# VIRTUAL WORLDS: NO INTERFACE TO DESIGN

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### Introduction

In a virtual world, we are inside an environment of pure information that we can see, hear, and touch. The technology itself is invisible, and carefully adapted to human activity so that we can behave naturally in this artificial world. We can create any imaginable environment and we can experience entirely new perspectives and capabilities within it. A virtual world can be informative, useful, and fun; it can also be boring and uncomfortable. The difference is in the design.

The platform and the interactive devices we use, the software tools and the purpose of the environment are all elements in the design of virtual worlds. But the most important component in designing comfortable, functional worlds is the person inside them.

Cyberspace technology couples the functions of the computer with human capabilities. This requires that we tailor the technology to people, and refine the fit to individuals. We then have customized interaction with personalized forms of information that can amplify our individual intelligence and broaden our experience.

Designing virtual worlds is a challenging departure from traditional interface design. In the first section of this chapter I differentiate between paradigms for screen-based interface design and paradigms for creating virtual worlds.

The engineer, the designer, and the participant co-create cyberspace. Each role carries its own set of goals and expectations, its own model of the technology's salient features. In the second section of the chapter I address these multiple perspectives, and how they interrelate in the cooperative design process.

In conclusion, I consider broader design issues, including control, politics, and emergent phenomena in cyberspace.

### Shifting Design Paradigms

We can identify the paradigm shifts between traditional interface design and designing virtual worlds by distinguishing those unique capabilities of virtual world technology that add new elements to the design task.

*From Interface to Inclusion*

An interface is a surface forming a boundary between two regions. On a computer, this surface is the screen of the monitor, a boundary between the information environment and the person accessing the information. Traditional interface design has concerned itself largely with how that screen can present the most effective indication of a program's scope and functionality, and how to interact with screens.

Using a head-mounted display (HMD) and position trackers allows us to move through the screen's barrier, to interact directly with various information forms in an *inclusive* environment. The quality of this distinction between viewing and inclusion can be illustrated with the following analogy. Viewing 3-D graphics on a screen is like looking into the ocean from a glass-bottom boat. We see through a flat window into an animated environment; we experience being on the boat.

Looking into a virtual world using a stereographic screen is like snorkeling. We are at the boundary of a 3-dimensional environment, seeing into the depth of the ocean from its edge; we experience being between at the surface of the sea.

Using a stereoscopic HMD is like wearing scuba gear and diving into the ocean. By immersing ourselves in the environment, moving among the reefs, listening to the whalesong, picking up shells to examine, and conversing with other divers, we invoke our fullest comprehension of the scope of the undersea world. We're There.

Is eliminating this boundary essential to participation in cyberspace? It depends on what you mean by "cyberspace".

Cyberspace is still in its definitional infancy. The lexicon is in formative turbulence, and the relationship of existing information technology to virtual world implementations is not entirely clear. The necessity of using HMDs is one of many questions. Is electronic mail cyberspace? What part do interactive video environments and multi-media play? Must cyberspace be a social experience or can there be personal cyberspaces? Is every 3-dimensional computer display cyberspace? Are multi-sensory systems necessary?

Using the broadest possible definition of cyberspace as any computer-moderated information system, the question of how we connect with this system can be addressed separately. Our participation in cyberspace then become a matter of the bandwidth of our access.

We can create and enter cyberspace in localized virtual worlds of video, computer graphics and sound. These interactive environments now run independently, but the goal is to connect them into a networked cyberspace matrix. We can interact with the existing matrix of computerized communications using text and two-dimensional graphics. When we add the capabilities of three-dimensional graphics, we both increase the information density and allow more accurate understanding of what we see. Multi-sensory interaction adds additional layers of perception and meaning to our experience.

The widest bandwidth of participation in cyberspace is enabled when we pass through the barrier of the computer screen, to inhabit, fully sense, and interact directly with people and information. Inclusion, this ability to get inside of information, defines a new generation of computing [1].

