# Virtual reality and virtual bodies

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## ABSTRACT

There are many ways to produce the sense of 'presence' or telepresence in the user of virtual reality. For example attempting to increase the realism of the visual environment is a commonly accepted strategy. In contrast, this paper explores a way for the user to feel present in an unrealistic virtual body. It investigates an unusual approach, proprioceptive illusions. Proproceptive or body ilusions are used to generate and explore the experience of virtuality and presence outside of the normal body limits. These projects are realized in art installations.

## 1. INTRODUCTION

An essential issue in virtual reality (VR) environments is the sense of 'presence' or 'telepresence' by the user within the interactive simulation. This notion of presence is one which acknowledges that the user must in some way feel convinced by the artificial environment and its ability to respond. This conviction for users is necessary for them to act and in a sense inhabit the artificial world.

It is likely that there is a set of characteristics in simulations which encourage a willing suspension of disbelief, that is a willingness on the part of the user, to accept the interactive environment as a reality. One obvious requirement is the threshold of reaction time. It is well known that a response time of 100 milliseconds is a threshold to meet before users feel convinced that the environment is reacting with them. Other attributes may be less measurable, such as, a clear goal or narrative which can focus the user's attention despite limited interaction or graphics, as can be seen in early video games. This paper is about work which explored another possibility for convincing the user: an exploration of proprioceptive or body illusions.

The proprioceptic sensory structure concerns the sense of position and movement of parts of the body. An illusion of this sense changes the impression of where the body limits might be. In effect a subject's illusionary body does not match their physical body. It is this mis match which the following explores. Can the user's body illusions enhanced by interactive images in a VR environment lead the user to feel present in, to inhabit, a virtual body which is visually and functionally different than their physical body? Rather than test this proposition scientifically this paper develops this experience through art projects.

## 2. VR PROJECT: SPECTRAL BODIES

In speculating about a user's sense of presence in a virtual body the project considered a physiological and perceptual basis for the sense of presence in our own bodies, that is the proprioceptive sense. The proprioceptive sense is not as recognized as our other senses such as aural and visual. Yet descriptions of its loss testify to its importance: " I've already noticed that I may lose my arms. There is a way the body feels itself. And if it goes, as it's gone with me, it's like the body is blind,



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it can't see itself"(1). This poignant description by a sufferer of a neurological disease, which destroyed her body sense, relates her experience of no longer inhabiting her body.
It appears that the propriopceptive sense is crucial to our sense of inhabiting our own bodies. It also appears that at least some of this body sense is not so much fixed as potentially modifiable as demonstrated by J. R. Lackner in his paper "Some Proprioceptive Influences on the Perceptual Representations of Body Shape and Orientation' (1988) (2). The results of his experiments "point to the great modifiability of perceptual representations of the body surface in the adult human; perceptual remappings can be generated within seconds". Using slight muscle vibration the subject has the illusion of their body changing shape and/or orientation. For example, the following relates the experience of a subject when J. R. Lackner's experimental methodology was replicated by this project. (figure 1)

> it (my head) is becoming square.
> my, my head is, is....
> no, let's say it differently....
> my neck is becoming very, very, short and broad, like a bull's neck and slowly disappearing into my body.....
> and it's like my hand is becoming one flat line with the top of my body.
> My hand is, kind of, disappearing....
> yea, it feels like I'm completely square now, very small, like one square metre, or something like that...
> it's really odd.
>
> could you get me back? (figure 2)

Could the proprioceptive sense of the VR user be modified to affect the normal mapping of the user's body so that the user's sense of inhabiting the user's own body could be remapped into inhabiting a visual representation of a body in a virtual environment, that is, a virtual body?

## 2.1 Approach

To initially investigate this proposition and for practical reasons the project focused on one part of the body, the hand and arm. The tracking of the hand was already established in VR using the DataGlove (3) and J. R. Lackner (1988) had established several propriceptive experiments for the biceps.

