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From Cyborgs to Cyberbodies: The Evolution of the Concept of Techno-Body in Modern Medicine

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ABSTRACT

This paper focuses on the ways in which the introduction of technologies in modern medicine is changing collective notions of the body. In particular, it describes two popular and imaginative conceptualizations of the body that have been inspired by progresses made by medical technologies during last century: the *cyborg*, and the *cyberbody*.

Although these two models stem from the same post-modern philosophical "post-body", "post-biological," or "post-human" visions, they are characterized by a fundamental distinction. While the *cyborg*, at least in its original conception, is linked to the “wild wired world”, the world of cells, neurons, blood and biological processes, the *cyberbody* can be defined as a wireless, inorganic entity, made of pure bits of information. However, both definitions assume that people no longer has a *direct* "sense of body", but a mediated sense of body. Further steps in this direction may be determined by the emerging technological paradigm of Ambient Intelligence. In this vision, people will be surrounded by intelligent and intuitive interfaces embedded in everyday objects around us and an environment recognizing and responding to the presence of individuals in an invisible way by year 2010. Although the Ambient Intelligence scenario is still in an early phase of development, it is somehow predictable that technological innovations that this paradigm will bring into medicine are likely to foster the production of a new collective notion of the body based on the “digital me”: a virtual reality representation of the patient as a virtual person, integrating all the diagnostic and clinical information of the patient into a single record continuous across time. In addition to explore this perspective from a theoretical viewpoint, implications for medical practice are discussed.

Keywords: *medicine, human body, sense of body, cyberbody, VEPSY UPDATED*

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1. Introduction

In the last century, biology and medicine were transformed through a new collection of biophysics instruments, such as electron microscopes, mass spectrometers and new agents such as radioactive isotopes. Advances in computing, semiconductors and microelectronics enabled the development of new fields of biomedical imaging such as ultrasound, computerized tomography (CT and PET scanners), nuclear magnetic resonance imaging (MRI), and endoscopic surgery. These massive changes in biomedicine, together with developments in immunology and pharmacology, enabled radical new ways of intervening in the body, including transplantation of kidneys, hearts, lungs and livers.

These dramatic new ways of remaking and altering the body through genome mapping, genetic engineering, aesthetic surgery and mechanical, electronic and biological prosthetics, have contributed to reshape the notion of the body in the cultural imaginary and to foster a transformation of the collective representation of the embodiment experience. As a consequence, the question of technology and the body has become relevant theoretical topic for anthropological, psychological and sociological studies.

According to theorists such as Arthur and Marilouise Kroker, the notion of the body is already obsolete (Kroker, 1997). Consistent with this assertion is the widespread belief that we are on the verge of the "post-body," "post-biological," or "post-human". This view is also shared by the and science historian J. David Bolter, who refers to the late-20th-century human as "Turing's Man" (Bolter, 1984).

Post humanists argue for a model of identity that is dramatically altered within technological cultures. In this perspective, western industrialised societies are experiencing a new phase of humanity "wherein no essential differences between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals, exist [...]. Embodiment is seen as an accident of history and consciousness is an evolutionary newcomer"(Hayles, 1999b).

In the following paragraphs, we describe two popular and imaginative conceptualizations of the techno-body that have been inspired by progresses of medical technologies during 20^{th} century: the *cyborg*, and the *cyberbody*. We argue that although these two models stem from the same post-modern philosophical "post-body", "post-biological," or "post-human" visions, they are characterized by a fundamental distinction. While the *cyborg*, at least in its original conception, is linked to the “wild wired world”, the world of cells, neurons, blood and biological processes, the *cyberbody* is a wireless, inorganic entity, which is made of pure bits of information. However, both definitions assume that people no longer will have a direct sense of body, but a mediated sense of body. Further steps in this direction may be determined by the emerging technological paradigm of Ambient Intelligence. According to this vision, people will be surrounded by intelligent and intuitive interfaces embedded in everyday objects around us and an environment recognizing and responding to the presence of individuals in an invisible way by year 2010 (ISTAG, Feb 2001). Although Ambient Intelligence scenarios and applications are still in an early phase of development, it is likely that technological innovations introduced by this paradigm into medical practice will foster a new collective conceptualization of the body. To characterize this notion, we propose the definition of *transparent body*.