The personal impact of inclusion within a virtual world has been documented; in questionnaires given 300 participants in Autodesk's cyberspace, "being inside" the virtual world was rated as the most compelling aspect of the experience.

An important design consideration stemming from inclusion is that while we interact within a virtual world, we are simultaneously inhabiting the physical world. People are functionally attuned to the earth's gravity and to vertical position. Perceptual conflicts between the virtual and physical worlds cause physical discomfort and feelings of disorientation that can last well beyond the period of inclusion.

We finesse the problem of conflict when using transparent HMDs, which allow natural orientation cues to exist behind superimposed virtual world elements. When using opaque HMDs, orientation cues imbedded into the design of the virtual world are essential.

The fundamental visual feature for vertical orientation is the extended ground plane. Using a clearly defined virtual horizon allows us to engage our natural use of peripheral vision for orientation. The elements of the virtual environment then exist in relationship to that horizon, which serves as a fixed point of reference. Including depth cues in the ground plane is helpful in judging the size and distance of objects: a grid works, so do elements like train-tracks or roads.

Maintaining congruence between the virtual horizon and of our physical position is another design consideration. Even a small disparity between the groundplane of the physical and virtual worlds can throw you off balance because your eyes and your inner ears are getting conflicting messages.

As a point of reference for our own location in cyberspace, the virtual hand (ideally, the virtual body) is both evocative and functional. It is compelling to see your virtual fingers move as you wiggle your hand. Watching your dynamic self-representation within the virtual world is convincing evidence that you're There. And when you're sitting in a chair and simultaneously swooping through a virtual city, focusing on the hand pointing out in front usually eliminates feelings of vertigo.

Slow system response-time can also cause dizziness; any lag between turning our head and seeing the world go by is disorienting. This is a design challenge for engineers; no amount of contextual artifice will compensate for lag.

### *From Mechanism to Intuition*

Virtual world technology adapts computers to human functioning, rather than training people to cope with interactions based on the computer's mechanism. When we use natural rather than symbolic behaviors, like reaching out to turn an object rather than specifying the view with a coordinate system, we don't have to think about how to do things. We can focus our attention on what we we're doing.

It's easy to make mistakes in a symbolic interaction, but turning your head to see what's behind you is inevitably successful. Moving around by pointing in the direction you want to go is equally straightforward, and speaking is the way most people communicate their intentions. These intuitive behaviors are hard to get wrong. There is a natural mapping between intention, action and feedback.

Visceral access and intuitive interaction evoke our full sensory-cognitive capacity to comprehend. The computational environment becomes a more powerful tool which is also easier to use. New groups of people have access to cyberspace. You don't have to know anything about computers; you don't even have to know how to read.

The task of designing a virtual world, then, does not rest on helping people interpret what the machine is doing, but on determining the most natural and satisfying behaviors for particular participants, and providing tools that augment natural abilities.

### *From User to Participant*

Among software developers, the term *user* refers to the generic person who, at the end of the programming and interface design process, receives a software application geared to "average" human functioning. *Participants* are active agents. In cyberspace we will use software tools to create our own applications, and to co-create the matrix.

Sensory coupling requires us to regard each participant as an individual, and individuals are highly idiosyncratic. Is tailoring this technology to each person too expensive and time-consuming to consider seriously?

A precedent for fast and easy customization exists in the configuration process of the DataGlove(TM). Gesture recognition is specific to the size and proportion of each hand, and hands are highly variable. So each person who puts on the glove makes three quick calibration gestures, after which the movement of that particular hand is recognized. It's a piece of code.

However, accounting for physiological differences is not always that easy. For example, a HMD used in the presence of vibration (such as jet cockpits) shifts position on the participant's head as it shakes in response to the oscillation. The display can be dynamically stabilized for a certain range of movement. But people respond differently to vibration, in proportion to their height, their weight, and even their level of muscular tension. Tense people get moved around by vibration more than relaxed people. Tailoring display stabilization to these differences is not a trivial task [2].

