependent artefact systems.

If it were simply a matter of no longer having to press a button when switching on the light or turning on the television, the matter of smart fabric would be a straightforward one of a pragmatic solution to a practical problem of how to make life easier, of how to make information accessible without fail, and of how to provide a layer of protection through an ever-ready system of surveillance. Yet, the matter is unlikely to be as straightforward or as uninteresting as it appears to be and the reason for this is that the fabric carries in its folds not just byte-sized digital information, but a potential for re-perceiving the world in a new way.

I want to convey in the next section of this article that I believe that such potential visions are materially driven, in that fibre carries with it a certain kind of modelling of connectivity which obfuscates both the depth ontology we classically associate with things that think or display signs of animation, and the network ontology we have come to associate with the distributed mind in action. That is, I want to argue, we are faced not just with profound changes to the way we model mind/world interfaces, but also with an era of innovation in which the materiality of a thing drives technical invention, rather than the other way around. Of course, on close scrutiny, this latter factor may not be an altogether new phenomenon, but it may inspire a new careful look at the topic of technology, which, despite much noise, has been given short thrift by the social sciences (Eglash, 2005). In fact it may explain the peculiar phenomenon that it is artists who have been reaping the benefits of this development as the necessary partners in a team of technicians (Küchler, 2003).

Fibre Technology and its Challenge

Cutting-edge material technology, Lyotard wrote some 15 years ago, is 'a matter of "giving body" to that artificial thought' of which it is capable

(1991: 19). Writing about the *Inhuman* in the late 1980s, Lyotard foreshadowed a necessary analogous relation between the body and its artificial second skin, prepared, as he saw it, to take over those matters of the mind in its entirety. Not everyone, of course, will be prepared to follow Lyotard's implied conviction that the technical development of the material mind is to allow the mind to continue past the 'necessary entropy', of earthly existence. And yet his remark is useful, as it summarizes a growing realization of something that became a working model for the design of artificial intelligence in the 1980s, namely that mental states, in particular the capacity for self-organization, can be realizable in *different physical systems* – not only in organic ones, like the brain, but also in inorganic ones, like computer hardware. This well-known insight is called the *multiple realizability thesis*.

Yet, despite the realization that the self-organizing capacity can be achieved in material forms that have no basis in either brain or body, the most prevalent theoretical description of artificial programming environments is still today a predominantly biological one (Amato, 1992; Cordeschi, 2002). This description operates at a number of levels: as a means of framing programs, as a means of framing wider technological systems, and as a means of making assumptions about how the world is going to shape up. The persistence of the biological as the frame from which to investigate and develop artificial intelligence would warrant an article in its own right; here it should suffice to note that a separation is emerging between the development of robotics, which is largely informed by biological concepts, and the development of wearable computing and so called 'ambient intelligence', which are now driving technical advances in the distribution of communication in ways largely independent of biological concepts, while utilizing the body as a platform for reconceptualizing inter-artefactual and systemic networks.

It is fairly well known that we have two general and distinct approaches to the design of the artificial mind, both of which are grounded in the science of biology: the first is Artificial Intelligence or AI, the top-down approach that explores the biological plausibility of the simulation of mind. Following the principles of biology, AI starts 'at the top', considering the organism as a complex biochemical machine which it intends to simulate in its function (material and look being significant only in structural and functional terms). Artificial Life or ALife, on the other hand, starts instead 'at the bottom', considering the organism as a large population of simple machines, and it works synthetically from there, constructing aggregates of simple objects that interact mutually and non-linearly in support of global, life-like dynamics. Proponents of both approaches regard their machines as tests for their theories, which are concerned to explain the emergence of life, biological evolution and development, as well as the functioning of neural networks in complex, integrated settings (Cordeschi, 2002: 230).

There are thus several biological descriptions that inform the designing of artificial life, yet one is particularly relevant to this context. It is the so called bottom-up approach of Artificial Life which has been credited

recently by researchers with assisting us in fundamentally reconceiving cognition as the operation, not of disembodied logical operations but of a massively distributed nervous system whose emergence can be simulated and observed in machines (Clark, 2001). While sympathetic to and working in accordance with this particular idea, smart fabric development has identified a problem with this and other existing biological approaches to artificial intelligence. It points out that the biological description conceives machine-like action to be the same as *retrospectively* studied actions that have an essentially repetitive character (Collins, 1990: 42–3). Cognition 'in the wild', however, which is outside of the laboratory and is in the nexus of biographical social relations, is characteristically *unpredictable*, transformative and *future-directed*.