2. From the Cyborg to the Cyberbody

Manfred E. Clynes, a designer of physiological instrumentation and electronic data-processing systems, and Nathan S. Kline coined in 1960 the term *cyborg*, short for cybernetic organism. In their paper, presented at the Psycho-physiological Aspects of Space Flight Symposium in San Antonio, Texas, they presented the idea to develop a machine system, which would continually monitor and regulate physical-chemical functions and other external conditions while the human participant concentrates on space exploration and doing other vital experiments. In their study, a 220-gram rat was implanted with a Rose-Osmotic pump to permit continuous injection of chemicals at a slow and controlled rate so as to modify and regulate homeostatic states (Clynes, 1995).

The concept of cyborgs is linked with the concept of cybernetics. Cybernetics is a field that recognizes random events where a simple change in a complex system would have far reaching implications leading to an unpredictable and radical change in the entire system. It was Norbert Weiner who in 1948 introduced this concept and coined the word cybernetics. He derived the word from the Greek word *kubernetes*, which means “steersman”. Since the sea is always in motion, steersman needs to adjust the wheel all the time. This causes changes in the ship's course, which in turn changes the motion of the water, which again impacts the ship and causes steersman to respond (Weiner, 1948).

According to Hailes (Hayles, 1999a), central to the construction of the cyborg are informational pathways connecting the organic body to its prosthetic extensions. In this sense, the beginning of the evolution of cyborg can be situated between 1950s and 1960s, as artificial hip joints and artificial heart were developed (Blanchard, 1995). Such a progress in bionics engineering, along with the discovery of electrical signals in nerve impulses, made it possible to use motor controlled body parts that served as prosthetics and initiated the era of implants. Since then, researchers throughout the world have looked for ways to improve these bionic devices to foster quality of life of disabled individuals. Their efforts have produced pacemakers, cochlear implants, implantable pumps, and neuroimplants so precise that they can even detect the firing of a single nerve. This is allowed by using a small piece of silicon to be attached to a neuron as a transmitter. Current research is using this technology to develop retinal and cortical stimulation where light is converted to electrical signals, which are directly connected to nerve cells and sent to the brain. For example, the USA Department of Energy national labs, partnering with the University of Southern California and North Carolina State University, are developing a micro-electronic device that will be implanted in the eye on the surface of the retina. A small video camera in the eyeglasses of the blind person captures visual signals, which are further processed through a microcomputer worn on a belt. The signals are transmitted to the electrode array in the eye. The array stimulates optical nerves, which then carry a signal to the brain. The prototype implants contain 16 electrodes, allowing patients to detect the presence or absence of light. The artificial retina project's "next generation" device would have 1,000 electrodes and hopes to allow the user to see images (http://www.icat.ncsu.edu/projects/retina/).

Further step in bionics would be the creation of artificial muscles and nerves, making it possible for progressive technological integration into the body, eventually replacing or augmenting the structures that mediate the various physical and mental attributes that we normally consider "natural" to human beings, including emotion, natural sensory modes, rational thought and properties of imagination. However, the progressive integration between human and machine, although motivated by the need to foster quality of life of impaired people, generates anxiety. As noted by Katherine Hayles, “fusing cybernetic device and biological organism, the cyborg violates the human/machine distinction; replacing cognition with neural feedback, it challenges the human-animal difference; explaining the behavior of thermostats and people through theories of feedback, hierarchical structure, and control, it erases the animate/inanimate distinction”. Other exponents of the post-human debate share this view. Donna Haraway, in “A Manifesto for Cyborgs,” writes about the potential of the cyborg to disrupt traditional categories: “The cyborg is a creature in a post-gender world; it has no truck with bisexuality, pre-oedipal symbiosis, unalienated labor, or other seductions to organic wholeness through a final appropriation of all the powers of the parts into a higher unity. In a sense, the cyborg has no origin story in the Western sense - a 'final' irony since the cyborg is also the awful apocalyptic telos of the 'West's' escalating dominations of abstract individuation, an ultimate self untied at last from all dependency, a man in space” (Haraway, 1985). The collective anxiety generated by the cyborg is also reflected by the work of several artists. Indeed, from the monster in Mary Shelley's 1831 novel Frankenstein, to nowadays, artists continue to be impressed and fascinated by this “bionic blasphemy”. Perhaps one of the most known contemporary interpret of this fear is Stelarc, an Australian visual artist whose work explores and extends the concept of the body and its relationship with technology through human-machine interfaces incorporating medical imaging, prosthetics, robotics, virtual reality systems and the Internet (http://www.stelarc.va.com.au/).

