# THE PHOSPHOTRON

Stephen Beck

Phosphene (<Greek: phos, a light + phainein, to show) "a bright light or visual image produced by stimulation of the retina through closed eyelids." Phosphotorn (phosphene + electron) "electronic instrument used to produce phosphenes by passing weak electronic currents through the eyes."

**As we go through daily life our eyes are open most of the time. During sleep our eyes remain closed, but often exhibit movements. The visual aspects of these two contrasting states of consciousness have long intrigued me. Much of the visual imagery in my video and film compositions is drawn from the substance of images seen with the eyes closed.**

To date no camera has been invented that can directly record the actual appearances of "closed eye" visual phenomena. Consequently any artist seeking to explore this visual domain must report back with constructions and re-creations of what can be seen with the eyes closed.

I invented my Direct Video Synthesizer to have a means of reproducing images I have seen with my eyes closed. These images have color, and are almost always moving, hence they require a cinematic medium to represent them.

Almost all visual art requires a screen or surface as a carrier of the image. For paintings there is the canvas, for lithography and photography there is fine paper, for video there is the cathode ray tube, and for film there is the "silver screen."

But I have wanted to eliminate the screen from my visual art for a long time. I want to be able to produce an image right inside your eyes, without the need for you to look at a surface.

The discovery of phosphenes has been for me a step in that direction.

You have probably seen a phosphene before. When you close your eyes gently and then squeeze them tightly for a few seconds, you will notice that you do not "see" a plain black, empty nothingness.

Rather you will see some colors washing across your field of view, perhaps some bright flashes or yellow or pale blue light. Furthermore, if you now relax your closed eyes and VERY GENTLY touch the fronts of your closed eyelids, very slowly, you can see even more phosphenes, perhaps brighter colors, more flashing, or even some very soft forms like chevrons, or crosses, or arcs.

There is an infinite number of phosphenes, and no two seem ever to be exactly alike. The conditions under which you can see them vary considerably, but they are there nonetheless, a distinct reality unto themselves.

Phosphenes can be stimulated by various methods, some mechanical, like pressing on your eyelids. Another mechanical source can be a blow to the head, by falling down, or having something fall on top of your head, or even by being "slugged" by another person. (Boxers are known to "see stars" after being knocked out.)

Another method of stimulating phosphenes is by dark adaptation. Yogis who enter deep, dark caves for extended periods of time can view personal mandalas of phosphenic forms.

Researchers in outer-space and military fields have placed volunteer subjects into totally dark chambers for days on end. After a few hours most subjects report seeing phosphenic activity, often with considerable visual details and brilliant colorings.

Still another method of stimulating phosphenes is by electronic currents. Weak currents can be passed onto the retina directly, with no light coming into the eye, and phosphenes can be produced. Specific visual effects can then be produced in the viewer by varying the current in time. This is the method that my PHOSPHOTRON utilizes.

Figure 1 shows a diagram of the human eye in cross section. Light normally enters the eye through the cornea and iris, which adjusts the amount of light passing onto the lens. A magnificent set of muscles operate the lens to focus the image onto the retina. At the retina the light falls on rods and cones, just two of the sensing nerves which make up the retina. On the rods and cones wonderful photochemical and electrochemical effects convert the light pattern into electrical signals. These electrical impulses travel up the optic nerve into the visual portion of the brain, which is only a short distance behind the eyes.

The locations at which phosphenes originate within the eye are generally considered to be on the surface of the retina and at the front of the optic nerve. Exactly how the phosphenes occur is not understood very well. One theory is that they are electronic in origin. Mechanical pressure on the eye produces photochemical action on the retina, triggering weak electrical impulses in the nerves.

The electro-chemistry of the retina is quite complex and includes many exotic biological substances. One of these substances is rhodopson. It is present in varying concentrations, depending on the intensity of light entering the eye at any given time.