Smart fabric development has thus decided to concentrate on creating material networks of artefacts that are not primarily intended to simulate the workings of the mind. Instead, the artificial mind in fabric is made to work faster, safer and longer than the embodied mind, as it is memory function and attentiveness that are woven into its folds and that are distributed across surfaces external to the embodied mind. In contrast to robotic artificial intelligence, the mind in fibre is mobile in a complex and open-ended sense, working additively between aggregates of smart materials, rather than endogenously within a machine. Revealingly, laboratories claim that their smart materials are 'better than' robotic products of artificial intelligence, as they serve as *Intelligence Amplification* or IA (Hartmann et al., 2000: 181).

There are at present two main metaphors, with a third one just being formulated, that reveal a notion of how this intelligence amplification is going to work, using specific structural properties of the material as their cue.

We have seen already that wearable computing uses electro or optical engineering solutions of conductive paints and fibres to extend the mind beyond its natural boundary. *Weave* metaphors capture here the embedding of switches, LEDs (light-emitting diodes) and conductive yarn into fabric surfaces that are capable of interlocking with other surfaces of the same kind. In the same manner as the surface of interwoven fibres requires a pattern, so the underlying structure of conductive fibre and LEDs has a decisive pattern of a geometric kind that will be replicated across all the surfaces that are to be connected in this manner. The manner of connecting, in fact, uses the planar properties of fibre and its capacity for geometric deformation.

In comparison to the weave metaphor of wearable computing, materials science deploys the metaphor of a *membrane* as it creates interactive fabrics of composite materials. Such membranes are layered and work without external support, but through the specific interactions between the layers of fibres, which open and close, contract or expand, depending on 'the environment' that is simultaneously inside and outside the membrane.

It is in fact chemistry and material science, and thus the notion of an active membrane that have been driving the development of smart fabric for some time, much longer that the weave metaphors of wearable computing, which have been flourishing only during the 1990s. Materials science research into smart fabrics first gained independent and autonomous support when it was adopted by the military and weapons industry, notably by NASA in the 1950s. It was NASA that supported the development of protective textiles in small, cutting-edge companies, such as the adventure-gear makers that have been supplying clothing for astronauts and elite soldiers for quite some time now (McQuaid, 2005: 25). Some of these textiles are now very familiar to us – Gore-Tex, Mylar and Kevlar – as they have been integrated into those apparels and accessories abundant in sport-fashion today.

An additive material layering that is attentive and 'ready' to act at any time is an idea most closely associated with the spacesuit, designed to protect the body from both anticipated and unknown hazards. Yet giving NASA credit for having funded technical advances in artificial intelligence does not explain *why* fibre began to be developed as a communicative system alongside robotic machinery – eventually to surpass it in its range of application. In fact, one could argue that smart textile technology really took its cue from a medium whose 'screeness', if not 'string-like' character, resembles that of textile – namely film (Geulen, 1992: 596). Like film – which, as Walter Benjamin (1969) has famously stated, makes the technical materially graspable – textile could perhaps most easily be invested with a capacity to make the technical tangible in close-up, invoking a loss of distance with an immediacy of response which is always material and technical at once. The aura, however, whose loss Benjamin had ascribed to the effects of mechanical reproduction in his famous essay on art, appears now to fasten itself onto materials that have become cognitively 'sticky' in ways we have not yet credited (Benjamin, 1969: 217–51; Gell, 1998).

An offshoot of material science that demonstrates this cognitive stickiness is the recent development of so called '*transfer technology*', which embeds functioning capacity into fibrous materials, not chemically or electronically, but via the structural properties of string- or thread-based membranes. It is this, not yet mentioned, third way in the design of smart fabrics that is currently attracting the greatest attention. An example is the development of *super fabric*, which was designed for cut and puncture resistance in medicine and adapted to industrial, military, recreational and household applications.

