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The Condition of Virtuality

N. Katherine Hayles

Virtuality is the condition millions of people now inhabit. What it means to be in a condition of virtuality was whimsically demonstrated with a device developed at Xerox PARC and exhibited at a recent SIGGRAPH show, the huge computer graphics convention where developers come to hawk their latest wares, hard and soft. From the twenty-foot ceilings of the Art Show exhibit dangled thin red cords, like monstrous strings of spaghetti left behind by naughty giants who got in a food fight. Sometimes the strings hung quiescent; at other times they writhed like lively plastic snakes. Connected by transducers to data lines, the cords were sensing devices that measured the flow of information moving through the room. The more bits being sent over the wires, the more the cords gyrated. They were information weather vanes. Inside the walls of the gigantic Los Angeles Convention Center, a sprawling complex larger than many small towns, which way the wind blows had ceased to be a concern of the ordinary citizen. But how currents of information were flowing—who had access, at what baud rate, to which data banks—occupied on a daily basis nearly every one of the fifty thousand people who had come to this show.

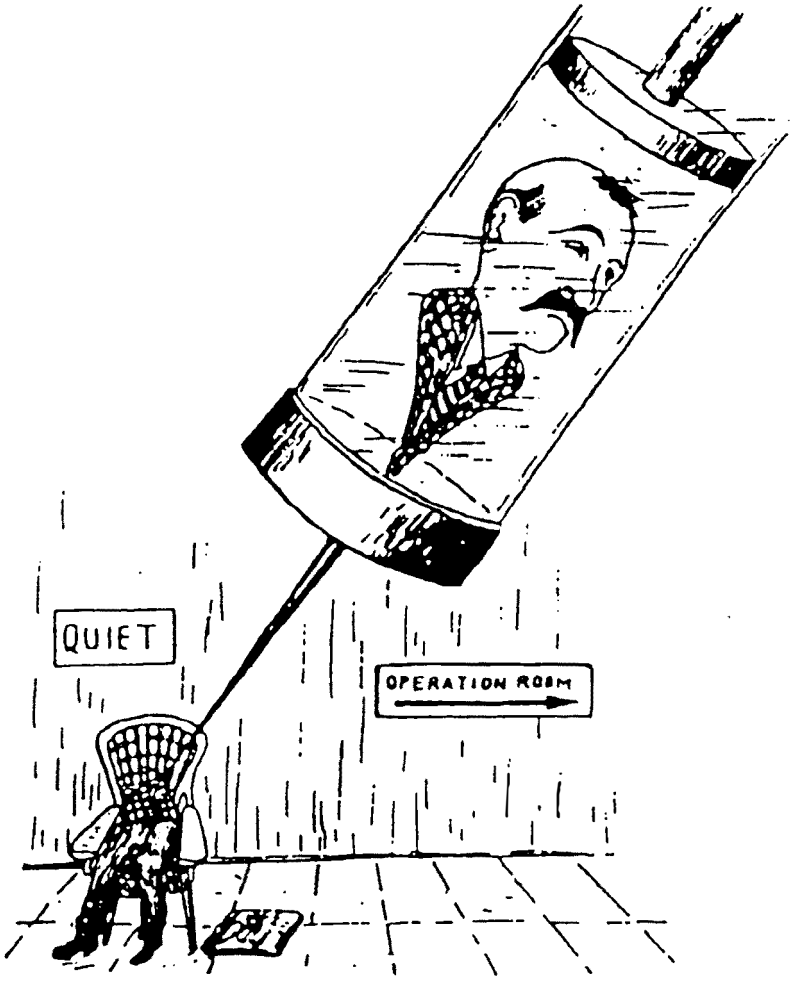
Let me offer a strategic definition. *Virtuality is the cultural perception that material objects are interpenetrated by information patterns.* Note that the definition plays off a duality—materiality on the one hand, information on the other. The bifurcation between them is a historically specific construction that emerged in the wake of World War II. When I say virtuality is a cultural perception, I do not mean it is merely a psychological phenomenon. It is also a mind-set that finds instantiation in an array of powerful technologies. The perception facilitates the development of the technologies, and the technologies reinforce the perception.[1] The analyses that constructed information and materiality as separable and discrete concepts developed in a number of scientific and technical fields during the 1940s and 1950s. The construction of these categories was far from arbitrary. The negotiations that produced them took into account existing technologies, and accepted explanatory frameworks and the needs of emerging technoscientific industries for reliable quantification. If the categories are not arbitrary, however, neither are they "natural." Whatever "nature" may be, it is a holistic interactive environment, not a reenactment of the constructed bifurcations that humans impose in order to understand it better.

One of the important sites for the construction of the information/materiality duality was molecular biology. In the contemporary view, the body is

said to "express" information encoded in the genes. The content is provided by the genetic pattern; the body's materiality articulates a preexisting semantic structure. Control resides in the pattern, which is regarded as bringing the material object into being. The idea that reproduction might be governed by an informational code was suggested by Erwin Schrödinger in his influential 1945 book *What Is Life? The Physical Aspect of the Living Cell*.[2] In his analysis of the discourse of molecular biology as "rhetorical software," Richard Doyle has shown how, in the decades following Schrödinger's book, the gene was conceived as the originary informational pattern that produces the body, even though logically the gene is contained within the body, not the other way around.[3]

This "impossible inversion," as Doyle calls it, is aptly illustrated by a popular science book of the 1960s that Doyle discusses, George Gamow's *Mr. Tompkins Inside Himself*.[4] On a visit to his doctor, Mr. Tompkins is sitting in the waiting room when he hears a sucking sound and feels a strange sensation of constriction. Somehow he is drawn into a hypodermic needle and then injected inside his own body. This mind-bending scenario reenacts the same manuever that is carried out, in more stolid fashion, in the scientific discourse when DNA is conceptualized as the genotypic pattern that produces the body as its phenotypic expression. Doyle's point is that this conceptual inversion is a rhetorical rather than an experimental accomplishment. It is in this sense that the discourse functions as rhetorical software, for it operates as if it were running a program on the hardware of the laboratory apparatus to produce results that the research alone could not accomplish.