If you are in the dark for some time, say an half-hour hour, the concentration of rhodopson on the retina decreases. Rhodopson seems to inhibit phosphene perception, and to upset the conditions required for maximum phosphenic activity. As the subjects in dark chambers become dark-adapted their rhodopson level decreased and they begin to see phosphenes in copious amounts.

The Phosphotron instrument I have been using allows a wide range of visual effects to be produced in the viewers' eyes. It has been carefully designed and operated, paying close attention to the safety of the viewer, and the viewers' total and complete isolation from any main power sources or earth grounds.

IT IS STRONGLY URGED THAT YOU DO NOT TRY TO REPRODUCE THE HUMAN CIRCUIT USED IN MY PHOSPHOTRON UNLESS YOU KNOW HOW TO ISOLATE THE VIEWER FULLY AND COMPLETELY FROM ELECTROCUTION!!!

Figure 2 is a schematic of the human circuit fundamental to my phosphotron. There is no surgical implantation required. Rather there is a pair of external electrode discs attached to the viewers' temples, just behind the corner of the eye. The electrodes are then connected to a waveform generator with an impedance matching circuit to optimize the electronic circuit through the viewer's head. Suitable voltage and current limiting circuitry is also included to protect the viewer from excessive currents or voltages that could prove damaging or fatal.

