EYE MOTIONS ILLUMINATED

by

Derith Ellen Glover

B.F.A., University of Arizona

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Signature of Author.......................................
Department of Architecture, 1977

Certified by...
Otto Piene, Professor of Visual Design, Thesis Supervisor

Accepted by..
Nicholas Negroponte, Chairman, Departmental Committee
for Graduate Students

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ABSTRACT

As a means to interpret visual aspects of human physiology, to extend perceptual capabilities, and to investigate some of the ways images and environments are perceived and created, a simple system using existing technology has been developed which makes possible the generation of images directly from voluntary eye motions. It is an attempt to combine the eyes' usual function of sensing and transmitting with that of manifesting expression.

In producing images by the same means they are sensed, the artist can see portions of the visual process and take advantage of any insights this experience might provide. The system may also be used like a traditional medium, to communicate visually.

The optical drawing machine (ODM) supplies immediate feedback and storage; and because it is designed only to track large eye movements, rather than to make careful measurements, many of the disadvantages that are associated with other instruments for measuring eye motions are avoided. It may also be suitable for use in teaching, as a means of communication for severely handicapped persons, or as an aid for persons with perceptual difficulties.

From the experience of designing and experimenting with this system, a set of six life-size figurative sculptures which 'view' a scene and move their eyes in response to changing light have been built from brown paper bags and photo-resistors.

Thesis Supervisor...

Otto Piene, Professor of Visual Design

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I. INTRODUCTION: PURPOSE AND SCOPE

This thesis represents a portion of a continuing attempt to interpret, and celebrate with images, human physiology: especially the aspect most interesting to me as a student artist--vision. To do this, a simple system was constructed which makes possible the generation of images directly from voluntary eye motions; in essence, allowing a person to draw with his/her eyes.

This project enabled me to interpret an aspect of human vision--motion of the eyes--as a potential direct means of expression, combining the optic system's usual function of sensing and transmitting with that of rendering. I hoped it would provide an extension for perceptual and conceptual capabilities, and an enhancement of the experience of vision for artists and others. Most important, it might also allow one to investigate some of the ways in which environments and images are perceived and created, since a graphic record of visual exploration is produced.

Although this concept has been discussed by several others,[1,2] to the best of my knowledge, no one has

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[1] R.G. Coss, "Electro-oculography: Drawing with the Eye," Leonardo 2 (1969): 399-401.

[2] Nicholas Negroponte, NSF Proposal, MIT Department of Architecture, October 1976.

actually developed a system for experimentation and application. There is a wide variety of equipment available for monitoring eye motions in clinical situations, but it is unsuitable, for a several reasons, for voluntary image-making with the eyes.

In addition to functioning as an expressive tool, the Optical Drawing Machine (ODM) was designed as a device to aid the 'perception of perception' in four major ways.

First, it indicates normal visual activity. Because it produces a graphic record of optic position, illustrating natural, undirected, and involuntary motions and changing conditions of the eyes, the ODM makes possible a look at that portion of the experience of sight. It allows the artist/user to see instantly the actual shape of part of his/her normal observing process, and also illustrates how radically these first shapes change with continued viewing, or time. For most persons, it is enlightening just to see the patterns that their old and valuable instruments create in the absence of any conscious direction, although there are many other techniques for measuring passive viewing.

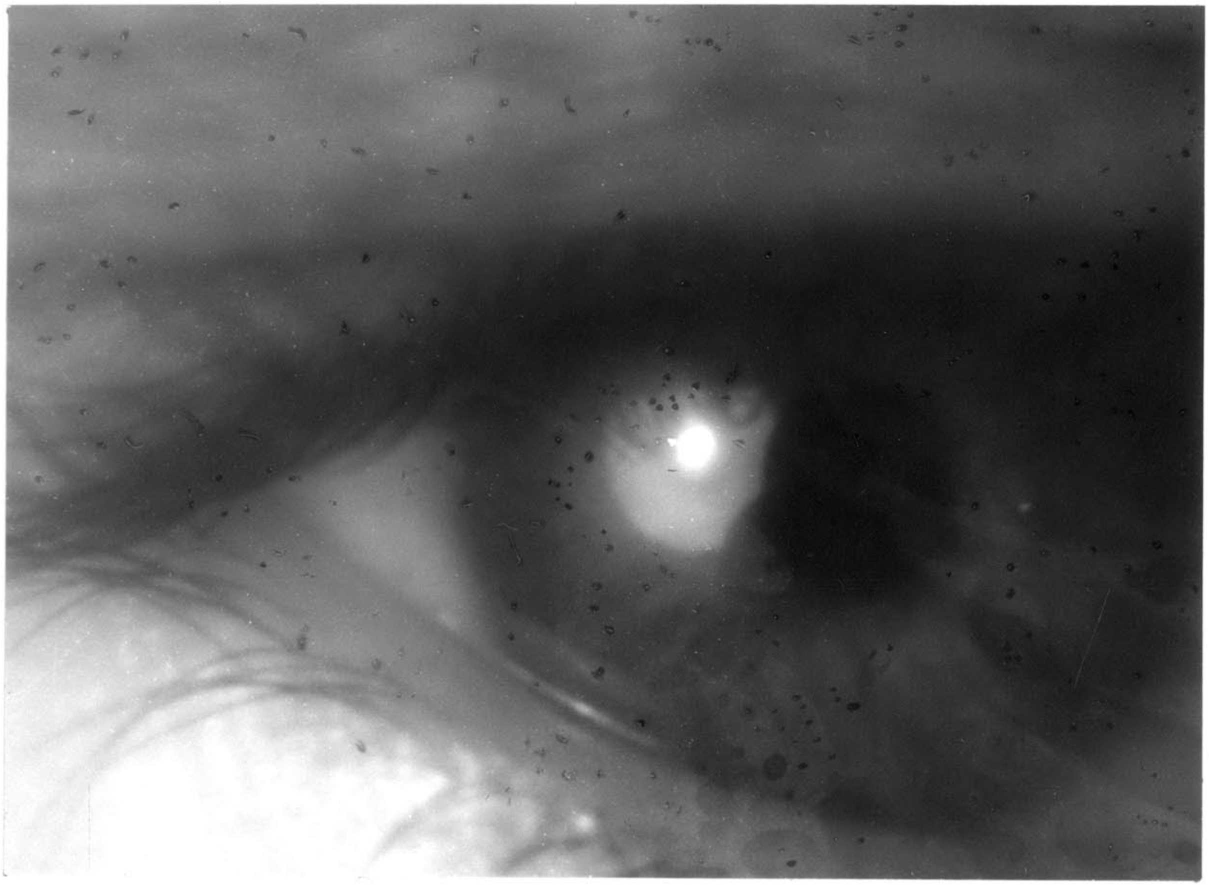
Second, it illustrates physical conditions in viewing. Focusing or defocusing, tearing, blinking, and nystagmic movement all change the quality of the line, or appear as spots, sprays, or darkened areas, and therefore indicate the physical conditions of the eyes during the experiment. At the same time, they mark the changing areas of relative importance in the scene being viewed, since they are often indicators of attention. Because the quality of line changes with focusing, the positions of objects in a field being observed are indicated and some of the aspects of depth perception can be studied.