The design of these customized virtual worlds will require our most sophisticated human factors expertise. Reciprocally, it seems inevitable that this new domain will enlarge the scope and diversity of human factors testing. In one HITL project, we're constructing a virtual airplane for doing research on human fit, view and reach in cockpit and cabin design.

In the virtual cabin we'll be able to move along the isle, choose a seat, and see what kind of view we get from the window beside our seat; we can stretch our our legs to see if they'll fit comfortably, and look to be sure we can see the the movie screen. In the virtual cockpit we can sit in the pilot's seat to see if the controls are easy to find and within reach, and if we can see the instrumentation readouts from that position.

By using virtual environments to do ergonomic testing on aircraft and other products during the design phase, the manufactured result will be more comfortable and efficient for us to use. And the manufacturing process will cost less because design mistakes are recognized and changed before they're implemented, saving time and materials.

*From Visual to Multimodal*

The more sophisticated virtual worlds are acoustigraphic environments, achieved by coupling 3-D sound systems with the stereoscopic head-mounted display. Both ambient and localized sounds are coordinated with the graphical representations and with the movements of the participant. We can hear the sounds of traffic in the distance and wind rustling the leaves that move in nearby trees; we can listen to each fish tell a tale as it swims through a musical stream. Haptic feedback devices are being developed to create the illusion of substance and force within the virtual world; we can feel textures or terrain or the pull of gravity [3].

These capabilities require designers to consider issues of sensory load related to individual learning and performance styles. People who understand what they hear more easily than what they see could have a world where objects are located by sound and acoustic icons are used.

Creating meaningful and aesthetic combinations of sight, sound, and touch in a virtual world is a complex engineering and design task. One parameter is fidelity between the location of a sound source and the location of its associated visual image. In some applications approximate locations of sight and sound will suffice; in the same way we perceive that a voice is coming from the ventriloquist's dummy, visual cues will override small discrepancies. Other applications, such as concert hall design, will require exacting acoustical models. Ranges of tolerance for mixed-modal operations and for sensory ambiguity and paradox are challenging research questions.

*From Metaphor to Virtuality*

Metaphors are essential to human understanding [4], and have been thoughtfully employed by interface designers to offer the computer user a clear mental model of what to expect from a particular application. The "desktop" metaphor is one of the most useful and widely known examples of this technique.

Cyberspace participants interact directly with the virtuality to experience the embodiment of the application. This environment is "as if real".

When we use a metaphor to describe an unfamiliar place or process, we think, "it would be approximately like that". When we are inside an environment, we think "it is exactly like this". We don't rely on the metaphor of "house" after we've moved in to our home; we do build a particular cognitive model of our specific domain (to predict where to find our socks, or get around in the dark).

Thus, metaphors serve a different purpose in virtual world design. They become valuable as organizing principles for designers. Theater, architecture, games, and foods have been suggested as useful metaphors for approaching the complex dynamics of cyberspace organization and interaction [5].

In cyberspace, appearance IS reality. And virtual appearances are completely arbitrary. Despite injunctions not to judge books by their covers, nor to assume that what glitters is gold, we judge real-world things and people by their appearance all the time. Within virtual worlds, we will need alternative criteria for evaluation, especially in our interactions with others. Is there a distinction between the message and the virtual messenger?

## Multiple Models of Cyberspace

Virtual world technology provides interactive environments tailored for participants. Hardware and software engineers create the interactive devices and tools; they focus on how systems work. Designers work with engineers to ergonomically refine prototypes and with participants to tailor systems to individual purpose; they focus on the people using the technology. Participants are concerned with costs and benefits of the system, and focus on their particular virtual world.

Because engineers are concerned with execution, designers with evaluation, and participants with function, they have different conceptual models of the system. To co-create cyberspace requires communication based on some reciprocity of perspective between these groups; awareness of these multiple models is a starting point.

*The Engineer's Model:*

The perspective of engineers is based on implementation. Their goal is to make the technology work. Their model of the system involves the functional intricacies of hardware and software, and their priorities are structured around what is technically possible, or at least feasible.