The first step was to construct a virtual hand/arm in a VR environment. The visualization was a simple spectral dotted image (figure 3a). There are several reasons for this choice. A spectral - like image would more closely resemble an illusionary transformation within the user. In contrast a realistic image of the body would carry with it an expectation of constraints from the material world. Consequently, impossible body motion in an illusionary image might be more accepted than in an image which was seen as realistic. Finally a spectral image was faster to process than a realistic one lessening delay in the response time of the VR environment.

## 2.2 Technical description of the VR project

The virtual hand was implemented on an SGI 4D/35TG and an SGI 3130 workstation using the MR Toolkit (4). The MR Toolkit was built with the assumption that the rendering of the user's body is always realistic and unambiguous, so the hand is drawn opaque, and the geometric configuration is as anatomically accurate as the position and glove sensors will allow. Therefore, two modifications were made to the MR Toolkit to render a hand and arm which would complement proprioceptive illusions.

### 2.2.1. Kinematics

To draw the arm, the position and orientation of the hand and the top of the head (from the Head-Mounted Display tracker) were used to calculate the position of the shoulder and the elbow. The main problem with using just head and hand position for inverse arm kinematics is that there are too many degrees of freedom in the kinematic linkage. Therefore, two simplifying assumptions were made: The user's head was assumed to be rigidly connected to the shoulders, and the shoulder, elbow and hand were assumed to lie in a vertical plane.

The shoulder position was calculated by translating down and to the right from the head tracker, as if the user is always looking forwards. If the user turned her head to the left or right, the shoulder position would rotate about the neck axis as if the user had a stiff neck, and was twisting her upper torso about the waist. The elbow position was generated by constructing a triangle with the longest side formed by the line from the shoulder to the hand, and the remaining sides formed by the upper and lower arms. The final elbow position hangs below the shoulder-hand edge, as if constrained to lie on the plane perpendicular to the floor that contains the shoulder and hand points.

Because of the stiff neck assumption, the distance from the shoulder to the hand sometimes exceeded the sum of the upper and lower arm lengths. In this case, the elbow was placed on the shoulder-hand line according to the length ratio of the upper and lower arms. The kinematics routine accepted upper and lower arm lengths as parameters, so that the kinematics could be tailored to the individual user. Arm lengths could also be changed to enhance the proprioceptive illusions generated during the experimental trials.

Given the elbow position, the upper arm was drawn with a "spectral rectangle" from the shoulder to the elbow, and the lower arm was drawn from the elbow to the wrist. A spectral rectangle is a flat rectangular area filled with numerous randomly located dots. A random dot pattern was used because neither transparent polygons nor textures were available on the graphics workstations.

### 2.2.2. Spectral Hand

The standard MR Toolkit hand is drawn using two primitives: the palm of the hand is an extruded trapezoid, and the fingers and thumb are each three box-shaped links connected by two hinge joints. The DataGlove senses only the two proximal hinge joints of the fingers, and the two distal hinge joints of the thumb, corresponding to the hinges in the three-link fingers and thumb. The fingers and thumb are rigidly connected flush to the palm trapezoid at appropriate locations. The spectral hand replaced each box with a spectral rectangle, such that the palm, thumb and fingers had no thickness. Thus, each box link of the thumb and fingers was replaced with one rectangle, and when viewed from the side, they looked like folding strips of paper. Two of the finger links represented the two proximal bones of the finger, while the third link represented the metacarpal bone of the upper palm. We will refer to this three-link extended finger as the "finger linkage". The palm trapezoid was replaced with a smaller spectral rectangle representing the wrist, which anchored the five finger linkages of fingers and thumb.

