variations VII

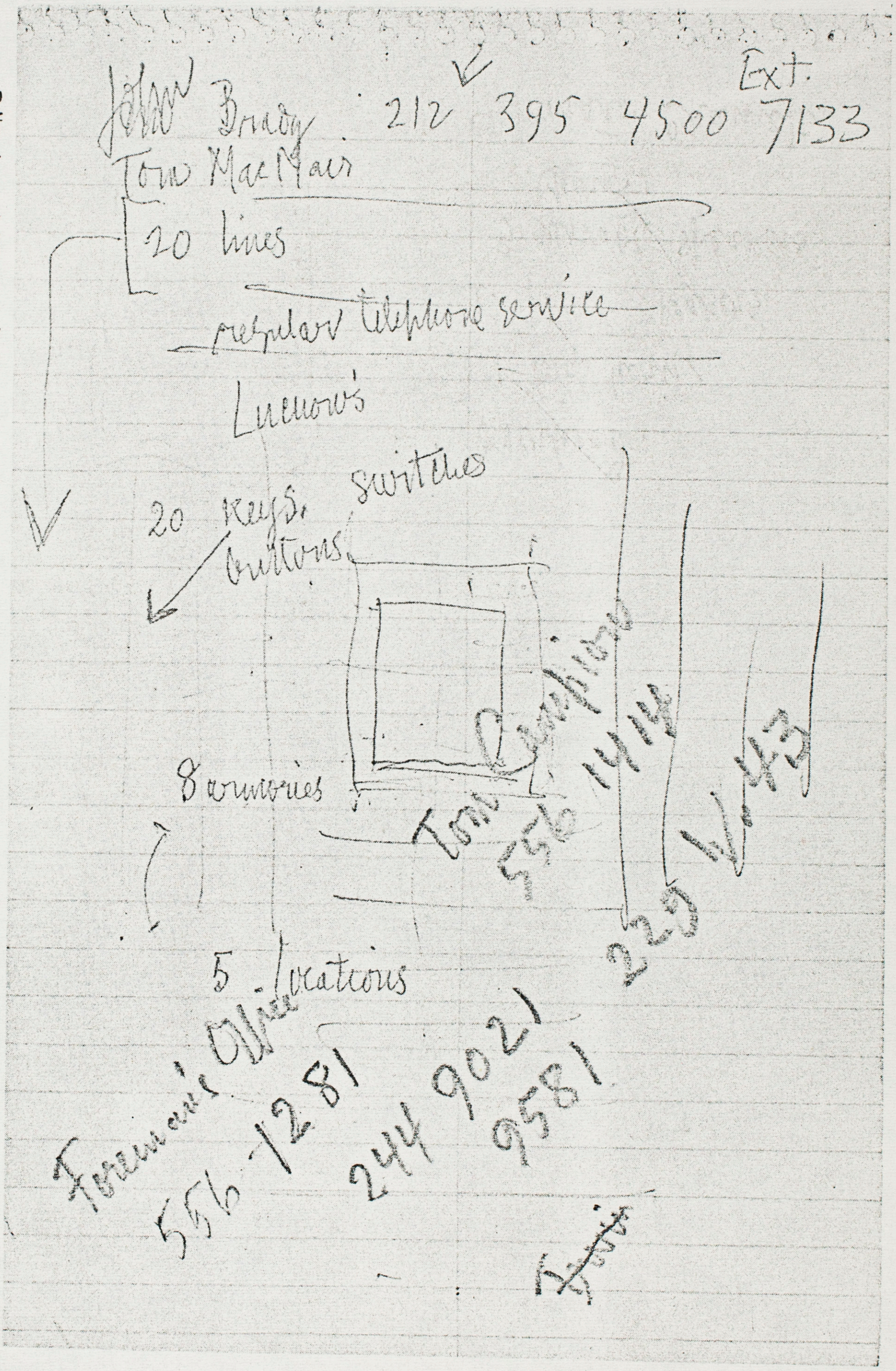
e

: Cecil Coker

ce Foundation

My project is simple to describe. It is a piece of music, Variation VII, indeterminate in form and detail, making use of the sound system which has been devised collectively for this festival, further making use of modulation means organized by David Tudor, using as sound sources only those sounds which are in the air at the moment of performance, picked up via the communication bands, telephone lines, microphones, together with, instead of musical instruments, a variety of household appliances and frequency generators.

The technical problems involved in any single project tend to reduce the impact of the original idea, but in being solved they produce a situation different than anyone could have pre-imagined.



9 evenings: theatre & engine

Billy Klüver

One of the problems faced by the contemporary artist is that everyone knows what art is. The scientist, by comparison, has it easy; nobody, not even fellow scientists, would dare to claim total knowledge about science. A scientist is, in fact, trained to balance between having no preconceived ideas and accepting reality.

Today it seems incredible that only 50 years ago there existed a "right" science and a "wrong" science. Battles were fought and lost that now seem inconsequential. At a recent APS meeting I heard Feynman talk about the reversibility of time while he was playing bongo drums on the viewgraph machine in front of an audience of 5,000. In the next room, another scientist was explaining that he had found a statistical correlation between the menstrual cycle in women and the period of the moon. His audience was 10.

Contemporary art is in somewhat the same position as science was during the explosive years between 1900 and 1910. Millions of people have become aware of contemporary art. For some art is an argument, an insult, a joke, a toy, a pastime or a sacred object. Art has become something to practically everybody. With the result that the artist must spend hours justifying himself and what he is doing. The end result is the undernourishing of one of the great resources of this country — the dedicated artist. We are too hard on the artist.

It is wrong, I feel, to make the withdrawal of the artist into his ivory tower a virtue. There are those who are interested in menstrual cycles. By the very fact of their participation in this project, the ten artists involved demonstrate a commitment not only to art but also to the presence of a general audience. Also, the involvement with professional technology is not only a logical extension of their previous work, but an approach towards the real world.

Nine months ago when a group of artists and engineers met for the first time this was not so clear as it is today. That first meeting on January 14th with a group of personally interested engineers from Bell Labs might well have been a flop. Everyone seemed to be scared of everyone else. Nobody knew quite what to say until one of the engineers suggested to another: "Let's tell them about something they can use." The ice was broken. About a dozen bull sessions followed during which the artists made suggestions of what they wanted and the engineers made counter suggestions. Many of the suggestions were wild and beautiful and unrealizable. By May we started to build equipment and tonight you will be able to see the results.

It has not been as easy as it sounds. The artists had to show an extraordinary amount of patience with the slow rate at which the engineer proceeds. And the engineer had to deal with the vagueness of the artist brought on by the fact that the artist had nothing to lay his hands on and work with. It was like lifting yourself by the hair: if you don't do it all at once it does not work.

The technical equipment built for "Nine Evenings" has cost over 30,000 dollars not counting invaluable help and advice given by specialists. It would, however, be foolish and irresponsible to describe this equipment as terribly extraordinary in technical terms. Compared to the missiles at Cape Kennedy and the large computers it is peanuts. This is rightly so. The artist cannot be expected to make use of the most sophisticated aspects of technology, even if he have access to these, since he is confronted with a new material. What gives our equipment its unique value is that it was built for no other function but to be part of the performances. The equipment is built from scratch and is a result of the direct interaction between artists and engineers.

But there is another side to the equipment — commercial potential of discoveries made as a result of its development. While working with Bob Whitman, we rediscovered a phosphor that has already become an important tool in infrared laser research. Another example is the small power amplifier which has also attracted commercial interest. The feedback to industry from the interaction between artists and engineers is very important. A direct involvement by industry is absolutely essential for any meaningful use of the potentials of professional technology by the artists. As a result the artists will help open new doors for the engineers and the engineers will give a fresh license to be poetic. Technology has, I believe, vast untapped possibilities to give pleasure and to make life more enjoyable. The Chinese fireworks 3,000 years ago were maybe the first use of advanced technology to give poetry, mystery and pleasure. I feel that our 9 Evenings performances will have some affinity to these long forgotten fireworks.