By the 1970s, this vision reached rhetorical apotheosis in Richard Dawkins's *The Selfish Gene*.[5] Although Doyle does not discuss Dawkins's text in detail, it provides a perfect illustration of his argument. In Dawkins's rhetoric, the genes are constructed as informational agents that control the "lumbering robots" we call human beings. Virtually every human behavior, from mate choice to altruism, is treated by Dawkins as if it were controlled by the genes for their own ends, independent of what humans might think. Although he frequently issues disclaimers that this is merely a colorful way of talking, the metaphors do more than spice up the argument. As I have argued elsewhere, they function like discursive agents that *perform* the actions they describe.[6] Through this discursive performativity, informational



Mr. Tompkins Inside Himself.

pattern triumphs over the body's materiality—a triumph achieved first by distinguishing between pattern and materiality and then by privileging pattern over materiality. The effect of this "impossible inversion" is the same whether it occurs in Gamow's cartoons, Dawkins's metaphors, or the lavishly funded Human Genome Project. *It constructs information as the site of mastery and control over the material world.*

It is no accident that molecular biology and other sciences of information flourished during the immediate post–World War II period. The case can be made that World War II, more than previous global events, made the value of information real. The urgency of war highlights the fact that information is time-dependent. It matters little what information one has if a message can move only as fast as a horse can run, for by the time it arrives at its destination, its usefulness often has passed. Shakespeare's history plays are full of messages that arrive too late. Only when technological infrastructures have developed sufficiently to make rapid message transmission possible does information come into its own as a commodity as important to military success as guns and infantry are. From this we can draw an obvious but nonetheless important conclusion: *The efficacy of information depends on a highly articulated material base.* Without such a base, from rapid transportation systems to fiber-optic cables, information becomes much more marginal in its ability to affect outcomes in the material world. Ironically, once this base is in place, the perceived primacy of information over materiality obscures the importance of the very infrastructures that make information valuable.

Nowhere is the privileging of information over materiality more apparent than in Hans Moravec's *Mind Children.*[7] Moravec argues that human beings are essentially informational patterns rather than bodily presences. If a technology can replicate the pattern, it has captured all that really matters in a human being. To illustrate, he offers a fantastic scenario in which "you" have your consciousness downloaded into a computer. Although the technology could be envisioned in any number of ways (since it is imaginary in any case), he significantly has the robot surgeon conducting the operation physically destroy your brain in the process. As "you" are transferred into a computer, the trashed body is left behind, an empty husk. Once "you" are comfortably inside in your shiny new body, "you" effectively become immortal. For when that body wears out or becomes obsolete, "you" can simply transfer your consciousness to a new model.

I will not bother to lay out all the reasons why this vision, in addition to being wildly implausible, is wrongheaded and dangerous. Let me instead point out a correlation that helps to explain the appeal of this fantasy (for those who find it appealing). In Moravec's text, and at many other sites in the culture, *the information/matter dichotomy maps onto the older and more traditional dichotomy of spirit/matter.* The underlying premise informing Moravec's scenario is the belief that an immaterial essence, which alone comprises the individual's true nature, can be extracted from its material instantiation and live free from the body. As this wording makes clear, the contemporary privileging of information is reinforced by religious yearnings and beliefs that have been around for a long time and that are resonant with meaning for many people.

There are, of course, also significant differences between a mind-set that identifies human being with the soul and one that identifies it with information. Spirituality is usually associated with mental and physical discipline, whereas the imagined escape of the soul-as-information from the body depends only on having access to the appropriate high technology. For Moravec, the difference means the problem of mortality has been rationalized so that it is possible to make steady progress toward achieving a solution rather than flailing around in mystical nonsense. This construction of the situation obscures the fact that his text is driven by a fear of death so intense that it mystifies the power of the very technologies that are supposed to solve the problem.

To probe further the implications of constructing information and materiality as discrete categories, let us return to the period immediately following World War II. In addition to molecular biology, another important site for articulating the distinction was information theory. In 1948 Claude Shannon, a brilliant theorist who worked at Bell Laboratories, defined a mathematical quantity he called information and proved several important theorems concerning it.[8] Jacques Derrida to the contrary, a message does not always arrive at its destination. In information theoretic terms, no message is ever sent. What is sent is a signal. The distinction that information theory posits between signal and message is crucial. A message has an information content specified by a probability function that has no dimensions, no materiality, and no necessary connection with meaning. It is a pattern, not a presence. Only when the message is encoded in a signal for transmission through a medium—for example, when ink is printed on paper or electrical

pulses are sent racing along telegraph wires—does it assume material form. The very definition of information, then, encodes the distinction between materiality and information that was becoming central in molecular biology during this period.

Why did Shannon define information as a pattern rather than a presence? The transcripts of the Macy Conferences, a series of annual meetings where the basic principles of cybernetics were hammered out, indicate that the choice was driven by the twin engines of reliable quantification and theoretical generality.[9] Shannon's formulation was not the only proposal on the table. Douglas MacKay, a British researcher, argued for an alternative definition for information that linked it with the change in a receiver's mind-set, and thus with meaning.[10] To be workable, MacKay's definition required that change in a receiver's mind be quantifiable and measurable—an accomplishment that only now appears within reach through such imaging technologies as positron emission tomography. It certainly was not possible in the immediate post–World War II years. It is no mystery why Shannon's definition rather than MacKay's became the industry standard.

Shannon's approach had other advantages that turned out to incur large (and mounting) costs when his premise interacted with certain predispositions already at work within the culture. Abstracting information from a material base meant that information could become free-floating, unaffected by changes in context. The technical leverage this move gained was considerable, for by formalizing information into a mathematical function, Shannon was able to develop theorems, powerful in their generality, that held true regardless of the medium in which the information was instantiated.

Not everyone agreed that this move was a good idea, despite its theoretical power. Malcontents grumbled that divorcing information from context, and thus from meaning, had made the theory so narrowly formalized that it was not useful as a general theory of communication. Shannon himself frequently cautioned that the theory was meant to apply only to certain technical situations, not to communication in general. In other circumstances, the theory might have become a dead end, a victim of its own excessive formalization and decontextualization. But not in the post–World-War II era. As we have seen, the time was ripe for theories that reified information into a free-floating, decontextualized, quantifiable entity that could serve as the master key unlocking the secrets of life and death.

How quickly the theory moved from the meticulously careful technical applications urged by Shannon to cultural fantasy can be seen in Norbert Wiener's suggestion in 1950 that it would be possible to telegraph a human being.[11] We can see here the prototype for Moravec's scenario of downloading consciousness into a computer. The proposal implies that a human being is a message instantiated within a biological substrate but not intrinsic to it.[12] Extract the information from the medium, and you have a pattern you can encode into a signal and reconstitute in another medium at the end of the channel. The fantasy has not lost its appeal as the twentieth century races toward the next millennium; indeed, it now circulates so widely as to be virtually ubiquitous. Telegraphing a person to a remote location may have been startling idea in the 1950s, but by the 1990s it has achieved the status of a cultural icon. What is "Beam me up, Scotty," but the same operation carried out with a different (imaginary) technology?