Third and more important for my purposes, the ODM illustrates consciously (deliberately) directed eye motion. Since the artist/user receives immediate feedback from the ODM, and is able to move his/her eyes voluntarily, the shapes and patterns can be directly controlled. Early results of experiments with this ability to consciously direct one's eyes are fascinating, and with practice, it becomes easy to alter and enhance the images as well. I believe the ODM encourages visual learning, and could perhaps indicate how some of the visual skills are acquired.

Fourth, the ODM illustrates possible perceptual changes, because it was designed to provide graphic storage of the images or patterns made during experimentation, so that they could be displayed later for comparison or even reworking. Therefore, any conceptual or visual changes and/or development of image-making skills that the use of this system might encourage can be seen. The storage system maintains an interesting history of a user's progress for his/her own benefit or for analysis by another person (audience, friend, teacher, therapist).

My technical background is weak, but because of the interdisciplinary program at MIT, I have been able to get advice and aid from several departments and persons; in addition to Otto Piene and CAVS, Dick Warren from CSDL worked with me for the entire project, and will continue to help me to develop it. Terry Lockhart of MIT's film section, John Tole and Charles Oman of the MIT Aerospace Department, and John Donovan have been helpful also.

With this support, a system was designed and experimented with, as described in the following sections, to be as inexpensive, comfortable and effective as possible. It incorporates existing technology, rearranged, as a tool which allows images to be drawn by the same means as they are perceived--eyes, eyes.



Photograph 1. Eye with reflected spot, as seen through video camera. Normally camera is adjusted so that only the brightest spot on the cornea is recorded.

II. OPTICAL DRAWING MACHINE: AESTHETICS

Between the imagining and realizing of a visual expression, eyes are the intermediary for the mind and the hands, although they never physically produce a drawing. Concepts are made tangible by means of skilled hands, tools, or recording devices. Now, with reflected light and video camera acting as pencil, and monitor as paper, artists can actually draw with their eyes.

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An artist spends many years learning the physical/ manual skills necessary to produce visual statements. But some later hope to escape from that same training, in favor of a more spontaneous form (to forget how to draw). The ODM can provide a novel and interesting chance to learn to draw again, and in a new way. In using it, the artist can discover how the physical side of the observing process looks (by producing a 'topographical' map of his/her uncontrolled eye movements) and can also create images by consciously drawing; at least temporarily without interference from old manual skills.[3] Of course, the

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[3]In the context of this thesis, the expression 'drawing' will refer to images produced by deliberate control of eye motions. 'Viewing', 'gazing' & 'looking' refer to unrestrained, natural eye movements, undirected by the user. However, it is recognized that the way the viewer gazes naturally can be affected by his/her intent, and records produced by undirected gazing can form images.

images produced are at first somewhat incoherent. The artist has to be receptive to all the different elements of this new medium. With experience in deliberate drawing, a type of training may occur, but probably not in the same manner as the manual skills are acquired. There is a potential for a novel type of conceptualization, exploration, direction, and adjustment that I think might be exciting not only for artists, but for anyone interested in the visual process.

The ODM monitors, records and displays almost instantly the eye's motions (see methods section). Because those eye motions can be directed/controlled by the artist to produce a very sensitive, personal drawing, the ODM can be described as an expressive tool or medium. But it may also provide a valuable complement to regular forms of artistic effort. In addition to possible improvements in 'sight', which might in turn improve an artist's capabilities; it allows the artist to view his/her own work, or that of another artist. By using the ODM and viewing normally the work in question, the user can generate patterns corresponding to the movements of his/her eyes in response to the work.

Many artists may be interested in the ways in which they see as well as the results of their sight. By producing a graphic record of the act of seeing, the ODM provides clues to the ways in which visual skills might be attained. It can reveal some unique qualities in an artist's perceiving personality, especially his/her means of examining and linking spaces, not as a rigid pattern, but as a sort of 'changing gestalt' of visual organization. However, it should be understood that the ODM produces a record only of the motions and some physical conditions of the eyes, and the head is in a relatively stabile position-- not the totally natural way of observing. There is obviously much, much more to vision, perception, and drawing than these aspects can indicate. But even with these limitations, I think this partial illustration is exciting.

The images resulting from deliberate drawing can be very pleasing. But if the artist is dissatisfied, and wishes to alter an image, he/she must alter the way in which the existing scene is viewed, the scene itself, or reconsider the reasons for judging the result as poor. Some interesting self-questioning can come out of this experience. In my own drawing with the ODM, I was surprised to find that the images I attempted to make by strictly controlling my eye motions were more legible, but less descriptive of the imagined image, than the somewhat blurry drawings made by rapid free scanning. (Compare controlled-imaginary-fish to free-imaginary-lizard, photos 2 & 3.)

I have made several admittedly subjective observations while using the ODM. In viewing existing scenes, both the areas which command attention, and the order in which they are given attention, seem to vary radically with viewing time and consecutive scans, with different intent, from day to day, and are especially inconsistent among different users.[4] The patterns produced by the viewing of existing architectural spaces are fascinating, although not easy to analyze. They seem to differ radically if one is viewing actual three-dimensional space as opposed to a photograph of the same space. Because the spot changes its size, position and quality (and therefore the line varies) with focusing, objects that are more distant from the observer are indicated in a very personal way, according to each individual's means of perceiving depth. The images produced seem to have an odd illusion of space, especially for the person who created them. These indications of the perception of third dimensions could be especially interesting for sculptors and architects.

Also, the old battle between representational and abstract artists appeared newly ridiculous to me after experimenting with the ODM. One realizes how difficult it is to create a representational image without seeing (and reproducing!) the abstract forms involved, and

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[4]These users include Richard Warren, John Donovan, Mike Moser, Thomas Concannon, and myself--hardly a scientific sample, but meant only to suggest some potential directions for later investigation.

conversely, how difficult it is to see "pure form without content".[5] Even the most non-objective gazing into space produces shapes that resemble those found in the 'real' world, and the patterns that emerge from concentrated gazing at an existing object break down into elemental abstract forms. A denial of either abstraction or representation would seem to be a denial of sight.

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The photographs of images I have made in these first few weeks of experiments may seem a bit crude and unclear (see photos 2-10). However, they are only beginning exercises. I am biased, but aside from being embarrassing for their artistic qualities, I find them exciting in other ways. One of the most beautiful aspects of the ODM is the replay of stored (taped) images-- watching a drawing slowly emerge on the screen. It is like watching a film of process, which builds to an image and fades down, and then begins to build again on the ruins of the first image. The photographs included here have been taken at the peak of the images' clarity, but the growth and disintegration aspect of the tapes is in some ways more absorbing than the 'finished' drawings.

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[5]M. Schapiro, "Nature of Abstract Art." Marxist Quarterly, January-March 1937, p.79.

The process by which different people draw is fascinating also; one user (John Donovan) has incredible control of his saccadic movements, making highly legible outlines, while others scan until the image appears--apparently in a random manner, but actually consciously controlling points of fixation rather than saccades. It is also possible to combine these methods, and by successive 'strokes' and 'stops' to develop the image. There are probably many more means of forming shapes and lines--whole vocabularies of eye movements for structuring images--yet to be discovered.