The technical feasibility of the HMD was demonstrated nearly 30 years ago, and engineers have been refining it ever since. Developments in computer chips and display technology have brought down costs, and now HMDs are economically feasible as well. Engineers are working to provide configurable or optional types of head-mounted display:

* Opaque (for immersion in the virtual world)

* Transparent (for virtual worlds superimposed on reality)

* Acoustically coupled (for 3-D sight and sound)

* Eye-tracking coupled (for control by looking)

* Microphone or ear-mike transducer coupled (for hearing and voice commands)

The obvious problems with the current HMDs are that they're bulky and low in resolution. In search of unobtrusive HMDs, projects that anticipate emerging capabilities in micro-chip and laser technology, such as the micro-laser scanner, are underway. The tiny HMD micro-laser is designed to safely scan pictures directly onto the retina of the eye. This device could allow us to see detailed virtual worlds with the comfort of sunglasses and the clarity of natural vision.

Engineers are also creating and adapting devices for interacting with virtual worlds. There are several kinds of peripherals for this purpose, including:

* Computerized clothing that recognizes physical gestures as commands

* Systems that track the movements of the body

* Trackballs and joysticks that allow movement of perspective

* Devices that allow interaction with 3-D objects such as the bat, wand, and glove

* Feedback devices that use force, pressure, or vibration

* Remote operation systems that translate human movements into the control of machinery

Software engineers are developing new ways for us to represent and interact with information. They are creating the tools we'll use to construct and manipulate virtual world objects and systems, such as:

* Virtual world and matrix operating systems

* Interactive 3-D graphics construction and animation packages

* Specialized information structures and query systems

* Multi-modal data visualization and display techniques

* Spatial fields and topologies

* Autonomous agents and entities

Sophisticated software can provide us with dynamic entities, forces, and patterns in even a relatively simple private virtual world. We can have weather, and gardens that grow and flower and seed to grow again, and independent creatures that come and go for their own reasons. Within these systems we can slow time or speed it up or run in different time-streams. Autonomous entities provide complexity and surprise [6].

*The Participant's Model:*

Most people are more interested in what they *do* in cyberspace than how the system works. The participant's model of the system is based on their experience with it [7]. From the participant's perspective within the virtual world, the environment exists "as if real". The interface technology disappears from view, and the particular acoustigraphic context defines the domain. The participant in the virtual world asks the essential questions of humankind:

Where am I? Your primary understanding of the virtual world will derive from what you see and hear when you put on the HMD. You can be nowhere or anywhere, as defined by the the acoustigraphic context in which you find yourself. Information forms are utterly malleable; you can be inside worlds patterned after real locations like a city, another planet or a human body, and you can vary the scale or physics or attributes of the location. You can create your own new worlds to explore, or you can travel through the matrix to visit public virtual environments.

Who am I? What will your virtual self look like? How will you sound? You don't need a body; you can be a floating point of view. You can be the mad hatter or you can be the teapot; you can move back and forth to the rhythm of a song. You can be a tiny droplet in the rain or in the river, you can be what you thought you ought to be all along. You can switch your point of view to an object or a process or another person's viewpoint in the other person's world.

Assuming multiple perspectives is a powerful capacity; only after young children are developmentally ready to understand that each person sees from a different perspective can they learn to relate to others in an empathetic way. What will we learn from adopting the countless perspectives of cyberspace?

What can I do? There are five general categories of behaviors:

* Relocation: You can move around in your virtual body the same way you do in the physical world, by walking and turning, bending and reaching; you're presently limited to the range of HMD cables and the field of the position tracker, but less constraining systems are being developed. You can fly; using a gesture, joystick or trackball, you can move smoothly with variable speed in any direction. You can jack in to a new perspective, instantly transferring to a new location with or without your virtual body, by naming or pointing to your destination. In cyberspace, the concept of "distance" is optional; relocation is independent of time and space.