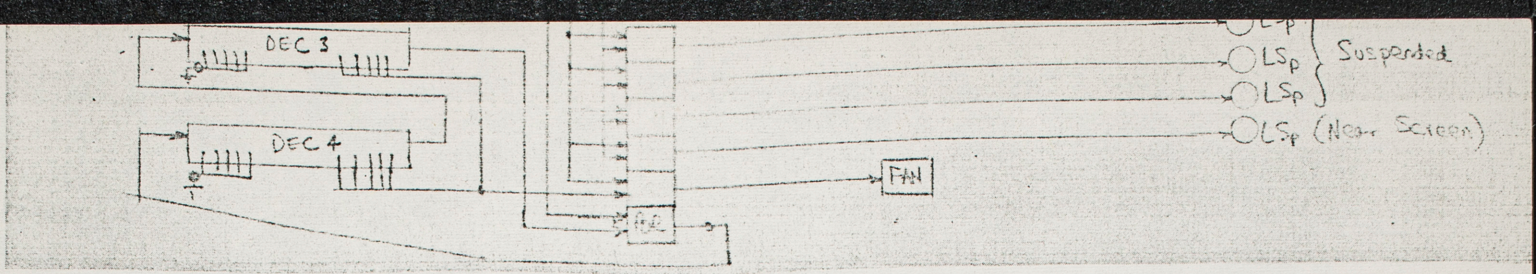
O O O

9 Evenings is a truly cooperative venture. All participants had an equal voice in the direction and all responsibility was shared jointly. While no one individual is responsible for 9 Evenings, certain people deserve special recognition and thanks:

Walter Gutman—our first contributor and friend;

Vera List—to whom goes great thanks for giving this Festival her generous personal attention and support;

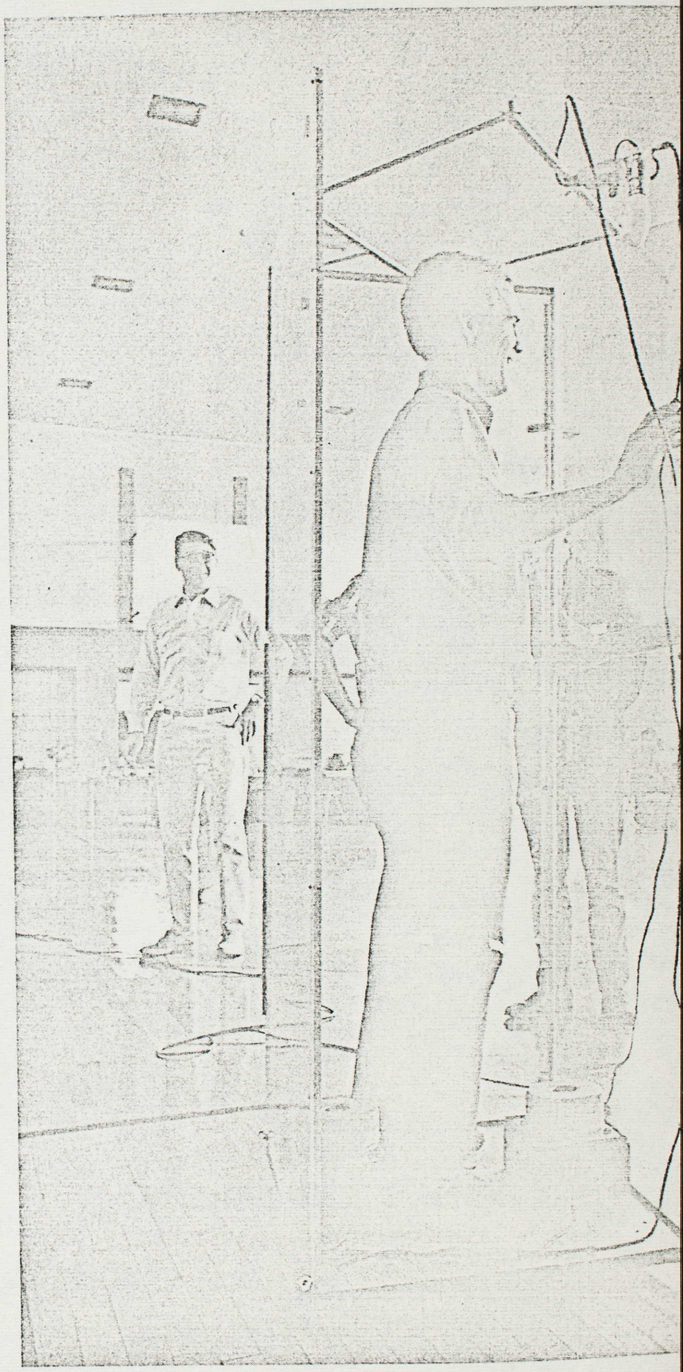
Mr. and Mrs. Seymour Schweber — who gave us help at a critical time and furnished invaluable connections in the electronics industry;



vehicle

by: Lucinda Childs

performance engineer: Peter Hirsch



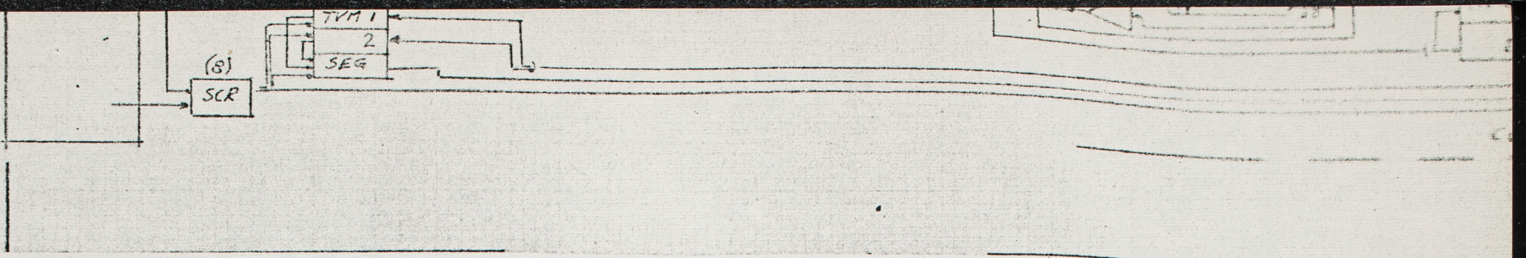
cast: William Davis
Alex Hay
slides by: Les Levine

Vehicle consists of materials animate, inanimate, air-supported (in one instance), which can exist in a non-static state and be observed in increased dimension as they come in contact with light and sound sources made available consistently or intermittedly by radio signals through-out the dance.

The Doppler sonar has ultrasonic beam sources and a receiver. The beam emits frequencies at a level which is greater than our hearing capacity. A moving figure or object passing in front of the beam interrupts it and sends frequencies back to the receiver of the sonar at a level determined by the velocity of the figure or object. What we hear is the proportional difference between the frequencies sent out and those returned through interruption of the beam, and the resulting reduction in the frequency level is what makes the sonar audible. Middle C (as we know it in music) is supposed to occur at approximately three feet per second of movement. This device, however, picks up movement of any duration or speed at the exact time that it begins or ends.

The ground effect machine is made from a General Motors refrigerator part which is designed as a platform to raise the 440 lb. weight of a refrigerator a fraction of an inch off the ground by the intake of air from a vacuum cleaner, thus making it possible to move the 440 lbs. with ease. The engineer, Per Biorn, installed two vacuum cleaner motors onto this platform so that I am in effect on a cushion of air when I use it.

I intend to utilize these devices in a set of circumstances as instruments which may or may not be efficient to the notion of completing anything. I do not feel that dance should be limited to the display of physical exertion alone; anything that can exist in a non-static state for a certain duration of time is of interest to me. My ideas are generally derived from the laws which govern the materials themselves and I attempt to allow the qualities and limitations of materials to be exposed in different situations.



