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Defining Virtual Reality: Dimensions Determining Telepresence

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Defining Virtual Reality:
Dimensions Determining Telepresence

Abstract

Virtual reality (VR) is typically defined in terms of technological hardware. This paper attempts to cast a new, variable-based definition of virtual reality that can be used to classify virtual reality in relation to other media. The defintion of virtual reality is based on concepts of "presence" and "telepresence," which refer to the sense of being in an environment, generated by natural or mediated means, respectively. Two technological dimensions that contribute to telepresence, vividness and interactivity, are discussed. A variety of media are classified according to these dimensions. Suggestions are made for the application of the new definition of virtual reality within the field of communication research.

Defining Virtual Reality: Dimensions Determining Telepresence

Virtual reality (VR) has typically been portrayed as a medium, like telephone or television. This new medium is typically defined in terms of a particular collection of technological hardware, including computers, head-mounted displays, headphones, and motion-sensing gloves. The focus of virtual reality is thus technological, rather than experiential; the locus of virtual reality is a collection of machines.[1] Such a concept is useful to producers of VR-related hardware. However, for communication researchers, policy makers, software developers, or media consumers, a device-driven definition of virtual reality is unacceptable: It fails to provide any insight into the processes or effects of using these systems, fails to provide a conceptual framework from which to make regulatory decisions, fails to provide an aesthetic from which to create media products, and fails to provide a method for consumers to rely on their experiences with other media in understanding the nature of virtual reality.

Theoretically, these inadequacies are manifest in three ways. First, a technology-based view suggests that the most salient feature in recognizing a "VR system" is the presence or absence of the requisite hardware.[2] In other words, a given system is arbitrarily classified as "VR" or "not-VR," depending on whether it includes a minimal corpus of particular machines. Second, such a definition provides no clear conceptual unit of analysis for virtual reality. If VR consists of a hardware system, where do we look to identify a single "virtual reality"? Examining the technological apparatus alone does not seem adequate for this purpose. A third and related problem is the lack of theoretical dimensions across which virtual reality can vary. All systems meeting the basic hardware requirements "are VR," and all others are "not-VR." However, once this initial classification has been made, such a dichotomous definition offers no suggestion of how systems classified as "not-VR" may resemble those that "are VR," nor how different virtual reality systems can be compared. In the absence of a clear theoretical unit or any relevant dimensions for study, it is difficult to perform social science research that addresses the similarities and differences among various virtual reality systems, or that examines VR in relation to other media.

Probably the most effective solution to the problems with the current usage of "virtual reality" would be to abandon the term entirely (at least for research purposes), in favor of a more theoretically grounded term. However, the term has stuck in academic as well as popular usage. It is therefore expedient to form a theoretically useful concept out of virtual reality. This paper is an effort to fill this need, addressing the aforementioned faults by defining virtual reality as a particular type of experience, rather than as a collection of hardware. Defining virtual reality in this way will provide

1 This paper presumes broad definitions of technology and media, such as those given by Beniger (1986, p. 9), who defines technology as "any intentional extension of a natural process, that is, processing of matter, energy, and information that characterizes all living systems," and McLuhan (1964, p. 21), who defines a medium as any "extension of man."

2 See Nass & Mason (1990) for an in-depth discussion of the practical and theoretical limitations of object-centered views of technology, and of the importance of variable-based strategies in overcoming these limitations.

(a) a concrete unit of analysis for VR, (b) a set of dimensions over which VR can vary, and, perhaps most importantly, (c) a means for examining VR in relation to other types of mediated experience.

DEFINING VIRTUAL REALITY

Most popular definitions of virtual reality make reference to a particular technological system. This system usually includes a computer capable of real-time animation, controlled by a set of wired gloves and a position tracker, and using a head-mounted stereoscopic display for visual output.[3] The following are three examples of such definitions:

> *Virtual Reality is electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations.* (Coates, 1992)

• • •

> *Virtual Reality is an alternate world filled with computer-generated images that respond to human movements. These simulated environments are usually visited with the aid of an expensive data suit which features stereophonic video goggles and fiber-optic data gloves.* (Greenbaum, 1992)

• • •

> *The terms* virtual worlds, virtual cockpits, *and* virtual workstations *were used to describe specific projects.... In 1989, Jaron Lanier, CEO of VPL, coined the term* virtual reality *to bring all of the virtual projects under a single rubric. The term therefore typically refers to three-dimensional realities implemented with stereo viewing goggles and reality gloves.* (Krueger, 1991, p. xiii)

Though these three definitions vary somewhat, all include the notions of both electronically simulated environments and of "goggles 'n' gloves" systems as the means to access these environments. The application of these definitions (and any other definition that is similarly based on a particular hardware instantiation) is thereby limited to these technologies; their units of analysis and potential for variance are left unspecified. However, it is possible to define virtual reality without reference to particular hardware.

Presence and Telepresence

The key to defining virtual reality in terms of human experience rather than technological hardware is the concept of *presence*. Presence can be thought of as the experience of one's physical environment; it refers not to one's surroundings as they exist in the physical world, but to the perception of those surroundings as mediated by both automatic and controlled mental processes (Gibson, 1979):

3 See Biocca (this volume) for a thorough description of the hardware involved in such systems, and for a brief review of the perceptual processes involved in the creation of such hardware.

- Presence *is defined as the sense of being in an environment.*[4]

Many perceptual factors contribute to generating this sense, including input from some or all sensory channels, as well as more mindful attentional, perceptual, and other mental processes that assimilate incoming sensory data with current concerns and past experiences (Gibson, 1966). Presence is closely related to the phenomenon of *distal attribution* or *externalization*, which refer to the referencing of our perceptions to an external space beyond the limits of the sensory organs themselves (Loomis, 1992).

In unmediated perception, presence is taken for granted—what could one experience other than one's immediate physical surroundings? However, when perception is mediated by a communication technology, one is forced to perceive *two* separate environments simultaneously: the physical environment in which one is actually present, and the environment presented via the medium.[5] The term "telepresence" can be used to describe the precedence of the latter experience in favor of the former; that is, telepresence is the extent to which one feels present in the mediated environment, rather than in the immediate physical environment.