* Manipulation: You can move virtual objects with your hands or with your eyes, or you can use a 3-dimensional cursor or wand. You can tell an object to move, or you can program patterns of movement for an object or set of objects.

* Construction: Presently, you build virtual worlds from the outside, and then enter into them. The ability to interactively create and alter these environments is being developed in the form of software toolkits. Your ability to shape and visualize information will depend on the tools you use; do you prefer virtual palette knives or hammers, lasers or sieves?

* Navigation: Finding your way around in a small virtual world is not difficult; when you can travel through large databases and within the interconnected systems of the matrix, new methods of locating objects, and navigating between domains may be needed. What techniques of wayfinding are most effective in large, complex worlds? Will you create a virtual guide? Or, will you choose an animistic universe in which guidance is embodied into the information form; when you want to find out more about a chair you can ask it, and if you loose it, call it's name and it appears. Or you jack in to its location. Do we need maps if there is no distance?

Who is with me? The feasibility of sharing virtual spaces has been demonstrated, but this aspect of cyberspace is now primarily speculative. How will other people be represented in your virtual world; do you control their appearance or do they convey a fixed form to you? The usual concept of "who" people are implies some consistency, but in cyberspace people can adopt an ambiguous form or multiple personae. The meaning of personal appearance changes; in the physical world, you predict certain behaviors from the way a person looks, but what expectations do you have of a winged lobster?

Unique social and cultural forms can emerge in cyberspace as we negotiate the mutual control of a shared environment and decide on conventions for our behavior within it. When we connect with the matrix, how will we choose the company we keep? Can cyberpunks form virtual tribes, and can intruders be deleted?

*The Design Model:*

Designers focus on the way people access and interact with cyberspace. The designer's objective is the creation of comfortable, functional virtual worlds that satisfy the needs and intentions of the participant. Four aspects of this design task are discussed.

1. Designers work with engineers to tailor the technology to people's physical and psychological needs by testing the usability of systems and suggesting refinements.

For example, some of the devices we use to move around inside a virtual world afford more maneuverability than the human body is accustomed to. In one phase of Autodesk's cyberspace project, engineers incorporated a trackball with six degrees of freedom and fast response time for moving around inside a virtual office. In first testing the trackball, we tumbled into perspectives we could barely interpret and careened through the walls and floor. Even after a significant amount of practice, control was elusive.

People found moving through space in this way both frustrating and disorienting. They would lurch into a weird position and then try to reorient toward an upright view. They approached that task by making a series of small adjustments in their perspective, but each one required conscious interpretation of the new position ("Where am I now?"), and planning of the next adjustment ("Where do I want to be?"). The simultaneous changes in pitch, roll, and yaw as well as direction in 3-space was confusing; people are not used to moving without the guiding constraints of ground and gravity. Readjustments were error-prone; many participants would get three or four of the degrees of freedom right, while spinning out in the others. It was an interesting sensation, but it stopped being fun almost immediately; queasiness set in.

In response to these observations, we constrained freedom of movement. We chose to hold roll constant to the horizon; rolling sideways had the most disconcerting effect on people. This change improved control, and we had fewer complaints of disorientation. Several people did ask to try the unconstrained mode, just for the experience; a few moments of swooping and plummeting satisfied their curiosity, and confirmed the usefulness of the constraint. Another approach that we didn't test would be to slow the trackball's response speed.

2. Designers work with participants to customize virtual worlds. This requires a dual awareness of the individual needs and preferences of the participant and of the capabilities of the technology.

Eliciting preferences can be done in much the same way an architect works with a client building his home [8]. Physical and perceptual characteristics of the participant will need consideration, such as motion sensitivity, color blindness, handedness and manual dexterity, information mode attention and retention.

The designer can provide participants with information about different cyberspace platforms, software packages and peripheral devices. Systems provide varying levels of complexity and dynamics in the virtual world.