Super fabric uses the age old technique of braiding thread as the most basic, but also structurally speaking the most efficient, technique in the manufacture of three-dimensional materials that distribute heavy loads and stresses evenly across a surface; this has been invaluable in the production of industrial ropes, as well as of machine parts that only betray their fibrous structure through their lightness. The seamlessness of braided form has also been used for inflatable architecture and objects such as airbags or

hydraulic actuators (known as Festo's fluid muscle) that operate on a membrane contraction system without the use of mechanical parts, thus making movements particularly smooth (McQuaid, 2005). Ideal for precision robotics, their light weight also gives such actuators potential as prostheses.

Knitting, rather than braiding the same fibres creates the opposite characteristic in the form of a stretchable fabric used predominantly in medicine (heart support), where knotted and woven surgical devices have been implanted for decades. Most recently, these techniques have begun to be superseded by embroidery, which has the advantage of being a surface technique that allows the placement of threads in any direction. By thereby making way for the imitation of natural fibrous arrays such as ligaments, as well as for a better transference of loads across a structure, a fabric is created that can be integrated with other features such as open mesh areas so as to promote tissue growth. Embroidery, most importantly, can also enhance fibrous strength in certain desired areas, while still allowing for stretch in others.

The nature of the thread that forms the material structure of the fibrous membrane are interestingly now coming into conflict with technology, as the required metallic fibres break the needles of traditional sewing machines not made for such tasks. While knitted fabric is only now being discovered as potential for smart fabric development, it is heralded as a *woven membrane* – a third way – that might be able to link electro-engineering solutions with those developed by chemistry and thus could open up a new perspective on how technological materiality could work. As different weaves of one or more fibres interrelate to make a connection between two points, super fabric shows that it is the complementarity of types of thread and weaves that create an effective membrane capable of distributing its effect to surrounding areas.

We see here a development that would have surprised Lyotard, in that the material is no longer just the carrier of a mind that is external to it, but has mindfulness built into its own inner architectural structure. Designing such a structure, as exemplified already by architecture, requires a spatial perception, the nature of which is perhaps the most interesting aspect of this material as it reveals a notion of innovation that proceeds from the potential inherent in the material, viewing it from the inside-out, and from a perspective of a logical interrelation between diverse parts of larger wholes (Spuybroek, 2004; Widdington and Harris, 2002).

There are clearly big questions arising from how smart fibres may influence the way we conceive of matters of mind and body (Thrift, 2005: 246–8). How will people think about body and mind as they are increasingly able to track the condition of, intervene in, and enhance or amplify not just its appearance, but also its working condition? If you can leave the iterative tasks, including those habits that support memory, to a material substrate, what new channels of creativity would be opened up? How will people think of the material world and relate to it creatively and

productively when it is suffused by thoughts, feelings, hopes and anxieties?

Yet perhaps a question that may turn out to be even more important, although it may be less on our mind is, 'Why fibre?', and how will fibre affect the way we conceive of information when it is drawn together with what is, after all, nothing but a piece of string? What, in fact, is really new in this use of fibre? Or is it simply that we have not noticed what fibre can do, as it was shut away from public life in the closets and living rooms of an industrial era (Jones and Stallybrass, 2000). Such attitudes to fibre and to clothing in general, as Webb Keane has reminded us, have been most succinctly summarized by the American Transcendentalist Henry David Thoreau who in 1854 wrote: 'I say, beware the enterprises that require new clothes, and not rather a new wearer of clothes' (Keane, 2005: 183).

Clothes, once so clearly feared, as fashion was thought to distract from the proper concern with the immaterial, are also, and always have been, the most effective way of inverting the proper relations between animate and inanimate things. The trick for social science should be today not to follow down the line of chasing fashion, but to take note of the fact long realized by science, that what clothes are able to do is by way of the material of which they are made.

Thinking Materiality

One hundred years ago, the art historian Alois Riegl published his now classic piece, 'The Modern Cult of Monuments: Its Character and its Origin' (1982 [1903]), originally written in German as a document on the restoration of public architecture. His observation of a decisive change in society's attitude toward things, which was shifting from a concern with age to a concern with the new, signalled a profound change in the relation between technology and materiality, whose fallout still impacts us today. For the 'new' came to be in the form of materials, technologically engineered, which foretold, in their synthesis of making and knowing, the dawn of an economy of knowledge which we see unfolding right now.