open sc

by: Robert Rauschenberg

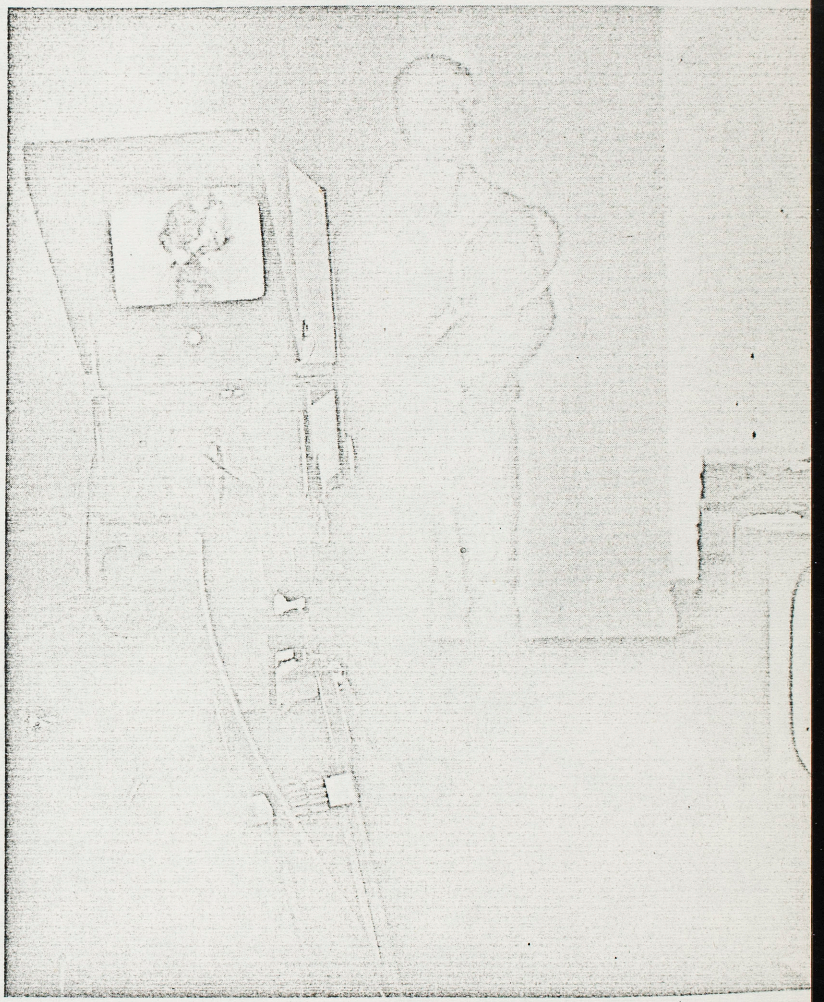
performance engineer: Jim McGee

cast: Frank Stella
Mimi Kanarek
a group of 500 people.

My piece begins with an authentic tennis game with rackets wired for transmission of sound. The sound of the game will control the lights. The game's end is the moment the hall is totally dark. The darkness is illusionary. The hall is flooded with infra-red (so far invisible to the human eye). A modestly choreographed cast of from 300 to 500 people will enter and be observed and projected by infra-red television on large screens for the audience. This is the limit of the realization of the piece to date.

Tennis is movement. Put in the context of theater it is a formal dance improvisation. The unlikely use of the game to control the lights and to perform as an orchestra interests me. The conflict of not being able to see an event that is taking place right in front of one except through a reproduction is the sort of double exposure of action. A screen of light and a screen of darkness.

The support of the Downtown Community School is responsible for the large cast in Open Score. Through the management of Marilyn Wood and the cooperation of parents and interested parties, the cast has been generously collected. The sources are varied and rich in intentions. The result of their voluntary involvement reaps the Downtown Community School $1000 for a scholarship fund. I would like to draw attention to the fact that all the names were not available at the time this program went to press. They should all be personally recorded, but the next best thing to do is to report that they well represent the world (our society) and are locally from such varied organizations as high school science classes, drama organizations, senior citizens groups, individual artists, reformed addicts' club and a New York fencing club. I am touched by the positive support, work, art, love and people.



NAM JUNE PAIK: EXPERIMENTS WITH ELECTRONIC PICTURES

"...science — the first universal religion, shared alike by Christians, agnostics, and Marxists — enjoys a magical prestige in today's world and few dare question proposals advanced in its sacred name."

(Arthur Schlesinger, jr. from a book review in LIFE, 1966)

May the approach of art and technology not soften the critical tongue of artists to society, science and everything **(NJP)**

In almost 10,000 essays reviewed in the Computing Review (1960—66), there are very few contributions to visual arts, as compared to a dozen or more to music, literature, and to history. In spite of interesting works done by Peter Denes, Michael Noll, Bela Julesz, K. O. Goetz, and Stuttgarter Group, many new possibilities are still left open for further development, especially if the extreme importance of the cathode ray tube and video tape recorder to the arts is considered. On the other hand, computerized video experiments derived from the unorthodox instinct of the artist will surely bring forth some unusual results in the research of pure science and applied technology.

1. The systematic study of **SCANNING** in a symmetric and asymmetric, geometric and ageometric, determinictic-probabilistic-indeterministic, periodic and aperiodic way.

The main reason for the quick success of my electronic art was that I gave up very early the production of video-signals (information quantity: 4 million bits per second), in order to concentrate my efforts on the creation of unusual scanning patterns (very manageable information quantity: 15,000 and 50 bits per seconds). Especially the addition of a third deflection yoke and triple modulation was a breakthrough. The quick switching of various deflection patterns (eg. spiral, oval, triangle, etc.) with adequate gate circuit as in chromatron color TV will enrich the variability by far. I am confident that the introduction of computer to this already well proven area will bring immediate success.

a) Artistic use: Whole movie, TV technique will be revolutionalized, the scope of electronic music will be widened to the new horizon of electronic opera. Painting and sculpture will be shaken up, intermedia art will be further strengthed, bookless literature, paperless poem will be born.

b) Pure scientific research: The new possibility of drawing every kind of form from abstract pattern to realistic image via every grade of mixture of both, will be helpful in the research of Gestalt psychology in its whole sphere, namely sensory organization, characteristic of organized entity, behaviour, association, recall, insight, learning etc. It might contribute also to 'hot' subjects of visual electronics today, such as optical recognition, optical character recognition, optical scanning of customer's account, video telephone, sparkchamber photography etc., needless to say, radar and anti radar.

c) Someday medical electronics will progress so much that vidicon artifical eyes will help the blind. My scanning experiments will be of some use for this ultimate goal.

d) Video telephone: Confidential pictures can be scanned with very complicated secret 'coded' frequencies, and sent to receivers. This will be useful, just as simple scrambling is useful, (eg. a Ford car designer showing his new car model to an executive in the coded picture via video telephone in complete confidence.)

e) 'SYNTHETIC FACE' for the identification, anthropological study of various face types, beauty surgery, and manicure industry etc. .

The above technique will enable us to construct any kind of face: with the long contour of John Wayne, melancholy eyes of James Mason plus Chuo-En-Lai etc.

2. I suggest to build a 7 channel video signal mixer, in which each camera shoots the separate parts of various faces, enabling to compose one face out of 7 men's characteristics. Beyond the above mentioned police use and possiblc use for pattern perception, beauty surgery, anthropology etc., it will enrich the TV & film technique tremendously.

3. The painful gap existing between TV video signal (4 meg c/s) and the output speed of computer (eg. IBM 7090: 400,000 bits per second) requires an unusual solution. One way would be to record the program in slow speed and speed it up in playback. But still astronomical quantity of information bit in single frame and its sequence requires enormously time consuming program work, and just this shortcoming demands an original programming system, with many short cut ways and artistic phantasies. As the first step I will establish many machine independent subroutines, which may be used by other programmers like twelve tone rows or raga in Indian music, e. g.:

a) subroutines of various basic forms, ranging from geometric to irregular form like bacteria,

b) subroutine of place inside a frame,

c) subroutine of size,

d) division of raster to many fields and its interchangeability,

e) stretch and shrink each field in various directions,

f) subroutine of combination of all 5 subroutines and the superposition with realistic images (as human laughter and dog's bark is superimposed in a Vocoder).

Among vast application of this method in art, science, and technology, one interesting example would be the imitation of the statistical movements of virus, bacteria, fishes, and mass people etc. .

4. Another important usage of computer in visual art is a concordance of movie and TV shows, as Cornell University did with a Shakspeare concordance. Cataloguing and indexing of all main actor's and director's scene by its contents (f.i. walking, waiting, anxiety, love, fight, pealousy, eating, joy, crying, including length of scene and emotional pitches) on videotape will be very valuable for cine-libraries, a good study material for students and a great fun for ordinary viewers. Also historians, sociologists, psychologists will profit from it.

5. Mood art in the sense of mood music can be invented and installed in the home. Big theater or opera houses could change their lobby designs everyday, matching to their repertory—this lobby design could progress in accordance with the developing plot. A big cathode ray wall with color eidophole or controlable electroluminiscence can be programmed for this purpose.

ALVIN LUCIER: MUSIC FOR SOLO PERFORMER

(to John Cage)

It is well known that the alpha rhythm of the brain has a range of from 8 to 12 cycles per second and if amplified enormously and channeled through an appropriate transducer, becomes audible.

It is also well known that the alpha rhythm can be blocked by such things as visual attention with the eyes open, mental activity when the subject is in a resting state with the eyes closed.

No part of the motor system is involved in any way.

The activity of the subject consists simply in alteration of thought content, for example a shifting back and forth from a state of visual imagery to a state of relaxed resting.

The following is a description of a performance of **Music for Solo Performer 1965** given at the Rose Art Museum at Brandeis University on May 5, 1965. It was also performed at the Fylkingen-Festival "Visions of the Present", Stockholm, 1966.