I have been concerned, in developing the ODM, that I might become caught in the cult of "technological fetishism"[6], and lose sight of the objective-- to create visually exciting and meaningful images. I hope that the work will be an interpretation of spirit, not device, and am sure that a wider and better collection of experiments will be possible soon. If art, as it is said, can create 'vision', maybe 'vision' (in the literal sense) can create art. Or ideally, a situation might be provided in which "The intensity of the sensory pattern strengthens the emotional and intellectual pattern; conversely, our intellect illuminates such a sensory pattern, investing it with symbolic power."[7]

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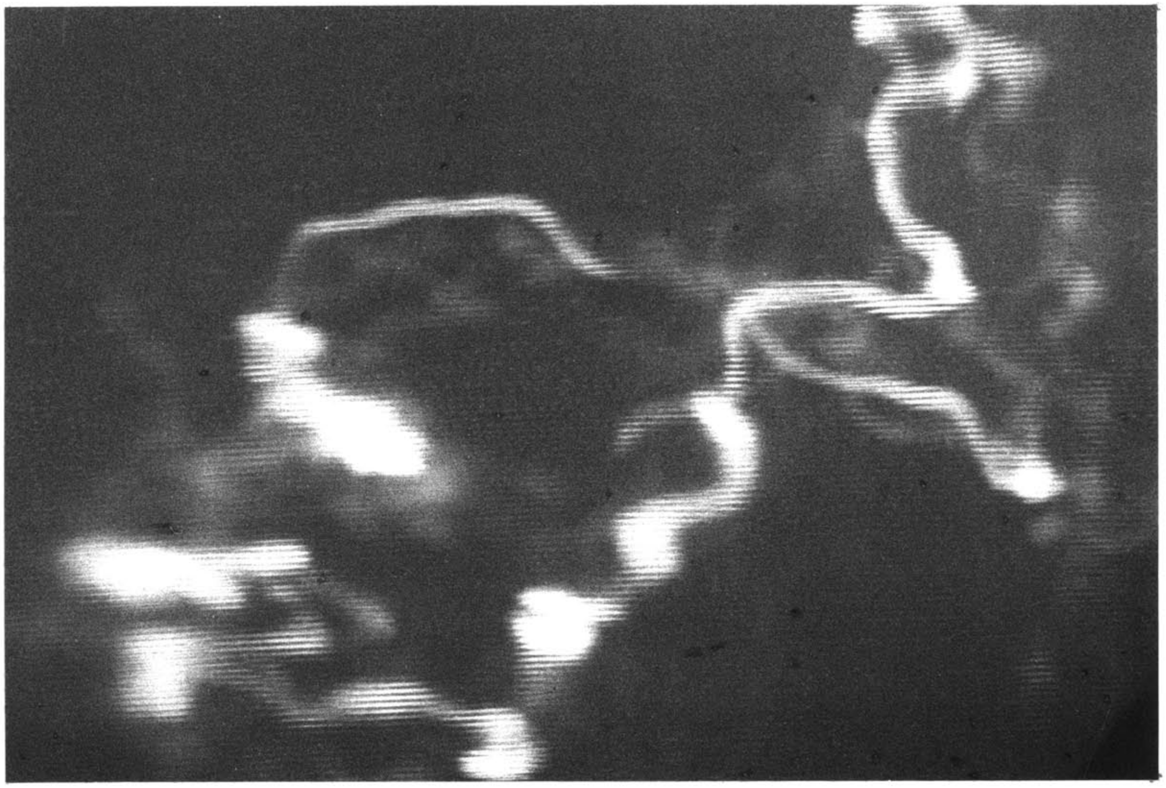
[6] Gyorgy Kepes, panel discussion, MIT, <u>Arttransition</u>.

[7] Gyorgy Kepes, <u>The Visual Arts Today</u>. Middletown, 1960, p.4.

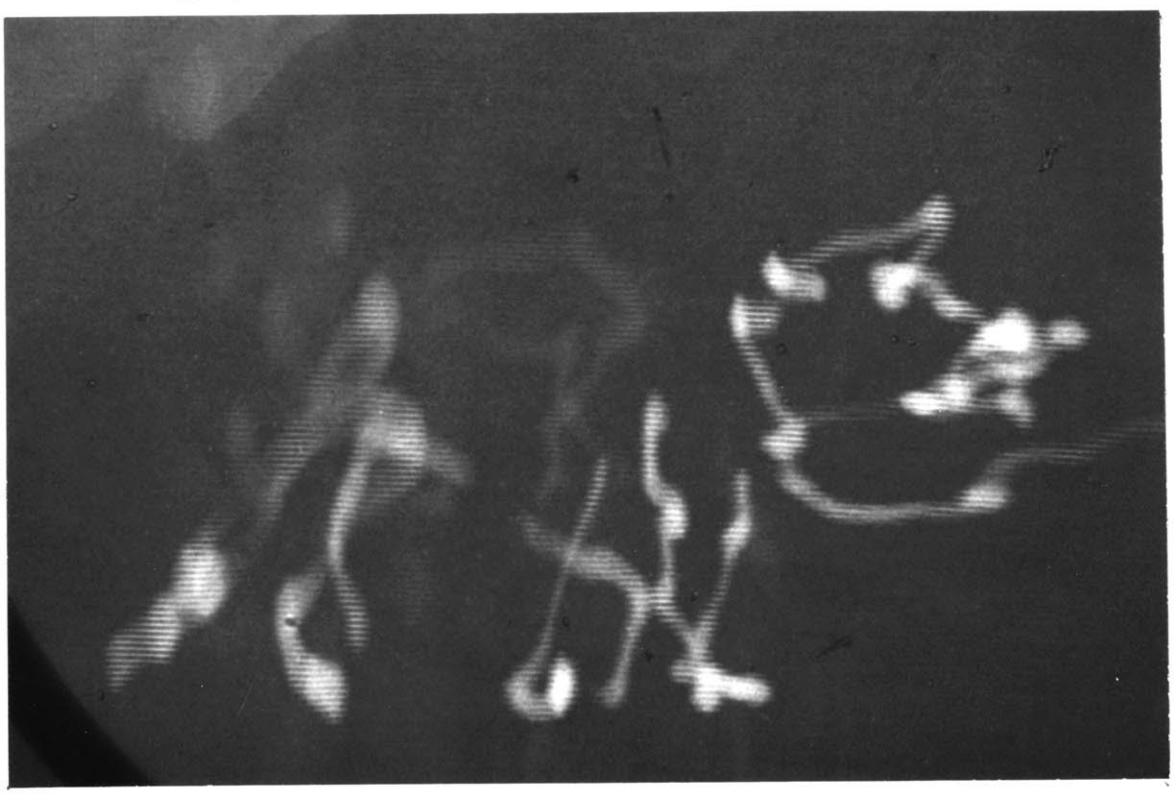


Photograph 2. Drawing: Fish.

Photograph 3. Drawing: Lizard.