- Telepresence *is defined as the experience of presence in an environment by means of a communication medium.*

In other words, "presence" refers to the *natural* perception of an environment, and "telepresence" refers to the mediated perception of an environment. This environment can be either a temporally or spatially distant "real" environment (for instance, a distant space viewed through a video camera), or an animated but non-existent *virtual world* synthesized by a computer (for instance, the animated "world" created in a video game).

Reeves (1991), in a discussion of responses to television, describes this experience as a sense of "being there." He claims that a combination of automatic perceptual processes, mindful direction of attention, and conscious processes such as narratization all contribute toward our perceiving mediated experiences as if they were real.[6] Others have also constructed taxonomies for examining

4 "Presence" as used here refers to the experience of *natural* surroundings; that is, surroundings in which sensory input impinges directly upon the organs of sense. The term is also sometimes used to describe the *mediated* experience of a physical environment; this is discussed further below.

5 For the purposes of this paper, a "communication technology" can be defined as any means of representing information across space or across time. "Mediated communication" and "mediated experience" are therefore considered to be essentially equivalent. Again, this is a very broad definition that differs from many typical views.

6 This is not to say that people are "fooled" into believing that TV or other mediated experiences are "real." However, two distinct research programs currently underway at Stanford under the general rubric Social Responses to Communication Technologies have demonstrated that in certain contexts, people respond to mediated stimuli in ways similar to their real-life counterparts. The research on "being there," led by Byron Reeves, includes a study that suggests that images of faces presented on a television screen evoke the similar rules of interpersonal space as do actual faces (Reeves, Lombard, & Melwani, 1992), as well as a study to determine the effects of representing auditory and visual fidelity and spatial characteristics in engendering "real-world"-like responses from televised messages (see Reeves, Detenber, & Steuer, 1993). The Computer as Social Actor

mediated experience. Shapiro and McDonald (this issue) differentiate between *reconstructed reality*, which is created in individuals based on accumulated data from mediated presentations or memories of events, and *constructed reality*, which focuses on how individuals accept mediated presentations of events as real. Heeter (1992) describes three distinct types of presence that contribute to the experience of "being there:" subjective personal presence, social presence, and personal presence. Robinett (1992) draws a similar distinction between real (unmediated) and synthetic (mediated) experience in the context of discussing presence.

The use of "telepresence" to refer to any medium-induced sense of presence is similar to some, but not all, previous uses of the term. The term was coined by Marvin Minsky (1980) in reference to teleoperation systems for remote manipulation of physical objects. Sheridan & Furness (1992) have continued this tradition by adopting the name *Presence* (rather than *Telepresence*) for a new journal dedicated to the study of both teleoperator and virtual environment systems. In the first issue of the journal, an entire section is devoted to the concept of telepresence. Sheridan (1992) uses the term "presence" to refer to the generic perception of being in an artificial or remote environment, reserving "telepresence" only for cases involving teleoperation. However, in the same section of the journal, Held & Durlach (1992) use "telepresence" to refer to the experience common to both teleoperation and the experience of virtual environments. The broader term is used here in order to highlight the similarities between teleoperation and virtual environments.

By employing the concept telepresence, we can now define "virtual reality" without reference to any particular hardware system:

- A "virtual reality" is defined as a real or simulated environment in which a perceiver experiences telepresence.[7]

Admittedly, this definition does not mesh precisely with typical uses of the term. Indeed, given the broad definitions of the concepts involved, this definition of virtual reality includes virtually all mediated experience. In so doing, it suggests an alternative view of mediated communication in general. Traditionally, the process of communication is described in terms of the transmission of information, as a process linking sender and receiver.[8] Media are therefore important only as a conduit, as a means of connecting sender and receiver, and are only interesting to the extent that they contribute to or otherwise interfere with transmission of message from sender to receiver. In contrast, the telepresence view focuses attention on the relationship between an individual who is both a sender and a receiver, and on the mediated environment with which he or she interacts. Information is not transmitted from sender to receiver; rather, mediated environments are created and then

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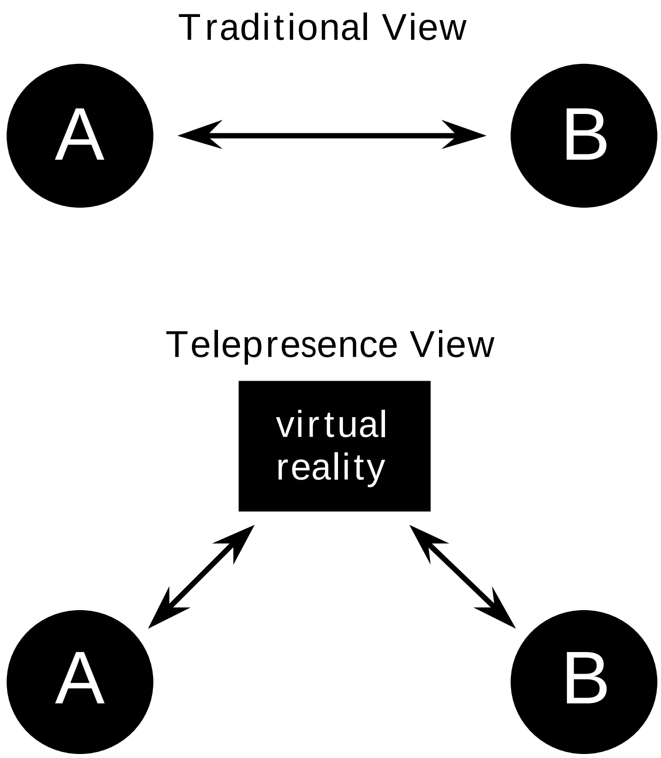
project, led by Clifford Nass, has shown that computers can evoke social responses similar to those evoked by other humans, even in situations where there is no logical explanation for such behavior (see Nass, Steuer, Henriksen, & Dryer, in press; Nass & Steuer, 1993)

7 I first encountered a similar definition of VR in a posting to the WELL computer conferencing system by Howard Rheingold, dated May 23, 1990. Rheingold's book *Virtual Reality* (1991) is an excellent survey of the history of VR.

