I Ping the Body Cybernetic:

Wearable Computing and Medical Diagnostics

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> I Sing the Body Electric;
> The bodies of men and women engirth me, and I engirth them;
> They will not let me off nor I them till I go with them and
> respond to them and love them.
> Walt Whitman (1819–1892). *Leaves of Grass*.[1]

Introduction

In the past decade the miniaturization of digital hardware and the proliferation of wireless communications have led to portable computing products that are networked. This trend**,** combined with the practice of storing patient medical records in computerized databases**,** has led to research projects that utilize wearable computing for continuous medical diagnostics, such as devices for diabetics that monitor blood glucose levels over the Internet. Developers of these technologies claim that they enable patients to gain autonomy within the health care system and empower them to take greater responsibility for the decisions that govern their health. However, when humans are inserted into a cybernetic feedback loop that reduces their health determinants to medical data they may find that their virtual bodies displace their social bodies and that they are further alienated from, rather than integrated into, decision-making within the health care system.

The Technological Environment

To uncover discrepancies between what medical professionals claim new information technologies will do for patients and what their actual impact will be, we need to develop a technological perspective that enables us to compare the workings of these individual technologies to the workings of health care as a system within our broader technological environment. To begin such an analysis we must consider what we mean by key concepts like “technology” and the “technological environment.” For the purposes of this investigation, technology is what we use to create, shape and maintain our technological environment, including what we find useful in nature, while nature is what we did not create. In practice, when we are aware of something useful we turn to it to solve a problem. Thus, a particular technology is a solution to a particular problem. Yet our technologies are not limited to the materials that we discover and the tools that we implement. Our procedures and techniques, as well as other ways we influence our environment, are all technologies. When we look for patterns in our approaches to problem solving, we see that the ways our technologies relate to one another form what I call the *ecology* of our *technological environment*. From an evolutionary perspective, our technological environment represents a cultural extreme within the problem-solving continuum of the natural environment. Yet our ability to apprehend the social and functional niches found in nature has enabled us to create our own social, functional and virtual niches apart from nature. As a result, we have the ability to influence the different niches that characterize our technological environment at any one time. It follows that shifts in the technological composition of our human habitat occur when we start to see our problems in a different light.

In health care problem-solving, when a patient presents a doctor with a problem there are actually two problems, which also could be considered two steps towards finding a solution. The first problem is the patient's need for treatment. The second is the doctor's need to provide a diagnosis, which in turn leads to a solution to the first problem. When the doctor perceives the problem of diagnosis as practical, he or she will examine the patient for symptoms and work with the patient by poking and asking questions, which may include asking the patient what is wrong. In this case, a practical diagnosis will contribute to the social niche within the technological environment such that the doctor-patient relationship takes on a holistic character. When a doctor perceives the problem of diagnosis as technical, he or she will request tests that will provide diagnostic data. Although the patient must undergo these tests, he or she does not contribute to the diagnosis. It is the doctor's task to provide a diagnosis based on the symptoms as represented by the data generated by the tests. In this case, a technical diagnosis will contribute to the functional niche within the technological environment such that the doctor-patient relationship takes on a prescriptive character.[2] In either case, once the doctor has made a diagnosis, that is, once the doctor has determined what the patient's problem is, the next step is to consider the solution to the patient's problem. If the doctor perceives the nature of the patient's problem to be practical, a thing like a crutch or a procedure like a change in posture is the chosen means, creating a solution with a social end. The social end in turn contributes to a social niche within the technological environment where the doctor and patient work together, and the patient works with his or her own body. As a result, the health of the patient is diagnosed in the same manner as a broken thing that can be repaired by the patient with the help of the doctor. If the doctor perceives the nature of a patient's problem to be technical, a device like a cast or a technique like amputation is the chosen means, creating a solution with a functional end. The functional end in turn contributes to a functional niche within the technological environment where the patient is told what the doctor can do for him or her. As a result, the health of the patient is diagnosed in the same manner as a malfunctioning device that can be fixed. If the doctor is unable to diagnose the nature of the patient's problem by the social means of working with the patient or the functional means of testing the patient, the nature of the problem of diagnosis itself may be perceived to be artificial, whereby the doctor requests an image like an x-ray. In this case, an artificial diagnosis will contribute to the virtual niche within the technological environment such that the doctor-patient relationship takes on a synthetic character. While the doctor and patient may appear to work together, they may never actually meet in person, as is the case when the doctor views the x-ray and decides that the bone is broken and must be re-set by a surgeon.

Technological Bodies

From a technological perspective, different kinds of medical problems require different kinds of solutions that in turn create different kinds of bodies within the ecology of the technological environment. It follows that technological bodies may be spiritual, cultural, social, functional or virtual, depending upon how the medical problems are perceived. To begin with, let us consider the cultural body.

The Cultural Body

From a cultural perspective, beings are used to solve natural problems, which in turn create bodies that are beings. When Walt Whitman composed and revised his poem "I Sing the Body Electric" throughout the later half of the 19th century, the body was "electric" because it was alive, that is, full of life. It was not charged by batteries; it was charged by the "soul." People didn't have bodies. They were bodies. Whitman even goes as far as identifying the "soul" with the body. Moreover, no "body" was isolated. His poem celebrates how the bodies of family members and friends are all intertwined in webs of relationships. Whether they are physically together or apart, they form cultural bodies that are full of life, for they give each other life. These bodies are not "electric" because they have nervous systems that utilize electricity. Nor are they a network of individual bodies "connected" by communications technologies. The cultural body is a being that discovers meaning by simply being in a web of relationships. It follows that health is being affective and that illness is an injury that needs healing. Health care is a web of ideals in which "care" is a way of being compassionate.