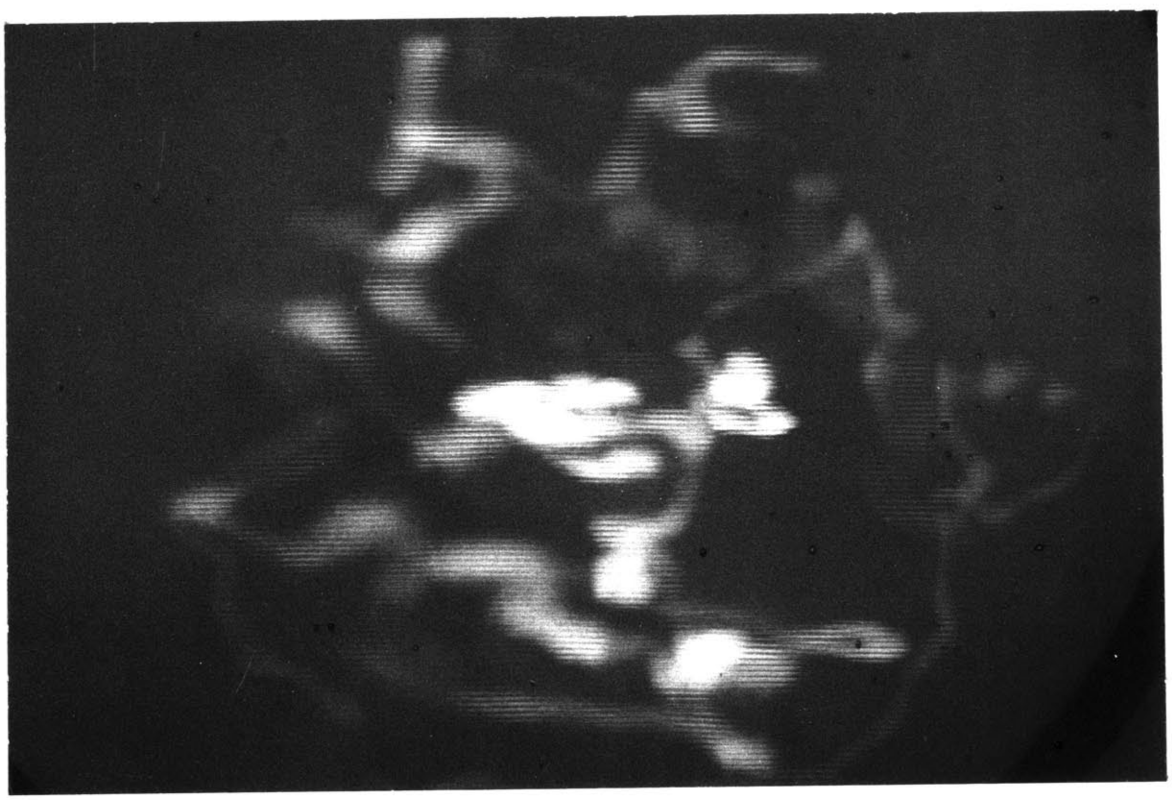
Photograph 4. Drawing: Dog.

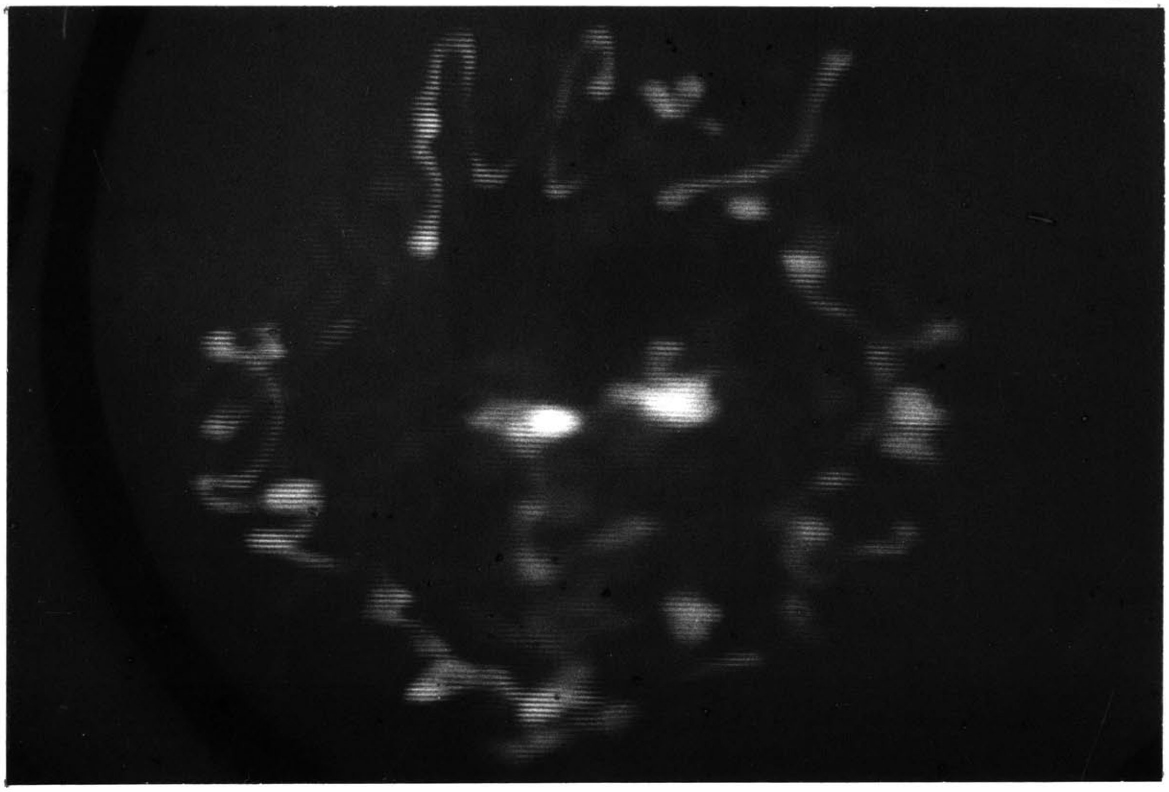
Photograph 5. Drawing: Cat.



Photograph 6. Drawing: Thin Man.

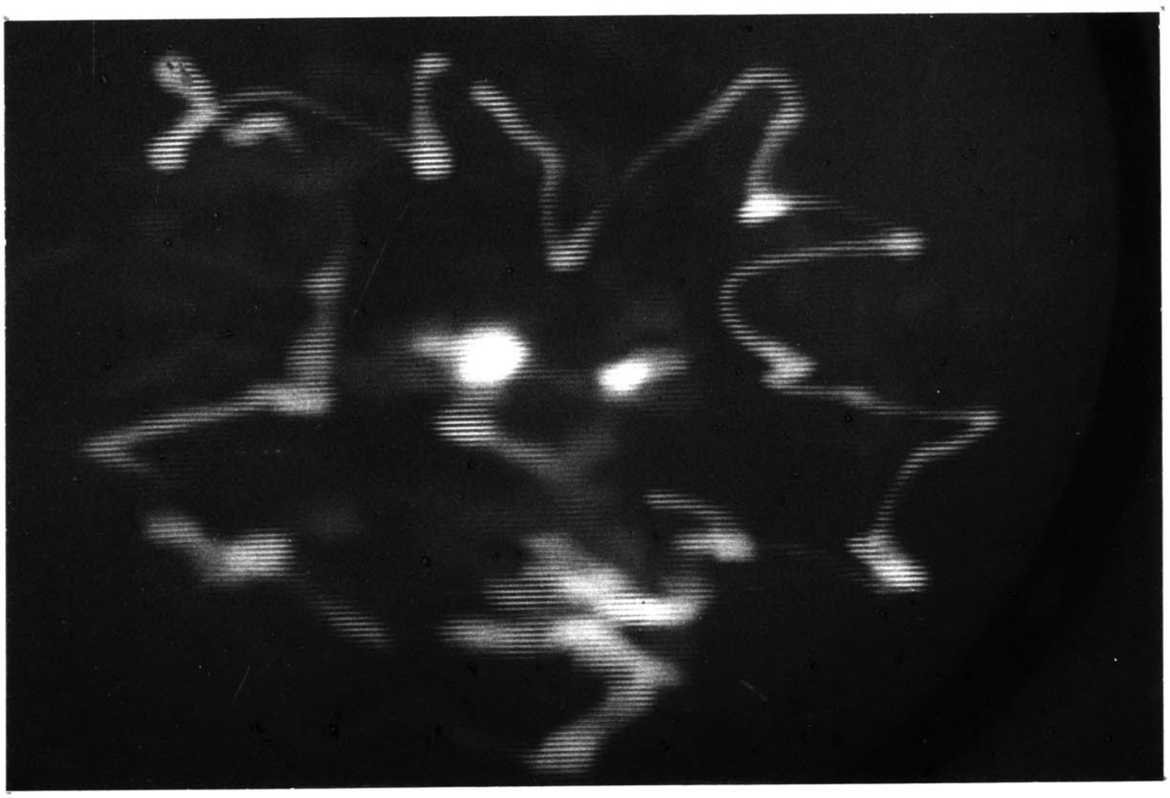
Photograph 7. Drawing: Fat Man.

