DOCUMENT RESUME

ED 370 586 IR 055 039

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TITLE	Avatars, Affordances, and Interfaces: Virtual Reality Tools for Learning.
PUB DATE	93
NOTE	11p.; In: Visual Literacy in the Digital Age: Selected Readings from the Annual Conference of the International Visual Literacy Association (25th, Rochester, New York, October 13-17, 1993); see IR 055 055.
PUB TYPE	Reports - Descriptive (141) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Computer Games; *Computer Simulation; *Design; Educational Media; *Educational Technology; Interaction; *Technological Advancement
IDENTIFIERS	Digital Imagery; *Virtual Reality

ABSTRACT

Virtual reality technology offers the promise of interaction with a computer-based environment that engages visual, auditory, and tactile perception. Three interrelated virtual reality design topics are particularly relevant to visual literacy. The first is the concept of avatars. Avatars are agents that appear in a virtual world representing the user. The second design topic is affordances. According to the theory of ecological psychology of J. J. Gibson, affordances are the distinctive features of a thing that help distinguish it from other things that it is not. As such, they provide strong clues to the operations of things. The third design topic is interfaces. Interfaces for both input and output link the user to the virtual world that exists only digitally. Examples are given of the use of each of these design topics in curent computer games and in the science fiction novel "Snow Crash" (N. Stephenson). These interrelated topics must be considered by designers who explore the potential of the new medium. (Contains 13 references.) (SLD)

Avatars, Affordances, and Interfaces: Virtual Reality Tools for Learning

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Introduction

Virtual reality technology offers the possibility of becoming immersed in and interacting with a computer-based environment that engages visual, auditory, and tactile perception. Building on the fields of computer graphics, computer-aided design, human-computer interfaces and simulation, virtual reality was devised to enable people to deal with information more easily. Virtual reality is potentially an extremely versatile and powerful creative tool.

Virtual reality is currently in the very early stages of development. The practical potential of this technology is still under exploration, but it appears to offer important educational potentials in the following areas: (1) modeling complex phenomena, (2) project planning and design, (3) the design of interactive forms of entertainment and learning, (4) communication and control at a distance, (5) virtual field trips, and (6) the design of experiential learning environments. In addition, virtual reality offers many possibilities as a tool for nontraditional learners, including the physically disabled and those undergoing rehabilitation who must learn (or relearn) communication and psychomotor skills. Virtual reality offers applications in many fields, including robotics, medicine, rehabilitation, scientific visualization, aviation, business, architectural and interior design, city planning, product design, military training simulations, law enforcement, entertainment, the visual arts, music, dance, communication and collaboration at a distance, and education.

In thinking about virtual reality, immersive technologies involving wired gloves and head-mounted displays first come to mind. But in addition to immersive VR, there are several other types of virtual reality, including mirror worlds, desktop VR (also known as 'through the window VR'), cab environments, Waldo World VR, and the CAVE.

In this paper, the focus will be on three inter-related VR design topics: (1) avatars; (2) affordances; and (3) interfaces. These topics are particularly relevant to visual literacy.

Avatars

Avatars are agents that appear in a virtual world representing the user. For example, in many VR systems, an image of a hand appears to represent the user's hand encased in a wired glove. Thus the user can see where her hand is in relation to the other objects in the virtual world. More sophisticated avatars can be seen in virtual reality games such as *Dactyl Nightmare* and *Legend Quest*.

To understand what an avatar is, think of Rene Magritte's painting of a pipe that included the words "Ceci ce n'est pas un pipe" (This is not a pipe). Magritte was playing with our understanding of reality and representation. With the introduction of avatars in virtual reality, representations (avatars) become dynamic and seamlessly linked to reality, in real time. With virtual reality, reality and representation are ever more closely intertwined.

The Legend Quest game hints at just how closely reality and representation can become merged in virtual reality. Based upon the Dungeons & Dragons role-playing game, Legend Quest uses four immersive virtual reality systems networked together so that four players share the same virtual world, which includes a forest, a castle, and a multilevel dungeon. Players are able to see and speak with each other. A special voice input/output system allows them to speak in the voice of the character they have chosen to play. Thus the avatar is not only visual but auditory. Each player sees and hears a representation of his or her character within the virtual world. There are eighteen possible characters. The possibilities are limited to an Elf, Dwarf, or Human of either sex who may be a Wizard, a Warrior, or a Thief. Every aspect of character has disadvantages as well as advantages, so a team with the most varied aspects and talents is the most likely to succeed in the quest. All four players are on a quest together, and the dynamics of the game create the most success when they cooperate with each other. The goal of the game is to master ten challenges while not dying in a hazard or from foul play. The programming of the monsters in the dungeon uses artificial intelligence that allows them to learn from experience and make countermoves. Winning is not easy (Hamit, 1993).