The Social Body

From a social perspective, things are used to solve practical problems, which in turn create bodies that are things. Potters use wheels, clothiers use needles, carpenters use axes and blacksmiths use hammers. Handing down crafts and trades from one generation to the next requires that masters and novices work together in one place. Social bodies are formed in the midst of the kind of teaching and learning associated with apprenticeship. However, we may find it difficult to appreciate that the making and using of tools entails technical aspects but at the same time is not completely divorced from cultural elements. While novices must have started their learning by appropriating the ways of their masters, the cultural dimension can also be seen in the tools themselves. Until the 20th century, tools were made such that their form dictated their use.[3] In other words, tools spoke of the social role of their users, which was grounded in culture. Carpenters would identify with the form of their own hammers and a blacksmith wouldn't think of picking up a carpenter's hammer. It is difficult for us today to appreciate that the form of a tool isn't simply a matter of function. Likewise, the social body is a thing with a purpose that is negotiated with other social bodies from within the system in which it works. It follows that health is effective performance and that illness is a breakdown that needs to be repaired. Health care is a system of goals in which "care" is just as much about natural ideals as it is about technical cure.

The Functional Body

From a functional perspective, devices are used to solve technical problems, which in turn create bodies that are devices. Printers use ink, computers use calculators and navigators use maps. The operator repeats the same task using the same technique over and over again. As other operators repeat their specialized tasks on the assembly line, functional bodies are formed that operate like machines. Just as a machine is made of parts that function together, the functional body is made of organs that operate together.

The heart is a pump. The brain is a computer. In order to maintain this machine, diets are followed and drugs are prescribed. The functional body is a device with a function that is defined by a network of operations and a collection of data. It follows that health is efficient operation and that illness is a malfunction that needs to be fixed. Health care is a network of objectives in which "care" is about cure and the productive implementation of technical resources.

The Virtual Body

From a functional perspective, images are used to solve artificial problems, which in turn create bodies that are images. The mirror, photograph, x-ray, ultrasound, CAT scan and MRI, as well as models and simulations, present us with images of our bodies that form virtual bodies. Instead of experiencing the well-being of the cultural body, the performance of the social body or taking the pulse of the functional body, patients examine their virtual bodies on film, televisions and computer screens. The virtual body is an image with a status that is defined by a collage of statistics. It follows that health is having a desirable self-image and illness is the exposure of a reality that needs to be spun. Health care is a collage of desires in which "care" appears to be natural or practical but is actually artificial.

In problem-solving in general, problems perceived as natural lead to solutions that nurture a cultural niche. Likewise, problems that are perceived as practical lead to solutions that contribute to a social niche and problems that are perceived as technical lead to solutions that produce a functional niche. These three niches form the core of our broader technological environment. Prior to the cultural, supernatural problems prompt solutions that create a spiritual niche, while beyond the functional realm artificial problems lead to solutions that synthesize a virtual niche. In other words, each kind of problem requires its own kind of solution such that each kind of means achieves a different technological end. The end of a solution is spiritual, cultural, social, functional or virtual, depending on whether the chosen means corresponds to perceiving the nature of the problem as supernatural, natural, practical, technical or artificial.

From this broad technological perspective, we able to consider what kinds of technological problems are solved by wearable computing and what kinds of technological bodies are created when these information technologies are used in medical diagnostics. Moreover, given the fragmentation of our technological environment into these various niches, we may also consider what we can do about the disintegration of our body into these different kinds of technological bodies.[4]

Wearable Computing

In *The Rise of the Network Society*, Manuel Castells makes a distinction between the terms "information" and "informational." While all societies, including the medieval as well as modern societies of the past, make use of information in maintaining their structures, postmodern informational societies are structured by the production and availability of information. Castells explains further by distinguishing between the medieval and early modern societies, which had industry, and the late modern societies, which were structured by industry and became industrial. Castells proposes that, with the increasing use of information technologies that are networked, an informational society is one that becomes itself structured as a network.[5]

From a technological perspective, we conclude that, while people in medieval societies existed within webs based on relationships and those in modern societies worked in systems based on roles, those in postmodern societies operate in networks based on jobs and tasks. In order to function within a network society, individuals must utilize and have access to information. As health care systems shift from being industrial to being informational, the management of information has become the domain of the new field of health informatics, which is primarily concerned with developing the software required to utilize the latest hardware developments in information technologies.

Wireless Devices

In the 1990s the development of small, low-powered integrated circuits and liquid crystal displays combined with the development of small, high-storage capacity batteries led to the development of the portable digital assistant (PDA), a hand-held computer used primarily to replace paper-based date and address books but with more computing power than the earlier electronic organizers. During the same period, bulky analog cell phones were being replaced by smaller and smaller digital models that included features previously associated with electronic organizers. Meanwhile, advances in PDA data entry and operating systems enabled these portable computers to run software applications, such as word processors and spreadsheets, previously restricted to desktop and laptop computers. These developments were combined in the development of wireless PDAs that can be used for checking e-mail stored on an Internet server. One of the popular wireless e-mail devices is the BlackBerry, developed by Research in Motion (RIM) in Waterloo, Ontario.[6]

Thus, in the past decade the miniaturization of digital hardware and the proliferation of wireless communications have led to portable computing products that are networked. These technical developments are representative of broader technological changes occurring in Canada. For example, in the corporate world, many employees use these devices to communicate with their co-workers and managers expect to be able to contact them whether they are just out of the office or travelling on business. In health care, in addition to these kinds of applications, PDAs are employed by doctors and nurses in a variety of ways, including scheduling medications and collecting patient medical data that are stored on a server. The increased use of devices represents a shift from a more social environment to a more functional one. Yet, as these devices are networked, there is potential for them to be used to reclaim social niches. For example, wireless devices can be used to arrange for face-to-face meetings in a particular place at a particular time. However, they can also be used to substitute for meetings in an actual place. In this case, they create virtual environments in which technical and artificial problem solving simulate practical problem-solving previously associated with the social environment.