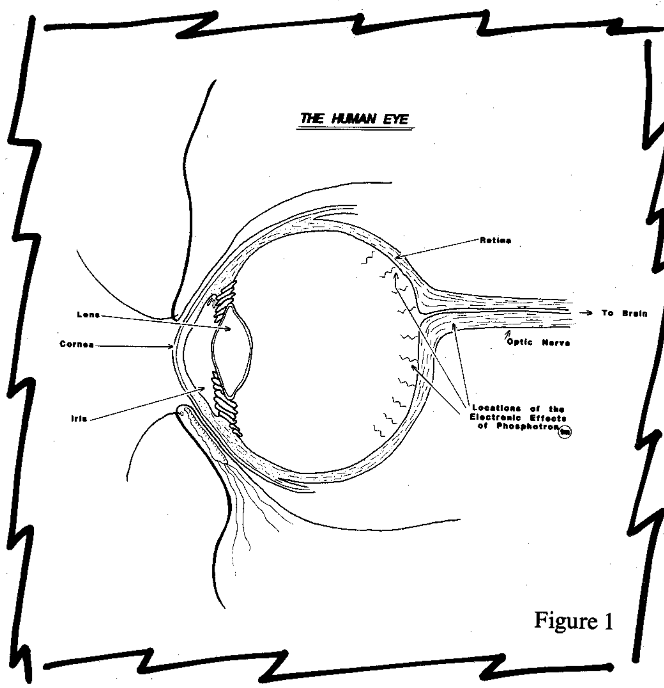


Figure 1

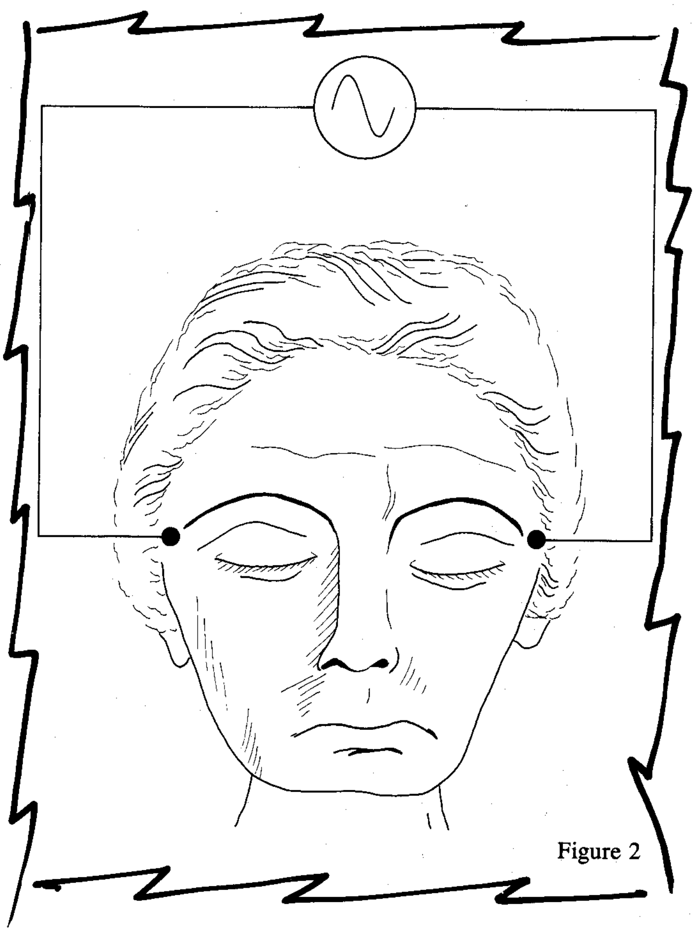


Figure 2

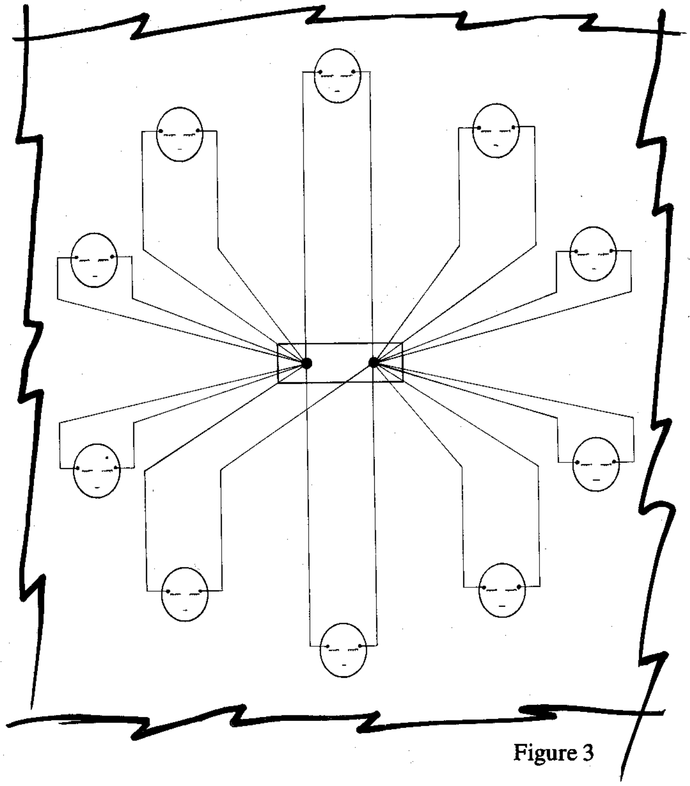


Figure 3

Voltage is limited to two volts, and current is limited to less than 10 microamps. The current limiting is adjustable to provide for group viewing with viewers wired in parallel.

Figure 3 shows the group participation version of my PHOSPHOTRON. It is essentially a parallel circuit of all the viewers' heads. I first explored this configuration in 1968 at the University of Illinois in Champaign. This is the configuration used in the recent revival of the PHOSPHOTRON at the 1983 San Francisco International Video Festival.

The parallel circuit feeds the same impulses to all viewers' heads simultaneously. All are presented the same view together. This configuration is opposite of the series circuit, where the source signal passes first through one viewer, then the next, and the next. Series has the undesirable problem that a much greater voltage must be used, and if one viewer removes the electrode set, the circuit is broken, and all others see nothing.

## THE PHOCABULARY OF PHOSPHENES

When you begin to observe phosphenes you will see there are many different kinds. Some phosphenes are simply specks or dots of bright light, usually ruby red or deep blue, scintillating against a black background. Others assume more specific forms such as wavy lines with a vertical, horizontal or diagonal orientation. Still others are distinctly radial or centripetal in structure and shape.