1. An EEG scalp electrode was placed on each hemisphere of the occipital region of the performer's head and a reference electrode was centrally placed above them and grounded as a means of cutting down electrical noise.

2. Two neurological amplifiers (Tektronix Type 122) were connected in series and used to raise the voltage of the alpha rhythm signal to 3 or 4 volts.

3. Next, the signal was sent through a bandpass filter (Model 330M Kronhite Bandpass filter, 2 cps to 20 Kps $\bar{c}$ 12 db/octave attenuation) which had been set for a range of from 9 to 15 cycles per second.

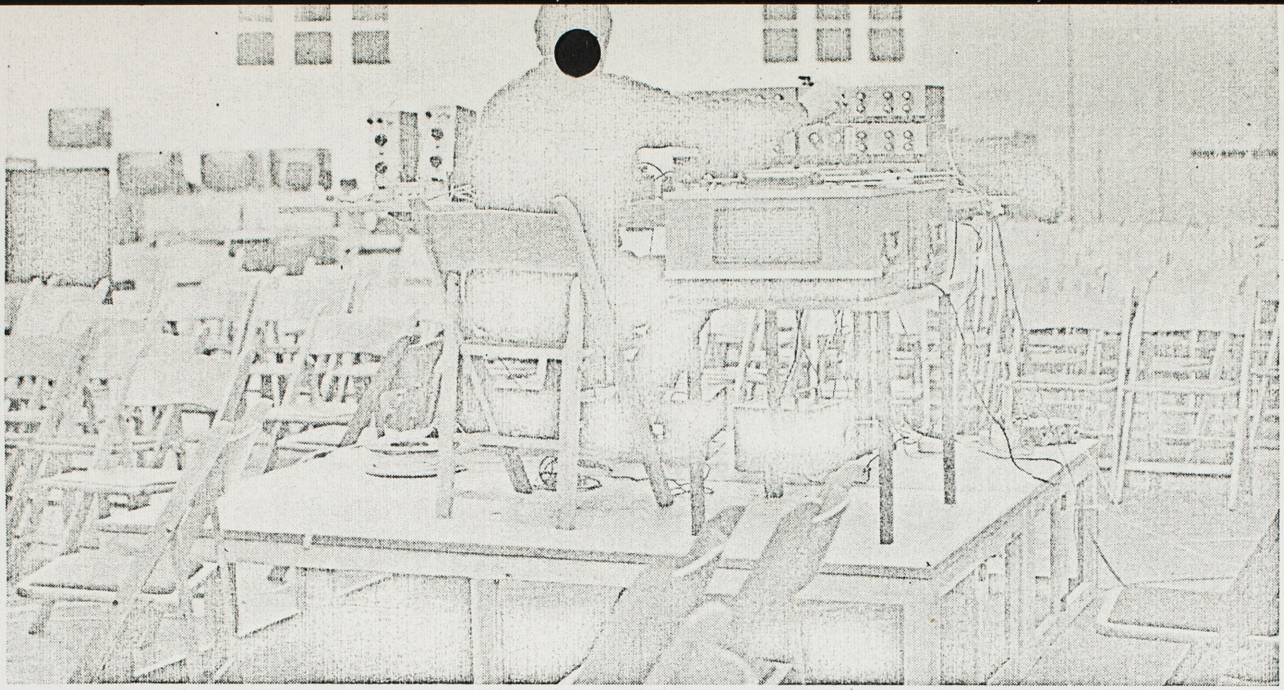
4. A cathode follower was inserted next for impedance matching purposes.

5. The signal was then sent through several hi-fi preamplifiers and amplifiers used to drive several speakers some of which were placed against resonators such as large gongs, timpani, a metal ashcan (the speaker was put inside). A cheap, small automobile speaker was placed face down on a bass drum head.

6. In addition to the speakers, an integrating threshold switch was employed to operate a tape recorder upon which was a tape of pre-recorded brain wave sounds accelerated 5 times to a frequency of 320 cycles.

7. Control of sound source:

a) The sound source was turned on and off by means of setting free and blocking the alpha rhythm. The composer found that by closing the eyes, relaxing, looking up into the eyelids and trying not to visualize in any way, the alpha rhythm was easily obtainable with a little practice.



Alvin Lucier at the controls used in "Musik for Solo Performer".

b) An assistant was used to control the volume and channelling of the speakers. By operating the controls on the preamplifiers, the assistant could channel the signal to any or all the speakers at any volume.

c) The assistant at various times throughout the performance attached the threshold switch which would turn on an amplifier to a tape recorder already running.

8. While no score was used a very simple set of hand signals was employed whereby the performer could direct the assistant regarding channelling, volume and when to turn on the threshold switch.

9. 40 minutes was decided upon as the length of the performance.

Remarks and suggestions for future performances.

1. Instead of using only one electrode on each hemisphere of the occipital region, the performer may experiment with several electrodes on other parts of the head in an attempt to pick up other waves of different frequency. This would necessitate adjusting the filter. Stereo effects using the two hemispheres may also be attempted.
2. More speakers of various sizes may be employed depending on such factors as size and shape of the hall, complexity desired and number of instruments to be resonated. A wide variety of instruments and resonating objects may be tried including pianos, harps, harpsichords, drums, cymbals, sheets of glass, metals, water and so forth.
3. More sophisticated use of the threshold switch may be used, some perhaps with relays which could activate several tape recorders in tandem, radios, machinery, television sets, lights, alarms and so forth.
4. It is possible that the solo performer may operate the controls himself without an assistant. Great care would have to be taken that visualization caused by thinking about the volume controls or whereabouts of the speakers would not cause blocking.
5. If more detailed instructions for the assistant are wanted, a more elaborate signal system could be invented. On the other hand, instructions may be dispensed with altogether.
6. Any time length is possible.

KNUT WIGGEN

Hardly anyone will deny that the advanced technology of our times is the foundation on which our continously higher standard of living rests. There are many, however, who at the same time appear to regard technology as the enemy of a happy and fully civilised life.

The reason for this is the discovery that material progress does not automatically bring a greater feeling of happiness. Since technology is the basis of the material progress, it is also made the scapegoat for those expectations which do not materialise. Technology is already being blamed in advance for a vision of the future which is considerably feared today—a situation in which human beings will lose their identity in order to serve more effectively the advancement of the technology they themselves inaugurated with such great effort, but which has since grown into a monster they are no longer able to master. To single out technology as the villain of the drama is rash, however, and perhaps even dangerous. It seems to imply that the only solution of the problem is to neutralize and isolate technology. The remedy is said to be a "return to civilization" or to "democratize culture", by which is meant to disseminate the type of artistic product which was created before modern technology changed the structure of our society.

The argument that technology **per se** is evil may be dismissed at once. Another opinion cherished by many people is, however, that technology is neutral —it is only as good or as bad as its user. In that case, however, we do not use it in the proper way, and the question then arises: why is this so?

Obviously it is not the **will** to put technology. to the best possible use that is lacking, nor is it a question of how the "best possible use" is to be defined. It is very easy to point out good, practical, uses for our technical knowledge, such as for instance a satisfactory volume of production of life's necessities, the extermination of illnesses, an effective system of communications between the peoples of the world so that conflicts are toned down, and essential practical measures such as birth control, etc. Likewise the examples of bad utilization are legion: the production of arms with which to kill each other; the development of methods and means with which to influence people's minds for the purpose of exploiting them for personal gain; the building up of bureaucratic and technocratic social systems, etc. If it is not the will, however, or the lack of clarity regarding the objective to which the unsatisfactory utilization of technology is due, then it must be the lack of "know-how" and of the capacity to "get along with" our advanced technology. Clearly we have to learn to understand what will happen when we tinker with technology, whether with good or bad intent. To contend that technology is as good or as bad as its user, is to simplify matters too much.

The relationship between man and his tools is obviously a complicated "feed-back" system which still conceals vital secrets. How to get at these secrets is, however, a knotty problem, since "scientific methods" are of course also one of our tools, a fact which must necessarily complicate a scientific investigation of this field. It is perhaps no mere coincidence that the most advanced artists are attracted by this problem in as high a degree as the scientists.

The focus of discussion is our use of the new mass communication media, which, to an artist, is of vital importance. However "uncommitted" he may

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think he is, he has of necessity to choose a medium for his artistic communication, and this medium ties him down to both compositional and social evaluations. The choice of such a seemingly unsuitable tool of manifestation for social engagement as a symphony orchestra is in reality a choice of the work's function in society and a "dedicated" support of the evaluation on which this function is based. And what is more; the medium plays a part in deciding the type of content the work is to have, with all the consequences this may have for artistic execution.