At this new juncture, a century later, we may wonder whether Riegl's thoughts are still fitting, capturing as he did attitudes toward materiality that were socially ubiquitous and yet for long oddly invisible. The 'new' – long born out of idealizations of social life either in the present or retroactively in the past – is arguably now no longer just a matter of a mere appearance that can be mapped in a temporal fashion. Things, once bought, were used and disposed of in quantities that mirrored a surplus value generated by an object-centred economy; such things, whose newness once indicated replaceable functionality as much as the material and technological limitations of production, had become precious tokens of a knowledge-based exchange whose traces, in turn, reanimated the material – and today such exchanges are in fact thriving on an immaterial base of digital codes and molecular fusions. Nothing new, in fact, is to be found in the things of the cybernetics age, as one could argue that its objects merely facilitate a further

de-materialization and disembodiment of information transmission, making the immaterial appear more dominant than ever before as agent of transmission. No wonder our notion of materiality is still largely confined to the fetish character of things that turn the immaterial inside out (Böhme, 2006).

We have barely begun to theorize materiality beyond the fetish, yet we have to get up and adjust our thinking again to a new scientific and technological revolution. But, as it is usual to be attracted to a phenomenon just as it is about to end, it may be no coincidence that this present age may become known as a time where materiality presided over disciplines as much as the body a decade before (Martin, 1992). For what is 'new' now appears not in the guise of what it 'is' on the basis of its form and associated interpretation, but as what it 'does' or can do of its own accord, without any additional technical support, revealing a *vehicular notion of materiality*, one that displays signs of what we call animation or agency without a hidden, interior, invisible essence, terms that now appear to be in as much need of revision as our notion of materiality. We must beware assuming from this that we are moving from a mechanical materialism to a kind of material vitalism, for what is really at stake is a new kind of surface ontology which replaces the opposition of inside and outside, invisible and visible, immaterial and material with a complementary relation that thrives on transformation rather than distinction. Cloth surfaces, as discussed in this article, are not merely a new cover for electronics but in fact *are* the new electronic equipment – equipment that is lightweight, durable, flexible and cost-competitive as well as additive, both in the built environment and on the body. What we need to develop are new methods and models adept to this surface ontology via a 'robust account' of technological materiality, moving on from the techno-scientific practices of innovation which have already been theorized by philosophers such as Karen Barad (2003) and the sociological anthropology of Bruno Latour (1996b). Technology's essentially *material* history, which has remained in the shadows of critical thought, might then enable us to write another history of modernity.

This new kind of materiality shatters our assumption that an explosion of information processing will remain merely an optical phenomenon. For what we have here is a materiality that reacts with what we once thought to be the immaterial stuff of the spirit – our thoughts, feelings, hopes, fears, beliefs and intellect – and which thus works as a form of mind-ware that displaces, with this fusion of mind and material, the opposition of object and subject, and its attendant models of analysis. Where, a century ago, the new relation between persons and things called for a new theory of mind that helped to explain and to amplify this relation with a host of practical interventions such as marketing or educational psychology, changes in the way we relate to the material world will undoubtedly now impact again on the way we think about matters of the mind.

While experiments in robotics are ongoing within research departments devoted to the study of artificial intelligence, cutting-edge materials science and electro-technology that interface with industry are making a radical

break from mechanical models of the cybernetics age in which the immaterial functioning of the mechanism was important over and above the material in which it was clothed. They are doing this by creating interactive, inherently transformative material surfaces that *enhance* rather than simulate the working mind through material, rather than immaterial, effects and that aim to offer new ways of drawing information together in a faster, more effective and reliable manner. Neither cognitive science nor media studies can tell us how this new materiality will impact our lives, nor can they suggest how this materiality will resonate with emerging forms of sociality, or point to the policies that may have to be effected so as to enhance rather than hinder the creative potential inherent in such material innovations. In fact, the new material face of knowledge technology is a classic domain of social science, yet it must open itself up theoretically if it is to capture the nature of materiality in ways that have been sidestepped to this point.

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