Wearable Data Collection

Wearable computing represents the next step in making portable computers ubiquitous in our technological environment. A PDA can be considered a wearable computer insofar as it can be carried in a holster. However, wireless computers are currently being development that can be strapped onto the body or worn as jewellery or as clothing. Renn Scott, the User Experience Architect at RIM, explored some of the possibilities for wearable computing in an award winner exhibition presented at the Ontario Science Centre. One of the prototypes was “the flow - bioGi,” a jacket based on the concept of achieving the “flow state” in athletics. It provides sound feedback while measuring and recording the quality of movement during sports training. The objective is to develop “alternate methods of capturing body data in order to improve sports performance.” Another prototype was the "+/- pulse bracelets," health self-monitoring devices based on the concept of pulse diagnosis, one of four diagnostic methods (looking, listening, questioning, and feeling the pulse) used by doctors in traditional Chinese medicine. The objective is to explore “how health can be achieved, and disease prevented, by maintaining the body in a balanced state.”[7] Scott says, “These prototypes for the most part look at how to develop a contextual relationship with the computer through what I call ‘attentive wearables’ - wearable computers that measure body data to approximate mood and/or one’s specifically indicated emotions to better understand the user, location and context of use.”[8] Wearable computing devices such as these must not only solve the technical problem of monitoring the performance and health of the body via data collection; they must also address the artificial problem of presenting an appealing look. Hence, consumer products for athletes are leading the way in technical developments and market trends. One such functional and fashionable device is the Polar HRM, a wrist watch that monitors heart rate via a wireless sensor placed on the chest.[9]

Medical Diagnostics

It was previously stated that problem-solving in health care usually involves two problems that can be considered two steps towards finding a solution. The first is the patient’s need for treatment and the second is the doctor’s need to provide a diagnosis. However, given the development of expert systems and diagnostic devices, the problem of diagnosis is no longer the doctor’s exclusive domain.

Expert Systems

In the 1960s expert systems were sophisticated software programs that used logical decision-making algorithms to calculate solutions to problems within a narrowly defined domain of expertise. By the 1970s it was clear that these deterministic techniques were insufficient to aid, let alone replace, human decision-making in areas such as medical diagnostics. Hence, work began on representing the knowledge of experts and storing it as information that could be processed to make probabilistic decisions in place of judgments made by human experts. On the one hand, structures were required to represent knowledge as information, and, on the other, methods were required to collect this knowledge from actual experts.

Extensive patient medical records are required to both develop and use expert systems for medical diagnostics. During development, patient records are used to correlate outcomes with the decisions made by medical doctors. During implementation, doctors who consult expert systems are asked a series of questions about the patient's condition and are presented with treatment options based on the knowledge represented by the system.

Diagnostic Devices

In the 1980s, once the software for expert systems was developed to the point where it could supplement human decision-making within specific problem domains, hardware devices were needed to run these applications. In some cases, medical doctors could query a personal computer to get advice on how to treat a patient. In other cases, real-time expert systems were needed that could monitor a patient's condition and generate a report for the doctor. As computers became portable, diagnostic devices could be strapped onto patients and worn while they went about their day. Early diagnostic devices such as wearable EKG units did little more than collect vital sign data that were later uploaded to a personal computer for processing when returned by the patient. However, developing devices that could both monitor a patient and provide a diagnosis without the need of a doctor's expertise soon became the objective.

The "Guardian Angel" Concept

In the 1990s, the trend towards wireless computing devices, combined with the practice of storing patient medical records in computerized databases**,** led to research projects that utilized wearable computing for continuous medical diagnostics. One of the first was MIT's Guardian Angel project.[10] In the introduction to their research proposal document entitled "Guardian Angel: Patient-Centered Health Information Systems," Peter Szolovits, head of a multi-disciplinary group that included computer scientists and medical doctors, stated that "we plan to build systems to support the health information needs of the consumers of health care rather than its providers."[11] Their vision was to develop expert systems known as "software agents" that would utilize wearable computing for continuous medical diagnostics, such as devices for diabetics that would monitor blood glucose levels over the Internet. In general terms, they hoped to improve the quality and reduce the cost of health care. More specifically, the opening of their proposal reads like a manifesto for revolutionary changes in health care as a system:

> Current health information systems are built for the convenience of health care providers and consequently yield fragmented patient records in which medically relevant lifelong information is sometimes incomplete, incorrect, or inaccessible. We are constructing information systems centered on the individual patient instead of the provider, in which a set of "guardian angel" (GA) software agents integrates all health-related concerns, including medically-relevant legal and financial information, about an individual (its "subject"). This personal system will help track, manage, and interpret the subject's health history, and offer advice to both patient and provider. Minimally, the system will maintain comprehensive, cumulative, correct, and coherent medical records, accessible in a timely manner as the subject moves through life, work assignments, and health care providers.[12]

These changes would appear to have the potential to shift health care from a technological environment in which patients are products of an impersonal yet efficient industrial system to one in which patients are given individualized and personal care. Thus, for patients the researchers claim that

> there are dramatic improvements to be gained in both the effectiveness and the efficiency of health care if we can empower the user to take a much more active role in monitoring his or her own health status and care, and to take greater responsibility for making informed and guided decisions concerning that care.[13]