For example, the PC-based cyberspace system currently limits the graphic image of the virtual world to about 500 flat-shaded polygons in order to achieve a rendering rate of 7 frames per second. (Alvy Ray Smith of PIXAR has estimated that we perceive the equivalent of 80 million polygons at 30+ frames per second when we look at a view of the real world. [9]) People often accommodate to the leisurely frame rate by slowing down their physical movements.

VPL's RB1 system allows models ranging from 1,500 to 15,000 Gouraud-shaded polygons to render at about 20 frames per second, depending on the power of the graphics engine. Elements of the display can be animated, at no cost to rendering speed.

3. Designers compose protoworlds that contain the graphical contexts and interactive possibilities appropriate to particular applications. A protoworld is composed of the default acoustigraphic context, appropriate libraries of objects and sounds, and the vocabulary of interactions available in the virtual world.

We can compare the protoworlds being considered for two HITL projects, Cyberseas and Virtual Mobility.

The Cyberseas system, intended for shipboard use, will translate real-time sonar and acoustic tomography data into a display of undersea terrain and objects. An opaque HMD configured for 3-dimensional sight and hearing will allow the wearer to perceive images of whatever lies in the depths below. The protoworld's default context is a configurable terrain horizon; this will update to reflect the shape of the sea floor as transmitted by remote sensors beneath the ship. The acoustigraphics library will contain objects such as fish that you can hear coming; the pitch of the associated sound becomes higher as the fish approach the participant and lower as they move away. Viewing interaction will allow relocation by virtual movement to any point or perspective within the sensors' range, or the ability to jack in to a remotely operated vehicle (ROV).

The Virtual Mobility project is intended to allow paraplegics to access cyberspace as a working environment for doing computer-aided design (CAD). A transparent HMD allows the wearer to maintain physical-world orientation and awareness. The default context is empty. This protoworld's graphics library will contain CAD objects and menus. Interactivity will be tailored to the individual, since the physical capabilities of paraplegics vary significantly. Pick and place tasks can be performed using voice, eye-tracking, and different facial muscles as controls.

4. Designers evaluate effective worlds by observing the learning, accommodation and performance of participants. The ideal computer domain is fully explorable [10], allowing the participant to build a specific cognitive model through experience. A virtual world is inherently information-rich, and if feedback is explicit, the discovery process appears be a relatively efficient way to learn.

One example of this learning process was observed in some detail. Nearly 100 people, including members of the CHI '90 "Local Showcase Tour", explored two virtual worlds at the HITL. Virtual Seattle and Octopus's Garden were designed at the Lab as introductory adventures in cyberspace. They were running on VPL's RB1 system. All demonstrations were videotaped for later data analysis.

Virtual Seattle was a large-scale model centered on the Puget Sound; the city contained landmarks such as the Space Needle, the King Dome and a reasonably accurate skyline. The horizon was defined by mountains. The model was animated; a ferry moved back and forth from a terminal under the Olympics to the docks of Seattle, and an Orca surfaced several times as it moved north in the Sound. This was a viewing and movement demonstration, and the participant could either fly around or jack into the perspective of the ferry as it shuttled between destinations.

Octopus's Garden was an undersea plateau with large rock formations, swaying seaweed, and a school of fish that drifted in and out of sight. The large pink octopus moved about under the control of the system operator using the mouse. There was a treasure chest containing a bag of gold that could be removed and a starfish that could be detached from the rock arch to which it clung. There was also a small remotely operated vehicle (ROV). One could jack into its perspective, or the perspective of the octopus, school of fish, or starfish.

A human guide acted as the kind of query system that might eventually be incorporated into virtual worlds. Participants were introduced into these worlds after a brief description of the gestures that allowed them to fly and to grab objects. Undirected exploration was allowed, and any questions were answered as asked.

Within the first one or two minutes, there were usually three kinds of questions: "Why can't I go there?" (we were testing the concept of a constrained zone of movement in Virtual Seattle; answer: "There are invisible walls around this world."); "Where am I?" (always asked from inside an object such as a mountain or building; answer: "You're inside the <object>"); and "Why aren't I moving" (pre-programmed glove gestures using thumb-controlled speed demanded more manual dexterity than many participants were capable of; answer: "I'll move your hand into the gesture for flying", followed by the physical action).