The spectral hand had six parameters to manipulate the shape and size of the hand, in order to transform the hand into a flowing, wing-like appendage. The first parameter changed the length of the middle and distal finger links, and second parameter changed the metacarpal bone length. The width of the finger linkages was controlled by the third parameter. The fourth parameter allowed the finger linkages to be evenly spread out like a fan, about a rotation axis perpendicular to the palm at the base of the wrist. The fifth parameter rotated the middle and distal finger links about the end of the metacarpal bone, which corresponds roughly to finger abduction. The sixth parameter rotated the distal link about the end of the middle link, an anatomically impossible rotation. With large values for finger lengths, small fan angles, and middle and distal finger joint rotations, the spectral hand looked somewhat like a spectral wing.

The spectral hand parameters were controlled by a keyframe animation system, which included a visual editor to control hand shape, and add, delete and modify keyframes. The keyframe editor used the current real time to determine the current time sample point, and performed linear interpolation to determine the current hand parameters. Each keyframe could be modified to exclude parameters, so that the user could interpolate a parameter using a single line from one keyframe to any following keyframe.

### 2.2.3 Experimental Testbed

The final immersive system used the kinematic spectral arm, and the spectral hand with multiple keyframe sequences. When the user donned the HMD and DataGlove, an experimenter could lengthen or shorten the arm. Arm length changes resulted in a translation of the hand along the line from the shoulder to the hand, and in a change in upper and lower arm lengths by half of the change in the overall arm length. Thus, as the arm length increased, the elbow still appeared appropriately bent, and acted approximately like a super-long arm. The experimenter could also start spectral hand animation sequences while changing arm length, so the user could experience a complete metamorphosis in arm and hand shape and proportion (figures 3a - d).

2.3 Antwerp '93 VR proposal

The following proposal for a VR art installation set out to explore the limits a user might accept in virtual body transformation. A description of this project proposal (figure 4) follows:

> The person using the VR system will be in the middle of the room, lying down, in a glass museum display case. The person's arm and head is tracked and possibly other parts of their body. They are blinded to the audience by the VR headgear. They see a spectral image of what they accept as their hand and arm (and perhaps other parts of their body) which moves in synch with how they sense their 'real' body moving. This virtual body begins to transform, the fingers lengthen, the arm grows longer and longer, the angles at the knuckles twist. There are sounds of evolving or devolving bones, of rerouted circulation, of stretching skin texture.
>
> Yet this person feels present in this body. There are small vibrators strapped to the biceps, destabilizing the person's sense of her own body limits as visual transformations takes place... and sounds of sprouting feathers as the arms twist backwards ...or...insect bee hums as the arms flatten, becoming more and more transparent.
>
> The proportions change scale, antennae - like legs shrinking and stretching as if trying to get into synch with each other, sound explosions coming from behind which bend the 'knees' stretching them until they snap back like elastics. The nose lengthens and body parts implode suddenly taking the person's point of view to the tip of the nose.... the little finger, or what's left of it.
>
> There may be other creatures there, submerging themselves in this virtual body.
>
> Meanwhile the spectators, slip across a floor of liquid crystal glass,opaque at the beginning of the cycle, glimmering a bit with seemingly reflected colours from the room. The central part, where the VR person is, slowly becomes translucent like a pond. The spectator sees not only what appears to be a reflection of the sky in the ceiling but at that moment his peering face amongst these clouds and a transitional moment of ripples across as the sound of water drops. As this scene fades in and out from the infinite space of water and sky the body transformations, sounds and visuals are projected.......there may be moments of perfect transparency...exposing the VR person below. (5)

This is now being considered for another site.

## 3. VIRTUAL BODY INSTALLATION (6)

The final installation that was built for Antwerp (figure 5) incorporated a different proprioceptive illusion (figure 6). This illusion investigated 'making the subjects visual surroundings move can give rise to sensations of self motion, which can either be restricted to the arm or involve the whole body" (7). The piece explored user's reactions to losing their physical body references and experiencing illusionary motion not dissimiliar to the contardictory motion experience in VR, a sensation of motion with no real motion.