8 Examples of models meeting this general description can be found in DeFleur & Ball-Rokeach, 1989; Schramm, 1974; Shannon & Weaver, 1962; or in virtually any introductory communication text.

experienced (see Sheridan, 1992). A graphical contrast between these two views of mediated communication is shown in Figure 1.

Figure 1:
Two Models of Mediated Communication
(after Krueger, 1991, p. 37)



Virtual Realities and Media

Machines mentioned in previous definitions of virtual reality (computers, position sensors, head-mounted displays, etc.) are all relatively recent developments. However, the definition of VR as telepresence can be applied to past, present, and future media technologies. Consider, for example, the telephone. Most users take for granted the possibility of talking to someone who is not physically present as if they were standing in the same room.[9] But imagine this scene (adapted from the film *Being There* [Ashby & Kosinski,1979]):

> You receive your first-ever telephone call. You are handed the telephone and lift it to your ear. You hear nothing, and exclaim, "No one is there." A friend standing nearby takes the receiver, speaks into it, and hands it back to you. "Oh yes, he's there," your

9 Obviously, telephone-mediated communication is not *exactly* the same as face-to-face communication: only auditory cues are provided over the telephone, and even these are very limited in terms of dynamic range and frequency spectrum. However, there is still a sense in which the *experiences* are quite similar.

friend replies. You look at your friend quizzically, then point to the telephone, point to your immediate surroundings, and inquire, “Where is he? There or here?”

How can one explain the seemingly bizarre ability to speak to someone who is not present by means of talking into a piece of plastic? Of course, as mentioned above, this process can be conceived in terms of senders, receivers, and messages. However, such an explanation fails to account for the odd *experience* of speaking to someone who is not actually there. Where does such a conversation take place? The most plausible conceptual model is that *both* parties, by means of the telephone, are electronically present in the same virtual reality created by the telephone system. A few additional examples illustrate this difference with respect to a number of different media:

- Reading a letter from a distant friend or colleague can evoke a sense of presence in the environment in which the letter was written, or can make the distant party seem locally present. This feeling can occur even when one is unfamiliar with the remote physical surroundings.

- When people telephone an airline using a toll-free number to make reservations for a flight, they often ask the operator where he or she “really is.” They do this because they are uncomfortable interacting in a virtual reality that has no other contextual clues, and I therefore wish to create a background into which to place the operator’s character.[10]

- Users of multiple online systems (such as bulletin boards, conferenceing systems, etc.) report that each system provides a distinct “sense of place.”

- Listening to live recordings of music (recordings made during a performance) gives the listener a sense of presence in the room (e.g. concert hall) in which the recording was made. However, recordings made in a studio can also evoke such feelings, even though there was no single “performance” at which a listener could have been present.

- Nuclear power plant operators observe the inside of the reactor by means of a remotely mounted moveable camera and handle radioactive chemicals by means of remotely controlled mechanical “hands.”

- Video game players describe the experience of moving an animated car on the screen as “driving.”

Each of these situations evokes, in some sense, a feeling of telepresence. A similar sense can be experienced via virtually any technology used in mediated communication. Newspapers, letters, and magazines place the reader in a space in which the writer is telling a story; television places the viewer in a virtual space in which both viewer and on-screen objects are present; and video games create virtual spaces in which the game-player is an actor.

Thus, the definition of virtual reality in terms of telepresence provides a conceptual framework in which such newly developed technologies can be examined in relation to other media technologies. Furthermore, defining virtual reality in terms of telepresence alleviates the three difficulties enumerated above. First, VR refers to an experience rather than to a machine. The

10 For a discussion of the importance of “grounding” connumication in this way, see Clark & Brennan, 1992.

definition thereby shifts the locus of VR from a particular hardware package to the perceptions of an individual. Second, this definition specifies the unit of analysis of VR — the individual — since VR consists of an individual experience of presence. Thus, dependent measures of VR must all be measures of individual experience, providing an obvious means of applying knowledge about perceptual processes and individual differences in determining the nature of VR. Finally, since this definition is not technology-based, it permits variation across technologies along a number of dimensions. The remainder of this paper will be dedicated to explicating virtual reality in relation to two such dimensions—vividness and interactivity.

Variables Predicting Virtual Reality

First-person experiences of the real world represent a standard to which all mediated experiences are compared, either mindfully or otherwise; face-to-face interaction with other humans is used as a model for all interactive communication (Durlak, 1987). The human perceptual system has been tuned through the process of evolution for the perception of real-world environments. The experience of virtual realities can be enhanced by appealing to these same perceptual mechanisms (see Reeves, 1991). However, since VR is defined in terms of an individual experience of a particular kind, it is difficult to arrive at operational measures of telepresence (see Held & Durlach, 1992). Since telepresence is necessarily experienced by means of a medium of some kind, properties of the medium will also affect the perception of virtual reality. Factors influencing whether a particular mediated situation will induce a sense of telepresence include the following: the combination of sensory stimuli employed in the environment, the ways in which participants are able to interact with the environment, and the characteristics of the individual experiencing the environment. Thus, telepresence is a function of both technology and perceiver.

Variation Across Technologies

Sheridan (1992) identifies five variables that contribute to inducing a sense of telepresence. Three of them are technological: the extent of sensory information, control of sensors relative to environment, and the ability to modify the physical environment (see Biocca, 1992, Figure 3, for a graphical depiction). The other two are task-, or context-based: task difficulty, and degree of automation. Zeltzner (1992) provides a similar matrix of variables that describe the capabilities of graphic simulation systems, which he terms autonomy (human control), interaction (real-time control), and presence (bandwidth of sensation). Naimark (1992) employs a six-category taxonomy for visually representing and reproducing experience. Robinett (1992) presents a more technically-driven nine-category taxonomy to describe environments presented by head-mounted displays: causality, model source, time, space, superposition, display, sensor, action measure, and actuator.