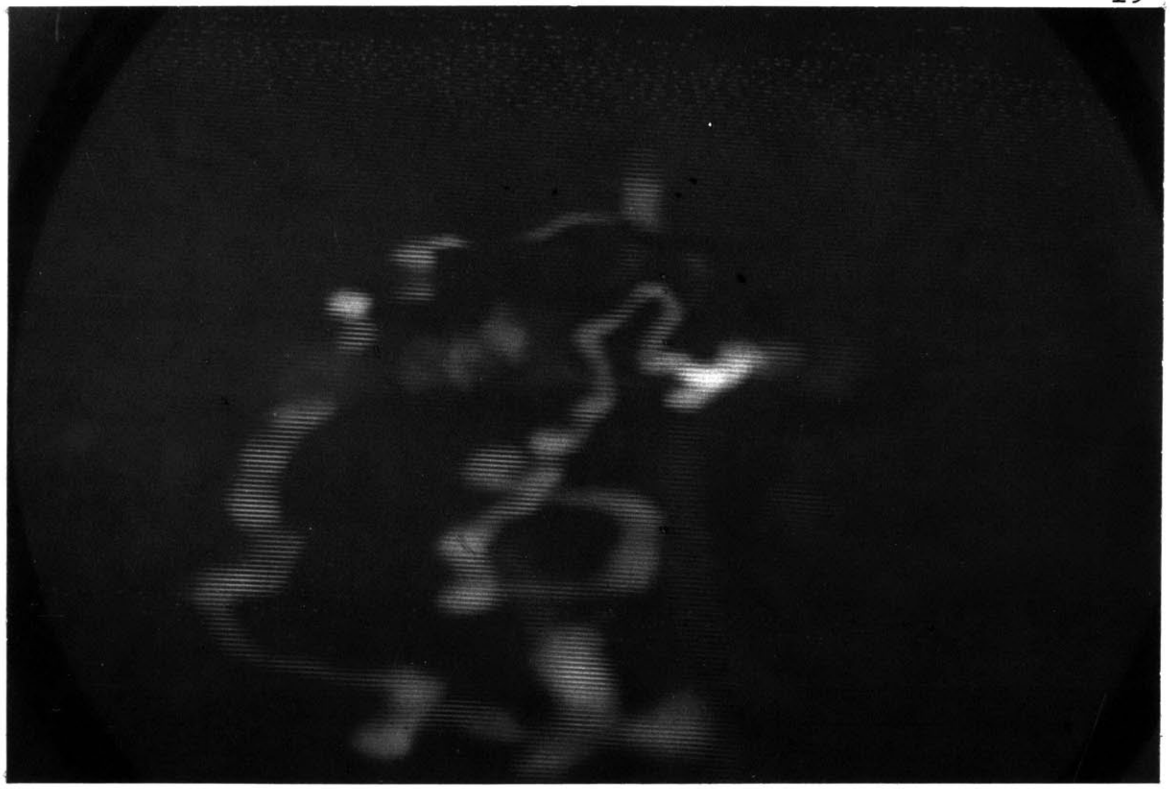




Photograph 8. Drawing: Mad Man.

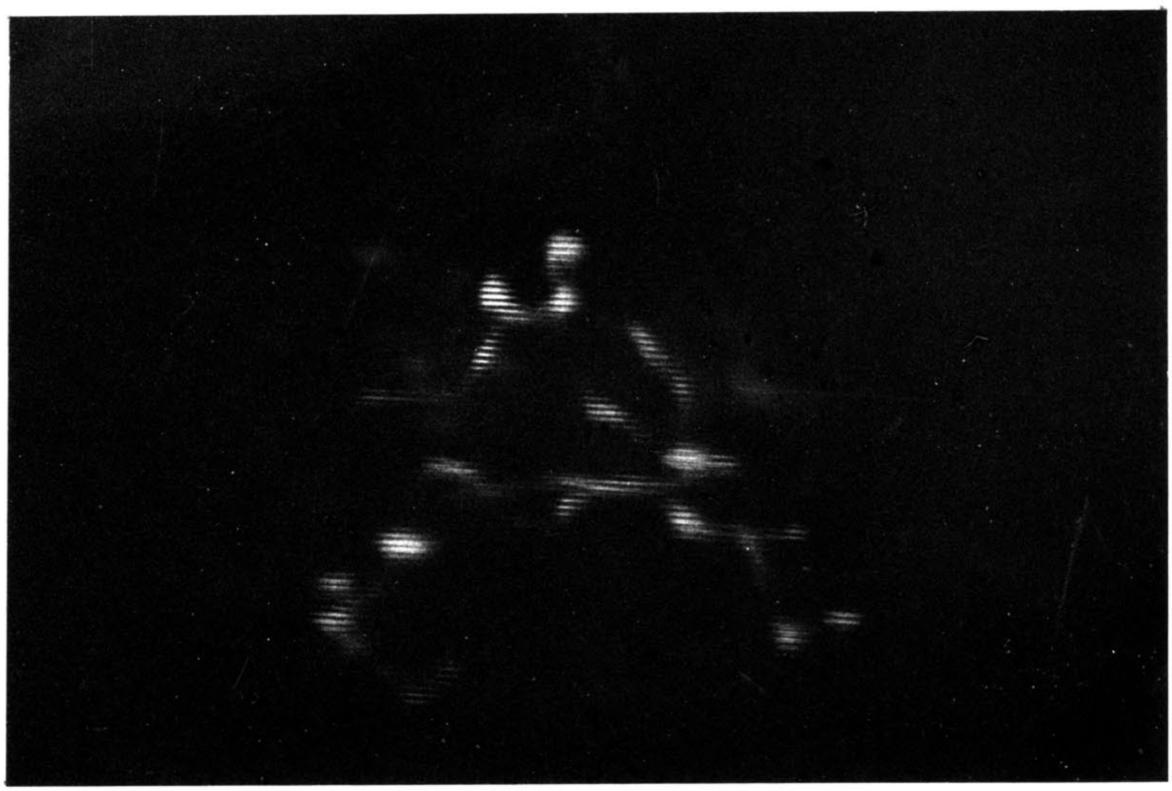
Photograph 9. Drawing: Madder Man.