After two or three minutes, most people demonstrated a clear understanding of the capabilities and constraints of these worlds. They were fully functional and without further questions. Participants engaged in a wide variety of behaviors. In Virtual Seattle they peered down the Space Needle, chased the Orca, got inside the ferry, flew down the city streets, and looked into the King Dome to see who was playing. In the Octopus's Garden they swam alongside the fish, played tag with the octopus, retrieved the bag of gold, stuck the starfish into the seaweed and explored the inside of the rock pile and the ROV.

These were relatively simple domains. Although few of the participants had experienced the technology before, individual learning time was remarkable short. There were no reports of frustration or feelings of failure; most people volunteered exclamations of exhilaration and enjoyment. This is not the typical novice response to a new computer program.

People really do seem to find virtual worlds easy to figure out. However, a closer look at the design criteria for these particular models is important. All virtual worlds are not equally learnable. How quickly and accurately we build a cognitive model of the environment is influenced by the environment's design. For example, when a virtual world seems familiar to us from some real-world experience, we may accommodate to it more quickly.

Virtual Seattle was approached by participants in much the same way that the actual city would be: key landmarks were quickly identified and located in relation to each other. Remembering where buildings were located did not seem to cause any difficulty. Participants who were local residents gave names to the buildings, identified the particular ferry route, knew where they wanted to go and spent more time exploring the edges and limits of the domain; out-of-towners wanted to ride the ferry, see inside the space needle and watch for the Orca. Although preference for activities varied, adaptation time was consistently short. There was very little disorientation reported by participants in this model.

The Octopus's Garden contained some familiar undersea elements in an unfamiliar context. It generally took longer for people to accommodate to this model. Relocating objects when they were out of direct view caused frequent difficulty. Participants tended to stay within the central area of the defined space, although there were no external constraints on movement in this world. Several people commented that they felt dizzy during or after the experience. Three participants were practiced scuba divers. They were quick to learn their way around and less constrained in their exploration than most; they all reported enjoying the experience very much, and agreed that it was "like really diving".

### Virtual Gods: Benign Design

Creating A World: giving form to intention, manifesting a dream, visualizing the unseen...this is a job for the gods, is it not? We are only human, but as we develop this technology and build worlds for individual and social use, we assume certain responsibilities. This final section is a personal perspective on subjective design considerations that seem particularly relevant to cyberspace. I'll address power, politics, and the undesignable.

*Power and Control*

There is no doubt that this is an empowering technology; but exactly who is being empowered? This is, in part, a design decision. The accessibility of affordable systems, the ease with which people can use them and the degree of control that individuals have over their participation in cyberspace will all be influenced by developers.

The power of the participant begin with access; who gets into cyberspace? The current development of relatively inexpensive systems along with high-end models indicates that the technology will be widely available. Once we're there, who's in control?

Application Control: The design of virtual worlds can induce passivity or facilitate creativity. An application that restricts the interactivity of the medium usurps the participant's power. Passive cyberspace experiences are being considered by some producers in the entertainment industry; their current priority is to reach mass audiences with canned worlds. They are not interested in training novices to become experts at creating their own entertainment; that doesn't sell tickets. Production cyberdramas will probably be enjoyable. But I'm bothered by the notion that we *need* them because its so hard to make interesting virtual worlds, and most people won't be good at it. Isn't the purpose of designing powerful intuitive tools to make it easy?

Social Control: When cyberspace becomes commonplace in corporations and schools, how will the power of the technology be distributed? The educational applications of cyberspace are stunning in concept, but I've heard teachers respond to this potential in two ways. One response focuses on the new experiences it will afford students, the other centers on the additional control teachers might have over student behavior. Who decides how cyberspace is used in schools?

