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The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments [1]

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> The intrinsic relationship that arises between tools and organs, and one that is to be revealed and emphasized – although it is more one of unconscious discovery than of conscious invention – is that in the tool the human continually produces itself. Since the organ whose utility and power is to be increased is the controlling factor, the appropriate form of a tool can be derived only from that organ.
>
> *Ernst Kapp, 1877, quoted in [Mitcham, 1994, p. 23]*

Abstract

How does the changing representation of the body in virtual environments affect the mind? This article considers how virtual reality interfaces are evolving to embody the user progressively. The effect of embodiment on the sensation of physical presence, social presence, and self presence in virtual environments is discussed. The effect of avatar representation on body image and body schema distortion is also considered. The paper ends with the introduction of the cyborg's dilemma, a paradoxical situation in which the development of increasingly "natural" and embodied interfaces leads to "unnatural" adaptations or changes in the user. In the progressively tighter coupling of user to interface, the user evolves as a cyborg.

Minding the Body, the Primordial Communication Medium

In the twentieth century we have made a successful transition from the sooty iron surfaces of the industrial revolution to the liquid smooth surfaces of computer graphics. On our computer monitors we may be just beginning to see a reflective surface that looks increasingly like a mirror. In the virtual world that exists on the other side of the mirror's surface we can just barely make out the form of a body that looks like us, like another self. Like Narcissus looking into the pond, we are captured by the experience of this reflection of our bodies. But that reflected body looks increasingly like a cyborg. [2]

This article explores an interesting pattern in media interface development that I will call progressive embodiment. Each progressive step in the development of sensor and display technology moves telecommunication technology towards a tighter coupling of the body to the interface. The body is becoming present in both physical space and cyberspace. The interface is adapting to the body; the body is adapting to the interface [(Biocca & Rolland, in press)].

Why is this occurring? One argument is that attempts to optimize the communication bandwidth of distributed, multi-user virtual environments such as social VRML worlds and collaborative virtual environments drives this steady augmentation of the body and the mind [(see Biocca, 1995)]. It has become a key to future stages of interface development. On the other hand, progressive embodiment may be part of a larger pattern, the cultural evolution of humans and communication artifacts towards a mutual integration and greater "somatic flexibility" [(Bateson, 1972)].

The pattern of progressive embodiment raises some fundamental and interesting questions. In this article we pause to consider these developments. New media like distributed immersive virtual environments sometimes force us to take a closer look at what is fundamental about communication. Inevitably, theorists interested in the fundamentals of communication return in some way or another to a discussion of the body and the mind. At the birth of new media, theories dwell on human factors in communication [(Biocca, 1995)] and are often more psychological than sociological. For example when radio and film appeared, [Arnheim (1957)] and [Munsterberg (1916)] used the perceptual theories of Gestalt psychology to try to make sense of how each medium affected the senses. In the 1960s McLuhan [(1966; McLuhan & McLuhan, 1988)] refocused our attention on media technology when he assembled a controversial psychological theory to examine electronic media and make pronouncements about the consequences of imbalances in the "sensorium."

Before paper, wires, and silicon, the primordial communication medium is the body. At the center of all communication rests the body, the fleshy gateway to the mind. [Becker & Schoenbach (1989)] argue that "a veritable 'new mass medium' for some experts, has to address new senses of new combinations of senses. It has to use new channels of information" (p. 5). In other words, each new medium must somehow engage the body in a new way. But this leads us to ask, are all the media collectively addressing the body in some systematic way? Are media progressively embodying the user?

1.1 The senses as channels to the mind

"Each of us lives within ... the prison of his own brain. Projecting from it are millions of fragile sensory nerve fibers, in groups uniquely adapted to sample the energetic states of the world around us: heat, light, force, and chemical composition. That is all we ever know of it directly; all else is logical inference (1975, p. 131) [(see Sekuler & Blake, 1994 p. 2)].

The senses are the portals to the mind. Sekuler and Blake extend their observation to claim that the senses are "communication channels to reality." Consider for a moment the body as an information acquisition system. As aliens from some distant planet we observe humans and see the body as an array of sensors propelled through space to scan, rub, and grab the environment. In some ways, that is how virtual reality designers see users [(Durlach & Mavor, 1994)]. Many immersive virtual reality designers tend to be implicitly or explicitly Gibsonian: they accept the perspective of the noted perceptual psychologist [J.J. Gibson (1966, 1979)]. Immersive virtual environments are places where vision and the other senses are meant to be active. Users make use of the affordances in the environments from which they perceive the structure of the virtual world in ways similar to the manner they construct the physical world. Through motion and collisions with objects the senses pick up invariances in energy fields flowing over the body's receptors. When we walk or reach for an object in the virtual or physical world, we guide the senses in this exploration of the space in same way that a blind man stretches out a white cane to explore the space while in motion. What we know about the world is embodied, it is constructed from patterns of energy detected by the body. The body is the surface on which all energy fields impinge, on which communication and telecommunication takes form.

1.2 The body as a display device for a mind

The body is integrated with the mind as a representational system, or as the neuroscientist, Antonio Damasio, puts it, "a most curious physiological arrangement ... has turned the brain into the body's captive audience" [(Damasio, 1994, p. xv)]. In some ways, the body is a primordial display device, a kind of internal mental simulator. The body is a representational medium for the mind. Some would claim that thought is embodied or modeled by the body. Johnson and Lakoff [(Johnson, 1987; Lakoff & Johnson, 1980; Lakoff, 1987)] argue against a view of reasoning as manipulation of prepositional representations (the "objectives position"), a tabulation and manipulation of abstract symbols. They might suggest a kind of sensory-based "image schemata" that are critical to instantiating mental transformations associated with metaphor and analogy. In a way virtual environments are objectified metaphors and analogies delivered as sensory patterns instantiating "image schemata."

In his book, *Decartes' Error*, the neuroscientist Damasio explains how the body is used as a means of embodying thought:

> "...the body as represented in the brain, may constitute the indispensable frame of reference for the neural processes that we experience as the mind; that our very organism rather than some absolute experiential reality is used as the ground of reference for the constructions we make of the world around us and for the construction of the ever-present sense of subjectivity that is part and parcel of our experiences; that our most refined thoughts and best actions, our greatest joys and deepest sorrows, use the body as a yardstick" [(Damasio, 1994, p. xvi)].

Damasio's title, *Descartes' Error*, warns against the misleading tendency to think of the body and mind, reason and emotion, as separate systems.