The emergence of the cyborg as process of progressive technological integration into the body coexists with the collective notion of progressive *virtualization* of the patient’s body. The virtualization of the body is the endpoint of the effort to realize the *cyberbody*, a digitalization of all body tissues and structures of interest, regardless of dimensional size and/or separation, that is sufficiently accurate and faithful so as to render the virtual representations indistinguishable from the real objects. This goal is accomplished by exploiting the capabilities of current 3-D and 4-D medical imaging modalities (Magnetic Resonance Imaging, Computed Tomography, Positron Emission Tomography etc.) along with computer reconstruction and rendering of volume image data. The use of these imaging technologies obviates the need for physical dissection or abstract assembly of anatomy, and provides powerful new opportunities for medical diagnosis. One significant example of the virtualization of the body in medicine is the National Library of Medicine's (NLM) *Visible Human Project* (www.nlm.nih.gov/research/visible/visible_human.html). Authors of this project have successfully recorded real human bodies in three-dimensional, living color, capturing these bodies in digital images through the technology of MRI (Magnetic Resonance Imaging) and CT (Computed Tomography) scans, as well as cadaverous dissection and high-resolution digital color photography.

As more and more of the medical technologies become information based, it will possible to represent a patient with higher fidelity to a point that the image may become a surrogate for the patient – the *medical avatar*: a virtual reality representation of the patient as a virtual person (Satava & Jones, 2002). The power of the “medical avatar” scenario (also called “the digital me”) is that it integrates all the diagnostic and clinical information of the patient into a single record continuous across time. It can be updated as needed, and made available to the patient on a personal credit card sized record, like the military's Personal Information Card (PIC), or perhaps contained on a secure webserver on the Internet and available for global consultation through telemedicine.

Apart from biomedical visualization, the use of virtual bodies in medicine was stimulated by the need of medical staff for medical education and surgery training. Virtual reality for surgery involves applications of interactive immersive computer technologies to help perform, plan and simulate surgical procedures. In particular, virtual simulation of the body is used to give the surgeon 3D interactive views of areas within the patient. Planning is carried out preoperatively, to find the best approach to surgery, involving minimum damage (Silverstein et al., 2002; Simpson, 2002; Wilhelm, Ogan, Roehrborn, Cadeddu, & Pearle, 2002). These applications of virtual bodies have naturally extended to include telemedicine and collaboration, involving sharing information across individual medical staff and across geographical locations.

Another medical field where the process of virtualization of the body is taking place is psychological therapy. Virtual reality is proving surprisingly powerful as a therapeutic tool for both mental and physical disabilities. In most of the existing applications, virtual reality is used to simulate the real world, including the patient's body, and to assure the researcher full control of all the parameters implied. Virtual reality constitutes a highly flexible tool that makes it possible to program a variety of procedures of intervention on psychological dysfunctions. In this sense, virtual reality provides a new human-computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer-generated three-dimensional virtual world. The key characteristics of virtual environments for clinical professionals are both the high level of control of the interaction with the tool without the constraints usually found in computer systems, and the enriched experience provided to the patient (MT, 2001).

The initial accomplishments will be at the macro level for the whole body, organ and tissue systems; then further levels of glandular structure, molecular, biochemical and genetic information can be added.