The coloring of phosphenes encompasses a wide range of hues and luminosity. After the dark adaptation period the first phosphenes observable are usually faint and pale, lacking much color saturation. However, as dark adaptation increases, and the rhodopson level decreases, the coloration becomes more vivid, with pale colors giving way to richer, more saturated colors.

The chart shown in figure 4 is adapted from a joint research paper by the German Institute for Electronic Research and the Department of History of Art, Yale University, published in 1962. In these experiments subjects were stimulated with rectangular impulses applied with frontal electrodes. The pulses were of a voltage range between 0.5 and 3.5 volts, and the ratio of off-on for the pulses was varied.

The horizontal axis of the graph shows the pulse frequency, while the vertical axis shows the various on-off ratios used. The researchers then plotted the sketches of different phosphene patterns reported by the subjects. The subjects were fully dark adapted before the experiment began.

The chart shows that most phosphene activity occurs below an excitation frequency of 40 Hz (cycles per second). While a few patterns were observed beyond the 40 Hz frequency, my own experience has shown that a sudden and abrupt cut-off does occur at 40 Hz.

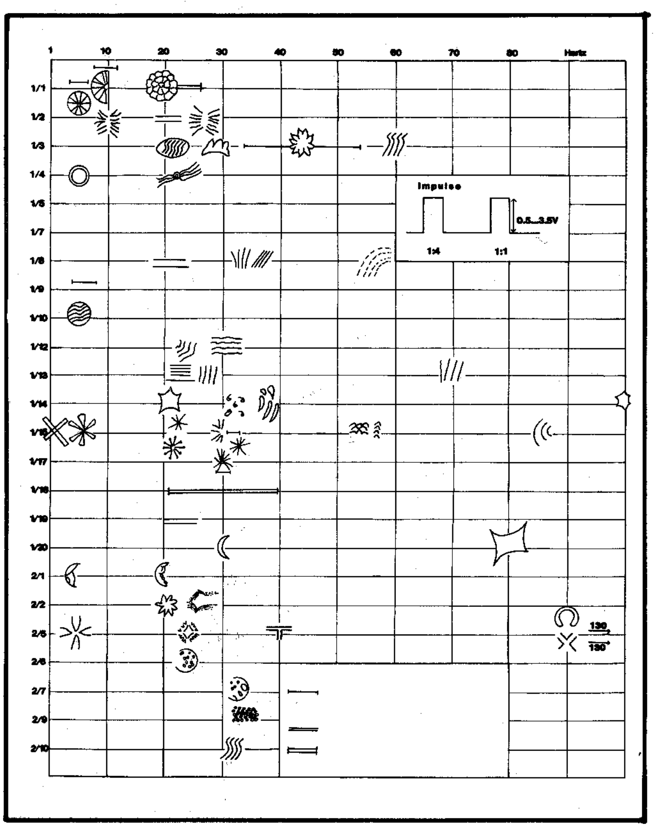



Figure 4

The types of phosphene patterns show some correlation to pulse frequency and ratio. For example, follow down the 20 Hz line of the chart. At pulse ratios of 1:1 there are radial patterns. As the ratio increases (the pulse becomes narrower) the patterns change to lines, both straight and wavy. At very short pulse ratios of 1:14 the pattern becomes radial or star-like. Finally at ratios of 2:1 or more some radial starbursts appear, and at ratios of 2:6 the patterns become dot or speck-like.

The sketches on the chart were representative of two subjects, and are certainly far from conclusive. My experiences with the PHOSPHOTRON in fact support the types of phosphene patterns indicated in this chart, but not necessarily at the same frequencies or pulse ratios.

My PHOSPHOTRON uses a much wider range of impulse waveforms than the German researchers'. I have the generator produce not only square or rectangular pulses, but also sine waves, triangle waves, and ramp waves. Each wave gives a different phosphene effect. Furthermore, the PHOSPHOTRON frequency range is from 1 cycle every 10 seconds to a maximum of 100 cycles per second. I also have included a "sweep" capability to continuously vary the waveform frequency at rates as fast as 1-40 Hz in 1 second.