Moravec's vision is extreme only in that it imagines "you" rematerialize inside a computer. If you had simply reoccupied your same body, nobody would have raised an eyebrow. Whether the enabling assumptions occur in molecular biology, information theory, or mass media, their appeal is clear. Information conceived as pattern and divorced from a material medium is information free to travel across time and space. Hackers are not the only ones who believe that information wants to be free. The great dream and promise of information is that it can be free from the material constraints that govern the mortal world. If we can become the information we have constructed, we, too, can soar free, immortal like the gods.

In the face of such a powerful dream, it can be a shock to remember that for information to exist, it must *always* be instantiated in a medium, whether that medium is the page from the *Bell Laboratories Journal* on which Shannon's equations are printed, the computer-generated topological maps used by the Human Genome Project, or the cathode ray tube that images the body disappearing into a golden haze when the *Star Trek* transporter locks onto it. The point is not only that abstracting information from a material base is an imaginary act. More fundamentally, conceiving of information as a thing separate from the medium that instantiates it is a prior imaginary act that constructs a holistic phenomenon as a matter/information duality.[13]

As I write these words, I can feel the language exerting an inertial pull on my argument, for only through the dichotomies constructed to describe

it can I gesture toward the unity that the world is. Even as I point to the historical contingency of the terms, the very history that exposes this contingency reinscribes the information/materiality dichotomy I want to contest. This reinscription is complicated and exacerbated by the fact that the matter/information duality is enmeshed in a network of related dichotomies that help to support, distinguish, and define it. In order of increasing generality, these include signal/not-signal, information/noise, and pattern/randomness. Although I cannot avoid using these constructions, I want to show that they function as dialectics rather than dichotomies. For each of these dualities, the bifurcated terms tangle and interact with each other. The slashes turn out to be permeable membranes rather than leakproof barriers.

Consider, for example, the information/noise duality. In Shannon's theory, information and noise are defined by similar mathematical expressions. The similarity makes clear that noise is not the opposite of information. Noise *is* information, but it is information not encoded by the sender. Noise may actually increase a message's information content (a theme that Michael Serres played multiple riffs upon in *The Parasite*).[14] We can visualize this situation by imagining information and noise as balls careening through a channel. It is not the case that the noise balls are blue, say, and the information balls are red, and we can sort them by putting the blue balls in one urn and the red balls in another. Rather, all the balls are blue (or red). Some have been thrown in by the sender, some have popped into the channel through holes in its sides, and some have materialized from the channel's lining as it is pulled and twisted. The receiver ends up with more balls than the sender intended. (Here noise leaks into my own message as the language slips from one metaphoric network to another, illustrating how the situation grows yet more complicated when information is related to semantics). The only way to distinguish between information and noise is by comparing the message the receiver decodes with what the sender encoded.

The mathematical equivalence of information and noise points to a deeper ambiguity: whether information should be identified with pattern or randomness. The associations that the word "information" evokes suggest that information should have an inherent structure, and thus correspond to patterned communication rather than random bursts of noise. Yet as as early as 1968, John Arthur Wilson pointed out that such an intuition is not justified by the formal structure of the theory.[15]

We can understand this heuristically by comparing the information content of a nursery rhyme with that of a sequence of random numbers. After I have said the first line of a nursery rhyme—for example, "Mary had a little lamb"—you can guess the rest because it is so familiar. The remainder of the message is redundant and conveys no new information. By contrast, every one of the random numbers comes as a surprise. (Remember that in Shannon's theory, information has no connection with meaning.) Since randomness by definition implies an absence of pattern, you have no way to reliably guess what will come next. This line of reasoning suggests that the more random a message is, the more information it conveys—a result that conflicts with our cultural expectation that information should be structured.

This conundrum proved to be a powerful paradox within information theory. It led to the realization that in certain instances in which there is no access to the original message (for example, when analyzing the electromagnetic spectra of stars, where the stars are considered to be the message senders and humans who interpret the spectra are the receivers), the best strategy for interpreting the data is to maximize entropy (or randomness). This procedure, called Maximum Entropy Formalism, works well in such situations because it encodes the least number of assumptions about the results and so minimizes the chances for error.[16]

The point of detailing these developments within information theory is to indicate that although the theory relies for its articulation on such distinctions as information/noise and signal/not-signal, the dualities are not dichotomies but dialectics. In Derrida's phrase, they are engaged in an economy of supplementarity. Each of the privileged terms—signal, information, pattern—relies for its construction on a supplement—not-signal, noise, randomness.

As an electrical engineer employed by AT&T, Shannon had a vested interest in eliminating noise. One of his most important theorems proves that there is always a way to encode a message so as to reduce the noise to an arbitrarily small quantity. But since noise is the supplement that allows information to be constructed as the privileged term, it cannot be eliminated from the communication situation, only compensated for in the final result. We can arrive at the same conclusion through a different route by thinking more deeply about what it means to define information as a probability function. The definition implies that randomness always had already

interpenetrated pattern, for probability as a concept posits a situation in which there is no a priori way to distinguish between effects extrapolated from known causes and those generated by chance conjunctions. Like information and noise, pattern and randomness are not opposites bifurcated into a dichotomy but interpenetrating terms joined in a dialectic.

I am now in a position to restate my major theme in a different key. As I have shown, the concept of information is generated from the interplay between pattern and randomness. Similarly, materiality can be understood as being generated by a dialectic of presence and absence. In each dialectic, one term has historically been privileged over the other. When the terms are inverted, assumptions become visible that otherwise would remain transparent. Deconstruction gained theoretical leverage by placing absence rather than presence at the origin of language; the Maximum Entropy Formalism gained theoretical leverage by regarding randomness rather than pattern as the generator of information. When information is privileged over materiality, the pattern/randomness dialectic associated with information is perceived as dominant over the presence/absence dialectic associated with materiality. The condition of virtuality implies, then, a widespread perception that presence/absence is being displaced and preempted by pattern/randomness.

Although virtuality is clearly related to postmodernism, it has distinctive features of its own. Table 4.1 summarizes some of these and compares them with parallel features in postmodern theory and culture. I will not have space here to develop the items in the table in detail, but a brief summary of a couple will serve to illustrate how virtuality both extends and modifies certain trends within postmodernism.