Another example of an avatar comes from Waldo World VR applications. This type of virtual reality is a form of digital puppetry involving real-time computer animation. The name "Waldo" is drawn from a science fiction story by Robert Heinlein (1965). Wearing an electronic mask or body armor equipped with sensors that detect motion, a puppeteer controls, in real-time, a computer animation figure on a screen.

One example of a Waldo World VR application is the Virtual Actors™ developed by SimGraphics Engineering. These are computer-generated animated characters controlled by human actors, in real-time. To perform a Virtual Actor (VA), an actor wears a "Waldo" which tracks the actors' eye brows, cheek, head, chin, and lip movements, allowing them to control the corresponding features of the computer-generated character with their own movements. The animated character is a form of avatar that makes subtle movements and expressions based on the corresponding gestures and expressions of the puppeteer. Here the avatar is at center stage. A hidden video camera aimed at the audience is fed into a video monitor backstage so that the actor can see the audience and "speak" to individual members of the audience through the lip-synced computer animation image of the character on the display screen. This digital puppetry application is like the Wizard of Oz interacting with Dorothy and her companions: "Pay no attention to that man behind the curtain!"

The science fiction novel *Snow Crash* by Neal Stephenson plays with the notion of avatars in the Metaverse, the networked virtual world where much of his story takes place. In the Metaverse, it is possible to have an expensive, custom-designed avatar that is capable of subtle facial expressions or, for the less affluent, it is possible to get a mass-produced avatar from someplace like Walmart. These mass-produced avatars come with model names. For a woman, the low-cost avatar goes by the name "Brandy." Here is Stephenson's description: "Brandy has a limited repertoire of facial expressions: cute and pouty; cute and sultry; perky and interested; smiling and receptive; cute and spacy. Her eyelashes are half an inch long, and the software is so cheap that they are rendered as solid ebony chips. When a Brandy flutters her eyelashes, you can almost feel the breeze" (p. 37). The male counterpart is a "Clint." A Clint avatar "is just the male counterpart of Brandy. He is craggy and handsome and has an extremely limited range of facial expressions." There is also a low-cost "Avatar Construction Set" for the more creative.

In the Metaverse, avatars offer certain advantages: "Your avatar can look any way you want it to, up to the limitations of your equipment. If you're ugly, you can make your avatar beautiful. If you've just gotten out of bed, your avatar can still be wearing beautiful clothes and professionally applied makeup" (p. 36). Celebrities can spend a night on the town in the Metaverse without fear of robbery, violence, or bother from over-enthusiastic fans.

Affordances

Let's now turn to the second design topic, affordances. Psychologist J.J. Gibson (1986) has proposed a theory of ecological psychology that emphasizes human perception of the environment, specifically the psychology of the awareness and activities of an individual in an environment. In Gibson's theory, "affordances" are the distinctive features of a thing which help to distinguish it from other things that it is not. Affordances help us to perceive and understand how to interact with an object. For example, a handle helps us to understand that a cup affords being picked up. A handle tells us where to grab a tool such as a saw. Affordances provide strong clues to the operations of things.

Affordance perceptions allow learners to identify information through the recognition of relationships among objects or contextual conditions. Affordance recognition must be understood as a contextually sensitive activity for determining what will (most likely) be paid attention to and whether an affordance will be perceived. The ability to recognize affordances is a selective process related to the individual's ability to attend to and learn from contextual information.

Gibson's model of ecological perception emphasizes that perception is an active process. Gibson does not view the different senses as mere producers of visual, auditory, tactual, or other sensations. Instead he regards them as active seeking mechanisms for looking, listening, touching, etc. Furthermore, Gibson emphasizes the importance of regarding the different perceptual systems as strongly inter-related, operating in tandem. Gibson argues that visual perception evolved in the context of the perceptual and motor systems, which constantly work to keep us upright, orient us in space, enable us to navigate and handle the world. Thus visual perception, involving head and eye movements, is frequently used to seek information for coordinating hand and body movements and maintaining balance. Similar active adjustments take place as one secures audio information with the ear and head system.

Gibson hypothesized that by observing one's own capacity for visual, manipulative, and locomotor interaction with environments and objects, one perceives the meanings and the utility of environments and objects, which Gibson calls "affordances." Following from this, one can predict that the ways in which the user is allowed to interact with virtual things in a computer-generated world will determine how well he or she can understand them. Gibson's ideas highlight the importance of understanding the kinds of interactions offered by real environments and the real objects in those environments. This knowledge from the real world can inform the design of interactions in the virtual environment so that they appear natural and realistic, or at least meaningful.

How does this relate to virtual reality? According to Rheingold (1991), a glove that controls a virtual object would be an "affordance," a means of literally grabbing on to a virtual world and making it a part of our experience. Rheingold explains: "By sticking your hand out into space and seeing the hand's representation move in virtual space, then moving the virtual hand close to a virtual object, you are mapping the dimensions of the virtual world into your internal perception-structuring system" (p. 131). So the image of a hand in a virtual world is both an affordance and an avatar.