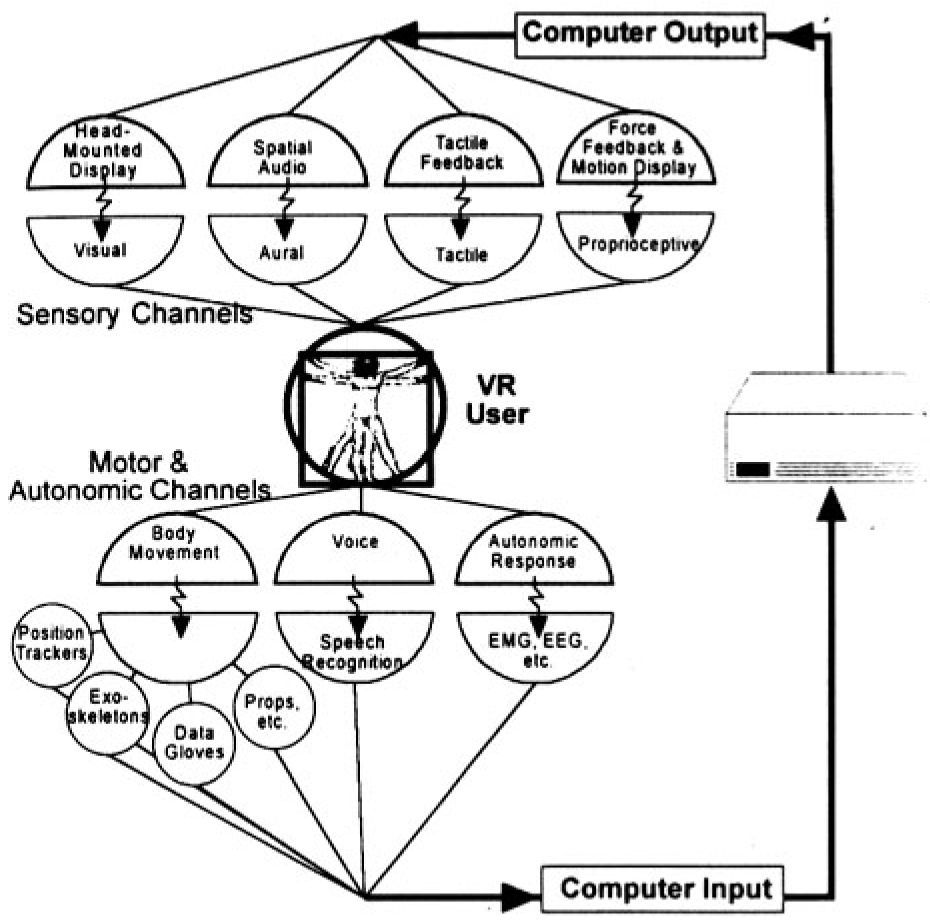

Figure 1. Range of possible input (sensors) and output (effectors) devices for a virtual reality system. Illustrates the pattern of progressive embodiment in virtual reality systems. Source: Biocca & Delaney, 1995

1.3 The body as a communication device

The body is also an expressive communication device [(Benthall & Polhemus, 1975)], a social semiotic vehicle for representing mental states (e.g., emotions, observations, plans, etc.) to others. The body emits information to the senses of other bodies, whether intentional or not [(Ekman, 1974)]. Observers of the physical or mediated body read emotional states, intentions, and personality traits by an empathic simulation of them [(Zillman, 1991)]. The body transmits information to other bodies through a kind of affective contagion.

Thinking of the body as an information channel, a display device, or a communication device, we emerge with the metaphor of the body as a kind of simulator for the mind. But as in a simulator, the software and the hardware cannot be cleanly separated; they both contribute to the fidelity of the simulation.

Embodiment: The Teleology of Interface Design

If the body is the fundamental communication hardware, a simulator for a mind, what is its relationship to media made of steel, plastic, or silicon? Instead of pulsing blood, pulses of electrons and light animate these media. McLuhan long ago pointed out that modern communication interfaces attach themselves to the body. In the words of McLuhan, "media are extensions of the senses."

The relationship of a human to an interface can be one of a body to an environment, or of one brain to another through a kind of conversation. McLuhan's vision of media environments is a slightly different vision than the one advanced by [Licklider (1960)] in his famous article on "man-computer symbiosis." For him, "man-computer symbiosis" is a subclass of "man-machine systems." The computer was not to be treated like other machines because it was "intelligent." This intelligent partner could be engaged in a kind of conversation. The disembodied human brain would be coupled to a machine brain rather than to cognitive environments:

> The hope is that, in not too many years, human brains and computing machines will be coupled very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today [(Licklider, 1960, p. 4)].

In a view of the computer as giant brain, widely shared in the 40s and 50s, we see another version of Descartes' error. This coupling was of one brain to another. The communication between human and machine was one of conversation. The conversation was with a large disemboded electronic brain, seen either as a peer, slave, or competitor. Instead of a mind communicating through a body to another body, we have only two disembodied conversations, a sterile coupling of abstract symbol generators. It is the symbol manipulating vision of early artificial intelligence, rather than the situated embodiment of intelligence augmentation [(Biocca, 1995)]. At the close of this century, the development of advanced computer interfaces appears to be increasingly characterized by what we might call progressive embodiment. Progressive embodiment is defined as the steadily advancing immersion of sensorimotor channels to computer interfaces through a tighter and more pervasive coupling of the body to interface sensors and displays.

This pattern of progressive embodiment is most evident in the discourse, research, and development of advanced immersive virtual reality, augmented reality systems, and wearable computers [(Biocca & Delaney, 1995; Durlach & Mavor, 1994)]. Writings growing out of early conferences on virtual reality and cyberspace enthusiastically welcomed the coupling of the body to virtual reality interfaces:

> The trajectory of Western thought has been one moving from the concrete to the abstract, from the body to the mind; recent thought, however, has been pressing upon us the frailty of that Cartesian distinction. The mind is the property of the body, and lives and dies with it. Everywhere we turn we see signs of the recognition, and cyberspace, in its literal placement of the body in spaces invented by the mind, is located directly upon the blurring of this boundary, this fault [(Novak, 1991, p. 227)].

Evidence that virtual reality was creating a tighter integration of sensors and displays with the body gave rise to this kind of pronouncement. Figure 1 displays the range of virtual reality devices and their connection to sensory channels or the motor and autonomic channels. The evolution of these devices is the evolution of the progressive coupling of sensors and display devices to the body. The vision of such a system foresees some applications where the body of the user is to be completely immersed in the interface, and the mind is set floating in the telecommunication system – in cyberspace. Like a body entering a sink, a bath, or a pool, communication demands and contexts will determine how much the body needs to be immersed in the electric-cool waters of cyberspace.

There is a teleology to human-machine symbiosis. Advanced communication interfaces are designed to assist users in those times when total embodiment is desired for information intensive communication (e.g., sensorimotor training in flight, battle, sports, etc.; certain forms of entertainment where simulations of the past places, telepresence to existing places, and the subjective experience of others is critical). Total immersion is the goal. There has been some temporary retreat from the aggressive pursuit of this vision because of the immaturity of the display and sensing devices. Early attempts to immerse the body in these immature technologies have led to imperfect mapping of the body to the interface. Physiological reactions of the body to this imperfect mapping have taken the form of simulation sickness [(Biocca, 1992); (Kennedy et al., 1992)] and visuomotor adaptation [(Biocca & Rolland, in press)].

Virtual reality is an immature technology. But simulation technologies are developing rapidly. Figure 2 shows the classes of variables that are critical to the continued refinement of virtual environments and progressive embodiment. Looking only at the evolution of the hardware and operation systems of virtual reality interfaces, we can characterize the design of progressive embodiment by developments in the following classes of variables:

Sensory engagement

Clearly the senses are connected to the interface. But how? How should we define this aspect of embodiment? Past theorists of virtual environments have attempted to define the degree to which the senses are connected to the displays of the interface. Upon analysis most of these definitions prove to be flawed. For example, Sheridan [(1992)] states that physical presence (defined below) may be related to the "amount of sensory information" in the interface. On the surface this seems acceptable. But this definition suggests using "information" as the unit of measurement. How does one measure the variable "amount of sensory information." It has been known since perceptual experiments in the 1950s that information theory measures of "information" [(Shannon & Weaver, 1949)], especially of perceptual information, are not usable because we are unable to predict chunking and other structural information. One "bit" of perceptual information is not definable in any useful way.

In another attempt to define properties of the interface [Steuer (1995)] arrays interfaces according to their amount of "vividness." This concept is also flawed. It confuses independent and dependent variables by defining a property of the interface, the computer, in terms of the effect of this property on the user. As a result it is difficult to operationalize.