1. Possession seriates into access. Material objects are possessions. I cannot eat my cake and also give it away. By contrast, information is not a materially conserved quantity. When I copy information from my disk to yours, we both have it. The crucial issue with information is thus not possession but access. Access has already become a focal point for questions about how information as a commodity is going to be integrated into existing capitalistic structures. How can you publish something on the World Wide Web and get paid for it? When interactive television becomes a reality, how can access be controlled so consumers will pay for the information they tap? The shift of emphasis from possession to access has important implications for

Table 4.1 — A Comparison of Postmodernism and Virtuality

	Postmodernism	Virtuality
Defining Dialectic	Presence/Absence	Pattern/randomness
Integration into capitalism	Possession	Access
Psychological Crisis	Castration	Mutation
Theoretical Inversion Formalism	Deconstruction	Maximum Entropy
Creation of Narrative	(De)Construction of Origin	(De)Construction of Chaos

literature. Think of how issues of possession have driven literary plots, from the penniless younger brothers of Restoration comedies to the labyrinthine inheritance disputes in Victorian novels. How will literary forms shift when plots are driven instead by questions of access?

2. *Castration seriates into mutation.* The grounds for theoretical inquiry shift as postmodernism shades into virtuality. In Lacanian psycholinguistics, the focus is on inverting the traditional hierarchy of presence/absence, in much the same way and for similar reasons as it is in most deconstructive theory. Castration represents a moment of crisis because it bodies forth the subject's realization that absence interpenetrates and precedes presence. Absence drives the engine of desire, and desire drives the engine of signification and, therefore, of subjectivity. When the focus shifts to pattern and randomness, the nature of the precipitating crisis changes. In the pattern/randomness dialectic, mutation rather than castration is central, for mutation bodies forth the realization that randomness interpenetrates and precedes pattern. Mutation occurs when pattern can no longer be counted on to replicate itself, when pattern's disruption by randomness becomes visibly evident in the body. It is no accident that theorists concerned with virtuality, from Allucquère Rosanne Stone to the Canadian artist Catherine Richards, focus

on mutation as the decisive event precipitating a changed subjectivity in a virtual age. What theories of language and subjectivity will emerge when mutation is constituted as the catastrophic moment of self-recognition?

As these questions suggest, the impact of virtuality on literary theory and practice will be far-reaching and profound. At present, virtuality is largely terra incognita for the literary establishment. In *City of Bits,* William Mitchell has written insightfully about how technologies of information are forcing a reconceptualization of the city on many levels, from architecture to traffic flow and urban planning.[17] My interest lies in how these same technologies are forcing a reconceptualization of literary theory and practice. In the next section, I explore the effects on literature of the changing material conditions under which it is written and read in an information age. Part of what is at stake for me in this analysis is to show that materiality, far from being left behind, interacts at every point with the new forms that literature is becoming as it moves into virtuality.

The Virtual Book

We have seen it dozens of times—that moment in a film when a book is opened and the camera's eye zooms through the pages into the imagined world beyond. Once we are in the world, the page is left behind. It no longer appears on the screen, no longer frames the world we witness. The filmic convention captures a reader's sense that the imagined world of the text lives less on the page than in the scene generated out of the words by the mind's eye.

Virtual books—that is, books imaged on and through computer screens—operate according to a different convention. As with film, the user is sometimes given the illusion that she is moving through the screen into an imagined world beyond. But unlike film, this imagined world contains texts that the user is invited to open, read, and manipulate. Text is not left behind but remains in complex interplay with the perceived space into which the screen opens. Technically speaking, of course, the interplay is possible because the computer is an interactive medium.

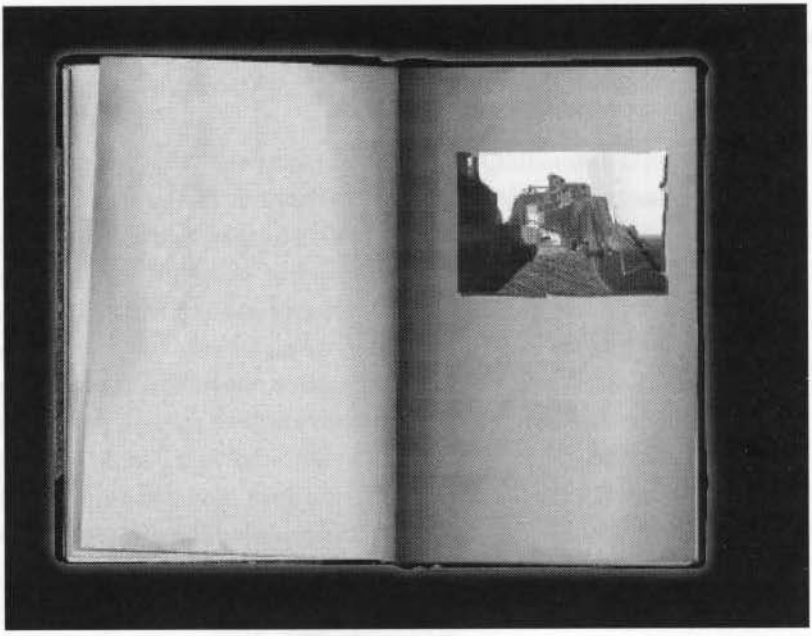
My focus here is on how this interactivity is rendered through visual conventions. *Visually* it is possible because textual space is rendered as having depth—if not a full three dimensions, at least the "two and a half" dimensions of text windows stacked behind one another. Texts can play a

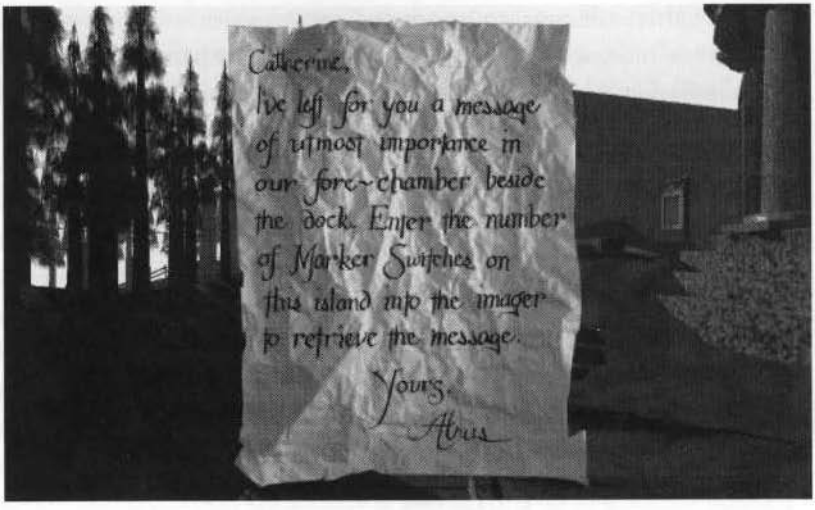
part in the three-dimensional world of the screen image because in this interactive medium, they have similarly rich dimensionality. The correlation suggests that in electronic textuality, spatiality is of primary concern.