3.1 What it looks like, what happens

The art installation is a short column, reminiscent of the column stereoscopes of the mid 1800's, (figure 7) when the new optical instruments were part scientific instrument , part aesthetic object and part perceptual media. ‘Virtual Bodies’ occupies this ambiguous ground of instrument and object . It stands in a Rococo room which is itself an illusionistic box designed to surround, overwhelm and trick the spectator just as in its own way VR is committed to creating a simulated sensorium, enveloping all the senses.

The room becomes a museum miniature standing on a platform in the middle of the room. As the spectator enters they sees the first state, an internally lit miniature glass room. The walls are semi transparent . The coloured images on the walls glow with light from the floor within. Approaching they see that the images are of a Rococo room.

Steps to the platform beckon for a closer look. Standing next to the glass room the spectator notices a brass oculus, in the roof/ceiling, for peering inside. The second state begins as the spectator peers inside. This triggers an image of the highly decorated ceiling fading in/out with the patterned floor, as if the room is turning upside down or the internal space is sandwiched.

On one side of the box,where a knob on an instrument would be, is a hole to put one's hand inside the room.....to enter. With this intervention by the spectator the third state begins. The miniature room suddenly becomes opaque from the outside and loses all it's transparency and detail. The spectator stares down at her hand spread across the room's floor. This floor moves away from her and her hand appears to be infinitely travelling away as if taking her body with it. Although it is clear to the spectator that their body is still, at the same time, the spectator experiences a strong sense of floating away and a confusion of where one's body might begin or end. As the spectator withdraws the transparent miniature room reappears, glowing once again.

3.2 Technical description of 'Virtual Bodies'

The piece is box-shaped about 1150 mm (3' 9") high and at most 600 mm (2') on each side (figure 5). The lower section of the box, 800 mm (2' 7"), has sloped sides and is finished in cherry and walnut wood veneer. Above this section is a steel metal frame which holds four panels. Each panel consists of a 4 layers of material: hand blown glass, Lexan, a Liquid Crystal glass (LC GLASS) [8), a positive film transparency, and another later of Lexan. One of the narrow panels has a hole bored through all layers. LC Glass changes state from translucent to transparent with the application of an 85 volt AC signal. The hole is lined with a machined brass fitting to give a finished effect. The transparencies are positive slides of the four walls of the room which housed the piece during its exhibition. Above the metal frame is a wooden top. In the middle of the wooden top is a hole fitted with a brass eye piece. Figure 8 shows a cutaway view of the piece, identifying the key elements of its construction. The top houses a set of lamps (both low voltage incandescent and 120 volt fluorescent type) arranged to project light downward. Below the lights is a piece of translucent plexiglass which diffuses the light projected by the lamps. On the underside of the plexiglass is a transparency of a photograph of the ceiling of the room. A hole in the plexiglass and transparency allow a subject to view the interior of the box through the eyepiece. The top of the work also houses two infrared distance measuring sensors (9). One of these sensors, mounted near the eye piece and pointing upward, measures the presence of a subjects head above the eye piece. The second sensor, positioned above the hole in one of the narrower panels. This sensor measures the presence of a hand in the hole. Although the both sensors measure distance to objects, in our application, a threshold circuit determines the presence of an object closer than .5 meters to the eyepiece sensor and closer than 20 cm to the hand detecting sensor.

The chamber described by the glass panels, and the plexiglass panel in the lid has as its floor a piece of half mirrored glass (mirrored side facing upward). Underneath the glass is the screen of a 19" (482 mm) video monitor for an Amiga 600 computer, housed along with sensing and actuating electronics below the monitor. The computer generates and controls the effects of a simulated floor for the room formed by the video display. The control electronics convert the analog sensor signals two switched signals that control the lights and LC GLASS material. These signals are also applied to the mouse port of the computer. The computer program and the electronics form a state machine that performs the functions shown in table form (figure 9), based on the state of the sensors.

When neither sensor detects the presence of a subject, the LC GLASS material is set to transparent, both the incandescent and Fluorescent lights are on. The side panels of the piece glow in the dim light of the display area. In this state the computer generates a constant high luminance image of the floor of the room. The image srolls slightly, under software control to reduce wear on the phosphors of the display. To an approaching subject, this presents an alluring image, drawing them closer to the piece.