I will use the term, sensory engagement, to define the degree to which the senses are engaged or connected to the interface. The amount of sensory engagement is defined and measurable using the following dimensions:

2.1.1 Number of sensory channels engaged by the virtual environment

Not all senses are channels for information for virtual environments. For example, the nasal and oral senses tend to be underutlized, and coverage of the haptic and tactile senses is highly limited [(see Biocca & Delaney, 1995; Durlach & Mavor, 1995)]. Media have not evolved that far. So in some ways, we are partially disembodied when interacting with most media. Interfaces can easily be classified as to the number of sensory channels they address.

There is also a trend towards increasing the number of sensory channels that are connected to the interface. In this century displays for the visual and aural senses have been steadily perfected. For example, the silent film evolved another display channel and became the "talkie." In the last twenty five years sophisticated tactile and proprioceptive devices have been incorporated into some simulators, and in the last few years nasal displays are beginning to evolve from the crude aroma releasers of a few decades ago to more sophisticated devices [(Krueger, 1997)]. In the process of progressive embodiment, more of the senses are entering cyberspace. If we look at the trajectory of interface development, it is fair to say that at some point all the senses may be connected to cyberspace for certain intensely sensory experiences.

2.1.2. Increasing sensory fidelity of displays and range of sensory cues within each sensory channel

Our knowledge of the senses is being directly applied to the design of increased fidelity (e.g., [(Biocca & Delaney, 1995; Durlach & Mavor, 1994)]. So for each sensory channel we can theoretically define the level of sensory fidelity for that channel. Sensory fidelity can be defined in terms of the pattern of energy impinging on the senses. Sensory fidelity is the degree to which the energy array produced by a mediated display matches the energy array of an unmediated stimulus. The quantification and measurement of the increasing match of the mediated display to an unmediated stimulus is easier for some sensory channels (i.e., the visual), than for others (i.e., olfactory). Good examples of commonly used measures in the visual channel are resolution and color fidelity, two quantifiable properties of array of light on a visual display.

Over time virtual environment designers hope that display devices will approach and exceed the full sensory capabilities of each sensory channel. At the moment, even the most advanced displays, those for the visual channel, for example, fall short of the full capabilities of human vision [(Durlach & Mavor, 1995; Kocian & Task, 1995)].

2.1.3. Increased saturation of the sensory channels engaged by the virtual environment and suppression of sensory channels not engaged

In an effort to fully embody the user in the virtual environment, the capacity of those senses engaged by the system must be immersed in the representation of the virtual world.

> *Level of sensory saturation* is defined as the percentage of the sensory channel occupied by stimuli (information) from the virtual as opposed to the physical environment.

For example, when a user looks at a typical monitor only a fraction of the visual field is occupied by stimuli from the virtual environment. But monitors are becoming progressively larger, and VR head mounted displays are moving to larger fields-of-view. The ambition is to saturate the field-of-view of the user with the virtual environment. A similar pattern of progressive saturation is found in other sensory display systems. The bandwidth of each sensory channel is being steadily taken up by stimuli from the virtual world.

When users use media it is often done in a setting that suppresses stimuli from the physical environment. We can call this phenomenon *sensory suppression of the immediate environment*.

> *Sensory suppression* of the immediate environment is caused by features of the interface or the user's environment that dampen, eliminate, or minimize the impact of stimuli on the sensory channels not engaged by the interface or by the part of a sensory channel not saturated by the interface.

A good example of sensory suppression is the environment of the typical movie theater:

- The mediated environment, the movie screen, especially in IMAX theaters, saturates the visual channel (i.e., field of view) of the user so little of the immediate environment, the theater, is visible.
- Dimming the lights makes the screen (the mediated environment) dominant, and suppresses visual information from the parts of the physical environment that are not displaying mediated information (i.e., the people seated beside you, the curtains on the walls, etc.).
- Sound volume and social rules about making noise suppress sound from the ambient physical environment.
- Soft comfortable seats and temperature controls suppress awareness of the haptic and proprioceptive channels.

The interface, the environment, and social rules during interface use are all designed to immerse the users' senses in the virtual environment of the movie screen. Communication flows to parts of sensory bandwidth not immersed in cyberspace are suppressed and decreased.

2.2 Motor engagement

The body's movement and activity is increasingly part of the interface [(Biocca & Delaney, 1995; Durlach & Mavor, 1995)]. It can be argued that historically the body enters cyberspace with the creation of the humble mouse [(Bardini, 1997)]. Why not use the keyboard someone might ask? The keyboard was primarily a symbolic input device for textual "conversation" with the computer. The keyboard did not map the movement of the body in space to cyberspace. So it was conversational input, not a somatic input. Over time more of the body's morphology and motion are being captured by the position trackers, motion capture systems, and other sensors, vivid 3D representation of the user, direct manipulation, and machine analysis of user intention (task selection).

2.2.1. Number of motor channels engaged by the virtual environment
Progressive embodiment can be seen in the number of interface sensors that map the motion of the body including joysticks, head trackers, eye trackers, facial motion systems, etc.

2.2.2. Resolution of body sensors
Sensors, like displays, are capturing finer and finer resolutions of body motion and physiological activity, e.g. fine finger movement, lip movement, etc.

2.3 Sensorimotor Coordination
One of the most important factors in immersing the user's body into the interface is sensorimotor coordination. It is the essence of feedback, especially the kind of feedback we experience in our interaction with the physical environment. Sensorimotor coordination is defined as the degree to which changes in body position correlate immediately and naturally with appropriate changes in sensory feedback. The presence of lag in immersive virtual reality systems between motor movement and sensory feedback is a significant source of simulation sickness and decrements in human performance [(Held & Durlach, 1991)].

Embodiment: Thinking Through our Technologically Extended Bodies

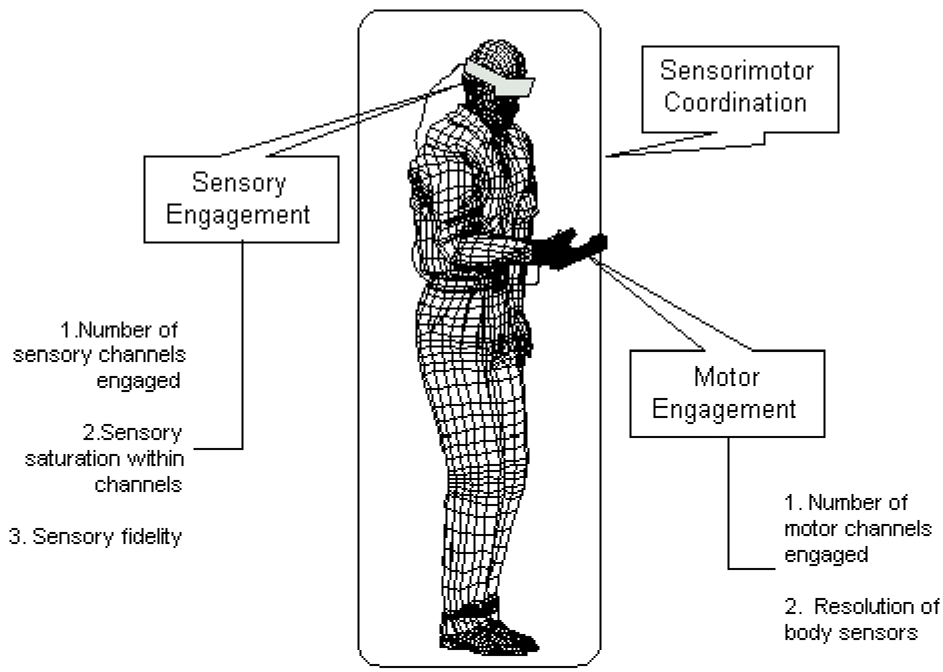

Figure 2. The users are progressively embodied in virtual environment interfaces through evolving technologies of sensory engagement, motor engagement, and sensorimotor coordination.