The changed conventions that operate with virtual texts are apparent in *Myst* (1993), the best-selling CD-ROM game. As the game opens, three-dimensional Roman letters spelling "MYST" appear. Then a book tumbles out of space and comes to rest in the foreground. Imagine that you are sitting at the keyboard with me so we can work together on solving the problems that *Myst* presents to us (a favorite way to interact with this challenging and complex game). As we peer at the screen, we notice that the same letters appear on the book. It comes closer, inviting us to enter. We plunge into it and find ourselves spinning through the air. Finally we come to rest on the island, the first of many worlds that *Myst* offers for exploration. We find that we have not left the book behind, for scattered about are pages giving important clues about the island's previous occupants. When we pick a page up (by clicking on it), it comes close enough for us to read.

The significance of the pages becomes clearer when we enter the library, perhaps the island's most important structure. In addition to the books lining the walls, the library features two podiums on which rest two books (one red and one blue, as if in recognition of red and blue balls flying through communication channels). When we open one of them (by clicking on it), we are greeted by a black rectangle inset on a white page. Inserting a nearby page into the book causes the rectangle to buzz into flickering life, and we realize it is a screen. Amid noise and static the image of a man appears on the screen. He tries to ask who we are, tries to communicate a message so broken up by static that we can catch only a few words asking us to find more blue (or red) pages and insert them into the book. When we do, the image gets progressively clearer and the messages become more intelligible.

To recapitulate: a book appears on the screen; we go through the book to the island, where we find fragments of more books. Reassembling the book in the library activates the screen inside the book; from the screen comes a message directing us back to the task of finding and reassembling the book. What are we to make of this extraordinarily complex interplay between screen and book? Here I want to point out something that is visually apparent to anyone who plays *Myst*. While the screens appear in a variety of high-tech settings, the books look archaic, with heavy leather bindings, watermarks, and ornate typefaces. Moreover, the screens are usually





The metaphor of the book in *Myst*®.

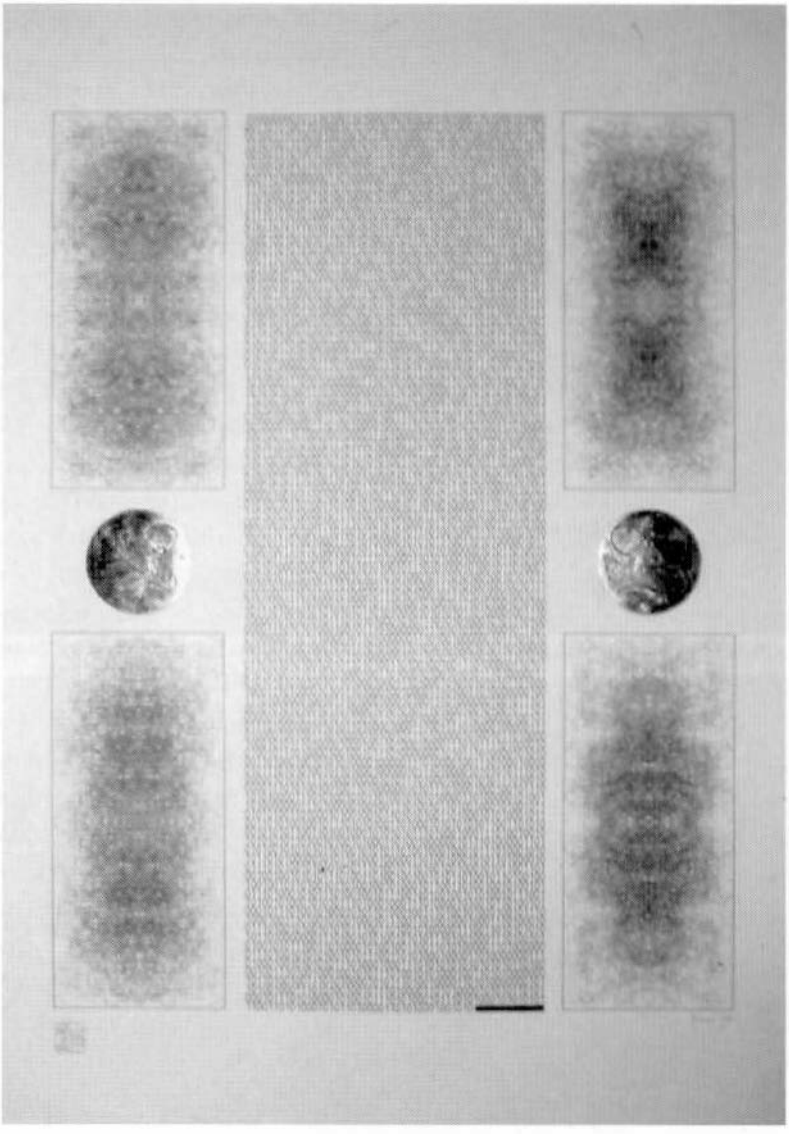
The virtual text worlds of *Myst*®.

activated by solving various numerical or coding problems, whereas the books require physical reassembly. The visual richness of the books compared with the screens, their fragmentation, and their archaic appearance hint that books have become fetishized. When we open the book in the library, we do not find the information we seek imprinted on its pages. Instead, we interact with a screen emphasizing that the book has become fragmented and urging us to put it back together. Books are associated with the object of desire—finding out information—but metonymically, by a glancing connection based on proximity rather than a direct gaze.

The fetishistic quality of the books in *Myst* is consistent with their representation as anachronisms. Everything about their presentation identifies them as artifacts from the late age of print. Books still exist in this virtual world, but they have ceased to be ordinary, matter-of-fact media for transmitting information. Instead, they have become fragmented objects of vicarious desire, visually sensuous in a way that implies they are heavy with physicality, teasing us with the promise of a revelation that will come when we restore them to a fabled originary unity. The same kinds of transformation are evident at many sites where virtuality reigns. Let me give two more examples, this time from the Art Show at SIGGRAPH '95.