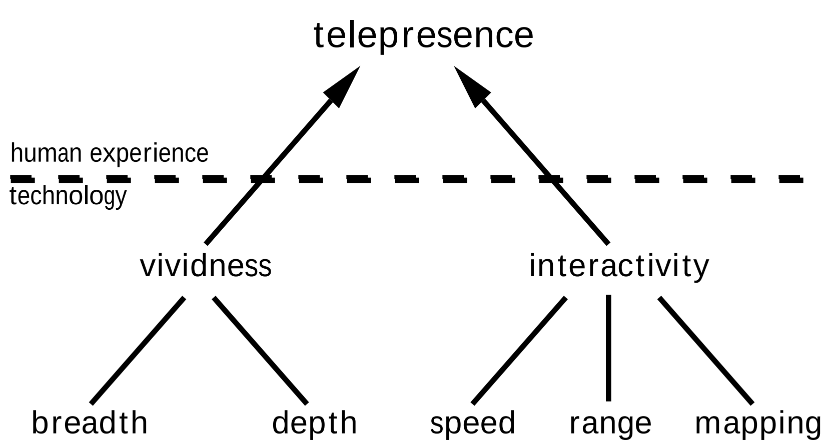
Two major dimensions across which communication technologies vary are discussed here as determinants of telepresence. The first, *vividness,* refers to the ability of a technology to produce a sensorially rich mediated environment.[11] The second, *interactivity,* refers to the degree to which

[11] Note that this definition *does not* make reference to resembling objects in the real world, and thereby avoids problems in describing the experience of artificial situations. For instance, how does one determine whether a unicorn in virtual reality looks like a “real-world unicorn”? By referring only to sensory richness, this definition avoids such concerns.

users of a medium can influence the form or content of the mediated environment. Media artist Michael Naimark (1990) refers to these same properties as *realness* and *interactivity*. Others, including Laurel (1991) and Rheingold (1991), make similar distinctions. See Figure 2 for a graphical depiction of these two dimensions and for some of the variables that contribute to each.

When considering these dimensions, one should remember that virtual realities resides in an individual's consciousness; therefore, the relative contribution of each of these dimensions to creating a sense of environmental presence will vary across individuals. Similarly, differences in the content of the mediated environment — that is, in the kinds of entities represented and in the interactions among them — will also affect the perception of presence. However, the variables vividness and interactivity refer only to the representational powers of the *technology*, rather than to the individual; that is, these variables determine properties of the stimulus that will have similar but not identical ramifications across a range of perceivers. The remainder of this section considers these two dimensions in some detail.

Figure 2:
Technological Variables Influencing Telepresence



Vividness

One variable property of media technologies that influences their ability to induce a sense of presence is vividness:

- Vividness *means the representational richness of a mediated environment as defined by its formal features, that is, the way in which an environment presents information to the senses.*

Vividness is stimulus driven, depending entirely upon technical characteristics of a medium. Rafaeli (1985) refers to this property as "transparency" (p.9). A highly vivid medium can be considered "hot" in the McLuhanesque sense, as it "extends one [or many] sense[s] in 'high definition.'" (1964, p. 36). Many factors contribute to vividness. Two generalized but important variables will be discussed here: sensory *breadth*, which refers to the number of sensory dimensions simultaneously presented, and sensory *depth*, which refers to the resolution within each of these perceptual channels.

Breadth is a function of the ability of a communication medium to present information across the senses. J. J. Gibson (1966) defines five distinct perceptual systems: the basic orienting system (which is responsible for maintaining body equilibrium), the auditory system, the haptic (touch) system, the taste–smell system, and the visual system. Inputs to several of these systems from a single source can be considered informationally equivalent (Gibson, 1966). However, the redundancy resulting from simultaneous activation of a number of perceptual systems reduces the number of alternative situations that could induce such a combination of perceptions and therefore strengthens the perception of a particular environment.

This concept is best illustrated by an example. Imagine standing on a street corner in a rainstorm. Which sense is responsible for generating a sense of presence in that environment? The haptic system is activated by raindrops hitting the body, but a similar sensation could result from being sprayed by a nearby sprinkler. Similarly, the smell of a soggy dog standing nearby could result from other situations. But when these perceptions occur simultaneously — the image of raindrops falling on the streets and the buildings, the sound of the raindrops hitting the ground and the cars driving across wet pavement, and the taste of wet diesel exhaust from passing buses — a sense of being on a street corner in the rain is clearly generated. The vividness of the street corner scene is not generated by any single sensory input alone but by the simultaneous juxtaposition of all sensory input. Often, redundant information is presented simultaneously: One hears an explosion, sees the flash, and smells the smoke simultaneously. This redundancy serves to further enhance vividness.

Traditional media such as print, telephone, television, and film are relatively low in breadth, relying primarily on the visual and auditory channels. However, some artists have attempted to expand these boundaries. Films such as *Earthquake* (Robson, 1974) and *The Tingler* (Castle, 1959) included vibrating devices attached to theater seats in order to add haptic sensation; the film *Polyester* (Waters, 1981) was originally presented in “Odorama” — on entering the theater, theatergoers were presented with a “scratch-and-sniff” card and were instructed to smell certain scents at appropriate points during the film. One notable early example of an attempt to provide great sensory breadth in a mediated presentation is the Sensorama device, developed by Mort Heilig (see Krueger, 1991, and Rheingold, 1991 for more detailed descriptions). This arcade-game style simulator utilizes four of the five senses to simulate a motorcycle ride: Users see the Manhattan streets go by, hear the roar of the motorcycle and the sounds of the street, smell the exhaust of other cars and pizza cooking in roadside restaurants, and feel the vibration of the handlebars. Similarly, many theme park attractions, particularly those at Walt Disney World and Disneyland, use a high degree of breadth in order to simulate a sense of presence. The addition of changes in orientation, haptic sensations, smells, and tastes, in combination with auditory and visual sensation, are particularly effective in this regard. For example, the *Star Tours* and *Body Wars* simulators combine a motion platform with multichannel sound and film to simulate space travel and a tour through the human body, respectively. Other attractions use similar means to enhance the sense of presence induced by scenes employing animated three-dimensional figures: In the *Pirates of the Caribbean* attraction, the smell of gunpowder is used to enhance the illusion of being in the midst of a battle; the *Universe of Energy* in the EPCOT Center employs heat lamps and humidifiers to simulate the experience of being among the dinosaurs; and the *Spaceship Earth* utilizes chemical smoke to enhance the perceived realism of sending smoke signals with a simulated campfire.