Photograph 10. Drawing: Man slipping off screen.

Photograph 11. Writing: The letter 'A'.



III. OPTICAL DRAWING MACHINE: TECHNOLOGY

A. Technical Background

Scientists have traditionally been interested in monitoring eye movements. The early methods ranged from direct observation and photography to strange and painful mechanical transducers, such as glass rods attached directly to a subject's cocainized eye, or tiny levers pasted to the eyelids. Much research has been done in recent years, and there is now a wide variety of sophisticated equipment and techniques for measuring eye motion. Most of the major techniques are listed below,[8] along with the reasons they seem to be unsuitable for direct generation of images.

Contact Lens Method. A specially fitted, snug contact lens is made for the subject, which may contain elements such as mirrors which reflect into a receiving device, sets of wire coils which provide voltage information, or other means of indicating position. These lens systems are expensive, uncomfortable, and potentially dangerous to the subject's vision. They often incorporate protruding stalks, and they are inappropriate for movements

[8]For a complete discussion of methods and techniques see the survey by L.R. Young and D. Sheena, "Survey of Eye Movement Recording Methods," Behavior Research Methods and Instrumentation 7(5) (1975): 397-429.

greater than five degrees. Careful head stabilization is required, tear film affects transmission, and usually the eye must be anesthetized.

Electrooculography. An electrostatic field rotates with respect to eye position, and a set of electrodes can be placed around the eye to measure the relative potential over time. Although this system is not uncomfortable to use, it is relatively insensitive to vertical eye motion, and there is often much interference from large muscle activity. It is also too sensitive to blinking, light adaptation, and state of alertness. Although relatively inexpensive, it requires expensive support systems (computers, amplifiers, plotters). And unless high quality gold or silver silver-chloride electrodes are used, skin resistance quickly destroys the signal.

Limbus, Pupil, and Eyelid Tracking. Various methods employ photo-detectors to determine the changing position of light and dark borders of the eyes. These systems, too, require expensive support systems and strict head stabilization. The light sources used are generally infrared, which tend to dry the eyes and reduce use time. They are also mostly insensitive to vertical motion.

Point of Regard Measurement. These systems track the center of the corneal reflection (see the Method section for discussion of corneal reflex technique) with respect to the pupil center. They are most interesting because they avoid many of the problems associated with the other systems, and often utilize video recording methods. Their major drawbacks are their great expense, complexity, and bulk. For the purpose of developing the ODM, these methods were most important.

There are several other systems manufactured as well, which combine some of the techniques described here. But none of these systems currently provide immediate feedback or drawing capabilities to the user.

B. SPECIFIC TECHNICAL GOALS

In almost all the above-mentioned systems, the subject's eyes are monitored so that careful scientific measurements can be obtained: these data are then tabulated and analyzed for use by researchers in physiology, education, military science, experimental psychology and cognitive processing.

Since the gathering of this data requires precise instrumentation and intense quality control of output, the existing systems tend to have one or several of the following limitations: they are fantastically expensive ($39,000-$175,000) or require expensive support systems such as large computers; they are bulky or difficult to operate, relatively insensitive to vertical motion or to large excursions of the eyes, and may require much training to operate and install; or more important, they may be painful or annoying to the user, limiting the time in which they may be safely operated or interfering with the user's field of view.

Because the purpose of the ODM work was to design a perceptual and physical extension for the subject with which he/she could interact freely, rather than a measuring device for scientists, the technical goals involved in its development were quite different. Many of the problems inherent in the other measuring techniques were avoided, but elements that were considered minor defects in the other systems became major problems in constructing the ODM.

First, the ODM was designed to be as simple, comfortable, and non-threatening to work with as possible. So that it might be easily accessible to various groups, the ODM was constructed to be inexpensive and easy to install and operate. This design was possible in part because the aspects of vision which must be eliminated in scientific recordings (nystagmic motion, tears, blinking, electrical artifacts, large excursions, small head movements, or defocusing) do not adversely affect the images desired in ODM recordings. In fact, they are an integral part of them. Also, the ODM almost exclusively employs parts which are already mass-produced and therefore are easily obtained, operated, and maintained.

The second set of requirements was more difficult to satisfy. Since the ODM is a tool meant to extend and interact with the human system, the users must have immediate process/progress feedback, the ability to store their experiments, and the ability to correct or alter the information they are creating. No real 'training' or experimentation can take place unless the user can see instantly the results of his/her eye motions, and store those results for later reference. He/she must also be able to erase or enhance certain elements, and to vary the vocabulary used (i.e., change the line width or create shapes, dots, flat areas).

The physical design had to be versatile, since it was meant for several different applications. The user's stimulus could be conceptual (imaginary images, communication), actual (existing scene scanning, environmental exploration), or directed (teaching, therapy). It was hoped that it could be used by a single person, which, in the case of those severely handicapped, meant incorporating gaze activated controls; or by a group as communication, requiring replay capabilities and storage again.

Most of these requirements have been met, but some are still creating problems.

C. METHOD

The method used in the current demonstration model is as follows: in a dimly lit space, a small, low-intensity, incandescent spot of light is 'bounced off' one cornea, picked up by a video camera, recorded, amplified, and displayed almost instantly on a storage tube monitor. This monitor records the time-history of the spot's movements, producing in essense a line drawing or written message.

The corneal reflection principle is as follows:

> The corneal bulge produces a virtual image of bright lights in the visual field and region. Because the radius of curvature of the cornea is less than that of the eye, the corneal reflex moves in the direction of eye movement, relative to the head. Because it only moves about half as far as the eye, it is displaced opposite to the eye movement relative to the optic axis or the center of the pupil....[9]

It is possible to add filters, lenses, and extensions to a common video camera (mounted on an adjustable tripod) that allow the image of the cornea to fill the entire camera's field, and then by adjusting the contrast and brightness levels of both the camera and monitor, to produce from the reflected spot a signal that can be amplified and displayed on the storage tube monitor. This monitor is equipped with a longer persistence phosphor than the ones used in standard picture tubes, and the bright spot leaves a trail.

The monitor image is reflected in a parabolic mirror, which is placed at a comfortable distance from the user. This mirror restores the correct right/left orientation, allows close (magnified) inspection of the drawing by the

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[9] Ibid., p. 402.

user, and creates a viewing surface size which encourages larger excursions of the eyes.

The user is required to be minimally stabile, and a simple chin or head rest is sufficient for that purpose. The light source is distant and not annoying, and may be positioned so that the user is not uncomfortable or even very aware of the light. He/she can easily find the head position in which the spot becomes focused (or an assistant can help, in the case of a handicapped user or a very young child), center the spot, and quickly understand the way in which the spot moves. The user determines the time spent drawing, and the process can be viewed simultaneously by others.

The video tape recorder is used to store the results of the experiments in exactly the same way they were carried out, so that the process can be studied. An image may be created one day, then displayed and further modified at successive sittings, or replayed for others, or photographed in its finished state.

D. MATERIALS

To hold the cost of developing and acquiring the ODM to a minimum, materials and hardware which are available commercially at reasonable prices are used. Video was chosen as the recording method because it provides the best immediate feedback, and because recent developments in video technology have made it widely available. In fact, many institutions may already possess most of the elements used in the ODM design. The combination of existing components also helps to insure that the system will be easily maintained.