The process of progressive embodiment is occurring at a time when there is increasing social integration of the interface. Social integration means that the interface is being integrated into everyday activity at work, home, and on the street. Increased social integration of the sensorimotor interface into everyday communication is giving rise to longer and more contextually varied access to cyberspace. The interface enters the social sphere via easier coupling with the body through miniaturization, portability, and wearability.

In most virtual environments systems, but especially in immersive virtual reality systems, progressive embodiment of the user inside the interface presents significant design challenges.

3.1 Designing a space for bodily action

How do we create the illusion of a stable and coherent spatial environment with at least most of the sensory properties of the physical world (i.e., visual space, auditory space, tactile resistance and pressure, smell and appropriate free floating molecules, etc.)?

3.2 Design of other intelligent beings

The space the body enters cannot be a ghost town, as many early VR worlds were in the early 1990s. So the challenge is to create the perception of other intelligent beings. These issues are normally found under the discussion of the design of agents and avatars, and of virtual humans.

The most pressing design issues are:

1. The design of body morphology.

   Here the concern regarding embodiment focuses on the design of the shape of represented beings, especially the engineering of their motion [(Badler, et.al.1991)].

2. Expressiveness of the body.

   Here the debate over embodiment dwells on the capability of the represented being to communicate the full range of human and non-human expression. Concern often focuses on the engineering of an expressive face from the 3D geometry of avatars and agents.

3. Perceived intelligence via bodily action and expression.

   The only evidence we have of another being's intelligence is the motion, motor behavior, and symbolic behavior of that being. By directly controlling the motion and behavior of an avatar, a human operator provides the intelligence in real time. Barring the expressive and kinematic inadequacies of avatar embodiment, the intelligence of human embodiment is perceived quickly. The challenge – best expressed by Turing, but evident in the work of previous designers of automata – is to have an agent that somehow possesses or creates the illusion of intelligence.

The ambiguity of intelligence can be a source of pleasure and not necessarily a flaw in virtual environments. As Randy Walser pointed out early in the design of VR environments [(Walser, 1991)], part of the pleasure in VR narrative environments might come from not quite knowing when a dynamic form is either an object, an avatar, or an agent. The challenge to the user's expectations about the correlation of morphology with intelligence might be a source of great art in virtual environments.

Clearly animation can communicate all of the above to a satisfactory– if not ideal – degree. Didn't Disney already do this? Have we not achieved the illusion? The real challenge is not achieving these goals under controlled point of views and interactivity such as that of a third-person voyeur (i.e., as in the way film and animation present us with intelligent behaviors). Nor is it experiencing second-person interaction in the way some video games allow the user to experience the interaction of a puppet with other apparently intelligent i.e., intentional, puppets. The challenge is giving the user full first-person interaction with other intelligent beings animated by a complex expressiveness.

3.3 Design of the represented body

The represented body is referred to as the avatar of the user. In immersive virtual reality systems the avatar is not the small puppet used in standard computer interfaces, those regular computer monitors on which an iconic representation of the self is moved in a world via a mouse or joystick. In immersive VR the whole interface defines the boundaries and shape of the body by defining the boundary between inside and outside, between the part of the VR world that is "me" and the part that is "the world" (see [Loomis, 1992)]. Both, of course, are just perceptual illusions generated on a head-mounted display (HMD). For example, users wearing a head-mounted display look down and readily accept the floating virtual hand of the immersive VR systems as their own. A part of the continuum of light in the HMD, a visual illusion, is given the distal attribution of "me" and the rest "other." From coherent patterns of energy impinging on the senses (i.e., the proximal stimulus) the virtual world is divided into "self" and "environment".

In immersive VR, more so than in any other medium before it, the representation of the user's body is a psychologically profound issue. This is especially true when the systems map the user's body directly to the first person experience of a full virtual body, as virtual body that provides feedback about the location of limbs and head in space. As I will discuss later, the design of this virtual body may be the source of a number of current psychological problems in coupling of the body to immersive VR systems.

User Embodiment and Three Forms in Which the Body "Feels" Present in the Virtual Environment

Embodiment plays an important role in the design of virtual environments, especially collaborative virtual environments (e.g., [(Benford, et al., 1995)]. In immersive virtual environments the environment surrounds the body, often engulfing the senses, and, therefore, the mind. We sometimes speak of sound environments, architectural environments, natural environments, etc. All suggest fields of stimuli that somehow engulf one or more of the senses.

Embodiment of the user is a critical dimension of the program for intelligence augmentation that motivates the advancement of virtual reality systems [(Biocca, 1995)]. The phrase intelligence augmentation describes the design theory that communication technologies can be cognitive prostheses amplifying or assisting cognitive processes or by developing cognitive skills. This postulate has a long history in telecommunication and human-computer interface design. In one form of another it is an implicit or explicitly goal in the work of [Vannevar Bush (1945), Douglas Englebart (1962), Douglas Licklider (1960; Licklider & Taylor, 1968) and numerous others (see also [Howard Rheingold, 1985)].

This leads us to ask of ourselves and the VR design community, if embodiment contributes to intelligence augmentation what does it mean to be embodied? In other words, what are the psychological effects of goals of embodiment in virtual environments? Most commonly the psychological effects or goals of progressive embodiment can be expressed as various forms of what is called *presence*.

Presence: Emergence of a Design Goal and Theoretical Problem

5.1 Telepresence: Origins of the design of presence

5.1.1. Emergence of the design goal and theoretical problem of presence

The concept of presence is central to theorizing about advanced virtual environments such as immersive virtual reality [(Barfield et al., 1995; Lombard & Ditton, 1997; Sheridan, 1992; Steuer, 1995)]. For example, a leading VR journal out of MIT enshrines the psychological goal of presence rather than the technology of virtual reality by calling itself *Presence*.

In its more general use the term presence has referred to a widely reported sensation experienced during the use of virtual reality specifically, but also found during the use of other media. Users experiencing presence report having a compelling sense of being in a mediated space other than where their physical body is located (e.g., [Slater & Usoh, 1993)]. Because we automatically construct models of the space around us [(Bryant, 1992)] more sophisticated analyses have suggested that we simply think of presence as a form of perceptual externalization or distal attribution. When media are involved the space constructed from the energy impinging on the sense is generated from mediated stimuli rather than unmediated stimuli [(Loomis, 1992)].

The *Random House American Heritage Dictionary* definition of presence refers to a "spirit inside a body" or to "immediate proximity in time and space." In telepresence, this sense of "immediate proximity" is no longer immediate environment and source of sensation, but "transported" using technology to a location that is not in the same place as the physical body. Presence is sometimes called telepresence to emphasize the use of communication media for transportation. In its original formulation in the NASA and robotics community, telepresence meant the illusion of being transported via telecommunication systems to a real, physical location experienced synchronously [(e.g., Minsky, 1980)]. The user's body was linked via an interface to sensors on a robot. Telepresence has since been generalized to a sense of transportation to any "space" created by media [(e.g., Steuer, 1995)]. The shorter and more common term, presence, has been generalized to the illusion of " being there" whether or not "there" exists in physical space or not. This generalization of the term allowed theorists of presence to include the fantasy environments of narrative and game designers as well as the abstract iconic representations of scientific visualization.

5.1.2 The desire for physical transcendence and the control of sensory experience

[Biocca, Kim, & Levy (1995)] argue that goal of virtual reality, presence, is part of an ancient desire to use media for transportation and experience "physical transcendence" over the space we live in and to experience an "essential copy" of some distant place, a past experience, or the experience of another person. These basic kernel concepts of the "physical transcendence" of the body and space, and the "essential copy" of bodily experience are intertwined into discussions that animate the pursuit of presence. We see a desire to use media to move beyond the limits of body and the sensory channels. This desire for physical transcendence is clearly visible in the work of one of the most revered pioneers in computer graphics and VR, Ivan Sutherland:

> A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.... There is no reason why the objects displayed by a computer have to follow the ordinary rules of physical reality... The ultimate display would, of course, be a room within which the computer can control the existence of matter [(Sutherland, 1965, p. 506, 508)].