When the subject places their head over the piece only or the subject places their arm in the hole, the fluorescent lamps are turned off, the incandescent lights are held on, the LC GLASS material is turned off (translucent), and the floor pattern slowly scrolls. At the same time the luminescence of the pattern on the display is stepped by the control program through 16 levels of luminance holding momentarily at both the full luminance and no luminance. When looking through the eyepiece, this combination of lighting and computer states causes the following effect. The image of the floor moves and varies in brightness while alternating with a reflection of the ceiling including the subject's eye in the center.

In the final state, if the subject views through the eye piece and places their hand through the hole onto the mirrored glass, both the incandescent and fluorescent lights are extinguished and the computer increases the scrolling rate with the image at full luminance.

## 4. DISCUSSION

The development of film may be an instructive analogy in how the engineering refinement of a technology as well as the development of expressive devices mutually determine the nature of the machine itself. Film creates in its own way an illusion of 'being there'. The technology which produces this illusion functions partly through physiology: the illusion of moving images through the persistence of vision, and partly through expressive devices used in the film itself.

We take these expressive devices for granted. In an interview before his death the well known experimental filmmaker Bunnel described going to the early movies as a young child. Once when he was watching the screen he was horrified to see a head which grew bigger and bigger until it seemed about to explode like a giant pumpkin. He had just seen his first zoom shot which was incomprehensible to him. It was before zooms became accepted as an expressive device in film. A zoom literally looks as if a person is being decapitated and their head is about to explode. As an expresive device we now read it as a sign to the audience to pay attention to this person (the head) and especially to what we might see on the screen of their interior motivation. The early zoom was likely constructed by the director inching the camera closer to the subject, shooting a few frames, inching closer again, and so on. It was not until the zoom was accepted as an expressive device that it was technologically implemented within the camera. In another example the animator Norman McLaren spent two years overprinting images in one of his earlier films (Pas de Deux). The effect was of a dancing couple's images constantly trailing a moving series of their own images through space. The effect is now part of the technology and can be used almost instantly in many computer graphics programs.

Virtuality and a sense of presence which extends outside our body limits are important issues in VR. They are simultaneously an issue for expressive devices which for example will allow us to navigate in a sophisticated way in virtual space and the technology itself. What expressive device will, for example, maintain a sense of self in VR if my sense of presence, and sense of self, is constantly being stretched beyond my body limits? Like the development of film, are there going to be new physiological thresholds and new expressive devices which will be the basis of convincing telepresence in VR? The projects documented in this paper were undertaken to inquire how humans expressively respond to this condition irrespective of what, or if any, technology is used.

## 5. ACKNOWLEDGEMENTS

I would like to acknowledge the assistance of the Canada Council for the Arts.

## 6. REFERENCES

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"The Body Obsolete", January 7, 1994, SAW Gallery, Ottawa.

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9. Technical Data, The Auto - Focus Module (H2152), 3 - Step Function, Hamamatsu Corporation, Corporate Offices, 360 Foothill Road, Box 6910, Bridgewater, New Jersey 09907-0910

## 7. FIGURES

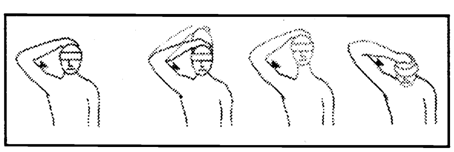

Figure 1. J. R. Lackner, 1988, see reference (4), pg. 285.

Figure 2. Proprioceptic illusion replication, excerpt, 'SPECTRAL BODIES', videotape, C. Richards 1991.