However, the advantages are not only for the patients. They also claim:

> Principal benefits for doctors and other health-care providers include access to accurate, comprehensive data, the opportunity to be alerted to changes in the patient's health that are either dangerous in themselves or deviate from an expected course of therapy, and the ability to communicate reliably with the patient.[14]

Moreover, the benefits for patients are not intended simply for those who suffer from chronic conditions. There is no doubt that the researchers hope that we will all one day have our very own Guardian Angel. In their words, “in the long run we envision GA as a routine health assistant for everyone, whether they are ill or well.”[15]

In the research proposal document the project team developed a schematic for the Guardian Angel architecture that puts the patient at the centre of a diagram. The schematic also includes computer-based patient records integrated with a communications network that connects the patient’s PDA and other instruments such as a glucometer and cardiac sensors with computers at their home, doctor’s office, hospital and insurer’s office.[16] They also discuss prototype applications for insulin-dependent juvenile diabetes and management of chronic hypertension.[17]

Although this ambitious research proposal has led to the development of only a few modest projects at MIT, the “Guardian Angel” concept is representative of a widespread shift to “patient-centred care” within health care systems in North America that is being driven by new technologies. Like the “Guardian Angel” visionaries, current developers of these kinds of technologies also claim that they enable patients to gain autonomy within the health care system and empower them to take greater responsibility for the decisions that govern their health. Following are two examples of such projects currently under development in Canada.

Mobile Decision Support

In 2002, Catherine Burns, professor in Systems Design Engineering, University of Waterloo, supervised a student’s design project entitled “Mobile Information Displays for Diabetes Management.” At this time she began to consider applying human factors engineering to mobile decision support for diabetics. Later she took on a diabetes management project sponsored by Bell University Labs Programs and the Ontario Ministry of Health and Long Term Care. She became interested in the project because it was similar in complexity and data intensity to her previous work in the design of nuclear power plant control room interfaces, and she was motivated by the realization that diabetics needed well-designed interfaces to help them in their difficult task of understanding and managing their condition in a proactive manner.[18]

In 2004, Burns published preliminary interface design results for the project, which employs commercially available hand-held wireless devices (BlackBerry, Palm Pilot and Nokia cell phone) that model and control blood glucose levels using a glucometer and an insulin pump. The two main objectives of this diabetes management system are: (1) to maintain blood glucose homeostasis within normal ranges, and (2) to maintain proper body weight. The system's problem domain includes the diabetic patient, food and insulin. The system's model consists of various sub-models that include energy input, storage and output as well as the main glucose processes in the body, which includes the major organs along with the circulatory system, muscles and tissue as well as transport components such as blood plasma insulin. The causal model maintains 150 data elements, including 23 variables, the values of some of which, like blood glucose, can be measured directly, and some of which, like calories from food or calories used during exercise, can be estimated. Other variables, like plasma insulin, must be simulated because they cannot be measured directly. While most of the diabetes management system's variables are inputted or calculated on the hand-held device, the simulated values are calculated by probabilistic algorithms running on a server accessed via the Internet. Finally, informative graphic displays are crucial to presenting the model in a manner that is readily understandable to the user; especially important is the design of charts and graphs that indicate changes in key variables over time.[19]

By aiming for what she calls *ecological interface design*, Burns is trying to provide diabetics with a diabetes management "tool" that reduces their mental workload and relieves them of the burden of making calculations. The displays are designed to present complex data in a visual format that allows the user to interact with the device in a "natural" manner, like a soccer player who intuitively knows how to react to and kick the ball. She compares these interface design considerations to what's needed to manage a power plant, where operators need to know at a glance that the equipment is operating normally. They also need to be able to readily distinguish between expected and unexpected abnormal operation. At this stage in its development, the mobile device utilizes server-side databases for calculating the calories contained in different kinds of foods and for calculating how many calories are burned off by different kinds of exercises. Hence, the user only has to enter the amount and kind of food or the amount and kind of exercise into the device and the model calculates what changes in diet or exercise regime are needed to maintain normal blood glucose levels. Thus, the user is not burdened with having to understand the 150 data elements in the model's database in order to make decisions about insulin dosage, diet and exercise. However, the device does not currently provide access to an expert system to predict expected abnormal conditions or direct the user under unexpected abnormal conditions. Instead, it relies upon the advice of a doctor who has direct access to the model's data elements and can be contacted by the user via the wireless device in an emergency. However, the doctor doesn't have to wait to be contacted by the patient. If concerned, the doctor can also check the data from his or her office computer in order to monitor how the patient is doing and can alert the patient via the device if he or she anticipates an abnormal condition.[20]

Patient Portal

In 2004, Grand River Hospital in Kitchener, Ontario launched what is believed to be North America's first comprehensive patient portal. The web-based service called *My Care Source* provides patients with access to their treatment plans and enables them to manage their appointments, monitor and self-chart their side-effects and symptoms as well as re-order prescriptions over the Internet. Designed to be accessed via a home computer or laptop, patients who experience unusual symptoms can contact hospital personnel for immediate feedback and assistance. Glen Kearns, vice-president and CIO of the hospital, claims, "The portal gives patients an active role in managing their care, and makes them a part of their care team. They're not just have things done to them, they're taking steps for themselves."[21]