5.2 Presence as transportation of senses via telecommunication (i.e. tele-phone, tele-vision)

The engineering and computer science use of the term telepresence, or presence, started as a telecommunication design goal and has evolved into an intriguing theoretical problem and philosophical issue [(e.g., Biocca, 1996; Loomis, 1992)]. The concept can be found in the HCI literature first as "telepresence," the illusion of being present in a distant location [(e.g., Minsky, 1980)], but the word "presence" appears by itself at the same time [(Corker, Mishkin, & Lyman, 1980)]. The word telepresence meant using sensors and effects to link the body of the user via telecommunication channels to a robotic system. The robot would move when the user moved. Sensors, such as cameras and force detection devices, would provide feedback to the user. The user would sense what the robot "senses." In a phrase, the user would be remotely embodied in the robot. Telepresence is about the telecommunication of the body, the transmission of sensory and motor data.

According to some of the early users of the term, the conditions for telepresence would be met when:

> At the work site, the manipulators have the dexterity to allow the operator to perform normal human functions. At the control station, the operator receives sufficient quantity and quality of sensory feedback to provide a feeling of actual presence at the work site [(Akin, Minsky, Theirl and Kurtzman (1983) quoted in Held & Durlach, 1992)].

Influential definitions of telepresence reflect this origin. For example, the treatment of presence by robotics pioneer [Tom Sheridan (1992)] defines telepresence as the feeling of a teleoperator being phenomenally "there" at the remote site of operation.

5.2.1.1. Why a theory of presence has become necessary

The arcane and somewhat philosophical concept of presence became more theoretically urgent with the arrival of immersive virtual reality (See the first volume of the journal *Presence*). Practical design problems made issues of conceptualization and measurement critical [(Held & Durlach, 1992; Sheridan, 1992; Zeltzer, 1992)]. Presence was a design goal of virtual reality. The difference between virtual reality and other media was defined as a difference in the level of presence [(e.g., Steuer, 1995)]. It can be argued that advanced forms of virtual reality only differ from previous media in quantity and quality of presence. While the design of virtual reality technology has brought the theoretical issue of presence to the fore, few theorists argue that the experience of presence suddenly emerged with the arrival of virtual reality. Most see the illusion of presence as a product of all media, and that virtual reality is the medium that at this point in time can generate the most compelling sense of presence [(Biocca & Levy, 1995; Lombard & Ditton, 1997; Steuer, 1995)]. But with the arrival of virtual reality, the creation of the sensation of presence becomes more of an explicit design goal.

5.3 Intense sensorimotor feedback from headtracking in virtual reality made people aware of their bodies

The experience of a much higher level of sensorimotor feedback and first person perspective generated the head-tracked [(Meyer, Applewhite, & Biocca, 1992)] head-mounted display that helped bring the whole issue of presence to the fore. The interactivity resulting from the sensorimotor coordination of the moving head with visual displays created a sensation not found with non-headcoupled media like film and television. *Users became aware of their bodies;* their head movements altered what they saw. Immersive virtual reality immediately distinguished itself from other media when users reported a strong sense of "being there" in the virtual environment. Early user's of VR systems where struck by the compelling sensation that their bodies were in a different place [(e.g., Rheingold, 1991)]. For some, the experience was powerful. They felt they were no longer in the lab, office, or entertainment center, but "there," inside the virtual world. It was hoped that this surprising experience could be made more compelling.

This medium was interactive in a profoundly natural way. The world was now all around the user's body. With advanced virtual reality technology, users and designers sought to increase this sensation of presence, pursuit of which has become the sine qua non goal of many immersive virtual environments, labs and companies. The day-to-day design of presence has temporarily outstripped the theory of the presence. In the history of science we have often seen the design of technology outpace our understanding of the principles that make the technology function. Designers know that presence is something their users experience, but don't know exactly what it is. What is presence? This is one of the important questions in VR design. Most discussions of presence thus far [(e.g., Barfield et al., 1995; Heeter, 1992, 1995; Lombard & Ditton, 1997; Steuer, 1992; Zeltzer, 1992)] can be subsumed into the following conceptualization of three forms of presence.

Being There: The Sense of Physical Presence in Cyberspace.

Clearly the sense of presence was not created just for use with virtual environments. But as [Loomis (1992)] points out, presence is a basic state of consciousness, it is part of the attribution of sensation to some distal stimulus, or more casually, to some environment. A topic that has traditionally been discussed by philosophers and perceptual psychologists as "externalization" and "distal attribution" is now a practical matter of virtual environment design. It has even been proposed that VR might be used to study the classic epistemological topics of consciousness [(Biocca, 1996; Lauria, 1997)].

When we experience our everyday sense of presence in the physical world, we automatically generate a mental model of an external space from patterns of energy on the sensory organs. In virtual environments, patterns of energy that simulate the structure to those experienced in the physical environment are used to stimulate the same automatic perceptual processes that generate our stable perception of the physical world.

As [Loomis (1992)] points out, the mediation of virtual environments leads us to reconsider how the active body mediates our construction of the physical world:

> The perceptual world created by our senses and the nervous system is so functional a representation of the physical world that most people live out their lives without ever suspecting that contact with the physical world is mediated; moreover, the functionality of perception impedes many reflective individuals from appreciating the insights about perception that derive from philosophical inquiry. Oddly enough, the newly developing technology of teleoperator and virtual displays is having the unexpected effect of promoting such insight, for the impression of being in a remote or simulated environment experienced by the user of such systems can be so compelling as to force a user to question the assumptions that the physical and perceptual world are one and the same [(Loomis, 1992, p. 113)].

Note that Loomis says that all "contact with the physical world is mediated," by which he means the primordial communication medium, the body. The default sense of "being there" is the basic state of consciousness in which the user attributes the source of the sensation to the physical environment. We have been present in this environment for so long and it is so natural, that the idea that presence might be a psychological construct is only raised by philosophers and perceptual psychologists. The experience of compelling virtual environments has disturbed this common complacency. The discussion of virtual reality and the strong sense of being there that it generates is often accompanied by questions about the stability of our perception of the physical world [(e.g., Lauria, 1997)]. If the senses can be so easily fooled, then how can we trust the day-to-day experience of physical reality? This is the century old insight born of all illusions, especially in dreaming where we directly experience interaction of the body and the mind as the primordial simulator.

6.1 Where are you? : Oscillations in the sense of presence

The compelling sense of presence in virtual environments is unstable. At best it is fleeting. Like a voice interrupting a daydream in the imaginal environment, presence in the virtual environment can be interrupted by sensory cues from the physical environment and imperfections in the interface [(Slater & Usoh, 1993; Kim & Biocca, 1997)].

At one point in time, users can be said to feel as if they are physically present in only one of three places (see Figure 3): the physical environment, the virtual environment, or the imaginal environment. Presence oscillates among these three poles.

6.1.1. The physical environment (distal immediate)

Here users are attentively constructing a mental model of the physical space [(Bryant, 1992)], responding and attending to cues in the physical non-mediated environment as the user plans and guides engagement with the natural world.

6.1.2. The virtual environment (distal mediated)

Users are primarily constructing a mental model of the virtual space and responding to and attending to cues in the virtual mediated environment. Presence in the virtual environment can be readily engaged, but can rarely be maintained at the same level as presence in the physical environment.