Personal Control: I watched someone take control from a participant in the middle of a demonstration; he quietly switched power from the participant's glove to a trackball, which he (rather than the participant) controlled. Without warning, he spun the participant's perspective in every direction for about 10 seconds. It had a literally staggering effect on the participant, who emerged pale, dizzy, and visibly upset. I felt like I'd witnessed an assault. Cyberbummer.

If I had the influence of a science fiction writer, I'd propose two laws of cyberspace:

* Any person can access the cyberspace matrix (voluntary citizenship)

* Each person has full control of their interactions within cyberspace (human rights)

*Politics of Appropriate Technology*

How does cyberspace fit into The Way Things Are? Assessing the long-term political and cultural impact of this technology is difficult, but predicting its immediate impact is almost as hard.

I mentioned the Cyberseas project earlier. The potential applications for this technology include navigation, fish and submarine tracking, undersea resource management, ROV operation, and underwater construction, maintenance and repair. It sounds quite useful.

But, political issues are as numerous as the application areas, and include intense competition between various groups of fishermen, Indian rights, military secrets, the activities and attitudes of the Department of Fisheries, and the relative wealth and political power of the fishing industry, shipbuilders, and the Port of Seattle -- to name a few.

So, who are we designing for? Who will use this technology, and for what purpose? These issues are inevitable aspects of cyberspace development and will affect the kinds of virtual worlds that come into existence.

*The Undesignable: Emergent Phenomena in Cyberspace*

Adopting what in Zen is referred to as *beginner's mind* means approaching cyberspace without preconception, resisting the temptation to explain this new technology in terms of previous technology. A car is not simply a horseless carriage; cars have completely changed society. So have movies and TV, and so will cyberspace.

The advantage of this approach is that we're open to surprise. And in cyberspace there are moments we never anticipated, and experiences we never imagined. Spontaneous events occur, things that aren't designed, and indeed are undesignable. For example:

Rich Walsh moves forward to enter a virtual world for the first time. His body is paralyzed from his neck downward, and he controls the motion of his wheelchair with a joystick that he operates with his chin. His eyes are sparkling and he expresses his keen anticipation. Because he cannot use his hands, he asks me to wear the glove and fly him around. I assure him that I'll take him wherever he asks to go.

I place the HMD over his eyes and see Virtual Seattle, from his perspective, on a large monitor nearby. I ask where he'd like to go and he responds, "Wherever you like."

"I'll take you into the city", I state confidently, and proceeded to veer through the sky with no directional control whatever. I feel utterly awkward, knowing that this person is depending on me to guide him and that I'm getting nowhere. Rich is turning his gaze one way and then another, moving his wheelchair around to get closer to Virtual Seattle, while I'm trying every conceivable orientation of my hand relative to the view I have on the monitor, without successfully steering into the city.

Beginner's mind was easy -- I was baffled by the difficulty of the task, until I recognized that we were struggling as separate individuals, ignoring our functional interdependence. We may have understood this at the same instant. I oriented my hand directly over his head, pointing in whatever direction he turned, while we talked about how I couldn't see where to go unless he was looking and he couldn't go unless I could move. We suddenly became a symbiotic organism, functionally fused and operating as smoothly as the way one being coordinates the actions of its hand and eye.

It was an emotional rush, this seamless functional bonding with a stranger during several minutes of elated virtual world exploration. Later, in reviewing the videotape of this experience, I realized that a spontaneous vocabulary shift accompanied the new relationship; after we figured out just who we virtually were together, both sides of our conversation took plural form: "Where will *we* go next? Can *we* get inside that building?".

This was not an experience I could predict and design for, even in anticipation of Rich's condition. The symbiosis arose from our novel cyberspace interaction, not from his disability or my world-building. One day, Rich will steer himself through cyberspace with the same joystick he now uses to control his wheelchair. But the possibility of functional fusion between participants in cyberspace will remain.

This spontaneous aspect of cyberspace reveals its essential vitality: the emergence of the unimagined signals life and growth.

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