Newer media technologies have made similar efforts to augment the breadth of mediated experience (see Biocca, 1992). For instance, sound has become increasingly important in computer interface design, and new tactile-feedback controllers have been developed for use in computer-based interactive systems. Given the great attention such technologies have achieved in recent years, it seems safe to assume that substantial advances will be made in this direction in the near future.

The vividness of a particular mediated representation also depends upon the depth of the sensory information available in each perceptual channel. This concept can be described in terms of "quality": an image with greater depth is generally perceived as being of higher quality than one of lesser depth; the same is true for auditory representation. Informationally, depth depends directly upon the amount of data encoded and the data bandwidth of the transmission channel. In real-world perception, depth is taken for granted, as our sensory mechanisms almost always operate at full bandwidth. However, the same is not true of mediated perception. In designing media systems, we must always make sacrifices in bandwidth; no currently available auditory or visual recording systems match the capabilities of the human auditory and visual system.

For instance, in the case of the auditory system, our ability to recognize the particular sounds, such as those of different musical instruments or different voices, results from the simultaneous perception of a complex combination of amplitude and frequency cues, as well as differences in arrival time and intensity between the signals from the two ears (see Wenzel, 1992). In order to represent a sound precisely by means of a medium, all of these characteristics must be precisely recreated. However, depending on the intended purpose of a medium, this is not always necessary: The telephone system has been optimized for the transmission of comprehensible speech in the minimum possible bandwidth and therefore utilizes only the minimum level of sound quality required for comprehensibly transmitting speech signals. Because speech perception is a direct symbolic process (Gibson, 1966), a lower-bandwidth representation is sufficient for conveying content. In contrast, compact discs (CDs) have been optimized for distribution of recorded music and thereby must be capable of representing a far wider auditory bandwidth. They therefore encode a substantially greater quantity of data and can provide much greater depth. But neither of these systems is capable of encoding the full range of ambient and spatial information that is essential in presenting a realistic auditory representation of a space; however, both "surround-sound" systems that use loudspeakers to create an illusion of space (Dressler, 1988; Mead, 1987), and immersive, headphone-based auditory displays that present acoustic environments keyed to the motion of the wearer (Wenzel, 1992; Durlach, *et. al.,* 1992) promise to extend the ability of media systems to recreate the spatial detail that is so important in inducing a sense of presence (see Blauert, 1983).

A similar tradeoff is evident in the case of television transmission. Most commercial films are shot using 35 mm film, which has a high visual resolution in terms of both number of picture elements (pixels) per unit area and the range of different colors that can be represented by any given pixel. Film therefore exemplifies great sensory depth. In contrast, television is technologically limited to only 525 lines of resolution (for the NTSC video standard used in America) regardless of screen size, and can capture a much narrower range of colors with each pixel. Television is therefore considerably lower in depth than film. The desire to bring greater sensory depth to the television image is the motivating force behind the Advanced Television (ATV) systems currently under study;

however, these advantages come at great cost in terms of bandwidth requirements.[12] Various non-immersive "three-dimensional" visual systems, including the ViewMaster, "three-dimensional" films, and holograms, attempt to accurately portray a sense of depth across part of the visual field, while immersive visual displays such as stereoscopic head-mounted displays create a sense of presence by presenting a visual environment that moves with the viewer.

The relative contributions of breadth and depth to vividness are not constant. For example, a silent film has considerably greater image detail than does a video presentation with sound; it is therefore greater in depth but lesser in breadth. Similarly, a compact disc recording of an opera has much wider frequency bandwidth and greater dynamic range in the auditory domain than does a standard videotape of the same performance, but the videotape includes image. The simultaneous engagement of multiple perceptual systems is an extremely effective means of engendering a sense of presence, even if some stimuli are quite low in depth (as is the case in the aforementioned Disney attractions). It is likely that breadth and depth are multiplicatively related in generating a sense of presence, with each dimension serving to enhance the other; the exact nature of this interaction clearly warrants further study.

New technologies promise to expand both the sensory breadth and depth of mediated experience (see Biocca, 1992, for a review). As media technologies become more and more vivid, it is possible that we will someday have systems capable of passing a "perceptual Turing test." The ramifications of media systems whose representations are perceptually indistinguishable from their real-world counterparts is both exciting and terrifying—exciting because of the possibilities afforded by such systems to experience distant and nonexistent worlds, yet terrifying because of the blurring of distinction between representation and reality.

Interactivity

Communication media can also be classified in terms of interactivity:

- Interactivity *is defined as the extent to which users can participate in modifying the form and content of a mediated environment in real time*.

Interactivity in this sense is distinct from *engagement* or *involvement* as these terms are frequently used by communication researchers (see Rafaeli, 1986, 1988); for the purposes of this paper, interactivity (like vividness) is a stimulus-driven variable, and is determined by the technological structure of the medium. This definition of interactivity differs substantially from that used by most communication researchers. Consider Rafaeli's definition:

> Interactivity is a variable characteristic of communication settings. Formally stated, interactivity is an expression of the extent that in a given series of communication exchanges, any third (or later) transmission (or message) is related to the degree to which previous exchanges referred to even earlier transmissions. (1988, p. 111)

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[12] Indeed, the development of algorithms capable of compressing the huge amount of data required for the transmission of high-resolution moving pictures into a manageable bandwidth has been the primary obstacle in the development of ATV systems.

The difference between Rafaeli's definition and that given above is not surprising, since his definition, like others in the communication literature (see Durlak, 1987; Rafaeli, 1988), is based on the traditional view of mediated communication discussed above. In contrast, the definition given here is based on telepresence view of mediated communication and thereby focuses on properties of the mediated environment and the relationship of individuals to that environment.

Interactivity is a variable of great concern to researchers in human-computer interaction (see Heckel, 1991; Laurel, 1986, 1990, 1991; Norman, 1986, 1988; Schneiderman, 1992; Turkle, 1984). As discussed above, both Sheridan (1992) and Zeltzer (1992) include variables that resemble the definition of interactivity given here as part of their discussions of presence. Indeed, the definition of interactivity used here may be viewed as collapsing two of the three dimensions in each of their models—control of sensors and ability to modify environment in Sheridan's model; autonomy and interaction in Zeltzer's model—into the single dimension that includes all aspects of the perceiver's control of his relationship to the environment.