Using the two frontal electrodes with the PHOSPHOTRON I am able to produce "stereo" sweep visual effects. By varying the duty cycle the image may be directed from the left to the right side of the viewer's field of sight. A balanced drive waveform centers the images.

With a sine or triangle wave impulse the visual effect is a "fade in—fade out" with soft, gradual edges. The triangle waveform produces a brief flash or point of light at its peaks, The square wave produces the most dramatic effects: bright flashes with a staccato or punctuated effect.

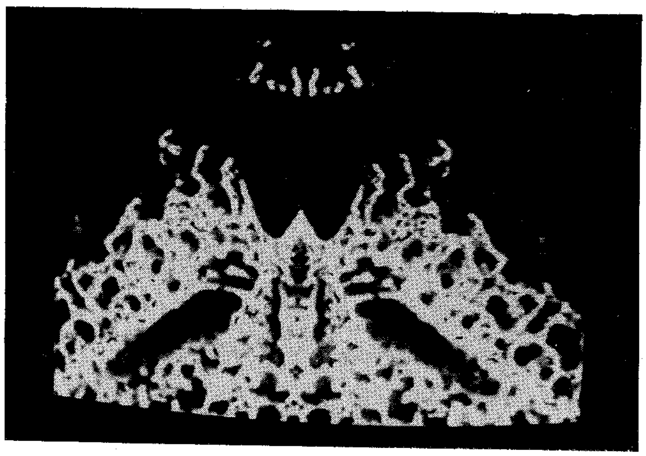
Experiences on the PHOSPHOTRON also lead to some remarkable frequency-sensitive effects. At low frequencies from less than 1 Hz to about 20 Hz the phosphene image is distinct and singular. Between 20 Hz and 30 Hz the singularity changes into more of a field effect, with a single phosphene pattern giving way to micropatterns. Then between 30 Hz and 40 Hz the entire field of view explodes with a myriad of detailed micropatterns.

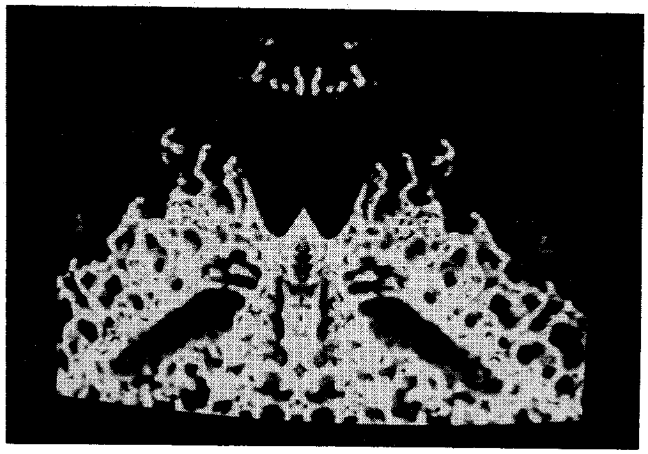
At frequencies above 40 Hz however, there is a sudden and complete blanking of all the phosphene effects. Perhaps with much higher voltages at the higher frequencies phosphenes can be seen again. But the voltage required could approach dangerous levels. The shock at voltages above 4 or 5 Volts DC is very painful, limiting my own exploration of any possible effects in this range.

The higher frequency patterns are the most interesting from a visual standpoint. Scintillating dots, or moire patterns, paisley-like forms, brilliant colors, and much animation all seem to be at a maximum in this higher frequency range. As the frequency is raised from the singularity range to the micropattern range a central, pulsing sphere will explode into thousands of colored bubbles.

There is clearly a correlation of this effect with the persistence of vision effect that makes cinematic forms like films and video perceptible as a continuous moving image instead of separate still images. Persistence of vision effects begin to occur at 20 Hz and improve at higher view-per-second rates.