There are typically electronic and typically instrumental musical structures. One discusses what is filmic in the film industry and televisionistic in the television production. The film industry wants to rid itself of the theatre, and television wants to rid itself of films. The driving force in these endeavours is not the technical differences between these media —for we have only too many examples of electronic church organs, filmed soap-operas and plays, televised cinema films, etc,-but instead the ever increasing realisation that the new medium calls for a new content. The debate about what is filmic, televisionistic or electronically musical is in reality a discussion between those who wish to use the new medium for giving greater effect to the diffusion of values created **before** the medium existed, and those who want to start communicating values that are appropriate to the situation which has arisen with the advent of the new medium. It is a debate between those who believe that our media are technical aids for the spreading of ideologies and those who believe that media contribute to the creating of ideologies. Finally, it is a debate regarding the relationship between man and his tools. Only too rarely is it recalled that Beethoven's, Chopin's and Wagner's music were to a great extent a result of mediathinking. The medium was the concert hall. The concert halls were built to hold the larger audiences which the increasing influence of the middle classes brought in its train. The instruments were improved so as to provide a greater volume of sound with which to fill the larger auditorium, and they were given greater technical brilliance in order to satisfy the larger audiences. The composition and size of the orchestra were changed to conform to the demands of the concert hall, and preference was given to musical structures which would fill the large volume of space. The length of the composition was adapted to the budding concert-hall tradition. The instrumentalists changed their playing technique in the same way as today they have adopted another technique in order to meet the demands of the microphone. That music we usually point to as "the music" is only **one** of many possible types, and with its media-thinking it is for the **cognoscenti** as good a picture of our times as any.

With current social values—e.g. that one should break down the social and geographical barriers that exist between the bulk of the world's population and the achievements of artistic creation—we have to abandon 18th and 19th century media such as concert halls and theatres and use instead media such as television, radio, magnetophone and video tape, grammophone records, films, etc. The objections raised in artistic circles to this method of solving the problems, for instance that music communicated through loudspeakers is not "live", that the intimacy of the theatre is lacking in television, that film cannot be good "literature" etc., may be ignored. Loudspeakers will not disappear because they do not function in the same way as concert halls. Television will not disappear because it does not function in the same way as the theatre, and films will not disappear because they do not function in the same way as books. Nor will artistic creative activity disappear because no one any longer composes for the concert halls or writes for theatres or publishers.

One cannot, for instance, demand a high literary standard in television, since television is an audio-visual high-speed massmedium, in other words a medium enabling many to see and hear what is happening at the moment, and by which the dimensions of time and space can be handled in quite a different way to that which is possible in literature. The proper medium for high-class literature is the book. Any attempts to try to raise the "quality" of television, meaning by this the literary quality, are meaningless. To raise the quality of television programmes means finding out what the "character" of this medium is, and then allowing it to influence the contents. This is a trivial contention only if one fails to realise that the theoretical and practical solution of this and similar problems will mean that people have found a new way of living together with technology, which is in our time identical with a new way of life.

Music entered the epoch of massmedia when it began to use loudspeakers. At that time the new medium was used—and this is still to a large extent the case—to disseminate more effectively an older medium's content and values, namely those of the concert hall. With the arrival of the first composition for electronic music, the attempts to give adequate content to this new medium began. Electronic music, however, is not in itself a "content" but only an applicable sound material for an adequate content. When the electronic music abandoned the inherited instrumental composition technique—manifested by notation requirements—and allowed the composer to construct his composition directly on to the tape recorder, we came still closer to the adequate content. The next step has in part already been taken, and it is as well to describe here in detail why it has had to be taken, since for most people it may be a bitter pill to swallow.

The genuine result of the concert hall medium was the musical Work of Art. As has been pointed out repeatedly, it is obvious that the choice of tempo and volume of sound are determined equally much by the hall as by the structure of the music. To this may be added other less well-known obvious things such as that the content, form, structure, instrumentation, interpretation and everything of which these Works of Art consist when they reach the ears of the public are dictated just as much by the functional demands of the concert hall as by the composer's creative imagination. Acoustically and socially the musical Work of Art will always be linked with the concert hall, and any other means of diffusion will result in a certain "distortion" of the Work of Art. Such distortion always occurs when the "content" of **one** medium is communicated through **another** medium, i.e. a "box within a box" technique, as is the case when symphony concerts are broadcast or telecast, ballet performances are filmed, etc. The concert-hall Work of Art enters into a state of disparity to the new media, and the battle, or "discussion" I previously mentioned in this article, will never end with the victory of the Work of Art. For these new media are powerful tools which play a part in directing society's development. It is not the task of the artist—and never has been—to oppose these media. The artists of today ought not to give in to the demands of the 19th century institutions that the Work of Art should be protected either by the artists refusing to make use of mass communication media, or—if they have to do so anyhow—by using these media as a **substitute** for the concert hall, i.e. an application of the "box within a box" principle.

It is therefore probable that the trend of music in this mass-media epoch will also involve the dominance of the Work of Art in artistic creation being broken. "Happenings"—before they became an object of financial speculation and entertainment—were the first step on this road. Other signs are the ever-growing interest in musical circles for musical machines as a technical solution of how to make music without resorting to the Work of Art form. This also applies to computer music, which deals with compositional and esthetic aspects of the same problem.

The substitute for the musical Work of Art which will finally be chosen will depend on the function in society one wishes music to have. One suggestion for such a function is that the music shall be a field in which people can learn to handle their own tools; shall learn to dissociate these tools from evaluations existing before the tools came into being, and to attune them to the evaluations the tools themselves have been instrumental in creating, by revealing their inherent "character".

With this suggestion as a starting point, Fylkingen in autumn 1965 put forward the idea of a Festival in which this enormous problem would be illustrated by lectures and artistic performances.

Sweden is probably one of the few countries in which a festival experiment of this kind can be carried out. In comparison with other countries, Sweden appears to have mastered the worst problems of social injustice and political and commercial ideologies. The country can "afford culture"; there is a public for it and, not the least important, an organisation for arranging such a Festival—Fylkingen.

Translation: Hunter Mabon

JOHN R. PIERCE

However science and technology and art may be related to one another, and whatever their mutual importance and interdependence may be, it is particularly appropriate that this be explored in Sweden, and that in doing so something of the technology and art of America be taken into account. Both of our countries have a prosperity based on technology, and that prosperity makes further progress in science and technology as inevitable as it is necessary to our continued well-being. Both of our countries have a lively interest and activity in the arts.

Such differences as there are between us in temperament and approach are complementary. In your country the approach to problems is perhaps more orderly than in mine, and your government has a traditional policy of support of the arts as well as of sciences. In my country, the government has come to support science and technology lavishly, but our chief tradition in all fields of human endeavor has been one of linking individual inventiveness to new social interests, needs and demands through a host of improvised nongovernmental institutions which include such disparate endeavors as the movie, automobile, TV and recording industries, a host of private universities, the Rockefeller and Ford Foundations, and the Battelle Memorial Institute.

Whatever the temperament and institutions of any country may be, science and technology are assuming in increasingly central position in almost every aspect of the lives of its people. This is a manifestation of one tradition of science—the motivation to change and improve, which was put forward most forcibly in words by Francis Bacon, a non-scientist, and has been exemplified in the work of Pasteur and of many others. Today, what Bacon dreamed of and what many others have worked toward and aspired to has become a commonplace of our lives.

At one time man's environment consisted of natural objects—grains and vegetables, cows and horses, rivers, lakes and seas—together with plows and boats, houses and mills, things man-made, but produced more by traditional skill than through deep intellectual understanding. Today we use trains and automobiles rather than barges and horses, and we live amid a host of other things which have no counterpart in earlier times, and which would have found no place in an earlier society. These new things include airplanes and electric power, but telephones, television and computers are better examples.

Our society has roots in the past, but it has had to grow and change in order to make use of the products of science and technology. We have developed needs and habits which are based on science and technology. And surely every human endeavor has been affected by this change.

Indeed, science itself has been profoundly affected by our progress in science and technology. Increasingly, science has found itself in a Baconian, Pasteurian world of effort toward human needs and human aspirations. Yet for many years, many scientists have given their chief allegiance to an older tradition and a very different though complementary philosophy.