The current demonstration model of the ODM is jerry-rigged and clumsy. It also uses some rather expensive components because they are available at MIT, but these could be replaced with much more efficient and less expensive new parts, or late model used parts. A list of the major components in the ODM, and their approximate cost (if used equipment is purchased) follows. Some of the elements could be cheaply built or borrowed.

Video camera and special lens system	$200.00
Tripod	50.00
Tape recorder and tape	250.00
Monitor	300.00
Mirror	10.00
Misc. (chair, headrest, light source)	20.00
	$830.00

A still camera is important, too, for photographing experiments for long examination. If microprocessing is desired (see Development section), single special-purpose systems are now available for $100 to $1,500, but that range does not include the cost of programming.

E. TECHNICAL PROBLEMS

There are still unresolved difficulties with some technical aspects of the ODM. In addition to equipment shortcomings, which are fairly easy to correct, there are other more serious limitations:

1. The image is still too small.

2. The image duration (length of time the image remains on the monitor before fading) is too short.

3. There is as yet no way to erase specific portions of a drawing.

4. The access to the taped images is somewhat confusing and not entirely reliable.

5. It is still very difficult for a person with severe strabismus to use the ODM, and eye glasses present some troubles.

6. Even though the present system allows for some head movement, more should be possible.

In general, the demonstration model of the ODM is not in shape for general use by various groups, but should be soon.

Photograph 12. APPARATUS
From left to right: long-phosphor monitor screen with spot and beginning trace, user with chin rest, video camera and lens system on adjustable tripod, parabolic mirror. Not pictured: video tape recorder (on low table beside user) and fifty-watt light source (twenty feet in front of user at eye level).

IV. OPTICAL DRAWING MACHINE: OTHER APPLICATIONS

In designing a human/machine interactive system to extend perceptual and expressive capabilities for artists, it was hoped that other groups might be able to use and benefit from the ODM as well. Some of these groups are listed below, with the particular ways in which they might find the ODM helpful.

A. EDUCATION

The ODM might be a useful addition to many teaching situations as a means of partially illustrating, in a unique way, the functioning of human eyes. It definitely increases awareness of the faculty of vision, and can suggest some of the ways the world is perceived.

It would be an interesting supplement to studio art courses (to illustrate both voluntary directed movement and involuntary gazing), and might provide important graphic information on environmental perception for architecture students (especially to show involuntary optic reactions to spaces and environments). But on a more elementary level, the ODM could be useful in teaching basic reading, writing, and drawing skills since it illustrates scanning and attention patterns, as well as indicating the spatial positions of objects.

B. ENTERTAINMENT

Too often, human relations with entertainment machines are of the passive sort (e.g., chronic TV-watching syndrome). There is usually little understanding of the technology, the images or output it produces, or the way in which the individual perceives the entertainment he/she receives.

The ODM provides and alternate situation in which the viewer is also the doer, participating directly in the process of creating or altering a visual scene. The system is enlightening, fun to use, and the results are visually pleasing. The possibilities for games and humorous forms of communication between several users have not been explored, but could be important.

No great amount of skill is required to use and operate the system, and the ODM might be manufactured cheaply enough to be available to the public for these and other uses.

C. COMMUNICATION: THE UNLOCKING POSSIBILITY

For totally paralyzed individuals, speech is usually impossible or unreliable because impaired throat and lung control inhibit sufficient air flow through the larnyx to produce sound. Eye movements and mouth gestures may be the only motor activities that are possible with this type of disability. A device that monitors eye movements and allows a disabled person to learn to direct them could become the basis for a system of communication--not only with other persons (friends, nurses, attendants), but as input to a number of common aids for the paralyzed such as automatic page turners and environmental control units. There is currently available a gaze- and focus-activated typewriter for severely handicapped persons, but it is expensive and very slow to operate, and of course only allows for typed messages. The ODM will be much cheaper and faster, and permits both written (because the user can quickly draw letters as well as images) and non-verbal communication. In this sense, the ODM could be considered an 'unlocking' device for persons who, in some cases, have not been able to communicate freely for years.

For those not as severely handicapped, the ODM could provide a form of entertainment, or for persons with severe speech difficulties, an alternate method of communication. With further development, the size of the apparatus should be reduced and it should be mounted on a rolling chassis so that a hospital or institution may acquire and install it with a minimum of trouble.

One of the earliest applications of computer-monitored eye movements was the study of persons with reading problems.[10] In these early studies the computer

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[10] L. Carmichael and W.F. Dearborn, Reading and Visual Fatigue, Boston, 1947.

was used mainly as an input data processor; the primary concern was to monitor natural or unrestrained eye movements as a painting or a printed page was scanned. Additional therapeutic benefits may arise from acquired skills learned in the ODM 'bio-feedback' system, and also from the later possibility of actually encouraging the eyes to move across an existing visual scene by making subtle changes in that visual scene (with a microprocessing system) as the eyes scan it. For example, one can imagine training sessions designed to promote or encourage better (i.e., smoother or less random) eye movement patterns as one reads a printed page, as well as exercises designed to improve focusing and fixating capabilities. Because it is easily possible to reverse the monitor image when working with the ODM, it might be especially applicable for use by individuals with dyslexia or their therapists.

A novel, graphic, and immediate form of feedback such as the ODM provides might make the practice of visual exercises and reading skills (or writing skills) quite fun for anyone, and perhaps especially for children with learning difficulties.[11]

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[11]Portions of this last section are taken from a general funding proposal written jointly by Richard Warren and myself, which has not yet been published or distributed.

V. POTENTIAL DEVELOPMENTS

A. TECHNICAL

The ODM's versatility and effectiveness could be greatly increased by making some simple mechanical modifications. Better quality equipment would eliminate much of the 'snow', flare, and interference present in the demonstration model. A redesigned system using new or late-model used components would actually be less expensive, since many of the elements used in the present ODM are necessary to correct for, or enhance, older parts. And in order to be used by the public, the ODM must be efficiently and safely housed.

Gaze-activated controls, connectors to other machines (and maybe leveling and smoothing devices to eliminate some of the visual 'jitters') should be incorporated for handicapped users.

These improvements, and perhaps the solutions to some of the more serious problems mentioned earlier, might be accomplished by the aid of a micro-processing system. A small, special purpose computer would allow an existing scene to be modified in numerous ways-- according to where, or how long, one looked at a particular part of the image. Additional elements (color, line width, texture, and shape) might be manipulated. A more reliable and rapid means of saving and accessing completed drawings (short- and long-term disc storage) would then be available.

A system like MIT's Architecture Machine might use the information the ODM produces in place of input from light pens and tablets, providing another range of abilities for the artist/user.

B. CONCEPTUAL

In addition to the obvious technical and mechanical improvements, there is a great deal of conceptual work still to be done, much of which may come out of continued use of the ODM. Some of the areas which need improvement are listed below.

1. The images produced are often incoherent, or have the quality of children's scribbles. (see photos #2-#10) With continued practice and experiment, more pleasing and coherent images may be produced. However, it is hoped that the training will take the form of a sort of subliminal understanding of eye motion, perception and vision, rather than strict, conscious muscular control.
2. A larger and more varied body of aesthetic examples should exist, with experiments in other sorts of visual effects such as blinking and defocusing, and tracking/scanning of moving elements (see photo #8). On conscious and subliminal levels, this should happen naturally with continued use.