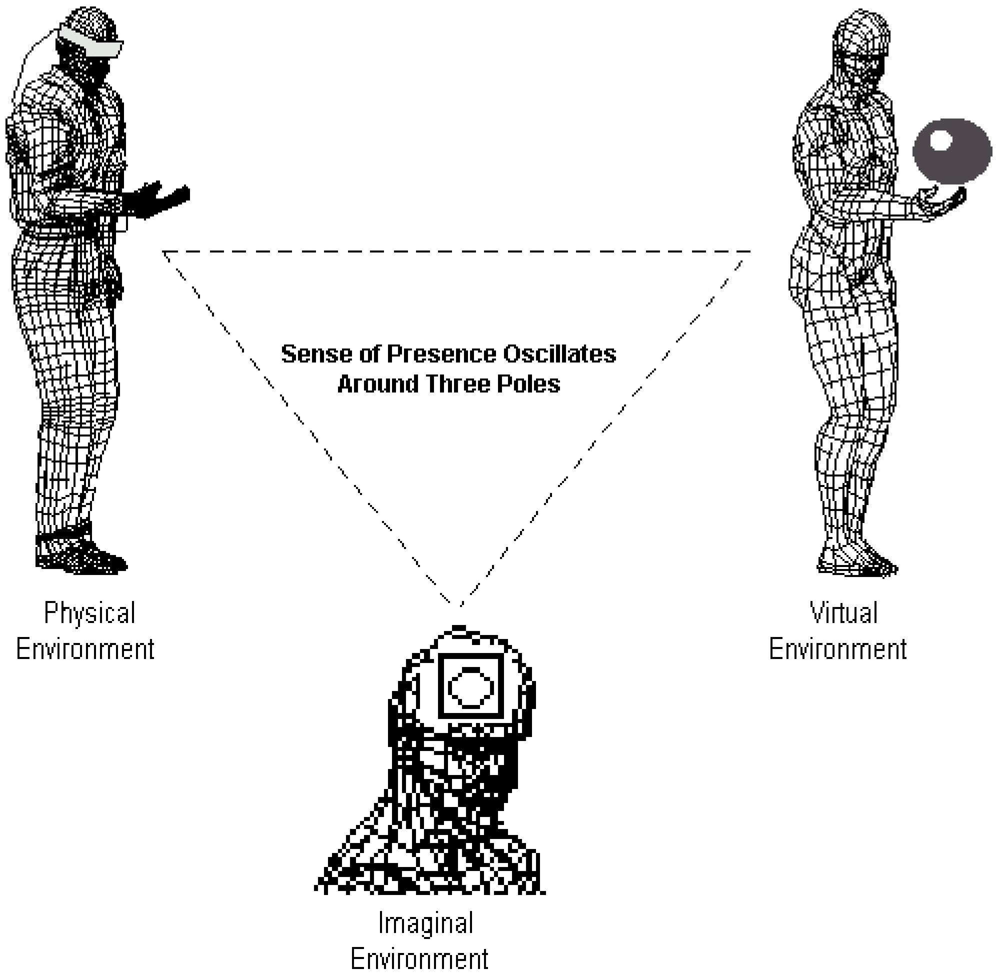

Figure 3: Users' sense of presence is not stable but labile. They variously feel present in the physical environment, virtual environment, or in the imaginal environment (e.g., dreaming, day dreaming).

6.1.3 The imaginal environment (minimal attention to distal stimuli)

Dreaming and daydreaming reveal that there is another place we can be present, the imaginary environment. We can say that the user is present in the internally simulated, imaginal environment when the user:

- has withdrawn focal attention to incoming sensory cues,
- is attending to internally generated mental imagery,
- has diminished responsiveness to sensory cues from either the physical environment or the virtual environment.

In dreams, and to a lesser degree in hallucinations and daydreaming, it is apparent that the mind is capable of producing very compelling spatial environments. In these environments, we have conscious experiences of moving through space (e.g., running down a busy street), interacting with others (e.g., talking with friends), and manipulating objects (e.g., throwing a ball). Clearly in a dream state we are present in a spatial environment. But it also clear that this environment has nothing to do with technology.

But dreams use what I call the mental simulator, the generator of mental imagery that makes of cognitive resources used in perception [(Farah, 1984; Kosslyn, 1980)]. But unlike states of presence in virtual and physical environments the mental spatial simulation is not based on incoming sensory stimulation but is mostly constructed from memory. I say mostly because there is evidence that in dream states, the mental simulation is responding to some environmental stimuli and somewhat random stimulation from the spinal system.

From a design viewpoint, physical presence is critical in applications that must involve spatial cognition, the transfer of spatial models from the virtual environment to the physical environment, or for sensory bombardment and escape from the physical environment. Applications where physical presence is critical include architectural walkthroughs, battle simulations, engineering design, and some entertainment rides.

Being with Another Body: Designing the Illusion of Social Presence

For many theorists, communication is essentially the connection of one intelligence with another. In this view, communication is the experience of another being. Even in the telecommunication model of [Shannon & Weaver (1949)], where communication is an abstract relationship between two machines, the source and receiver of communication are most often interpreted as one intelligent being connected to another.

For many face-to-face communication is an ideal that media technologies attempt to replicate [(Palmer, 1995; Rafaeli, 1988; Schudson, 1978)]. In an elaborate book length attempt at a taxonomy of all present and future media, [Ciampa (1989)] presents all media as vain attempts to recover the immediacy of face-to-face communication. [Michael Heim (1993)] in his discussion of virtual reality interfaces takes this one step further. He inserts the ideal of face-to-face communication into the general notion of inter-face, "a mysterious, nonmaterial point where electronic signals become information":

> In ancient times, the term interface sparked awe and mystery, The archaic Greeks spoke reverently of *propsopon*, or a face facing another face. Two opposite faces make up a mutual relationship. One face reacts to another, and the other face reacts to the other's reaction, and the other reacts to that reaction, and so on ad infinitum. The relationship then lives on as a third thing or state of being [(Heim, 1993, p. 77)].

The ideal of the face-to-face interaction is the background against which comparisons are made for all technologies that link two humans together. It is against this background of immediate or non-mediated communication that the concept of social presence has been discussed [(Short, Williams, & Christie, 1976; Rice, 1993)]. Typically, mediated communication is depicted as mechanically convenient, sometimes appropriate, but ultimately a limited substitute for face-to-face communication. If mediated communication is an inadequate substitute for face-to-face communication, then to what degree does a medium simulate the face-to-face presence of another? Or to what degree does a user feel the social presence of another?

The institutional context for the discussion of social presence has usually been organizational communication: communication in workgroups, business, and other settings involving decision-making, negotiating, and work coordinating groupings of human beings. This discussion is found most often in the context of computer supported cooperative work (CSCW) [(e.g., Walther, 1996)]. Issues of presence, how much, how little, and what kind are mapped to social psychological and sociological discussions of group harmony, social hierarchy and status, interaction satisfaction, deception, etc.

There are two practical design problems that have always been there in the design of media:

7.1.1. Transporting and displaying patterns of energy (e.g., light of video, the sound energy of a telephone) to generate the illusion of another (e.g., puppets, pictures, and avatars)

This is the perennial quest of telecommunication, the transportation of the senses. How can we use telecommunication technology to collapse space and storage devices to collapse time so that communication between two distant human beings is possible? At present, further advancement of this long standing design goal takes the form of the design of social virtual environments populated by avatars who display the real time transmission of some of the body's communication cues (e.g., morphology, motion, sound, and physical force).

7.1.2. Creating an artificial other (robots and animals)

Creating an artificial other is the age-old, God-overthrowing dream of human creativity, (i.e., robotics, artificial intelligence, etc.), the desire to create a device that can mimic the morphology, motion, and communication behaviors of intelligent sentient beings (i.e., humans, animals, etc.) or serve their creators in the performance of menial tasks [(Sheehan & Sosna, 1991)]. In virtual environments this social presence is the social presence created by agents.