Science has roots in technology, artisanship and common experience. Thermodynamics would scarcely have developed as it did except for the invention and development of the steam engine. And the steam engine came into being through artisanship guided by common experience. But in the classical world, the ends of science were those of philosophy, of which it was a part. Philosophy, like religion, seemed to offer a means of understanding the world. Greek and Roman philosophers hoped that man could comprehend and explain all important phenomena through a few scientific or philosophical principles. And in a far later period ranging from Newton through Maxwell, many men believed such a triumph of understanding to be near at hand.

I believe that traditionally the highest value of science to scientists has been this value of understanding, of the human mind comprehending the universe in a philosophical sense. Twentieth century science has increased our understanding of a wide range of natural phenomena immensely, in the fields of chemistry and genetics as well as in physics. Yet I believe that this very wealth of progress has undermined rational hope of comprehensive understanding —of science or anything else enabling man to understand the universe. By insisting on details and verification, science destroys the intellectual and emotional appeal of sweeping generalizations. And the very wealth of understanding which the pursuit of science opens up convinces us, not only that no one man can understand everything, but that of all the things that are amenable to human understanding, mankind has time and energy enough to understand a small fraction only. Thus, whether or not the choice is conscious, science and scientists are faced with a choice—what shall they understand, and what shall they pass over.

The traditional answer in the matter of choice is that everyone knows what is important. What everyone is presumed to know to be important is to understand and resolve fundamental discrepancies between the theories of physics and the experimental facts. Einstein's relativity resolved both discrepancies and logical inconsistencies involving Maxwell's equations of electricity and magnetism and Newton's laws of motion of material bodies. Quantum mechanics resolved discrepancies between the laws of motion, the laws of electricity and magnetism, and the behavior of atoms and of the electromagnetic radiation they emit. Moreover, through the work of Nils Bohr, quantum mechanics led to an understanding of the nature of the chemical elements, and of radioactivity and other nuclear processes including those of atom and hydrogen bombs and nuclear reactors.

But in the very process of explaining, science has uncovered new phenomena of high energy particles, many of them new particles which are not clearly understood. Moreover, many scientists believe that an understanding of these phenomena, when and if it comes, will not necessarily produce a "final" understanding. Rather, we may be led to a new range of phenomena which will call for yet further understanding. Equipped with particle accelerators which are among the most expensive tools ever built by man, some physicists, at what they regard as the forefront of science, push toward an understanding of the peculiarities of particles, while other more scholarly physicists try to reconcile quantum mechanics with the general theory of relativity.

But these men are neither our most influential scientists nor even our most productive physicists. Whatever fallibilities our understanding of the laws of physics may have, everyone believes that **in principle** quantum mechanics can explain all the everyday phenomena of nature. This means not only physical phenomena such as magnetism and superconductivity, but chemical and biological phenomena as well. But with our increased understanding the words **in principle** have become increasingly unsatisfactory, even if they may be in some sense true.

In actuality, today we understand a good deal about individual atoms, although, with the exception of hydrogen, we cannot accurately compute their properties from fundamental laws. We understand a good deal about gases, but fundamental discoveries, such as those of Alfvén concerning the collective behavior of ionized gases, can be made within the scope of known physical laws. And even such discoveries are not final. Any plasma physicist will tell you how limited our understanding of the behavior of highly ionized gases is. We lack a fundamental understanding of liquids. Our understanding of solids seems great in many respects—it has given us transistors, and new magnetic materials, but the study of the solid state generates new problems at a faster rate than it generates solutions to known problems.

We owe to quantum mechanics our understanding of what holds elements together in chemical compounds. But it would be foolish to say that quantum mechanics has solved the problems of chemistry—it has only supplied us with tools and insights. The study and synthesis of complex compounds, whether they be plastics or biologically active materials, which is a worthy intellectual field in itself, is by nature very different from the pursuit of physics.

Neurophysiology and the biochemistry of genetics, where we have seen profound progress recently, are still further afield from the ultimate understanding which particle physicists seek. And some fields—geophysics, and psychology, and the investigation of complicated machines such as computers, and what such machines can be used for—are still farther afield from the ultimate laws of physics, and yet they are equally challenging to human understanding.

I think I can sum up what I have been driving at in a few words. According to its earliest tradition, science sought to explain natural phenomena in logical, and later in a verifiable, rather than in an emotionally persuasive way. Science succeeded remarkably. In so doing science has shown that nature is far more complex than we could ever have imagined.

Whole new areas of fascinating and complicated phenomena are now apparent to us. We can hope to discover and understand other new and extensive phenomena in the future, and our understanding will be an understanding in great detail. But, in a given age what we understand may not be of our own choosing. Phenomena of nuclear and particle physics had to wait on advanced technology for their discovery and elucidation. To a degree, understanding comes where it will. Beyond this, we cannot in any age understand everything. Science does not enable us to comprehend the universe.

What science clearly does do is to offer us opportunities to change the world in which we live and the lives that we live in that world. Science does not enable us to understand everything, but the understanding which it does give us is very powerful in our lives. Partly, we understand an airplane or a computer better than a bird or a nervous system because an airplane is simpler than a bird, and a computer is simpler than a nervous system. But partly we understand airplanes and computers so well because these devices are built according to our understanding. They do what we know how to do, and limited as it is, that knowledge is very powerful.

Our limited knowledge of the world has given us automobiles, and telephones, and electric power systems, and automated factories for making these things, and medicines—a nearly uncountable number of things, large and small, which make our lives longer, or easier, or richer, or at least profoundly different from the lives of people in remote centuries or primitive lands.

Science is important to men and nations, not because it enables us to comprehend the universe, but because it enables us to change the world. The American government spends billions on science and technology primarily because these have demonstrated their power in producing radar, and atom bombs, and missiles, and the supposition is that adequate support of science will go right on producing militarily and socially useful marvels.

Physics and chemistry and medicine are supported lavishly, not because they are harder or deeper or philosophically more worthy than other areas of science, but because they have demonstrated their ability to produce marvels. Psychology, a very difficult, important and promising science, receives less support, not because it is less challenging and less worthy, but because it has not produced anything with as obvious, as clearly defined, as inescapable an effect on the world as the atom bomb, plastics, or penicillin. And if art and the humanities have received even less support, it is because they have not furnished new and clearly apparent tools which government and society can identify and use.

Science and technology can continue to change the world as they have changed it in the past. To work this change we must first find that part of new knowledge which will give us more in return than the effort we put into it, and we must be willing to accept unforeseeable consequences.

In a prosperous society, the telephone, radio, television, computers, and automobiles all offer more than they cost. We prefer what they give us to whatever small luxuries of food, or clothing or housing or art we might have in their place. But many things that technology could provide us do not meet that test today—newspapers transmitted into a home by facsimile, television with telephones, private helicopters and landing areas at our homes. Some things are beginning to meet the test of giving more than they cost—air conditioning in homes and cars, electric heating and private swimming pools.

If science and technology are to change the world, we must first opportunistically find, extend and exploit that knowledge which will give us new things that are worth what they cost. And we must be willing to accept what these new things give us and do to us.

In general, individuals appear to accept innovation avidly and indeed thoughtlessly. So we have taken to the automobile, and radio, and television, and the electric guitar.

But to survive, a society must have a conservative as well as an innovative component—otherwise it would collapse into chaos. Unconscious custom is of course conservative, but it can often be overcome with surprising ease. The conscious forces of conservatism are government, whose bureaucratic machinery and divisions of power and responsibility are rooted in the past, and that portion of the intellectual community which compares the best of the past with the average of the present and wants somehow to impress the past on a new and unrelated world.

Today in America the wired distribution of broadcast television programs, called community antenna TV, or CATV, seems to have the potentiality of revolutionizing television by economically providing in the home a far larger number of channels than available frequencies can make possible in broadcast TV. Yet some people have proposed drastic government regulation of this promising new technique, regulation which might prevent it from developing into something very different from present TV.

The field of TV also illustrates the conservative side of the intellectual community. TV has its strengths and its faults, but these are not and cannot be the strengths and faults of concerts, phonograph records, books, plays or newspapers. Intellectuals who compare TV with these other media often find it an abomination, and want to make it conform. They cannot, and to my mind their criticisms are unjust and their proposed remedies are impractical for a service which goes into every home and which must please most of the people most of the time.

Another great and successful innovation in America is the portable home, the almost-never-moved trailer. Fifteen percent of all new single houses are portable homes. Portable homes provide living space much more cheaply than conventional houses. They introduce an entirely new concept in housing—houses that do not pretend to be built forever, but can wear out and be disposed of, just as we change automobiles. Yet many decry portable homes because they do not look like houses, and are, at least to our eyes, ugly in comparison.