Dennis Egan, Grand River Hospital CEO, came up with the idea for the project about a year-and-a-half before its launch while attending a seminar on how to increase health care productivity by integrating the Internet with existing hospital databases. Egan expects that the portal will relieve pressure on medial specialists who are continually asked by patients to provide them with information, test results and prescription renewals. He also expects that it will provide patients with a more reliable source of information than what is generally found when doing a search of the World Wide Web and will improve communications with their physicians. The result should be more extensive diagnostic data for doctors, better outcomes for patients and fewer admissions to the hospital due to treatment complications.[22] The productivity seminar was provided by Cell Exchange Inc., a software and technology developer from Cambridge, Massachusetts founded by John Donovan, a former MIT professor.[23] Although John Donovan wasn't involved with MIT's Guardian Angel project,[24] the *My Care Source* promotional material makes similar claims concerning patient empowerment: "available for you and your family 24 hours a day, 7 days a week," "personalize your care," "work with your health care team," "provide feedback," "patient-focused," and "allows you to take control of your health care."[25]

The hospital's information technology team developed the portal over a six-month period working with McKesson Information Solutions, an Atlanta-based company that had already developed a physician portal to access patient records over the Internet. The project began trials by offering the service to cancer patients. There are also plans to extend it to renal dialysis, diabetic and surgical patients.

The Cybernetic Body

As we have already considered, from a technological perspective, different kinds of technologies solve different kinds of problems that in turn create different kinds of technological bodies. In light of the vision of MIT's Guardian Angel concept, we should expect that technologies like the Waterloo wireless diabetes management device will eventually be combined with technologies like the Grand River Hospital patient portal.

Given trends in wearable computing, we should expect that these wireless medical devices will be developed into items that are worn on the body. As a result, continuous medical diagnostics will be combined with life-long medical records in the use of wearable technologies that we put on everyday in the form of clothing and jewellery. Eventually technologies like these will be combined with an expert system that acts as an early warning device and replaces the need for a doctor to monitor the patient continuously. In fact, the "patient" may be a perfectly healthy person who is concerned about the possibility of becoming ill or gaining weight. One such device currently in use is the Polar WM, a wrist watch that calculates caloric intake and schedules the required amount of exercise to manage body weight.[26] Therefore, we may ask, what kind of technological body will the convergence of these technologies create? Moreover, given our fragmentation into different kinds of technological bodies, how might we integrate them into a single, whole technological body rather than create yet another kind of technological body?

I say "we" because much of what was envisioned by the Guardian Angel concept architects is currently being implemented for people with chronic conditions and if their vision continues to be implemented, we will all one day be wearing medical diagnostic devices and participating in the health care system in a new way. What they reported in the 1990s not only anticipated current technical developments like Waterloo's diabetes management device and the Grand River Hospital's patient portal, in the following excerpt they also envisioned how these technologies are current being used and how they are currently converging:

> [I]n the short term it will be easier to apply the architecture as adapted for high-intensity medical interventions, for specific populations of patients who are undergoing active and complex therapy. In such circumstances, some of the monitoring of that therapy can be offloaded to the patient, with the help of GA, making the patient, the "human in the loop." For example, patients with chronic conditions such as diabetes can help to monitor and adjust their own care, and the ambulatory patient undergoing acute care such as chemotherapy may be able to judge certain aspects of his or her own care and tune them, with the aid of GA, for best results. GA could also help make possible the scheduling of visits to the care provider based on the patient's actual response to care rather than on a general schedule. Most users of GA could benefit greatly from the development and deployment of small, non-invasive sensors that can autonomously and continually monitor characteristics of the patient that are of vital concern.[27]

In light of their vision of putting patients into a feedback loop within the health care system, I would like to suggest that the convergence of these technologies will create a cybernetic body.

Norbert Wiener first described *cybernetics* as the "entire field of control and communication theory, whether in the machine or in the animal."[28] However, given the interdisciplinary nature of this field, others later broadened this functional and behaviouristic notion of regulation to include the more social considerations of organization and self-regulation. Yet whether cybernetics is narrowly defined in terms of causality and probability, or more broadly defined in terms of agency, the concept of feedback is essential to all cybernetic systems. Hence, the Guardian Angel proposal to put the "human in the loop" of health care is in essence a cybernetic vision of the body. However, the extent to which cybernetics will enable us to put our technological bodies back together depends upon how broadly our feedback loop extends within the health care system.

First-Order Cybernetic Body

The narrow definition of causality and probability denotes first-order cybernetics. Here a control device that monitors the system's variables for deviations and employs feedback conditions the system and achieves regulation. This is precisely how a diabetes management device achieves blood glucose homeostasis. The human in the loop provides feedback by inputting information concerning variables for food, exercise and weight as well as current blood glucose, and the device in turn outputs how much insulin is required to maintain a normal blood glucose level. Either the human manually sets the pump to inject the required amount of insulin or the device communicates this information directly to the pump. In fact, some insulin pumps have diabetes management devices built into them. In addition to this causal model, the University of Waterloo project utilizes a simulation to increase the probability that the amount of insulin administered will have the optimum effect. Other projects, such as the one currently under development by InterMed Advisors, an American company that has partnered with the Joslin Diabetes Center in Boston, utilize wireless devices to automatically collect data on blood glucose, blood pressure and weight for the control device, which automatically administers the required amount of insulin. It also employs sensors that detect motion, skin temperature and galvanic response in order to gauge physical activity. In addition, an expert system monitors the data and provides advice on diet and exercise via animated clinicians called "virtual doctor" and "virtual nurse." If these "relational agents," as they are known in the field of affective computing, are not able to change the human's behaviour by conditioning, the control device will alert actual clinicians. Once the expert system has gathered three months of data, its simulation of the patient's virtual body can predict life-threatening events weeks in advance and advise corrective measures in order to avoid a crisis.[29]