Roman Verostko's *Universal Turing Machine* illustrates how the function of the book changes when its materiality is conceived as interpenetrated by informational patterns. The title alludes to a conceptual computer proposed by Alan Turing in the 1950s.[18] The Universal Turing Machine is simply a string of binary code that contains instructions on how to read the code, as well as the code that describes itself. Verostko appropriated the code describing the Universal Turing Machine (which visually appears as a string of ones and zeros) and used a computer to print it out on thick parchment, formatted as if it were the text of a medieval illuminated manuscript. Then he fed the same string of code into a program for a line plotter and used it to generate the four illustrations surrounding the text, which look like not-quite-random nests of snaky red lines. In the centers of the side margins are two gorgeous gold decals that repeat, in simplified form, one of the motifs of the line drawings; Verostko noted that he intended the decals to suggest control points for the computer.

Like *Myst,* this work shows a keen interest in the physical and visual properties of the codex book, including its arrangement of space, its tradition of combining text and image, and its use of colored inks and gold leaf.



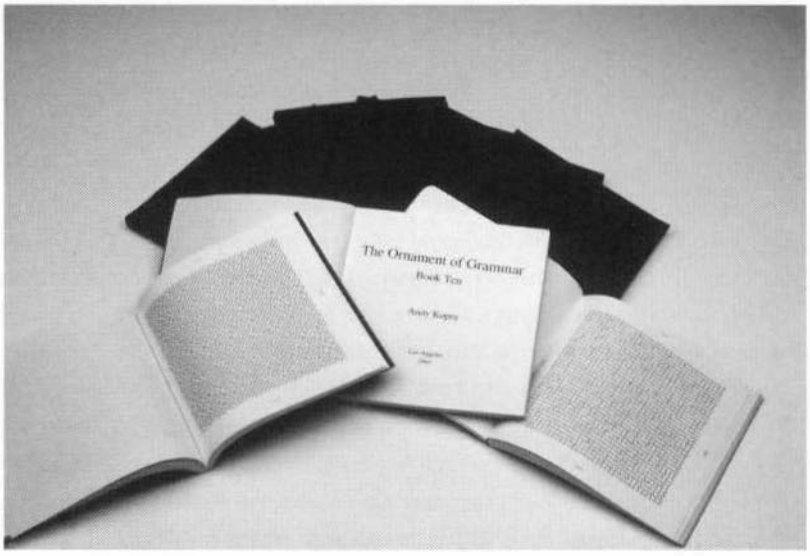
The Illuminated Universal Turing Machine.
Courtesy of Roman Verostko.

But the book's traditional function of conveying verbal information has been given over to computer code. Just as illuminated manuscripts were used for sacred or canonical works, so Verostko uses his visually splendid work to enshrine the universal computer code that is universal precisely because it both explains and enacts its own origin. As with *Myst,* the materiality of the book is celebrated for its archaic and physical qualities, but it is a materiality interpenetrated by the informational patterns that generated it and that are rendered visually incarnate in the drawings. In this work commenting upon and exemplifying the late age of print, the book supplies image and visual form, while the computer supplies text and signifying code.

The materiality of the codex book is also celebrated in Andre Kopra's *The Ornament of Grammar.* although the properties selected for celebration are very different than in Verostko's work. Kopra intended his title to allude to Owen Jones's nineteenth-cenrury text *The Grammar of Ornament*, a collection of decorative patterns from different cultures. Kopra's work consists of a collection of ten different texts bound in cheap, black, generic paper covers, printed on inexpensive paper, and displayed in an unpainted pine bookcase holding multiple copies of each of the ten texts. The pages of the books are filled with line drawings generated by computer programs. The drawings are laid out on a grid of thirty-six by thirty-six squares, yielding a total of forty-one different patterns. As one flips through a book, the drawings grow progressively more complex, an effect achieved by varying the parameters of the computer program generating them. Some of the books use rectilinear patterns; others feature curved lines. The patterns tease the eye, challenging the reader to discern in their visual form the algorithm that created them. Commenting on the tension between the underlying code and the visual surface, Kopra wrote that the "possibility of rationalizing visual imagery is called into question by an apparent encyclopedia of the arbitrary."[19]

The material qualities celebrated in this piece include the print book's sturdiness, its relative cheapness and portability, its technological robustness and ease of use, and its potential for mass production. (When I talked with him about the work, Kopra mentioned that several of the books had been stolen by the time SIGGRAPH ended, a fact that delighted him. He said the perfect ending of the display, from his point of view, would have been to have the bookcase emptied by bibliophilic thieves.)

Although he focuses on different material qualities, Kopra echoes Verostko in having the book's verbal content displaced by visual forms



The Ornament of Grammar.
Courtesy of Andre Kopra.

generated from a computer. The computer's role in producing the book is highlighted by the interplay between pattern and randomness in the visual forms. This interplay at once instantiates the dialectic of pattern/randomness and draws into question the ability of computer codes to produce significance, as if recollecting for the reader Shannon's move of divorcing information from meaning. Kopra's work has an ironic undertone that reflects, he says, his growing concern that we are drowning in an ocean of information that is produced not because it is meaningful but because it can be used to generate a profit. For him the SIGGRAPH context in which the work was exhibited was significant, for over the years he has seen SIGGRAPH itself change from a coterie of people who shared mutual interests ro a huge commercial enterprise where millions of dollars are at stake.[20]

In an art show devoted to computer graphics, the focus on the book was remarkable. In addition to Verostko and Kopra, at least a dozen other artists produced works that were concerned with the interplay between print and algorithm. For them, the codex book functions as a crossroads at which one can see displayed the traffic between visual objects and computer programs, words and codes, images and language, fragmentation and wholeness, hand-

work and machine production, pattern and randomness, rationality and numerical permutations of the arbitrary. The overarching message is that the interpenetration of materiality by informational patterns is everywhere around us, even—or especially—in the books, at once virtual and physical, that are being produced in this late age of print.

Spatiality and Virtual Writing

Not all virtual books, of course, have their verbal content displaced by codes. Usually the codes work to introduce into the text's visual form a spatial dimensionality that operates in complex syncopation with language. The interplay between spatiality and text is central to electronic hypertexts. As most readers will know, hypertexts are electronic documents that are structured as networks of discrete units, or lexias, rather than as a linear sequence of bound pages. Hypertexts have encoded within them certain "hot spots" or interactive links. When a reader clicks on them, the link is activated and a new block of text comes up on the screen. As George Landow has pointed out, hypertexts are now becoming the standard way to convey information in many technical and engineering areas because they are easily updated, richly associational, and reader-directed. They can be found in everything from manuals for aircraft mechanics to electronic directories for museums. The World Wide Web is a vast hypertext, and most of the documents within it are hypertexts as well. Hypertext also provides a rapidly expanding arena for literary writing, both creative and critical.