I have painted a picture of science and technology as powerful but limited. Science gives us not what we think we want, but what we can have. We get plastics instead of the philosopher's stone, and TV instead of the elixer of life. And because science gives us what it can, not what we think we want, the world that science makes for us is more surprising, more different, and in many ways more challenging than the world we would have if science did give us what we think we want.

Because of science we all are in the process of making a marvelous journey into a strange and surprising land, even when we never travel beyond the place of our birth. In the course of this marvelous journey, art is bound to change and adapt along with all the rest of our life and customs. I think that art is particularly suited to go hand in hand with the exploitation of science.

Art has traditionally shown the same sort of opportunism that is essential to the progress of science. Art has shown admirable opportunism in exploiting new technical resources. The introduction of oil as a medium drastically changed the character of painting. The introduction of mathematically correct perspective and correct anatomy revolutionized renaissance painting. In modern times, whatever is attractive about motion pictures and television is an element of artistry, which may be as crude as it is compelling.

Art has also been as socially opportunistic as science and technology. Music changed profoundly as it moved from the church to the drawing room and private theatre, and again as it moved from the drawing room and private theatre to the public theatre and the concert hall. The music of the streets and of the ballroom and of the discotheque cannot and should not be the same, nor should they be the music of the long playing record or of the stereo tape.

I do not know what sort of world science and technology will give us in the future, though I sometimes try to envision it. Whatever world science gives us, that is the world in which art will have to be created and enjoyed. If the world of the future is a world of ephemeral TV programs and houses which we change as often as we change cars, it may be a world which calls for an art as ephemeral as much of the music which eighteenth century composers provided for social occasions. Art is more than eternal masterpieces. Art must thrive in the real lives of people, not in a vanished past or a nebulous future.

If art is to show to best advantage in a real present and a real future, it must be opportunistic in using what it can of the knowledge provided by science and the tools provided by technology.

But what of this knowledge and what of these tools can be powerful and apt to the hands of the artist? This can be settled only by trial. That which is apt and useful must be that which actually helps in producing art, or at least in understanding art. As an engineer who is acquainted with various fields of science, some things seem to me to be far more likely to contribute usefully to art than others.

Mathematics seems to me to be a field which can make few direct contributions or have little direct impact on art. Of course, mathematics must be indirectly important to art because mathematics is necessary to creation and exploitation in all scientific fields, including acoustics and psychology as well as physics and electronics.

Some have suggested that mathematical curves have an inherent beauty, and that mathematical patterns form the basis of op art. But fruit, trees, airplanes, junk and people often have an equal beauty. Curves or graphs are a superficial aspect of mathematics, and not all of them are beautiful. The patterns of op art belong to the realm of the psychology of perception, not to that of mathematics.

Some feel that the logic and order of mathematics can somehow form or contribute an essential basis to art. As a generality, this is contrary to the view I put forward earlier, that science is a toolgiver, not a source of philosophical certainty. But further, the idea that order as recognized in mathematics has much to do with the order recognized by the human senses, which we must use to perceive art, is not only philosophically baseless; it is demonstrably false. I can show this by means of a few computer-generated pictures which I have borrowed from a colleague of mine, Dr. Bela Julesz, who works in the field of visual perception.

Dr. Julesz has used the computer to produce slides which consist of 100 by 100 regularly arranged dots of varying shades of gray. If the shade of each dot is chosen randomly, one gets a speckled pattern, like noise or "snow" on TV, (Fig. 1). One can, of course, also produce regular patterns, (Fig. 2).

Dr. Julesz has produced slides ranging between the mathematically random and the mathematically regular. Some sorts of mathematical regularity or order produce an effect of visual order; others do not. Figure 3 includes a great number of each of six different triangular patterns of dots. A picture including a large number of patterns of dots is far from random in the mathematical sense. Yet in this picture, the only pattern (or order) that we see is the triangles made up exclusively of black dots, and these do not form a very strong pattern.

As further examples, I shall comment on pictures, in which part of the area has what is called probability of a different "order" from the rest.

In Figure 4, the "first order probability distribution" is different in the left and right halves. This merely means that on the average the dots on the right are lighter than the dots on the left. The boundary between two areas with different first-order probability distributions is immediately apparent to the eye.

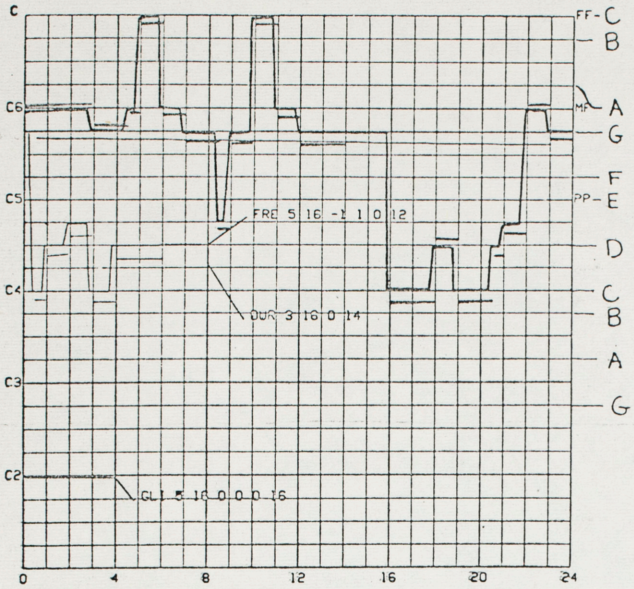
In Figure 5, the first order probability distribution (average brightness) is the same over the whole slide, but the second order probability distribution is different for the lower right hand quarter than for the rest of the slide. This is also immediately apparent to the eye. A high second order probability distribution tends to put light dots near to light dots and dark dots near to dark dots; this produces short horizontal line segments which the eye immediately sees as a horizontal smearing.

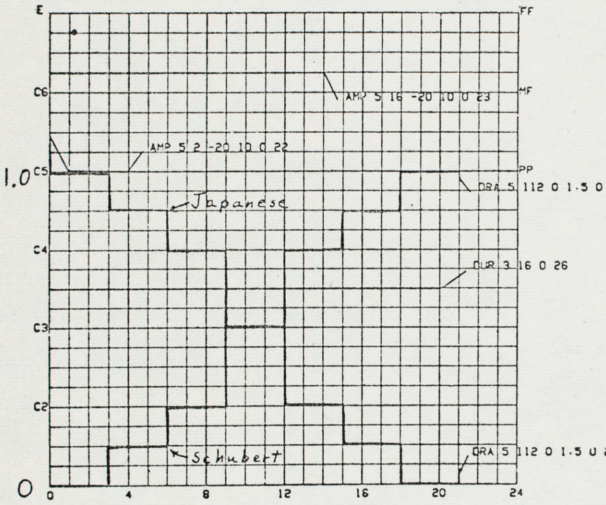
In Figure 6, the first order and second order probability distributions are the same for the whole slide, but the third order probability distribution is different for the left and right halves of the slide. In a mathematical sense, the two halves of the slide are very different, yet the two halves look just alike to the eye. This conclusively demonstrates that the senses are not sensitive to some sorts of mathematical order—even though they are sensitive to other sorts of mathematical order.

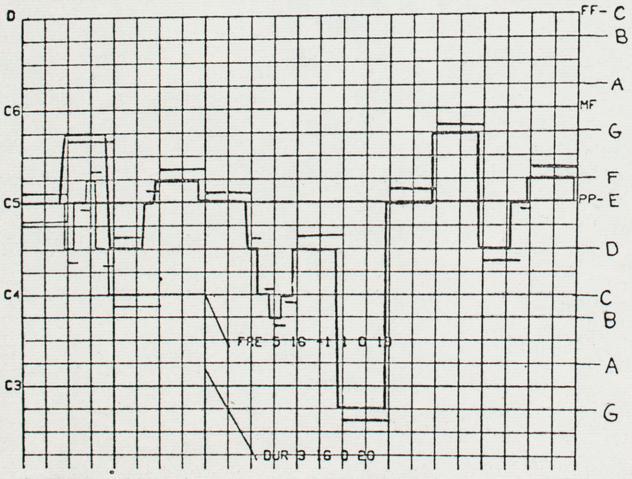
In the course of his work, Dr. Julesz has investigated many aspects of visual phenomena. Figure 7 shows a pattern of real and nonsense words. The distinction is not readily apparent visually. Superficially the left side looks like the right. Only by reading the words can we see which are real and which are nonsense. There is no immediately apparent boundary between them. This picture calls to my mind elaborate contrapuntal devices which are apparent on close inspection of a score but are almost undetectable when the music is played.