Regardless of the extent to which the patient is required to input data or administer insulin, these diabetes management devices employ causality and some degree of probability to generate feedback and maintain blood glucose homeostasis. Hence, these technologies create a first-order cybernetic body that is functional and to some degree virtual. As a result, humans who use these diabetes management devices are caught in a feedback loop that controls their functional body by means of a virtual body. Since their virtual body resides in a database, they can check their progress by accessing the computer running the diabetes management software. Likewise, patients who use a portal like the one developed by Grand River Hospital to access their medical records can, as it was described in one article, "keep better tabs on their condition."[30]

Moreover, doctors who want to check on a patient's condition can log onto their computer network and examine the records and simulations that make up the patient's virtual body. In effect, doctors can ping the body cybernetic. "Ping" is a command that is used to troubleshoot a computer on a network. Different operating systems provide different versions of ping, but the basic function is to send a short burst of data to the host computer you are concerned about and wait to see if it responds normally. If the data returned is corrupted, severely delayed or doesn't return at all, then there is definitely a problem with either the network or the host computer. Stelarc, an Australian performance artist, called one of his works *Ping Body*. Participants on the Internet pinged Stelarc's computer, which in turn used the ping data to map spatial distance and transmission time to body motion. Ping values, which are measured in milliseconds and represent the distance and density of Internet activity, activated a multiple-muscle stimulator that applied 0-60 volts to various parts of Stelarc's physical body and caused his limbs to move involuntarily. A graphical interface of virtual limb motions was used to simulate and initiate the physical body's movements.[31]

At his Web site, Stelarc states,

> During the Ping Body performances, what is being considered is a body moving not to the promptings of another body in another place, but rather to Internet activity itself - the body's proprioception and musculature stimulated not by its internal nervous system but by the external ebb and flow of data.[32]

Whether you are wearing a diagnostic device to manage a chronic illness or to monitor your body's condition and alert you before a health crisis arises, your doctor will be able to ping your body cybernetic over the Internet rather than examine you in person. Despite the claims that management devices and patient portals "empower" those "in the loop," mobility and activity should not be confused with human agency. Claudette DeLenardo, Director of Grand River Hospital's patient portal, was more nuanced than the My Care Source brochure when she wrote an article describing the program's merits. She claims that patients "become their own 'project manager;' they are given a tool that assists them in making informed choices about their care while also promoting communication, and giving them a sense of autonomy and control." She also explains that "a number of methods will be used to evaluate outcome measures related to patient satisfaction, patient perception of control over illness, utilization, staff satisfaction and return on investment."[33] Moreover, while the portal provides patients with online access to medical information like lab results, their doctor must first authorize the posting of any information.[34] A "sense of autonomy" and the "perception of control" may improve a patient's morale and provide placebo-like psychological benefits for patients who feel overwhelmed by their condition. However, when humans are inserted into a cybernetic feedback loop that reduces their health determinants to medical data and statistics, they may find that their virtual bodies displace their social bodies and that they are further alienated from rather than integrated into decision-making within the health care system. Nevertheless, there is still hope that the social body can be integrated with the functional and virtual bodies.

Second-Order Cybernetic Body
The broader definition of cybernetics that includes agency denotes a system of the second order. Heinz von Föerster distinguished the two kinds of systems by identifying first-order cybernetics with the "cybernetics of observed systems" and identifying second-order cybernetics with "the cybernetics of observing systems."[35] In other words, first-order cybernetics is about the regulation of observed systems while second-order cybernetics is about the self-regulation of observing systems. Second-order cybernetic agents observe the system from within and provide feedback to regulate the system to the degree that they have autonomy within the system. If the feedback loop is extended from the workings of the disease management device to the workings of the health care system, then the patient goes from being an observed sub-system within the health care system to observing the health care system from within the system. When stuck in a first-order cybernetic loop, the patient has a feedback function and can only ask the questions prompted by the data requirements of the disease management model. When placed in a second-order cybernetic loop, the patient is given a role within the health care system and is empowered to question those who also have roles, people such as the modeller, the nurse and the doctor, without being prompted for feedback. Glen Kearns says of patients who use Grand River Hospital's patient portal, "They're not just having things done to them, they're taking steps for themselves."[36] However, until patients can exercise agency within the health care system and influence decisions made in the broader system, they will not have gained autonomy within the system. They will have gained mobility outside the hospital and may be more motivated to function as part of the solution to their health problem, but they will not be empowered within the social realm of the system that makes health care a community. If patients are empowered to offer critical feedback concerning the workings their medical devices and the governing of the health care system, then they will have integrated their social, functional and virtual bodies into a second-order cybernetic body.

Ping the Body Cybernetic

I don't blame engineers and medical professionals for not recognizing the discrepancies between what they claim new information technologies will do for patients and what patients actually gain when the technologies are implemented within the health care system. When developing new technologies it is difficult to appreciate the difference between my practical goals as a developer and the technical objectives I design into a device for the sake of the user. Steve Mann, an engineering professor at the University of Toronto and self-professed cyborg, understands that using machines that don't require our agency can compromise our sense of purpose as humans. In light of this concern, he claims:

> In marrying the body with the computer, we have a new approach to the technology, to mechanism, and ultimately to memory and being. This approach has informed -- even driven -- my creation of personal cybernetics systems. Can we extend our projection and memory storage capabilities without reducing what makes us, ultimately, human? I believe we can, and have sought to do so with my inventions.[37]

However, Mann doesn't fully appreciate that it is not the operation of his inventions that enable him to maintain his humanity. On the contrary, it is his role as an engineer and the agency he exercises as an inventor that empowers him to use cybernetic technologies without diminishing what makes him human. When he hands over one of his inventions to someone who was not part of the development process, the user must rely on the causality he has designed into the device and will find his or her humanity confined to functional and virtual ends. Yet Mann is not naïve. He does express concerns:

> There has always been a dark side to wearable devices. Simple examples of wearable technology that enslave rather than liberate the individual include handcuffs, leg irons, and any other implements that the individual wears but does not have control over. More recently, the beeper, the cellular phone, the PalmPilot – all these innovations can be viewed not just in terms of their liberating possibilities, but also in terms of their capacity to reduce freedom. So, too, might the wearable computer be misused and become part of the apparatus of control.[38]

The pattern is now well-known. As Marshall McLuhan put it in the 1960s, "We shape our tools and afterward our tools shape us."[39] He was concerned that we blindly adopt new technologies without being aware of how they change our environment. Mann is not blind. However, his response as an engineer is to hold that we must keep shaping our technologies. Thus, he proposes,

> The distinction between 'developer' and 'end user' needs to be redefined. We should be encouraged to learn and understand how computers work, and we should be allowed to modify and adjust software and hardware according to the needs of both ourselves and our particular communities.[40]

In other words, he thinks that all of us, whether we are engineers or not, should become technically educated like him and that we should all take on the role of the engineer in designing and re-designing the technologies we use within the social systems that make up our communities. Although I am an engineer, and I agree that people in general should have some technical education, even if it were feasible, I believe it would be unreasonable for all of us to become engineers. Moreover, it isn't necessary for all of us to become engineers in order for each of us to influence how new technologies shape our technological environment. What is needed is enough of a social niche to empower all of us -engineers, developers and users- to engage in political discourse about the appropriate ends of our systems.

All cybernetic systems require that homeostasis among certain sub-systems be maintained. We have seen that, in the first-order cybernetic body, blood glucose homeostasis is maintained by the functions of various organs. However, in the case of the diabetes, the operation of a functioning pancreas can be replaced by various technologies that require the diabetic, to a greater or lesser degree, to input date and make decisions in order to maintain blood glucose homeostasis. This substitution is appropriate because the problem is essentially technical and the use of these technologies achieves a functional end. However, it does not follow that the patient's participation in achieving this objective empowers him or her to make practical decisions concerning the purpose of their lives. When it comes right down to it, they have no choices. Their only choice is prescriptive participation or death.

In the first-order cybernetic body, maintaining blood glucose is like maintaining balance while walking. If I slip, my body automatically flails with arms sticking out and back twisting in whatever position will keep me upright. This is completely involuntary, as should also be the operation of a properly functioning pancreas. If my inner ear is damaged and my body isn't able to maintain its balance, then it would be appropriate to invent a feedback device that enabled me to make decisions about my body posture that would allow me to stand upright and walk. However, it would be misleading to assume that such mobility automatically empowered me with the liberty to walk wherever I so choose. While the first-order cybernetic body maintains balance when walking, it is the second-order cybernetic body that decides where to go. Balance is a functional objective; direction is a social goal. Moreover, when we are prevented from walking where we should be able to go, we recognize that this is a practical problem that requires our participation in a political response that may include negotiation with others or outright protest. Thus, if I as a patient am to gain autonomy within the health care system, then my second-order cybernetic body should be in a position to question why, in an online system that purports to empower me with access to my medical information, the doctor may not authorize the posting of all my test results. Likewise, if I am a diabetic patient wearing a wireless medical diagnostic device, my second-order cybernetic body should be in a position to question why, when my doctor pings my first order-cybernetic body, the computer not only responds with the necessary data to determine how I am but also where I am. After discussion in person and perhaps negotiation, I may support the surveillance use of the technology; however, if I am to be empowered to take greater responsibility for the decisions that govern my health within the health care system, it should be the choice of my social body.

At the present time, many people in Canadian society are rethinking the functional character of medicine. We have come to realize that health care must be holistic and that technical problem solving alone, especially in the form diagnosis and treatment that are practiced in a prescriptive manner, does not adequately address all our medical problems. In fact, an over use of functional solutions like drugs can make matters worse and leave patients out of the loop when it comes to making decisions about health and the health care system. Participation is an important social value. If health care is going to become patient-centred, it must be more than just patient administered. As we shift from an industrial model of health care in which patients are products of a productive but perhaps not effective system to an informational model that has potential to integrate patients into the decision-making that governs their health, we need to clear about what we mean by terms like "autonomy," "care" and "empowerment." When patients are told that new information technologies create a role for patients in the health care system, are they being integrated into the political decisions made within a social system or are these diagnostics devices simply being incorporated as the next functional step in a device-driven system? What kind of technological bodies do we want? What kind of "guardian angels" do we need?

These questions become particularly important in light of the significance currently being placed on the social determinants of health and the need for more holistic medical practices. There is a need to reclaim the social body, which is inherently a political body. Given that doctors probably won't be able to bill the state for taking the time to monitor patients via early warning diagnostic systems and that consumers, with athletes leading the way, will demand access to such technologies, we are likely to see wearable medical devices proliferate in the same manner that security has been offloaded from the state and privatized by security corporations that offer home security systems and gated communities with personnel who check on your home if there's an alarm. A wearable, wireless vital signs monitor has already been developed by NASA scientists at Stanford University for explorers on Earth.[41] Surely this technology or a device like it will soon be commercially available for people concerned about their health failing. However, as we incorporate new technologies into the health care system, the outcome need not be predetermined by technical advance. These issues are system design consideration, and I suggest that we would do well when we are debating design decisions to consider the rhetoric of tool-talk that doesn't distinguish between social and functional ends, that is, between practical and technical tools. When I ping the body cybernetic, I am using a technical tool and contributing to the functional and virtual niches of our technological environment. When I use practical tools I contribute to the social niche and am empowered to question the purpose of the health care system and the extent to which it should be privatized. Although the ping body has a space in health care, it doesn't have an actual place. We mustn't forget about the poke body, a body that does have a social role and that can be poked and can unexpectedly poke back. Moreover, with the further integration of the cultural body into the health care system, along with the social, functional and virtual body, and perhaps even with the spiritual body, we may create a third-order cybernetic body that is empowered to provide non-technical feedback by asking questions about the meaning of health, the meaning of illness and the meaning of death. If this were made possible, then I would agree with Steve Mann when he says,