Virtual reality pioneer Jaron Lanier (1992) has commented that the principle of head-tracking in virtual reality suggests that when we think about perception -- in this case, sight -- we shouldn't consider eyes as "cameras" that passively take in a scene. We should think of the eye as a kind of spy submarine moving around in space, gathering information. This creates a picture of perception as an active activity, not a passive one, in keeping with Gibson's theory. And it demonstrates a fundamental advantage of virtual reality: it facilitates active perception and exploration of the environment portrayed.

Anthropologist Lucy Suchman (1988) has said, "Every human tool relies upon, and deifies, some underlying conception of the activity that it is designed to support, as a consequence, one way to view the artifact is as a test on the limits of the underlying conception" (p. 3). The underlying conception is based upon the affordances the tool offers. Virtual reality is no exception. We expect that when the representation or avatar of our hand encounters a wall, it will be afforded resistance; we don't expect to be able to walk through walls. Since virtual reality is a representation of some reality, we expect it to offer the same, or at least comparable, affordances as the real world it imitates.

Stephenson's science fiction novel *Snow Crash* provides the most intriguing examination of design issues related to affordances in virtual reality to date. In Stephenson's story, the main character, Hiro Protagonist is a man of many talents. He is "the last of the freelance hackers." He is also "the greatest sword fighter in the world." In addition, he gathers and sells information. His avatar in the virtual world of the Metaverse is represented with swords. Hiro carries swords in real life, too; they are family heirlooms. What happens in virtual reality when there is a sword fight and someone's virtual legs are hacked off? This presents a design problem. Stephenson describes the aftermath of a sword fight:

> The [man] lies cut in segments on The Black Sun's floor. Surprisingly (he looks so real when he's in one piece), no flesh, blood, or organs are visible through the new cross sections that Hiro's sword made through his body. He is nothing more than a thin shell of epidermis, an incredibly complex inflatable doll. But the air does not rush out of him, he fails to collapse, and you can look into the aperture of a sword cut and see, instead of bones and meat, the back of the skin on the other side. It breaks the metaphor. The avatar is not acting like a real body. It reminds all The Black Sun's patrons that they are living in a fantasy world. People hate to be reminded of this (p. 103).

So what happens to restore the metaphor, so that it meets the virtual traveler's expectations in terms of affordances? Stephenson explains:

> ...the first thing that happens, when someone loses a sword fight, is that his computer gets disconnected from the global network that is the Metaverse. He gets chucked right out of the system. It is the closest simulation to death that the Metaverse can offer, but all it really does is cause the user a lot of annoyance.

Furthermore, the user finds that he can't get back into the Metaverse for a few minutes. He can't log back on. This is because his avatar, dismembered, is still in the Metaverse, and it's a rule that your avatar can't exist in two places at once. So the user can't get back in until his avatar has been disposed of.

Disposal of hacked-up avatars is taken care of by Graveyard Daemons, a new Metaverse feature that Hiro had to invent. They are small lithe persons swathed in black, like ninjas, not even their eyes showing. They are quiet and efficient. Even as Hiro is stepping back from the hacked-up body of his former opponent, they are emerging from invisible trapdoors in The Black Sun's floor, climbing up out of the nether world, converging on the fallen businessman. Within seconds, they have stashed the body parts into black bags. Then they climb back down through their secret trapdoors and vanish into hidden tunnels beneath The Black Sun's floor (p. 102-103).

This is an elaborate and fanciful vision of how continuity and affordances can be restored in virtual reality. However, there are already some comparable situations in existing virtual reality systems where the design metaphor must be readjusted. For example, in *BattleTech* -- a VR entertainment system for multiple players -- players who lose their vehicles to enemy firepower get wafted to a new one so they can play out their game time, even after they crash. This is a way of upholding the metaphor and maintaining continuity while at the same time giving players their full money's worth. The players pay for each game, so they get to play out the simulation during the entire time they have paid for, even if they lose a round.

In his more recent work on VR as a form of scientific visualization for planetary exploration, Michael McGreevy (1993) of the NASA Ames Lab has taken up the Gibsonian idea that the environment must "afford" exploration in order for people to make sense of it. McGreevy has linked Gibson's concept of affordance to the idea that people can begin to learn something important from the data they have retrieved from planetary exploration by flying their points of view through the images themselves. McGreevy (1993) explains: "Environments afford exploration. Environments are composed of openings, paths, steps, and shallow slopes, which afford locomotion. Environments also consist of obstacles, which afford collision and possible injury; water, fire, and wind, which afford life and danger; and shelters, which afford protection from hostile elements. Most importantly, environments afford a context for interaction with a collection of objects" (p. 87). As for objects, they afford "grasping, throwing, portability, containment, and sitting on. Objects afford shaping, molding, manufacture, stacking, piling, and building. Some objects afford eating. Some very special objects afford use as tools, or spontaneous action and interaction (that is, some objects are other animals)" (p. 87).