A limitation of defining interactivity in terms of the malleability of a medium's form and content is that such a definition does not include control over how the medium can be experienced. Thus, a book, which cannot be changed easily in real time without cutting it apart is not considered interactive, though one can certainly read a book interactively, jumping at will from page to page and from chapter to chapter. Conversely, a laserdisc system that includes programming that enables a user to control the order in which its content is presented in real time based is considered somewhat interactive, because the medium itself can change. And clearly, both a position-sensing, head-mounted display controlling a computer-generated graphical environment in real time and a text-based multi-user dungeon (MUDs, see Bruckman, 1991; Rheingold, 1993) that allows physically distant participants to interact with each other are considered quite interactive. Most traditional media systems are not particularly interactive in this sense: Interaction with a newspaper is possible only by writing letters to the editor or by writing stories for inclusion; call-in shows and request lines provide the only means of interaction with radio; most paintings are not interactive at all.

Three factors that contribute to interactivity will be examined here (although many others are also important): *speed*, which refers to the rate at which input can be assimilated into the mediated environment; *range*, which refers to the number of possibilities for action at any given time; and *mapping*, which refers to the ability of a system to map its controls to changes in the mediated environment in a natural and predictable manner.

Speed of interaction, or response time, is one important characteristic of an interactive media system. Real-time interaction clearly represents the highest possible value for this variable: The actions of a user instantaneously alter the mediated environment. Many new media attempt to reach this level of interactivity, thereby enabling mediated experience to substitute for or amplify perception of the world in real time. This immediacy of response is one of the properties that makes even low-resolution video games seem highly vivid. Computerized virtual-world systems using "goggles 'n' gloves" also seem highly interactive, as they attempt to map user actions to actions in the virtual environment in real time (though some delay is still common). The telephone permits such real-time interaction among two parties (three or more in the case of a conference call); teleconferencing systems and *groupware* computer applications similarly extend real-time interactivity to multiple users and multiple modalities. Other media systems permit less immediate interaction: Films, like books, allow no interaction at all (a long time!); an answering machine allows messages to be left and retrieved at a later time but offers no indication of how long the intervening interval may be; and computer conferencing systems permit nearly instantaneous interaction, requiring users only to finish typing a message before sending it. Both MUD's and online "chat" systems (such as Internet Relay Chat and the "chat rooms" on commercial online services) expand this level of interactivity to include 30 or more simultaneous users.

The range of interactivity is determined by the number of attributes of the mediated environment that can be manipulated and by the amount of variation possible within each attribute. In other words, range refers to the amount of change that can be effected on the mediated environment. The specific dimensions that can be modified depend on the characteristics of the particular medium but include temporal ordering (discussed below), spatial organization (where objects appear), intensity (loudness of sounds, brightness of images, intensity of smells), and various frequency characteristics (timbre, color). The greater the number of parameters that can be modified, the greater the range of interactivity of a given medium. Video-based systems, listed here by increasing range, provide a good set of examples along which a subdimension of range, temporal ordering, can vary:[13] A television broadcast permits a very small number of possible actions at a given instant, since a particular program is either on or off (continuous play). A program recorded on videotape can be paused at any time (start-stop), and portions may be skipped or repeated at the whim of the viewer (search). An interactive laserdisc augments these capabilities by allowing random-access jumps to any portion of the program in a matter of seconds. A computer-based animation system actually can permit interaction with objects *in* the mediated environment (rather than with the environment as a whole) in real time.

Mapping refers to the way in which human actions are connected to actions within a mediated environment (see Norman, 1986, 1988). At one extreme, these mappings can be completely arbitrary and unrelated to the function performed. For instance, wiggling one's left toe might increase the loudness of sound from the television speaker, or typing arbitrary commands into a computer might shift the perspective of the image in a head-mounted display. At the other end of the spectrum, mapping may be completely natural: Turning a steering wheel on an arcade video game might make the "virtual car" on the screen move accordingly, or mimicking the action of throwing a ball while wearing a glove controller might initiate the throwing of a "virtual ball." Mapping is thus a function of both the types of controllers used to interact with a mediated environment and of the ways in which the actions of these controllers are connected to actions within that environment. In situations in which action in a mediated environment has a direct real-world counterpart, such as the automobile and baseball examples discussed above, the appropriate mapping strategy should match the natural action as closely as possible. In other cases, appropriate use of *metaphor* can help match controller and controlled. For example, the Apple Macintosh computer uses a "desktop metaphor" for organizing its file system (see Erickson, 1990); the "jog-shuttle" motion-control wheel found on many VCRs uses a directional metaphor for mapping hand controls to tape motion—twisting one way moves forward, the other backward, and the amount of twist determines the shuttle speed. In some cases, a completely arbitrary system must be learned, such as is the case with the QWERTY layout of

13 Of course, each of these media also has a range of interactivity across many other dimensions, such as image brightness, contrast, color, hue, etc. However, the technologies listed do not *differ* in this regard.

most typewriter and computer keyboards. However, even an arbitrary but standardized mapping system is better than no system at all, because such a system need be learned only once.

Since our perceptual systems are optimized for interactions with the “real world,” mapping is generally increased by adapting controllers to the human body. Many such controllers are now under development (see Biocca, 1992); speech-recognition systems and gloves epitomize such designs. As these and other technologies become more advanced, the mapping of controller actions to actions in mediated environments is likely to become increasingly natural.

Variation Across Individuals

If virtual reality is defined in terms of telepresence, then its locus is the perceiver. Under this definition, virtual reality refers only to those perceptions of telepresence induced by a communication medium. Therefore, virtual reality can be distinguished from purely psychic phenomena (such as dreams or hallucinations), since these experiences require no perceptual input at all, and can be distinguished from the “real” reality as experienced via our unaided perceptual hardware, since virtual realities (unlike real realities) can be experienced only through a medium.