For example, video displays 30 frames-per-second. But each frame is split into two field or alternation lines, so that the eye is presented 60 views per second. Likewise, most film projection occurs at a 24 frames-per-second rate. But a rotating shutter further divides each frame into 2 or 3 flashes so that the eye receives 48 or 72 views per second. The overall effect of these techniques is a smoother perception of motion by the viewer.





Steve Beck's

PHOSPHOTRON

(with special musical guests Henry Kaiser and Charles K. Noyes)

Presented at the 1983 San Francisco International Video Festival
October 6, 1983

THE PERFORMANCE:
I. Prelude for Dark Adaptation
II. Phosphene Fantasia

The PHOSPHOTRON is a "closed eyes" visual experience.

After you have become dark adapted and are wearing the phosphene headset your visual field will become filled with pulsating light patterns.

At first you will sense dark and light without much coloration. After about 10 minutes more of dark adaptation you should begin to see colorings.

We will be flooding your eyes with weak electrical signals in the range of .1 to 40 cycles per second, using a variety of waveshape patterns.

The richness of the phosphene images increases as your eyes become more dark adapted, so patience is necessary.

Phosphenes originate in the retina and the optic nerve. With your eyes open the incoming light overpowers the normally weak phosphene patterns.

Experiments have shown that most people will begin to see phosphenes after some period of dark adaptation. Subjects enclosed in totally dark rooms will begin to see brilliant optical images after 1-3 hours.

Classically, those who enter deep, dark caves to meditate for long periods of time will be treated to a marvelously rich light show of phosphenic images.

You may also cause phosphenes by pressing your finger tips VERY GENTLY on your closed eyelids.

Electrically induced phosphenes suggest the possibility of directly placing a television image into your vision without the need for TV monitors. The simple techniques used in the PHOSPHOTRON may some day be sufficiently refined to this point.

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(with special musical guest Henry Kaiser)

Presented at the 1983 San Francisco International Video Festival
October 6, 1983

THE PERFORMANCE:
I. Prelude for Dark Adaptation
II. Phosphene Fantasia

Each performance will be of 45 minutes duration, and can only accomodate 8 participants at a time.

You will have to sign your name up on the computer for the time you wish to participate.

Persons subject to heart conditions or epileptic siezures, or who use pacemakers, cannot be permitted to participate.

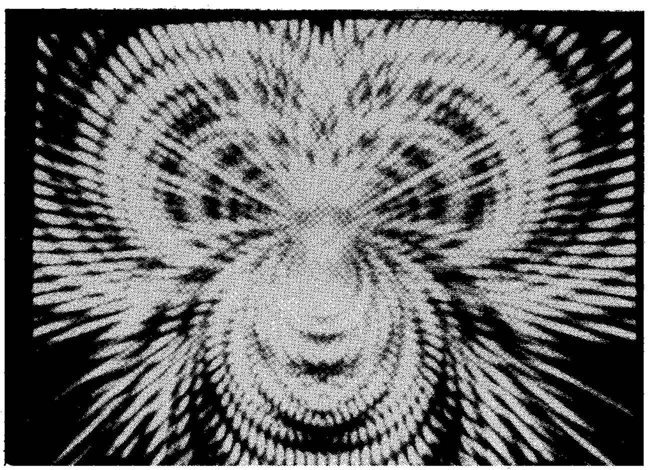
You will be required to sign a release form before being wired up.

Performance times will be:

7:45 PM
8:30 PM
9:15 PM
10:00 PM
10:45 PM

Please sign up on the computer.

Figure 5



# THE PHOSPHOTRON PERFORMANCE

Figure 5 shows the program notes for my recent participation performance piece presented in San Francisco. Each group of guests was limited to nine persons. Each guest was required to sign a release form, as shown in figure 6.

I was playing the phosphotron as part of a trio that included musicians Henry Kaiser on processed electronic guitar, and Charles K. Noyes on percussion. The musicians and myself were also wired into the PHOSPHOTRON, all in a parallel configuration with the audience.

After bringing the guests in to be seated we first placed the electrode set headbands I had designed on each guest, along with a dab of STIMUGEL electrolytic paste to improve conductivity into the skin.