McGreevy (1993) points out that natural objects and environments offer far more opportunity for use, interaction, manipulation, and exploration than the ones typically generated on computer systems. Furthermore, a user's natural capacity for visual, manipulative, and locomotor interaction with real environments and objects is far more informative than the typically restricted interactions with computer-generated scenes. A virtual world may differ from the real world, but virtual objects and environments must provide some measure of the affordances of the objects and environments depicted (standing in for the real world) in order to support natural vision more fully.

Interfaces

Let's now turn to the third design topic, interfaces. Interfaces for both input and output, link the user to the virtual world which exists only digitally. Interface devices such as the glove and the full-body input devices offer far more than the convenience of being able to manipulate virtual objects by reaching out and picking them up. So the image of a hand in a virtual world is an affordance and an avatar, linked directly to an interface device: the wired glove. Interface devices such as the wired glove are very important for creating a sense of presence and establishing a feel for the spatial dimensions of the virtual world.

According to Ellis (1992), a large part of our sense of physical reality is a consequence of internal processing rather than being something that is developed only from the immediate sensory information we receive. Our sensory and cognitive interpretive systems are predisposed to process incoming information in ways that normally result in a correct interpretation of the external environment, and in some cases they may be said to actually "resonate" with specific patterns of input that are uniquely informative about our environment.

These same constructive processes are triggered by the interfaces used to present virtual environments. However, in these cases the information is mediated through the interfaces, including the display technology. The illusion of an enveloping environment depends on the extent to which all of these constructive processes are triggered. This is related to the continuity of the affordances between the real world and its electronic virtual surrogate. This includes the options we have for interfacing with the virtual world, and these options have serious limitations, as Brenda Laurel (1992) points out.

According to Laurel, there is a serious navigation problem n virtual reality, limiting how designers can give people the sense that they're moving through large virtual spaces. The most common way to do this is by pointing a finger enclosed in a wired glove and "finger flying." In the real world, we walk, we don't point a finger and expect to move.

Pointing and flying don't give the user the kinesthetic satisfaction of being able to move all over the place. Some developments, such as Fake Space Labs' BOOM visual display and the University of North Carolina's treadmill, work toward providing partial solutions to this problem, but a fully adequate solution remains to be discovered. No one has yet come up with the winning answer to the question of virtual locomotion.

Laurel points up another important issue related to multisensory interfaces in virtual reality: "sensory combinatorics." According to Laurel, "We're working in a multisensory medium: we're trying to cram as many senses as we can into telepresence and virtual environments. How do these senses interact with each other? How do you design for this medium?" (p. 291). This notion of sensory combinatorics, then, concerns putting sensors together properly in a multisensory environment.

One example of the design potential of combining sensory interfaces concerns the role of audio in virtual reality. Laurel explains that audio affects the perception of video: "In the computer game business, we learned that high-resolution audio caused people to report that the game's graphics were higher resolution. It doesn't work the other way though; really high-resolution video does not cause people to report that the little beeps on their PC are suddenly rich, full-bodied sounds. Something interesting is going on here. In one case, audio pulls video along, and in the other, a disparity shatters the illusion" (p. 289).

According to Laurel (1992), "audio pulls us along in a dimension that we might call "involvement," or the dimension of "constructive involvement": pulling stuff out of the imagination of your user to achieve a very deep level of participation. It turns out that audio is a whole lot better at that, in general, than video" (p. 290). When you create an audio-intensive environment, the effect tends to work better, although there is no guarantee. Laurel advises that three-dimensional audio is much better than video at creating a sense of real space.

Conclusion

This paper has focused on three important design issues in virtual reality: avatars, affordances, and interfaces. As we have seen, these three design themes are closely interrelated. They deal with the changing inter-relationship between reality and representation that virtual reality compels us to deal with. Every technology has forced a reconsideration of this issue, but none more profoundly than virtual reality.

In exploring these design themes, the focus has been upon examples, including fictional examples from the science fiction novel *Snow Crash*. Design in virtual reality is almost completely new. In thinking about design for this new medium, past technologies must be considered, together with new visions. Jerome Bruner (1990) proposed a bipolar model of storytelling: paradigmatic storytelling ("just the facts") and narrative storytelling. Designers exploring the potential of the new medium, virtual reality, need to consider both kinds of storytelling in order to get the technical specifications right while at the same time understanding what the virtual world really feels like to the user. Neal Stephenson has referred to this second kind of understanding as "condensing fact from the vapor of nuance."

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