In literary hypertexts, spatial form and visual image become richly significant. For hypertexts written in Storyspace (a hypertext authoring program developed by Mark Bernstein, Michael Joyce, and Jay Bolter), the map view shows how different lexias are linked to one another. The way they are arranged in space is used to indicate logical or narrative relationships. Some lexias may nest inside others; others may have multiple connections; still others may function as autonomous units or dead ends. Color coding also indicates various kinds of relationships, from highlighted text within lexias to different-colored links and boxes. In Toolbook (another authoring program), sound can be added to enhance textual or visual effects. As a result, space in hypertexts operates as much more than an empty container into which virtual objects are placed. Rather, it becomes a topography that the reader navigates by using multiple functionalities, including cognitive, tactile, auditory, visual, kinesthetic, and proprioceptive faculties.

Since I am focusing here on spatiality, let us dwell for a moment on proprioception. Proprioception is the sense that tells us where the boundaries of our bodies are. Associated with inner-ear mechanisms and internal nerve endings, it makes us feel that we inhabit our bodies from the inside. Proprioceptive coherence, a term used by phenomenologists, refers to how these boundaries are formed through a combination of physiological feedback loops and habitual usage. An experienced tennis player, for example, frequently feels proprioceptive coherence with the racquet, experiencing it as if it were an extension of her arm. In much the same way, an experienced computer user feels proprioceptive coherence with the keyboard, experiencing the screen surface as a space into which her subjectivity can flow.

This effect marks an important difference between screen and print. Although a reader can imaginatively project herself into a world represented within a print text, she is not likely to feel that she is becoming physically attached to the page itself. On the contrary, because the tactile and kinesthetic feedback loops are less frequent, less sensually complicated, and much less interactive, she normally feels that she is moving *through* the page into some other kind of space. The impression has a physiological basis. The physical stimuli the reader receives with print are simply not adequate to account for the cognitive richness of the represented world; the more the imagination soars, the more the page is left behind. This difference in the way that proprioceptive coherence works with the computer screen, compared with the printed page, is an important reason why spatiality becomes such a highly charged dimensionality in electronic hypertexts.

It makes sense, then, to insist, as Michael Joyce does, that virtual writing is also topographical writing.[21] He points to a number of assumptions that we absorb through our everyday work with electronic texts; together, they make our experience of electronic texts distinctively different from that of print texts. They include the following items, which I have adapted from Joyce's list and altered to suit my purposes here.

1. *Writing is inwardly elastic.* It expands and contracts; it allows the writer to work backward and forward; and it instantly adjusts the screen image to reflect these changes.
2. *The topology of the text is constructed rather than given.* Mechanisms that construct this topology include such humble devices as file names, as well as the more explicitly spatial commands used in hypertexts. As Joyce points

out, file names are more powerful than they may appear. They imply that writing done at different times is the same writing if it has the same file name, and that writing stored under different file names is different, even if it was done at the same time and contains the same text. File names also imply that writing is recognized as identical with itself through labeling rather than through spatial proximity within the computer. In contrast to printed books, where the physical location of the pages coincides with labeling conventions, in electronic texts, memory address and physical proximity have no necessary relation to one another. Topology is constructed by naming, not by physical assembly.

3. *Changes in a text can be superficial, corresponding to surface adjustments, or structural, corresponding to changes in topography.* Superficial changes are carried out through such formatting tools as spell checkers and font alterations, while structural changes involve such editorial functions as cut, copy, and paste. The different way these tools are organized within the authoring program, and the different coding operations to which they correspond, embody the assumption that the text possesses both surface and depth. Alterations in the surface are of a different kind than alterations in the topography.

The power of these assumptions lies in the fact that we do not need to be consciously aware of them to be affected by them. Like posture and table manners, they implant and reinforce cognitive presuppositions through physical actions and habitual motions, whether or not we recognize that they do so. As with any ritual, to perform them is on some level to accept and believe them.[22] The materiality of these interactions is one way in which our assumptions about virtual writing are being formed. Through mechanisms and procedures whose full impact we are only beginning to understand, virtual writing is being constituted as distinctively different from print. Even when its output is printed and bound into codex books, we know from the inside that it operates according to spatial principles and a topographical logic of its own.

The Physics of Virtual Writing and the Formation of the Virtual Subject

With all of this emphasis on spatiality, the reader may wonder how time enters into virtual writing. To understand the interaction between time and

space in this medium, it is important to know something about the way the medium works. When computers speak their native languages—assembly code, and beneath that, machine language—they operate within a profoundly non-Cartesian space. Distance at this level is measured by clock cycles. The computer's CPU (central processing unit) has a characteristic clock rate. When you buy a faster computer, you are essentially buying a faster clock rate. Imagine a drummer on a Viking sailing ship, pounding out the beat for the rowers' strokes.[23] Every two beats, a rowing cycle is completed. The drummer's pace controls the rate that which the oars move, and consequently the speed at which the boat slices through the water. Similarly, inside the computer the CPU reads a byte of code every two clock cycles. The clock rate thus controls the rate at which computations occur. It follows that addresses at memory locations 1, 50, 1000, and 1001 are all equidistant. Each is exactly two cycles away if it is in local memory, and eight cycles away if it is in remote memory.

How does this non-Cartesian relation between time and space express itself at the level of the user's experience? It is relatively easy for a computer program to generate a two-dimensional array, for it simply assigns each pixel on the screen an address. But to build a three-dimensional representation, the program must layer a series of two-dimensional planes on top of one another, as if a mountain had been cut horizontally into very thin slices and was being reassembled by the computer. This means that three-dimensional representations take many more cycles to build than do two-dimensional maps. Hence the user experiences the sensory richness of a three-dimensional topography as a lag in the flow of the computer's response.

In *Myst,* for example, the user experiences movement through the represented three-dimensional space as a series of jumps interspersed by pauses. You click, the computer pauses, and then jumps to a point perhaps ten feet away where a flight of steps begins; you click again, the computer pauses, and jumps halfway up the steps. Distance within the screen is experienced as an inertial pull on your time as you navigate the topology. The result is an artifactual physics that emerges from the interaction of the computer clock cycle with the user's experience.

In this physics born of interactivity, the more complex the screen topography, the more inertial pull is exerted on the user's flow. The exact relation between the two is determined by the structure and programming of the underlying codes. Thus these codes, which normally remain invisible to the

nonspecialist, are nevertheless felt and intuitively grasped by the user, in much the same way that the earth's gravity is felt and intuitively understood by someone who never heard of Newton's laws. Apples fall down; it takes effort to climb mountains. As inhabitants of cyberspace, we similarly understand in our muscles and bones that space belongs to the computer, and flow belongs to the user.