3. Before even any limited hypothesis about aspects of personal perception (or "psychology") can be made, carefully controlled experiments must be designed (e.g., spontaneous gazing v.s. gazing with a purpose in mind). Elements such as the intent of the user, his/her visual experience, state of mind, etc., must be accounted for. These experiments would require the skills of a physiological psychologist. At this point, I can only describe subjective insights into my own viewing, and suggest some areas that might be worth exploring later; such as the apparent changes in line involved in viewing objects in space, or the continuously changing scan pathways observed in repeated viewing of scenes. (See the aesthetics chapter.)

4. The ODM should be further experimented with in interdisciplinary contexts. I definitely hope to become more involved with handicapped and community applications, and to use the ODM as an input device with the Architecture Machine.

5. The feasibility of using the ODM for the handicapped and the public must be fully demonstrated, with much input from a variety of experienced persons. Testing and improvements that arise from such input must be made before it is taken to clinics, schools or hospitals.

There are many other interpretations to be made from the visual system. In addition to less serious responses (the Mummies described in the appendix), I would like to explore other potential physiological and expressive extensions that are suggested by this system, and would like to apply the information gained from this experience to other art forms.

LIST OF PHOTOGRAPHS

APPENDIX: WATCHFUL MUMMIES

From the experience of making the ODM, I built a set of six life-size figurative sculptures to illustrate some aspect of eye motions, and the strange phenomenon, the life-suggestive power of moving objects that look like eyes. A rock, a tree, a car, will appear animated if it is given spots to represent eyes, and even more alive if those eyes move. In fact, the presence of moving (and especially responsive) eyes seems to be a major subjective criterion for determining an object's 'liveness'.

Also, in watching myself (on tape) and others use the ODM, I was amused at the odd scene of a motionless person, transfixed as it were, with all attention directed to the results of their eye motions, watching a tiny light on a screen. It is an absorbing experience, and impressive to watch, but also a humorous one. The appearance of any responsive eye movement to stimuli is so funny, powerful, and at times even frightening, that I wanted to try to take advantage of this effect.

At the same time, I was a bit appalled at the costs involved in making 'technological art', and so decided to make some stationary creatures with eyes that respond to changes in light levels (especially changes that result when a live person enters their field of view), and to make them as cheaply as possible.

The making of the Mummies was not only a turn-around financially, but a light-hearted reversal of concepts used in designing and building the ODM. Rather than person acting, machine providing feedback, person reacting to machine response, the roles were reversed. The machine (Mummy) acts, the person provides the feedback, and the machine reacts to human response. In this 'experiment' the Mummies are interested in the dark spot, rather than in the light spot.

The materials used in the Mummy construction were carefully shredded brown paper bags and starch (brown bag machė), cheap scrounged electric and photoelectric parts, and magnets.

The Mummies are seated to one side of the room, with their eyes slightly below the viewer's eye level. There are photoresistors around the Mummies, which receive light from sources directly across the room. As the viewer approaches the Mummies, he/she interrupts that light source. Their eyes are designed in such a way as to seek the dimmest area of the room, in this case the human viewer. (See photos 14-17.)

> But do we not all feel that certain portraits look at us? We are familiar with the guide in a castle or country house who shows the awe-struck visitors that one of the pictures on the wall will follow them with its eyes. Whether they want to or not, they have exploited this reaction to reinforce our natural tendency to endow an image with a 'presence': Alfred Leete's famous recruiting poster of 1914 gave every passerby the feeling of being addressed by Lord Kitchener in person.[12]

This phenomenon, as described by E.H. Gombrich, is combined with a favorite trick in many rather recent horror movies and comedies, that is the manipulation of a statue's eyes by stagehands, giving the viewer that ever-popular creepy feeling.

The Mummies are quite fun to interact with, the viewers are fun to watch, and a strange affection for them seems to develop-- something not always found in human/machine or human/sculpture interactions.

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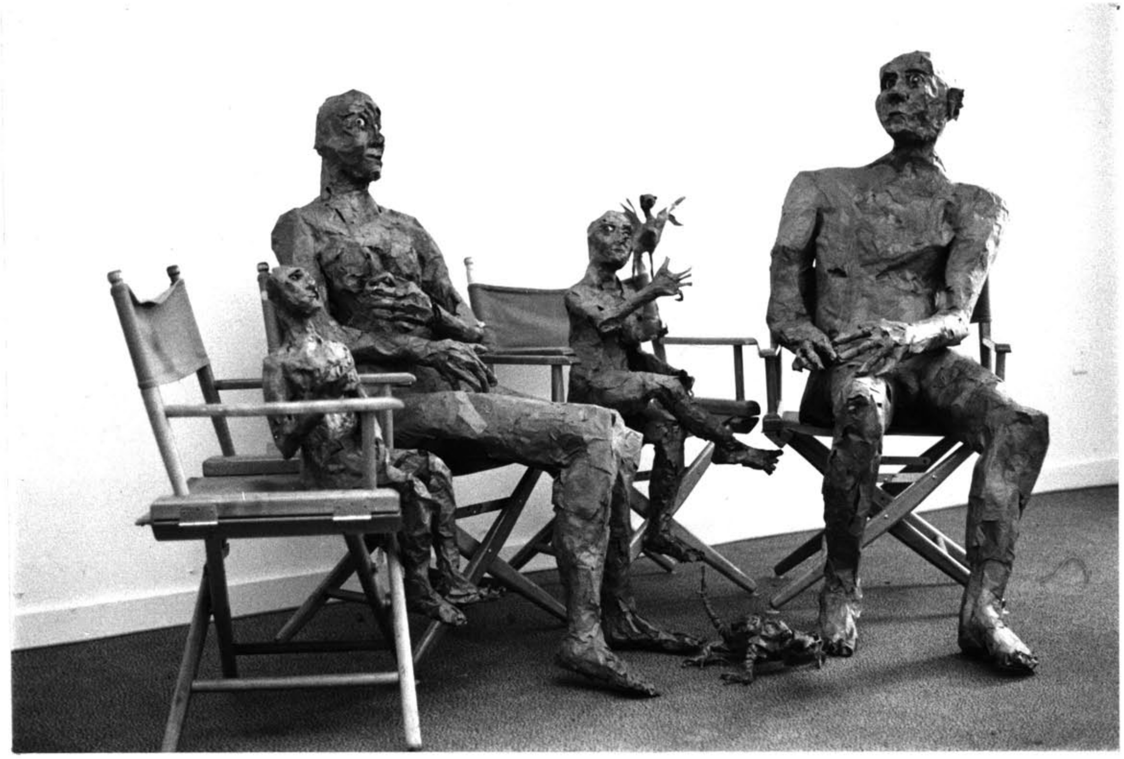
[12] E.H. Gombrich, Art and Illusion. New York, 1960, p.113.



Photograph 14. MUMMIES: Group, far right.

Photograph 15. MUMMIES: Group, right of center.

Photograph 15. MUMMIES: Group, left of center.

Photograph 16. MUMMIES: Group, far left.

Photograph 17. MUMMIES: Woman.

Photograph 18. MUMMIES: Man.

Mummy photographs by Ragnhild Karlstrom.

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