On the surface the goal of social presence seems simple enough. But the design of truly interactive social presence is horrendously complex. The symbol of this challenge is the Turing test. It some ways it is only a limited challenge, because it requires little embodiment of the other -- the computer only types text messages to the "judge" who determines whether the other is an artificial intelligence or a human intelligence. A convincing, fully articulated being may be more challenging, and given the technology of the day, beyond the possibility that Turing imagined. But the presence of another body make the Turing test easier. If convincing morphology is present, less intelligence may be required to fool the user into believing that a human intelligence is "present." Users may be fooled by convincing morphology and believe an artificially intelligent agent is really a humanly directed avatar.

7.2 Definition of social presence

In past research it has been useful to consider what aspects of social presence are supported in media such as the telephone or email systems [(Short, Williams, & Christie, 1976; Rice, 1993)]. Researchers in this tradition have listed social cues and semiotic devices that are present or absent in a particular technology. The emphasis has been on the consequences of the absence of such cues on comprehension, collaboration, and other forms social interaction. Discussion focused on whether the glass of social presence was half-full or half-empty.

But if we dig a little deeper, we find that social presence may be a little more complicated and interesting than this initial discussion. The perception of social presence might be defined as:

> The minimum level of social presence occurs when users feel that a form, behavior, or sensory experience indicates the presence of another intelligence. The amount of social presence is the degree to which a user feels access to the intelligence, intentions, and sensory impressions of another.

How does this definition help us? As [Husserl (1973)] pointed out, we have phenomenal access to our intelligence, intentions, and sensory impressions. The perception of the other is the empathetic simulation of internal states of another "if we were there in the space" over there. The simulation of the other is based on bodily motions and cues. It occurs so easily that we fail to see the artifice of it all. A few, like severe autistics, cannot do it at all. Others overdo it when they anthropomorphize animals, the sun, plants, and other physical phenomena. Given the thousands of years of anthropomorphic projection, it is perhaps not surprising when recent research reminds us that we tend to anthropomorphize computers and treat them as "social actors" [(Reeves & Nass, 1996)].

Rather than seeing social presence as a partial replication of face-to-face communication, we should more generally see social presence as a simulation of another intelligence. The simulation is run in the body and mind of the perceiver, and models the internal experience of some other moving, expressive body. It is a simulation because the simulation occurs whether or not the moving object has intelligence or intentionality, whether the "other" is a moving human being or an animation composed of nothing more than moving patterns of ink. The definition above suggests that social presence applies to the mediated experience of *all forms of "intelligence."* This perceived intelligence might be another human, a non-human intelligence such as an animal, a form of artificial intelligence, an imagined alien or a god.

7.3 Hyperpresence

The definition of social presence also opens up other possibilities. It also suggests that although mediated social presence should be measured against the yardstick of face-to-face communication between two human beings, it may be possible to develop a medium in which one feels ***greater*** *"access to the intelligence, intentions, and sensory impressions of another" than is possible in the most intimate, face-to-face communication.* One aspect of what might be called ***hyperpresence*** [(Biocca, forthcoming)] may be possible in the social presence domain as well.

Of course, it is hard for us now to imagine a medium that can create greater intimacy than face-to-face communication. But this misses the point of social presence and the very artifice of the body itself. In face-to-face communication the body is used to communicate one's sensory experiences, observations, and inner states to another. The body is the medium for this transfer. Communication codes such as spoken language and non-verbal codes such as facial expression, posture, touch, and motion are used. But, for example, inner states might be communicated more vividly through the use of sensors that can amplify subtle physiological or non-verbal cues. These can augment the intentional and unintentional cues used in interpersonal communication to assess the emotional states and intentions of others.

Is This Body Really "Me"? Self Presence, Body Schema, Self-consciousness, and Identity

The definitions of telepresence [(Biocca & Delaney, 1995; Sheridan, 1992; Steuer, 1995)] imply that telepresence is possible because the subject of presence, defined as the subjective sense of being somewhere, is not the physical body of a person. Specifically, [Loomis (1992) and Heeter (1992, 1995)] refer to the "phenomenal body" and "self," respectively, as the subject of presence, and imply that the phenomenal body or the self does not always correspond with the physical body.

This phenomenal body or body schema has certain properties: e.g., perceived shape and size, perceived relative location of the limbs and senses, etc . Beyond this there is also an internal model of the self: e.g., perceived qualities or traits that "cause" behavior, perceived states, etc. So inside the virtual world there is more than a computer graphic representation of the self, there is an internal subjective representation of the self, that is a model of the self's body and a model of one's identity.

> *Self-presence* is defined as users' mental model of themselves inside the virtual world, but especially differences in self-presence due to the short term or long term effect of virtual environment on the perception of one's body (i.e., body schema or body image), physiological states, emotional states, perceived traits, and identity.

Self-presence refers to the effect of embodiment in the virtual environment on mental models of the self, especially when that model of the self is foregrounded or made salient. As with other forms of presence, designers share the assumption that increases in self-presence are correlated with higher levels of cognitive performance, and, possibly, emotional development. In the words of Socrates, the goal to "know thyself" is a worthy journey -- it may be the only journey!

Questions of identity formation and self-consciousness are very broad issues pertaining to the formation of the individual. Most processes are by no means unique to virtual environments. But the interaction with computers raises some interesting questions in this domain [(e.g., Turkle, 1985)]. So in assessing the role of virtual environments in influencing self-presence, we should concentrate on those aspects of the environment that are radically different from the physical world.

Two issues emerge as most pertinent to virtual environments as opposed to physical environments. Both pertain to the effect of progressive embodiment, that is, the embodiment of the user's body via close coupling to the interface and representations of coupled body via first person avatar geometry and behavior.

8.1 Embodiment in an avatar and the effects of mental model of the self

When the user is embodied in an avatar two things are occurring:

- the mental model of the user's body (body schema or body image) may be influenced by the mapping of the physical body to the geometry and topology of the virtual body,

- The virtual body may have a different social meaning (i.e., social role) than the user's body.

The latter, the social meaning of the avatar, is situationally or environmentally dependent. For example, a "cowboy" avatar will have different social meaning in historic "wild west" environment, a "New York Bar" environment, or inside a pickup truck in a contemporary southern rural environment. The social role of avatar body is partially determined, but not defined, by its geometry and kinematics. Implicit and explicit social norms that may be partially idiosyncratic to the virtual environment and imported from the user's social environment finalize the social-semiotic role and identity of the avatar. Issues of class, gender, occupational role, body type, etc. are raised when considering this aspect of embodiment. The social meaning of body morphology and social role and its effect on the self-schema is a rich area. But most aspects of it (e.g., stereotyping) are not particularly unique to virtual environments, and only partially under the control of designers. For this reason, I will not pursue it further here.

Rather I will pursue a topic more unique to virtual environments. The interaction of the virtual environment with the user's body schema in immersive virtual environments may have a number of implications for the design of virtual worlds. We can say that in almost any virtual environment system with any significant level of embodiment, there are three bodies present: the objective body, the virtual body, and the body schema. These three bodies may be present even in comparatively primitive, non-interactive virtual environments like standard television [(Meyers & Biocca, 1992)]. The objective body is the physical, observable, and measurable body of the user. The virtual body is the representation of the user's body inside the virtual environment. The body schema is the user's mental or internal representation of his or her body.