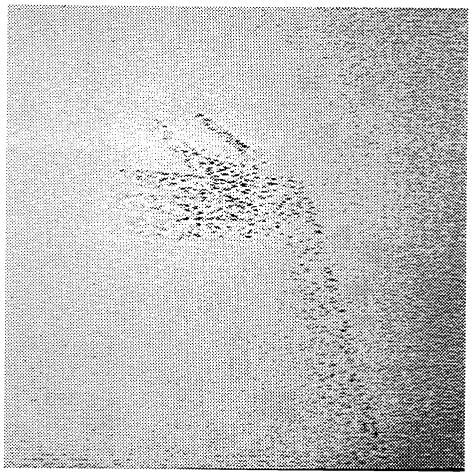

Figure 3(a).

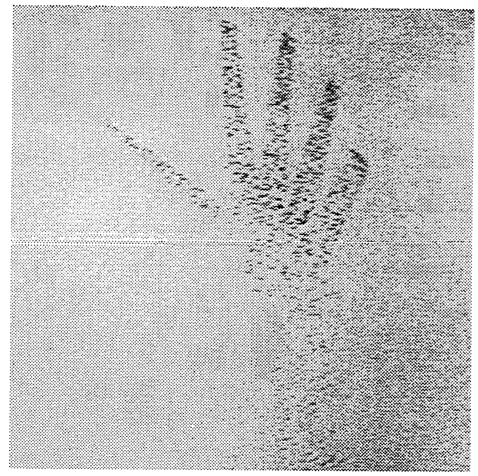

Figure 3(b).

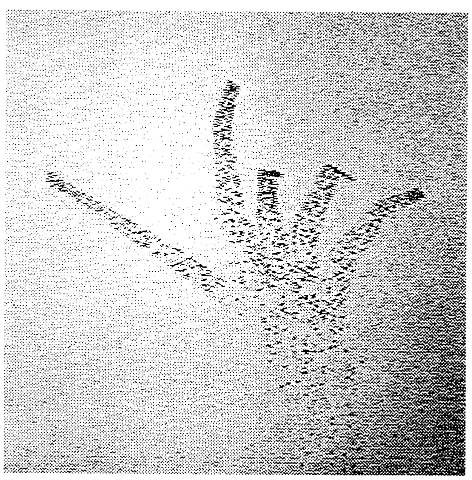

Figure 3(c).

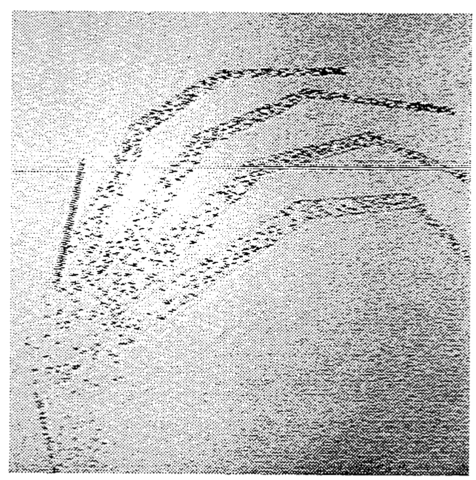

Figure 3(d).

Figure 3. Examples of spectral hand transformations.