The number of actors present in a virtual world can also affect the perception of telepresence. Since humans are well accustomed to interacting with other humans in the real world, the apparent presence of others in virtual worlds should enhance the experience of telepresence. Although virtual reality refers to individual experience, multiple individuals can experience *similar* virtual realities by sharing the same virtual space, either electronically or through other technological means. This process occurs over a wide range of technologies: in electronic bulletin-board systems (BBSs), conferencing systems, and MUD's by means of text, in teleconferencing systems by means of video, and in movie theaters by simultaneously bringing everyone in the theater into the same projected world.

Both immediate situational factors and ongoing personal concerns (referred to as *background* by Winograd & Flores [1986]) are important in determining the extent of telepresence. These factors also interact with the vividness and interactivity of the medium itself. The relative importance of each input modality varies from situation to situation. Consider the earlier example involving standing on a street corner in the rain: Which sensory input is most important in generating the impression of being present on the street corner? The answer depends on the particular individual. If a friend is waving from across the street, then sight is most important; however, if he or she is yelling rather than waving, then hearing is most important. An asthmatic might rely on smell to identify situations in which breathing problems might arise, whereas touch is most important to the Wicked Witch, who must seek shelter or melt in the rain. Situational characteristics are also important: A low-flying jet aircraft renders the auditory channel temporarily useless for attracting attention, a city bus similarly blocks vision, and an oxygen mask or raincoat could help the asthmatic or the witch.

Laurel (1986, 1990, 1991) emphasizes the experiential nature of our interaction with media technologies.[14] Laurel describes media use in terms of *mimesis* (a form of artistic imitation typically applied in dramatic contexts), likens the relationship between user and technology to action in a play, and emphasizes the importance of encouraging the user of a technology to develop a first-person, rather than third-person, relationship with his or her mediated environment. *Engagement*, which Laurel (1991) describes as a primarily emotional state with cognitive components, serves as a critical factor in engendering a feeling of "first-personness" (p. 113). Engagement is likened to what poet Samuel Taylor Coleridge called the "willing suspension of disbelief":

> Coleridge believed that any idiot could see that a play on stage was not real life. (Plato would have disagreed with him, as do those in whom fear is induced by any new representational medium, but that is another story.) Coleridge noticed that, in order to enjoy a play, we must temporarily suspend (or attenuate) our knowledge that it is "pretend." We do this "willingly" in order to experience other emotional responses as a result of viewing the action.... The phenomenon that Coleridge described can be seen to occur almost identically in computer games, where we feel for and with the characters (including *ourselves* as characters) in very similar ways. (Laurel, 1991, p. 113)

This willingness to interpret mediated experiences as if they are veridical results from a complex interaction among factors including both the conscious desire to "let oneself go," and less mindful processes entailed by the formal characteristics of the medium itself (see Reeves, 1991) and by the social content of that environment (see Nass and Steuer, 1993). This process is of great interest in the context of all kinds of mediated experience; however, further discussion is beyond the scope of this chapter.

Dimensions and Media

Media systems that are both highly vivid and highly interactive are not yet widely available. Indeed, video games are the closest most people have come to such systems. So too, media systems that allow individuals to interact with each other in natural ways within virtual environments are not yet common, nor are systems that can represent the seemingly infinite range of sensory raw materials present in the real world. However, systems that rate high on both dimensions are quite common in science fiction: The Holodeck on *Star Trek: The Next Generation* provides real-time interactive multisensory simulations, as does the nursery in Bradbury's short story *The Veldt* (1951). *Cyberspace*, an electronic realm conceived by science fiction author William Gibson (1984), provides a somewhat different vision of an interactive multisensory environment. Cyberspace encompasses both real and synthesized realities as a unified *matrix* of data and is experienced by *jacking in* one's nervous system directly to the mediated world by means of special hardware. Thus, unlike traditional mediated experience, cyberspace bypasses the sense organs completely, presenting its stimuli directly to the perceptual systems in the brain, thereby presumably maximizing both sensory breadth and depth. Gibson delineates the experience of cyberspace from another, non-interactive

[14] Though Laurel explicitly discusses human-computer interface design, most of her points are equally applicable to other media as well. Indeed, what makes her writing fascinating is the extent to which her concepts apply across media.

medium called *simstim*, which is also experienced via direct neural interface but permits only passive experience (much like television).