> We are at a unique stage in history, a time when it is possible to facilitate a dispersal of personal technologies that could counteract repression through ubiquity and diffusion. This opportunity to enhance human possibility is the reason why we must insist that wearable computers not be uniforms tied to specific functions but rather overall systems that include human beings in the cybernetic loop.[42]

When this happens, I will sing the body cybernetic.

[1] Walt Whitman, *The Portable Walt Whitman*, ed. Mark Van Doren (New York: Penguin Books 1977), 126.
[2] For a discussion on the differences between prescriptive and holistic technologies see Ursula Franklin, The *Real World of Technology* (Toronto: CBC Enterprises 1990), 24-25.
[3] Henry Petroski, *The Evolution of Useful Things* (New York: Vintage Books 1994), 114-129.
[4] For the purposes of this paper, technology is the awareness of usefulness and what I call the technologian is someone who strives to study our awareness of usefulness in all its breadth. Since the technological field of inquiry is inherently interdisciplinary, this does not make "technology" a new discipline or specialization. The technologian is anyone from any discipline who questions how the problems studied by his or her discipline are related to the problems studied in other disciplines. In order to develop a technological perspective and appreciate the breadth of our technological environment, the technologian must take a phenomenological approach to the study of technology. At the core of this analysis is what I call the problem-solving postulate, whereby the perceived nature of the problem dictates the character of the solution. This paper is a demonstration of a technological approach to the study of wearable computing in health care. For a full treatment of the technological environment and the analysis proper to the technologian, see my book *Understanding Technologies*, which I am currently writing. For more information, visit http://technologian.org.
[5] Manuel Castells, *The Rise of the Network Society* (Oxford: Blackwell Publishers Ltd, Second Edition 2000), 21.
[6] http://www.blackberry.com/products/handhelds/archive.shtml. Accessed 24 October 2004.
[7] Renn Scott, "Poetic Innovations: Attire Your Body with Wearable Clothing and Articles that Capture Your Mood, Emotion or Body Performance," winner of the New Voices Competition at *digifest 2004*, Ontario Science Centre, Toronto, Ontario, 8-21 May 2004.
[8] http://www3.sympatico.ca/renn_scott/. Accessed 27 October 2004.
[9] http://www.polar.fi. Accessed 28 October 2004.
[10] http://www.ga.org. Accessed 28 February 2004.
[11]Peter Szolovits et al., *Guardian Angel: Patient-Centered Health Information Systems* (http://www.medg.lcs.mit.edu/projects/ga/manifesto/GAtr.pdf. Accessed 28 February 2004), 4.
[12] Szolovits, 4.
[13] Szolovits, 4.
[14] Szolovits, 4.
[15] Szolovits, 4.
[16] Szolovits, 14.
[17] Szolovits, 17-22.
[18] Catherine Burns, *Mobile Decision Support in Health Care*, presentation given at the University of Waterloo, 15 September 2004.
[19] Catherine M. Burns and John R. Hajdukiewicz, *Ecological Interface Design* (New York: CRC Press 2004), 225-232.
[20] Catherine Burns, interview by author, University of Waterloo, 30 September 2004.

[21] Jerry Zeidenburg, "Web portal gives patients an active role in care plans," *Canadian Healthcare Technology*, April 2004, http://www.canhealth.com/apr04.html. Accessed 25 September 2004.
[22] Zeidenburg.
[23] Glen Kearns, e-mail to author, 29 September 2004.
[24] Peter Szolovits, e-mail to author, 1 October 2004.
[25] http://www.grandriverhospital.on.ca/grc/03grhannual/images/pdfs/MyCARESourceBrochure.pdf. Accessed 29 September 2004.
[26] http://www.polar.fi. Accessed 28 October 2004.
[27] Szolovits, 4.
[28] Norbert Weiner, *Cybernetics: Control and Communication in the Animal and the Machine* (Cambridge: The MIT Press 1948) 11.
[29] Eric Bender, "Your Daily Doctor," *Technology Review*, 20 February 2004. http://www.technologyreview.com, Accessed 1 October 2004.
[30] Zeidenburg.
[31] Stelarc, http://www.stelarc.va.com.au/pingbody/index.html. Accessed 28 February 2004.
[32] Stelarc.
[33] Claudette DeLenardo, "Grand River Hospital's Internet-Based Solutions Empower Patient Managed Care," *Health Care Quarterly* 7 no. 3 (2004): 111.
[34] Zeidenburg.
[35] Heinz von Föerster, *Observing Systems* (Seaside: Intersystems Publications 1981), xvi.
[36] Zeidenburg.
[37] Steve Mann with Hal Niedzviecki, *Cyborg: digital destiny and human possibility in the age of the wearable computer* (Doubleday Canada 2001), 28.
[38] Mann, 44.
[39] Marshall McLuhan, quoted by Lewis H. Lapman in the "Introduction" to McLuhan's *Understanding Media: The Extensions of Man* (Cambridge: The MIT Press 1994), xxi.
[40] Mann, 37.
[41] http://lifeguard.stanford.edu. Accessed 21 October 2004.
[42] Mann, 73.