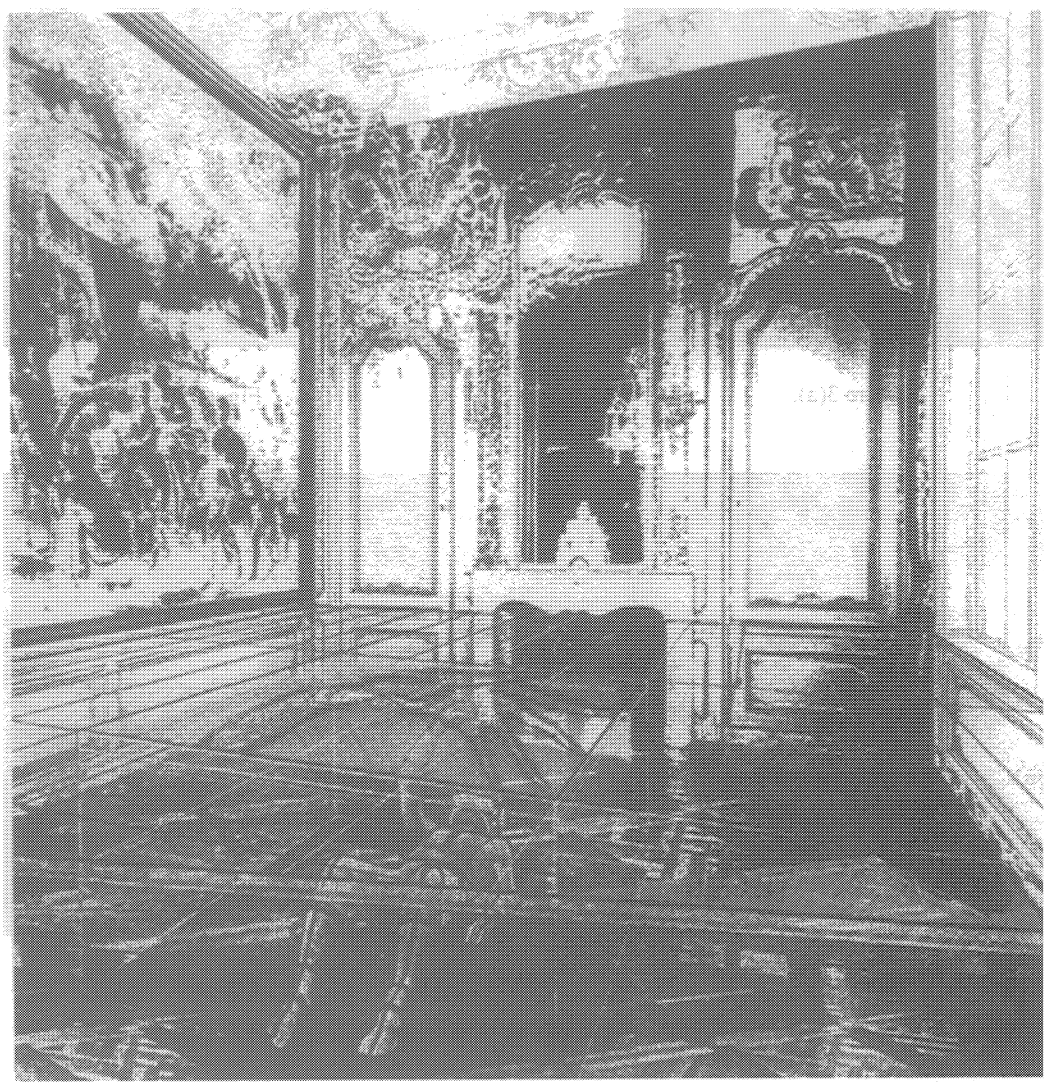

Figure 4. 'Virtual Bodies': Virtual Reality Art Installation Proposal, Eldorado Museum, Antwerp, Belgium, 1993.