3. Emerging conceptions of the body: the transparent body

In the previous paragraph we have described how the introduction of medical technologies such as prosthetic extensions and virtual reality has contributed to further two popular conceptualizations of the body, the *cyborg* and the *cyberbody*. How will further medical innovations reinvent or affect these notions? Although answering this question is not easy, it is at least predictable that in the next decade the emerging technological scenario of Ambient Intelligence (AmI) will most likely be the most active field in fostering new conceptions of the body. Ambient intelligence is a way of making interfaces between humans and computers disappear. This paradigm builds on three recent key technologies: Ubiquitous Computing, Ubiquitous Communication and Intelligent User Interfaces.

Ubiquitous Computing means integration of microprocessors into everyday objects like furniture, clothes, vehicles, roads and smart materials even particles of decorative substances like paint. Ubiquitous Communication enables these objects to communicate with each other and the user by means of ad-hoc and wireless networking. An Intelligent User Interface enables the inhabitants of the AmI environment to control and interact with the environment in a natural (voice, gestures) and personalised way (preferences, context). Medical applications of this new paradigm may be represented, for example, by the BAN (Body Area Network), PAN (Personal Area Network), smart clothes and other body integrated devices that will be able to detect patients' vital signs and retransmit them to sorting nodes, in real time. Body Area Network means wireless communication between various components attached to the body, such as data spectacles, earphones, microphones and sensors. Through its wireless connections between the individual components Body Area Network will allow a variety of different medical applications, such as transmission of the body parameters (blood pressure, pulse rate, body temperature) and transmission of parameters of body implants.

A Personal Area Network (PAN) is a technology that could enable wearable computer devices to communicate with other nearby computers and exchange digital information using the electrical conductivity of the human body as a data network. Smart clothes, or intelligent textiles, can be described as textile materials that incorporate electronic devices such biosensors and multi-function processors (see figure 1). While still in an embryonic stage, biomedical clothing and textiles have the potential to change the provision of health care services for patients suffering chronic diseases (such as cardiovascular, diabetes, respiratory and neurological disorders) and the elderly with specific needs.

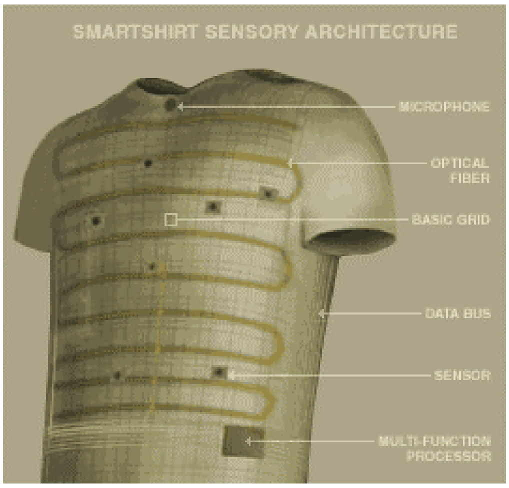

Figure 1. A prototype of smart shirt for medical applications

Currently, these Ambient Intelligence devices are under development to provide the right balance between the need of non-invasiveness, real time vital sign monitoring and telediagnosis. Such embedded devices will be part of the human body as implanted prosthesis, but instead of being "passive" extensions of the body, these intelligent biomedical instruments will be used as an active interface that makes physiological signals transparent to the outside world. As a result, the patient's body may be reduced to a mere collection of anatomical and physiological data that will be accessed directly or remotely by the physician.

In this perspective, the definition of *transparent body* seems appropriate to label this progressive "digital disembodiment" of the patient. How these innovations will affect medical practice in the next years is somehow predictable. In fact, the concept of 'transparent body' will make the physician facing a new paradigm. Nowadays, the physician is supposed to take decisions on which clinical tests to prescribe to his patients, according to his clinical experience but also taking into account economical considerations. Therefore, since time and financial resources are limited, the physician needs some fixed standards to make a preliminary choice among the wide range of available tests.

This criterion is still based on the Hippocratic vision of medicine inherited from ancient ages, which teaches to interview the patient before anything else. In the Ambient Intelligence future scenario, the whole set of tests may be integrated in the patient's body or at least in his clothes, and may be visible from the outside by embodied imaging (with video-clothes) as well as by showing the end-user vital parameters in a digital or graphical form. Accordingly, physicians' decision process may no longer focus on the most suitable clinical test, but rather on the interpretation on clinical outcomes.