Our body schema is a not stable, but labile [(Fisher & Cleveland, 1968; Fisher, 1970)]. The use of media can radically alter one's body schema. In virtual and augmented reality systems, changes in the location of the represented head or hands can significantly distort the body. [Biocca and Rolland (in press)] found that a small displacement of vision in an augmented reality system triggered disruptive visuomotor adaptation [(Welch, 1978)], or to put in another way a recalibration of the body schema. When the users exited the virtual environment and reached for objects in the physical environment, they exhibited significant distortions in hand-eye coordination. A short anecdote will make this clear. The first subject in the Biocca and Rolland experiment was drinking a cola prior to beginning the study. As the end of the study, she reached for her cola and quickly raised it to drink only to discover that she was about to pour it into her eyes! In this case, the coordinate system of the visual system and the motor system (specifically, the hands) had adapted to the geometry of the virtual body, which had a different structure. The objective body was now "out of sync."

Distortions in body schema can also result from exposure to implicit representations of the self, even in non-immersive environments like television. [(Meyers & Biocca (1992)] found that exposure to videos that emphasized an ideal body shape for women led to distortions in the their body schema. The saw themselves as thinner than the young women in the control group.

There are other ways in which the objective body and phenomenal body may be in conflict. Virtual environments cannot perfectly synchronize and map the moving physical body of the user with the user's virtual body or avatar. Representations of the body are never completely free of some form of mismapping between user action (motor outflow) and sensory feedback (sensory inflow). This mismapping often leads to some form of intersensory conflict. Intersensory conflict, or the mismapping of the moving body, is believed to be the source of simulation sickness [(Biocca, 1992)], a form of motion sickness experienced by some users of immersive virtual reality.

What are we to conclude about embodiment and the design of avatars? It appears that embodiment of the user in virtual environments may not be a trivial design question. Problems such as intersensory conflict suggest that the design of the user's avatar should not be seen as some virtual environment equivalent of the selection of clothing or costume, especially in immersive virtual environments. It appears that embodiment can significantly alter body schema. Metaphorically, we might say that the virtual body competes with the physical body to influence the form of the phenomenal body. The result is a tug of war where the body schema may oscillate in the mind of the user of the interface [(see Meyers & Biocca, 1992)].

The Cyborg's Dilemma

As we approach the beginning of the next century, the problem of embodiment and the representation of the body has become a central problem in a number of overlapping, intellectual debates. Most appear to be directly or indirectly stimulated by the progressive development of technologies of the body, especially the development of new sensing and display devices. In the neurosciences the development of sensing devices such as MRI, CAT, and PET scans has contributed to a discussion of the role of body in fundamental representational processes associated with reason and emotion (e.g., [(Damasio, 1996)]. In the design of artificial intelligence, embodiment is debated in discussions of the role of body, its function in ongoing representations of the external world, and its role in plans and action (e.g., Haber & Weiss, 1996; Johnson, 1987; Lakoff, 1987; Lakoff & Johnson, 1980)]. In the humanities, a concern over embodiment, fanned by feminist studies, debates the representations of the body, mostly as circulated in media technologies such as film, TV and the Internet, and its effect on social roles and identity. Here we see Foucault-influenced [(Foucault, 1980)] debates about "technologies of the body."

Another version of our concern with the progressive embodiment is becoming visible. The evidence of this concern can be found in our fascination with the idea of the cyborg, the interface of the physical body with technology (e.g., [Gray, Figeueroa-Sarriera, & Mentor, 1995)]. The level of progressive embodiment found in advanced forms of virtual environment technology can be characterized as a form of cyborg coupling, the body coupled with its technological extensions. This coupling, I have suggested, is progressive. It is increasing over time and the body is getting tighter and more integrated into every life (e.g., miniaturization, ubiquitous computing, and wearable computing). This soma-technic coupling is beginning to highlight what I call the cyborg's dilemma, a kind of Faustian bargain between us and our technological alter-egos:

> *The cyborg's dilemma:* The more natural the interface the more "human" it is, the more it adapts to the human body and mind. The more the interface adapts to the human body and mind, the more the body and mind adapts to the non-human interface. Therefore, the more natural the interface, the more we become "unnatural," the more we become cyborgs.

In this article I have suggested ways in which the interface is becoming more "human": in virtual and augmented reality, for example, the interface's sensors and effectors are increasingly mapped to the body's senses and motor systems; in the design of agents and avatars the interface presents itself with a human face; and once inside the interface the user's body is experienced in digital form. These are the immediate sources of the cyborg's dilemma.

But my characterization of the cyborg's dilemma also raises a number of important issues. First, my description might suggest that there is an escape from the cyborg's dilemma. Some might feel that we can reject the new technologies and avoid the uncertain choices and changes implied by the cyborg's dilemma. It is not that simple. Anyone who believes that there is a "natural" place where the body is not wedded to technology may be embracing both technology and self-deception. Cyborg theorists point out that "we are already cyborgs." We may have been cyborgs for centuries. The cyborg's dilemma is present in our acceptance of the most primitive technologies: in a piece of clothing, in a wrist watch, in a baseball bat, in short, in all technologies that attach themselves and augment the body.

Secondly, it raises questions of what is "natural" about our relationship to our technology. We tend to think of technology as something alien, not a reflection of ourselves. Maybe we have been designed to be cyborgs. It may be our nature, therefore "natural," to embrace our technologies. What do I mean? A number of scholars have pointed to the similar neurological, cognitive, and structural substrates shared among language, fine motor movements, and tool use (see [(Gibson & Ingold, 1993)]. It may well be that the human brain and body evolved to fully inhabit these externalizations of mental processes and amplifications of the body that are our technologies. We are inhabiting and building what [(Popper (1972)] calls the third world, a world that is not the first world, the self, or the second world, the physical world, but the stamping of human form on matter and energy. In the cyborg there may be part of an evolving harmony of the self with the humanly design and extended forms of physical matter and energy.

In his classic essay, "The role of somatic change in evolution," [Gregory Bateson (1972)] outlined what he called "an economics of somatic flexibility." In the push for somatic flexibility in response to pressures in the environment, he posited three classes of beings: adjusters, regulators, and extraregulators. Humans were the classic example of the class he called "extraregulators." Extraregulators achieve "homeostatic control outside the body by changing and controlling the environment" (p. 362). Evolution, he said favored the "extraregulators" who pushed the "locus of control" for the somatic change to engineered changes in the environment. In this way they achieved greater level of somatic flexibility. There is much detail in this argument to work out and I cannot attempt it here. But if this perspective on human and technological evolution is on the right track, it says something significant about the relationship of the body to technology. It suggests that we are designed to be cyborgs, to achieve a tighter and tighter coupling of our minds and bodies with the externalizations of ourselves, that part of the physical world that is mixed with human forms, that part that is our technology.

Thirdly, the cyborg's dilemma raises profound questions about the locus and stability of our individual identity. The pursuit of presence and the telecommunication of the body pushes a tight coupling of the physical body and the computer interface. To the degree that cognition and identity are embodied in the simulations run by our sensors and effectors, then the mind in advanced virtual environments becomes also adapted to a mediated body, an avatar, a simulation of the cyborg body. Observing the day-to-day movements of our consciousness between the experience of our unmediated body and our mediated virtual bodies, we may come to ask: Where am *"I"* present?

Footnotes

[1] © 1997 IEEE. This article is an expanded version of a keynote address given at the International Cognitive Technology Conference in August, 1997. This expanded version is printed with permission from J. Marsh, C. Nehaniv, & B. Gorayska (1997). *Proceedings Second International Conference on Cognitive Technology* (pp. 12-27). August 25-28, 1997, Aizu, Japan.

[2] Those readers familiar with McLuhan's work will see the echo of McLuhan's warning about the "Narcissus trance" that our technologically "amputated" senses present us. But here, I argue that rather than technological "amputation," I have a form of technological adaptation.

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