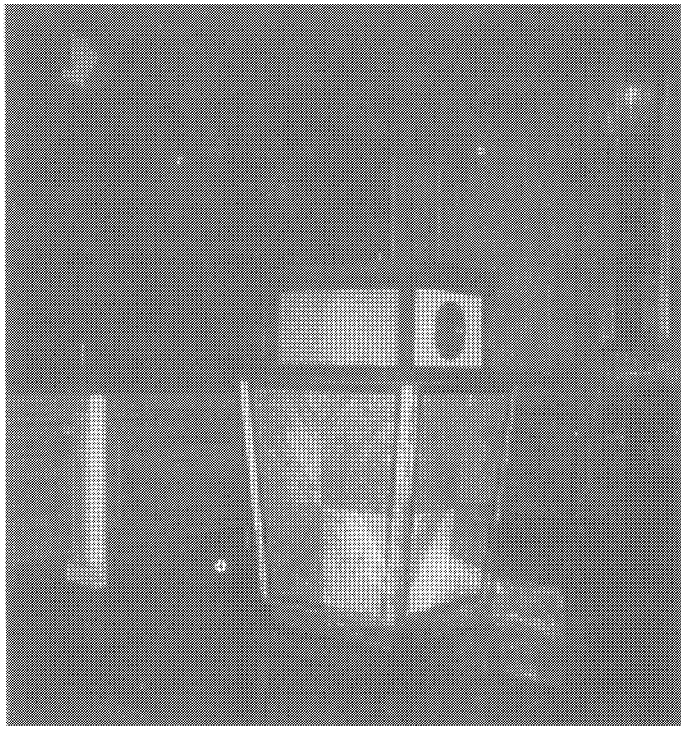

Figure 4. 'Virtual Bodies' installed in the Eldorado Musuem, Antwerp, Belgium, 1993.

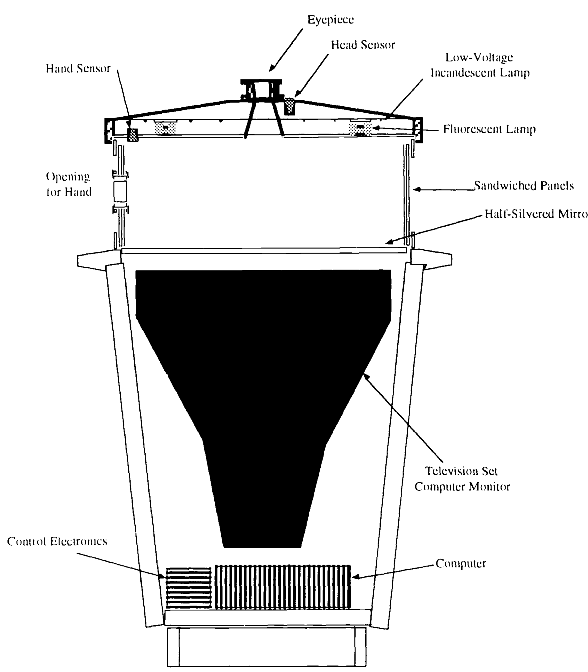


Figure 7. Cut away schematic diagram illustrating the technical components of 'Virtual Bodies'.

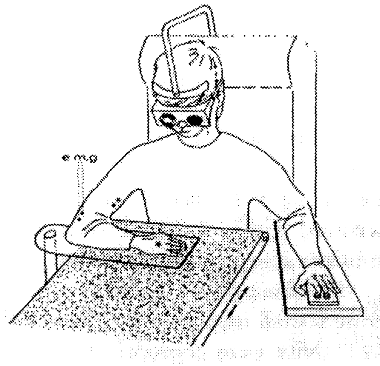

Figure 6. Experimental situation from reference (7), pg. 352.

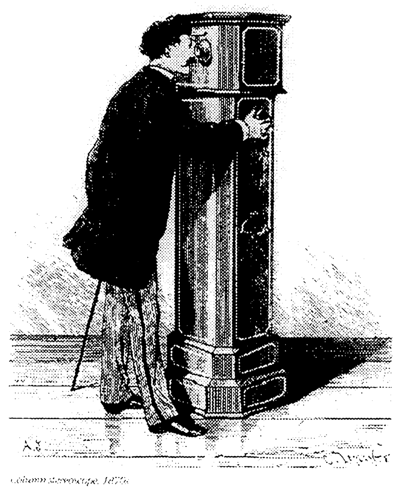

Figure 7. Column stereoscope 1870's, Techniques of the Observer, Jonathan Crary, MIT 1990, pg. 135.

| Head | Hand | Incandescents | Fluorescents | Floor Pattern |
|---|---|---|---|---|
| Off | Off | On | On | Full brightness Floor |
| Off | On | On | Off | Oscillating Brightness and Rolling Floor |
| On | Off | On | Off | Oscillating Brightness and Rolling |
| On | On | Off | Off | Rolling Pattern Floor |

Figure 9. The state machine functions generated by the computer program and the control electronics.