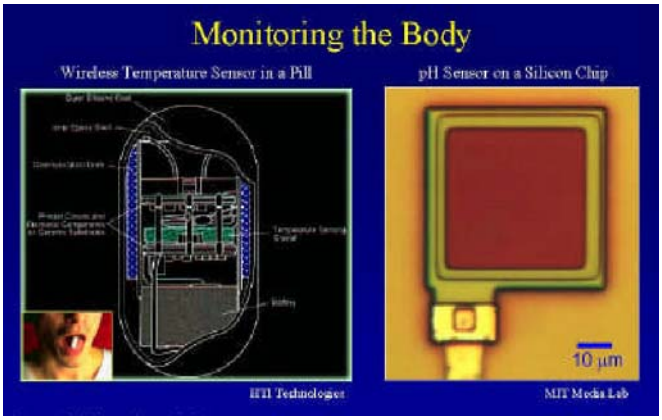

Figure 2. New generation of wearable sensors enable real-time wireless readout of internal bodily signals such as temperature or pH.

4. Conclusion

With the incoming new technologies in the biomedical field, particularly those dedicated to prosthesis and bioimaging, Hippocrate and Galeno's conceptualization of human body as 'sacred inviolable temple' is progressively abandoned and replaced by new coexisting posthuman notions of the body, as the cyborg and the cyberbody. Within twenty years, applications of Ambient Intelligence devices in health care will probably further a new notion of the body, the "transparent body". According to this vision, first-level diagnostic and therapeutic procedures may be mainly performed at home or during activities of everyday life, with the remote support of clinicians (i.e. teleassistance).

The next step will probably be a 3-D computer generated representation of a specific person (a "digital me") or medical avatar that will act as a surrogate for optimizing (and possibly predicting) individual patient care (Satava & Jones, 2002). The more devices which are developed that can acquire information about a person the richer the medical avatar and the more accurate the results from modeling and simulation, pre-operative planning or intra-operative assistance. Not only is this relevant to patient care for medical conditions, but also to be used at all levels, including school age.

A possible use of this "digital me" is described by Satava & Jones (Satava & Jones, 2002): "Imagine the power of each child having a medical avatar which "grows up" with them, which they carry on a credit card device and use in class. By inserting their avatar into the virtual environment, they can learn health and nutrition by observing the consequences to their avatar. For example, by implementing the "smoking" module, the child's avatar could grow a cancer, get bronchitis and emphysema and decrease the ability of the avatar - as a prediction of what would happen with long term smoking." (p. 234).

Theoretically, if a "generic" or standardized medical avatar could be created, the early phases of clinical trials (on drugs or devices) or virtual "crash dummies" could replace some of the extremely expensive and high-risk testing-and-evaluation occurring today. As a consequence, hospitals and health care facilities may progressively become highly specialized structures for medical research, or emergency-oriented facilities. Then, traditional, face-to-face clinical examinations would take place in these facilities only if the patients' conditions are critical or unstable; in the other cases, the physician would be expected to deal only with "transparent bodies" or their 3D representations. In fact, through digital processing, data dispersed over many different sites may be combined into virtual patient records, specifically tailored to the health care professional's needs, and affording unprecedented potential for the coordination and accumulation of health care data (Dick, 1997). Clearly, this scenario is not safe from risks. If on one hand the application of the Ambient Intelligence vision may lead to a dramatic lowering of costs (reduction of time to diagnosis and time to treatment, outpatient diagnosis and treatment, etc.), on the other hand the risk of de-humanization and de-personalization of the patient should be carefully considered. This dehumanization may consist in a progressive identification of the patient with the collection of his vital parameters. In other words, the risk is that the patient will be progressively disembodied, reduced to the sum of his biological and physiological functions. There is, of course, the obvious physical separateness of patient from the patient's medical data, but this is of small importance when one considers the overwhelming significance of the unity of the patient and the recorded information that describes exclusively the health care of that patient. A second risk may arise from the possibility for the patient to monitor directly data detected and stored by wearable biometric devices. This capability may contribute to increase awareness of patient's body, but it may also increase the likelihood of self-diagnosis, with potential serious implications for patient's health.

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