The lighting was a subdued red light to help begin the dark adaptation process. The PRELUDE included a verbal recitation of the phenomena, then segued into the opening music. Each guest was reminded that they could easily remove the electrode headset at any time if they began to feel any shock pain. Of course many guests were not at all bothered by the minor shock pain, similar to a small needle prick, and in fact, some seemed to quite relish the sensation.

Unfortunately we had to accelerate the dark adaptation process, and allowed about ten minutes to elapse before fully beginning the second movement of the performance, the PHOSPHENE FANTASIA. While some guests reported perception of the effect immediately, others required several more minutes to begin seeing the effect.

The highlights of each performance included the interplay between the musicians and myself, the phosphenist. As the music ranged from slow adagios and subdued modalities, to lively, quick andantes and allegro tempos, I could vary the PHOSPHOTRON frequency and waveform accordingly. Sometimes the musicians would follow the tempo set by the PHOSPHOTRON, other times I would follow their tempo.

Only about five out of the fifty guests did not see any effects at all. In fact over twenty guests reported quite vivid phosphenes, especially as dark adaptation improved later in the piece. Guests were freely encouraged to describe their perceptions verbally, and many times several guests simultaneously spoke up about "the blue lines" or "all those colored dots".

I purposely limited the duration of each performance to about thirty minutes. By the end of the evening six shows had been given. At that point the musicians and myself had been wired for a total of three hours, and had incurred minor electrode burns on the temples.

There were no reported after effects by any of the guests,

and my vision was not affected even after the total accumulated time of exposure. In fact, my own vision seemed to be sharpened and focused by the currents.

# CONCLUSION

The result of the PHOSPHOTRON performance was to establish a new form of television, an "ultra-video", beyond video in its current form.

While we are at the primitive stages of developing this visual artform, we know that there is a vocabulary of elements, and can begin to pursue the grammar and syntax of this language. We are at the "dot and dash" code level at this point, and many technical problems need to be solved to develop the art of phosphenes.

There are other aspects to this research that have practical and medical significance. For example, a diagnostic tool could be developed that uses a known set of phosphene stimulation to develop a standard set of responses for healthy eyes. Then, comparison of a subject to the standard might prove to reveal latent problems in the subject's visual system before they become dangerous. It might also be possible to diagnose other aspects of the human organism with the phosphene stimulation-response measurements.

Another area of research that might prove fruitful is in aiding the blind to see. A pair of eyeglasses equipped with microelectronic chips and ultrasonic sensors could "sweep" the space around a person, and develop a waveform to place bright phosphenes in the location of obstacles or hazards. Much work needs to be done to determine if various forms of blindness can respond to electronically induced phosphenes. State of the art research conducted at the University of Utah is currently involved in placing electrodes directly into the brain, which requires a surgical operation. An external set of electrodes that stimulates phosphenes would be safer than surgery, and less costly, making it more readily affordable by sightless persons.

Finally, there is the long-term goal of making a phosphenic form of television. Can we develop enough precision in the stimulation waveform to produce a specific, photographic image in the viewer? If so we might be able to eliminate the screen from television entirely.

These questions and others remain to be answered by dedicated researchers in the life sciences. Just as artists were the catalyst in developing photography, I hope that my simple experiments in the visual art of phosphenes may lead to future developments beneficial to humanity. □

ACKNOWLEDGEMENTS

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I would also like to thank the musicians Henry Kaiser and Charles K. Noyes for their participation in the performance, and Katie McGuire for photographic documentaion of the event.

Finally, I must thank the original "guinea pigs" from the 1960's at Champaign, Illinois, for joining in the earliest experiments I conducted, particularly Rob Fisher, Teddy Timreck, Barry Fasman, and Jim Cuomo.

And last but not least, Steve Agetstein and Wendy Garfield of SEND magazine who organized the Video Festival and were daring enough to ask me to re-present the PHOSPHOTRON.

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