Figure 3:
Various Media Technologies
Classified by Vividness and Interactivity

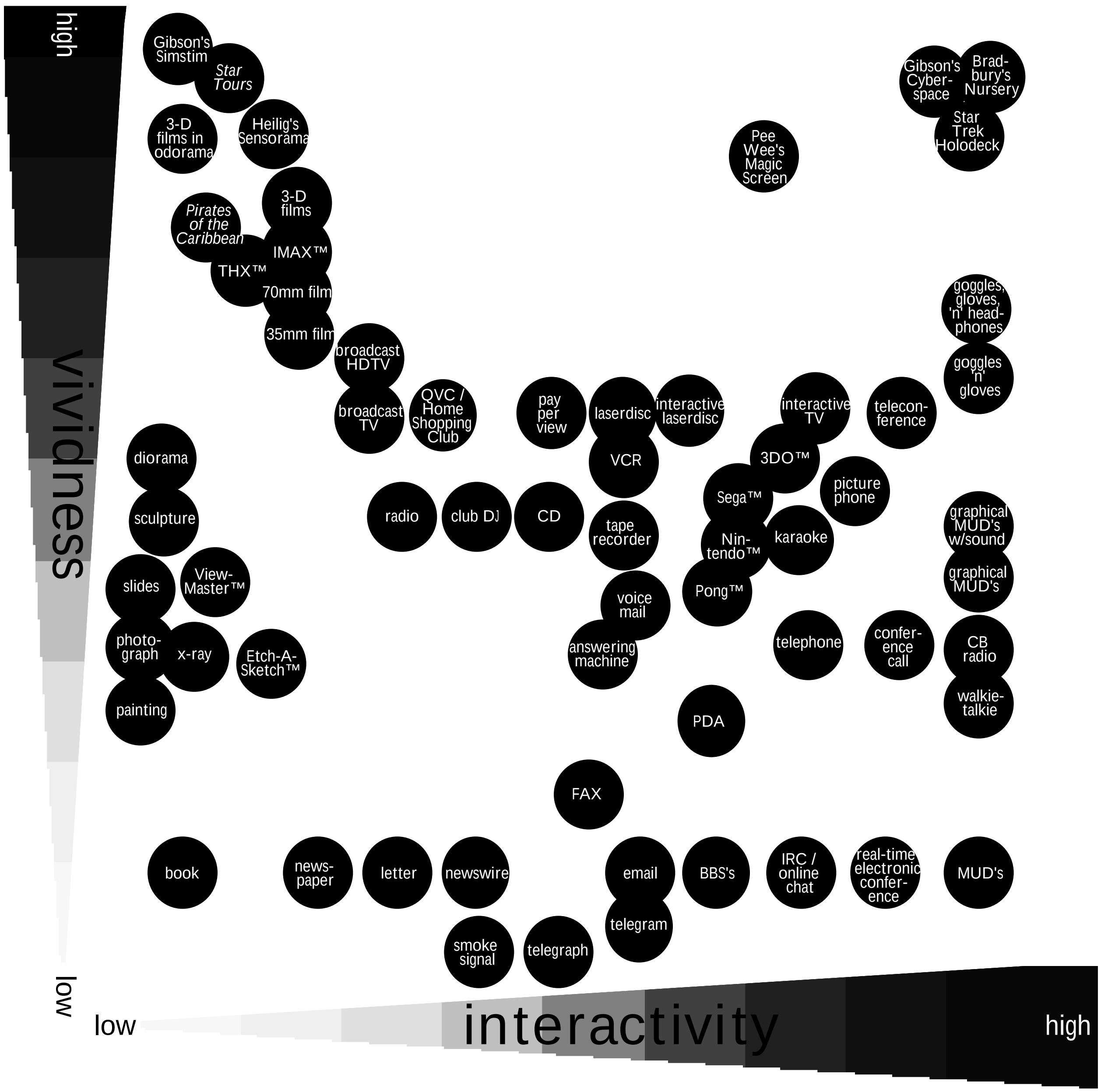

Figure 3 classifies a wide range of media technologies, both real and fictional, in terms of vividness and interactivity.[15] In considering this chart, it is interesting to note both the areas that are covered by technologies that are currently present, and the areas that remain blank, for which the appropriate technologies have not yet been developed.

Since the dimensions discussed here depend on a wide variety of independent variables, the exact relationship between these properties and the experience of telepresence (a dependent variable) is a matter for empirical study (though many hypotheses can be generated). It seems that vividness and interactivity are both positively related to telepresence; that is, the more vivid and the more interactive a particular environment is, the greater the sense of presence evoked by that environment. However, these predictions may not always hold and may be dependent on other mitigating factors. For example, as McLuhan (1964) predicted, an extremely “hot” medium (one that designed to maximize vividness) may actually decrease the ability of subjects to mindfully interact with it in real time. This may be a result of limitations on cognitive processing power available in the perceiver; rapid-fire, high-bandwidth, multisensory stimulation might engage such a great portion of the brain’s cognitive capacity that none is left for more mindful processes (see Lang, 1992; Reeves, Detenber, & Steuer, 1993).

Communication Research and Virtual Reality

Many studies regarding media content and individual factors contributing to mediated perception have been performed in the field of communication. However, few studies have explicitly addressed interactivity, vividness or similar variables. Quite a bit of research on interactivity has been done in the field of human-computer interaction, but, as noted by Rafaeli (1985, 1988), interactivity research has been sorely neglected by communication researchers. Similarly, most of the research on vividness has been technology oriented, in order to determine whether the cost of implementing a particular technological improvement is warranted by users’ increased “liking” (see McFarlane, 1991, and Neuman, *et al.*, 1987, for examples of such studies; see Reeves, Detenber, & Steuer, 1993, for one counterexample). Thus, the precise ramifications of these variables and others like them are largely unknown.

Progressively more advanced media technologies will enhance the sense of telepresence in a wide variety of virtual realities. Rapid advances in both multimedia computer technologies and in high-speed data networks hasten the development of a truly global village, in which our ability to interact with friends, family, and others who share interests smiliar to our own will no longer be limited by physical proximity. Such “virtual communities” represent one of the most exciting aspects of these developing new media, as they offer individuals a method for participation in, rather than mere observation of, the mediated worlds that surround them. The Internet, commercial online services, and BBS’s have already begun to offer the interactive capabilities required for such communities to form on a large scale.[16] The development of increasingly vivid media is likely to

15 Since interactivity and vividness are such rich concepts, some of the placements are somewhat arbitrary, as they result from differences between media across many different dimensions.

16 See Rheingold, 1993, for a ground-breaking in-depth discussion of virtual communities and the factors underlying their formation.

further expand these possibilities, though the exact nature of the effects of these changes on the characteristics of interpersonal interactions in these virtual realities remains an open (and fascinating) empirical question.

New media may greatly expand the ability to experience telepresence in virtual realities; however, these new developments are also certain to enhance the possibilities for using the media to manipulate and control beliefs and opinions. Furthermore, as an increasing proportion of most individuals' experiences come via mediated rather than direct sources, the potentially detrimental effects of such manipulation increase exponentially. Regardless of the particular medium used, be it telephone, electronic mail, online chat system, computer-video conferencing, or immersive virtual reality, all mediated interactions fall within the domain of communication research. Indeed, communication researchers are uniquely suited to address the perceptual, technological, and social issues surrounding new media technologies *before* they become problematic by building upon the lessons learned through the study of earlier media. Rather than relying on engineers in laboratories to design the media systems of the future and then waiting for media behemoths to implement and distribute these new media, communication researchers have a responsibility to respond proactively by using what they have learned about people and media to study the concepts related to these developments, to make predictions about their possible effects, and to become involved in the design and implementation of new media systems *before* they are institutionalized. Rather than waiting for media industries to develop new offerings to be studied *post hoc*, researchers should be prepared to address general variables and to look *across* media while their work can still have significant impact on design and development of new media. It is hoped that the definitions and dimensions described here will facilitate the study of virtual realities in this way.

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