The physics of virtual writing illustrates how our perceptions change when we work with computers on a daily basis. We do not need to have software sockets inserted into our heads (as William Gibson envisions in *Neuromancer*) to become cyborgs. We already are cyborgs in the sense that we experience, through the integration of our bodily perceptions and motions with computer architectures and topologies, a changed sense of subjectivity.

Much has been written about how the transition from orality to writing affected subjectivity. In *Preface to Plato,* Eric Havelock initiates a fascinating line of inquiry when he asks why Plato is so adamant about banishing poets from the republic.[24] Havelock suggests that poetry is associated with oral culture, and consequently with a fluid, changing, situational, and dispersed subjectivity. Plato wants to establish a fixed, stable, unchanging reality, and to do this, he needs a fixed, coherent, stable subject to perceive it. So the poets have to go, for they produce through their linguistic interventions exactly the kind of subject that Plato does not want and cannot tolerate. Similarly influential has been the work of Walter Ong on the differences between oral and written culture, of Elizabeth Eisenstein on the effects of printing in early modern Europe, and of Marshall McLuhan on the effects of electronic technologies.[25]

We are only beginning to understand the effect of computers on culture and on subjectivity. Marsha Kinder has spoken about the importance of "shifting," the perception young children have when watching such programs as the Power Rangers that they can morph and shapeshift into various forms;[26] Brenda Laurel and Rachel Strickland have embodied similar perceptions in their virtual reality simulation "Placeholder";[27] and Allucquère Rosanne Stone, in *The War Between Technology and Desire at the Close of the Mechanical Age,* has written about the virtual subject as a "multiple" (analogous to someone who experiences multiple personalities) warranted by the body rather than contained within it.[28] Catherine Richards and Don Idhe have focused on proprioceptive coherence, looking at the way perception of body boundaries changes through technological interactions and interven-

tions.[29] Michael Joyce, Jay Bolter, George Landow, David Kolb, and Jane Yellowlees Douglas, among others, have pointed out how navigating the topologies of electronic hypertexts creates new conditions for writing and reading, and thus for both producing and expressing new kinds of subjectivities.[30] Operating without any illusions about comprehensiveness or rigor, I venture in Table 4.2 to sum up a few salient comparisons between the oral subject, the written subject, and the virtual subject.

In the transition from the written to the virtual subject, deconstruction played a significant theoretical role, for in reinterpreting writing (emphasizing its instabilities, lack of originary foundations, intertextualities, and indeterminacies), in effect it made the written subject move much closer to the virtual subject than had traditionally been the case. This process is typical of what elsewhere I have called "seriation" (a term appropriated from archaeological anthropology), an uneven process of change in which new artifacts or ideas emerge by partially replicating and partially innovating upon what came before.

Although the shape of virtual subjectivity is only beginning to emerge and is therefore difficult to envision clearly, certain features are coming into focus. Proprioceptive coherence in interplay with electronic prostheses plays an important role in reconfiguring perceived body boundaries, especially when it gives the user the impression that her subjectivity is flowing into the space of the screen. When the interface is configured as keyboard and screen, the user will perceive that space belongs to the computer, and flow to the user. The symbiotic relation between humans and intelligent machines has complex effects that do not necessarily all point in the same direction. For example, it can evoke resistance and a privileging of human qualities that machines do not share, such as emotion, or it can lead to the opposite view that humans should leave to machines the things they do best, such as memory recall, and concentrate on the things humans do best, like language and complex pattern recognition. Whatever the symbiosis is taken to mean, it seems clear that the virtual subject will in some sense be a cyborg. These attributes are summarized below.

What Is to Be Done?

Should we respond with optimism to the products of virtual writing, or regard them (as an elderly gentleman informed me when he heard some of

Table 4.2 — Figuring Virtual Subjectivity

The Oral Subject
Fluid, changing, situational, dispersed, conflicting.

The Written Subject
Fixed, coherent, stable, self-identical, normalized, decontextualized.

The Virtual Subject
Formed through dynamical interfaces with computers.

When interface is keyboard and screen, space belongs to the computer, flow to the user.

Body boundaries extended or disrupted through proprioceptive coherence formed in conjunction with computer interfaces.

A cyborg.

these arguments) as abominations that are rotting the minds of American youth? Whatever we make of them, one thing is certain: Literature will not remain unchanged. It is sometimes difficult to convey adequately to an academic audience the very rapid pace at which computer technologies are penetrating virtually every aspect of our culture. In this respect, academe in general and literature departments in particular tend to lag far behind other sectors of the society. With some noteworthy exceptions, academe is not where it is happening as far as computer culture is concerned.

Yet academics can make, I believe, vitally important contributions to the development of these technologies. Perhaps the most crucial are interventions that provide historical contexts showing how and why the technologies developed as they did. Although certain paths of development may be overdetermined, they are never inevitable. Other paths and other interpretations are always possible. The point I want to underscore is that it is a *historical construction* to believe that computer media are disembodying technologies, not an obvious truth. In fact, this belief requires systematic erasure of many significant aspects of our interactions with computers. It is almost never used as a working hypothesis by the people who are engaged in developing

the technologies, for they cannot afford to ignore the materiality of the interfaces they create or the effects of these interfaces on their customers. If we articulate interpretations that contest the illusion of disembodiment, and if these interpretations begin to circulate through the culture, they can affect how the technologies are understood, and consequently how they will be developed and used. Technologies do not develop on their own. People develop them, and people are sensitive to cultural beliefs about what the technologies can and should mean.

Brenda Laurel has called recognizing the importance of embodied interaction an "endangered sensibility" that she believes the arts and humanities should fight to retain and restore. For me, this means being attentive to the materialities of the media and their implications. The illusion that information is separate from materiality leads not only to a dangerous split between information and meaning but also to a flattening of the space of theoretical inquiry. If we accept that the materiality of the world is immaterial to our concerns, we are likely to miss the very complexities that theory at its best tries to excavate and understand.

The implications of my strategic choice of definition now stand, I hope, fully revealed. Virtuality is not about living in an immaterial realm of information, but about the cultural perception that material objects are interpenetrated with informational patterns. What this interpenetration means and how it is to be understood will be our collective invention. The choices we make are consequential, for it is in the complex, doubly figured, and intensely ambiguous condition of virtuality that our futures lie.