Certainly, these examples demonstrate that mathematical order need not be order for the senses. If we believe (as I do) that art must have an element of order, then if science is to help in putting order into art we must first find out what gives a sense of order in the process of perception. But this is a psychological, not a mathematical problem. And our perceptions are tricky almost beyond belief.

Figure 8 demonstrates what is called "Cornsweet's rings". The outer and inner gray annuli or rings are physically equally bright. But to the eye, the outer ring is brighter than the inner ring. This effect is produced by placing a narrow dividing annulus between the inner and outer annuli. The dividing annulus is darker on one side and lighter on the other. The annulus on the dark side appears dark; that on the light side appears light. Here we have a case in which there is no difference of brightness measured physically, but there is a difference of brightness to our senses.







Today, many composers and artists speak glibly about mathematics and use mathematics, or say they use it in their art. A great deal of this is stupid nonsense, even though the artist may be sincere. Some very able mathematical work has been done, largely in connection with serial music. I doubt, however, whether this has anything to do with art.

Statistics, which is quite different from mathematics, may prove a valuable tool in finding unsuspected or unformulated order in ethnic music, and even in western music. But statistics may be a more powerful tool for the musicologist than for the artist.

I will reiterate that I believe that mathematics can be of little direct use to art. Its value to art is that of a tool in seeking out and codifying knowledge in various fields of science, and a tool in the construction and use of complicated electronic devices, including electronic digital computers.

The sciences which may be of direct value to art center around experimental psychology in the fields of vision, audition, learning an memory. Unhappily, psychology is a very difficult field. It is full of promise, but it cannot yet compete with physics in changing the world.

The pictures which I have written about earlier are the product of work in the psychology of vision. I believe that they are relevant to art.

Helmholtz put forward and Plomp and Levelt have elaborated a theory of musical consonance which is supported by considerable experimental evidence. I believe that this theory has far more relevance to music than does the number of permutations of the tone row. Indeed, proceeding from this theory of consonance it is possible to produce a scale of tones with nonharmonic partials which exhibits consonance and dissonance very different from that of the conventional scale of tones with harmonic partials.

A considerable problem of electronic music is the "unnatural" or "electronic" tone quality of many of its sounds. It is through psychoacoustics that we should seek the source of this quality, or conversely, the source of the pleasing quality of traditional timbres. Music owes a considerable debt to Fletcher and his students for showing that slightly nonharmonic partials are essential to the warm tone of the piano. James C. Tenney has done useful work in applying the computer to the analysis of violin sounds. The work of Carleen Hutchins on the violin and its relatives is admirable. It appears that Jean Claude Risset has found the elements essential to the sound of a short trumpet tone.

Sounds are the materials of music. What of musical structure? In learning a language, we do best if we resort to the native speaker, who knows how to use a language even if he does not understand how he speaks, rather than to grammarians, who have been unable to formulate a satisfactory description of language. In the same way, it seems to me that in music apprenticeship must be better than formal knowledge. Psychology is not yet ready to help much with complicated problems of structure and organization.

Yet I believe that we can get some guidance from experiments on memory and learning. George Miller's magic number, seven plus or minus two, applies to a host of tasks involving short-term memory—and especially in remembering numbers, letters, and words. We cannot grasp and recall very many new, randomly ordered sensations.

Yet other experiments show that we can recall whether or not we have recently seen one among hundreds of pictures of common objects or scenes. Other experiments show that we can accurately remember and match certain "cardinal" colors which have common names, but cannot remember and match in-between colors. And, the cardinal colors are different for different cultures.

These various experimental results cannot offer us conclusive guidance, but they are suggestive. We have a poor memory for unfamiliar and disordered material. Strange music may seem chaotic because it embodies strange scales, strange associations of notes, strange rhythms, or strange principles of organization. If the strange music is ethnic music, its patterns must be apparent in som culture. If the strange music is the product of an experimental artist, its pattern and formula may very well be either unlearnable, or they may be identifiable only with such difficulty as not to be worth the effort.

The sciences which comprise experimental psychology can perhaps be of some use to art, but the greatest impact of science on art must come from the tools and media which technology supplies to art. In a world of movies, TV, and longplaying records, art must conform and expand or perish.

New media shake and challenge art. But technology offers art new tools more powerful than electric organs and electric guitars. Perhaps the most powerful is the electronic digital computer.

We usually think of the output of a computer as numbers, but these numbers may be only an intermediate stage in the production of pictures (the patterns I showed as slides are such pictures) or sounds, or physical objects which are produced by machines controlled by computers.

We usually think of the users of a computer as putting numbers into the computer in order to get an output, but the input may be a pattern we draw on the face of a cathoderay tube by means of a "light pen". And the computer itself can make our rough drawing more regular if we wish.

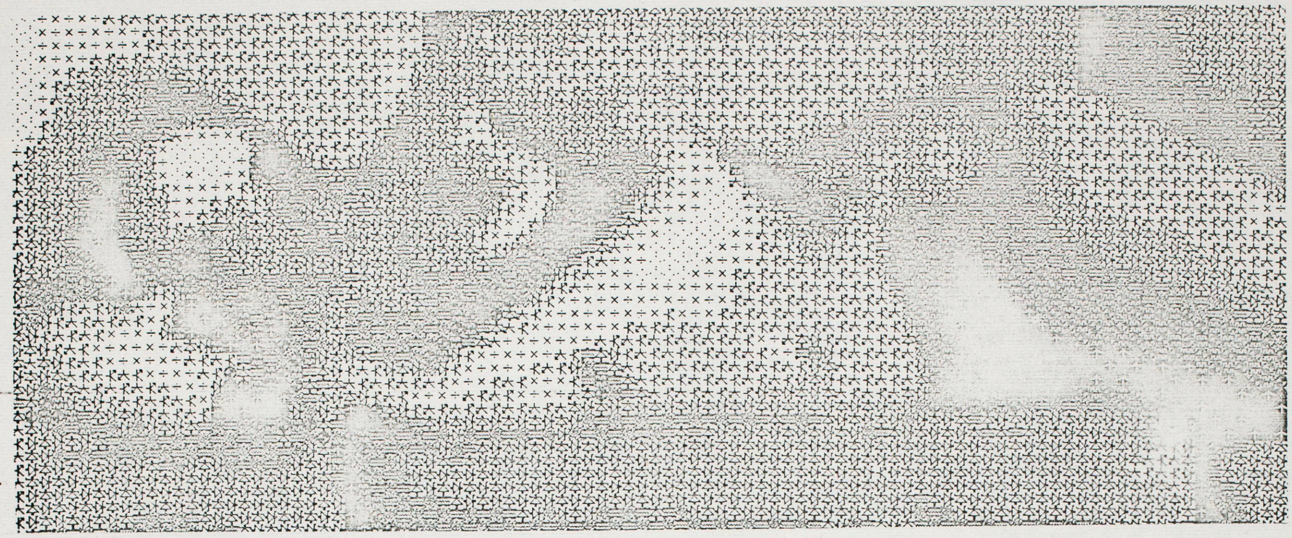
In manufacture, the computer promises to break the dull repetitiveness of mass production. Computer controlled machines can produce in succession different objects and different designs merely by feeding new data to the computer which controls the process. As a simple example, suppose we controlled a weaving or knitting process by means of a computer. The computer could look at a sketch and use it as a pattern for a design woven or knitted into the product. The computer could use the same one pattern repetitively to form a larger pattern or mosaic. Or, it could choose regularly or randomly among many pattern elements.

To illustrate something of the versatility of a computer as an experimental tool, I will use as an example some work done by Dr. M. V. Mathews at the Bell Telephone Laboratories.

Dr. Mathews uses a light pen to draw a musical "score" on the face of a cathode ray tube which is part of a "Graphic I" console (Fig. 9). The score (see fig. on page 15) consists of lines indicating rise and fall of pitch, intensity and tempo, and a pattern of dashes indicating the rhythm. The computer then synthesizes the corresponding sequence of sounds. In a short experimental example, called "International Lullaby", Dr. Mathews has also used the computer to interpolate between two tonal and rhythmic patterns. The first is a Japanese lullaby and the second a Schubert cradle song. The rhythmic and tonal patterns he wrote on the face of the cathode ray tube gradually change from one into the other according to rules programmed into the computer. Thus we hear at first the Japanese lullaby, finally the Schubert cradle song, and between them something with an intermediate pattern of pitches and durations.

In the visual field, the computer has been used to produce animated motion pictures, some of them stereoscopic, of planetary motion, a rotating four-dimensional cube or tesseract, stick figures moving randomly in proper perspective, and other phenomena.

A small sample of the versatility of the computer in the visual arts is a short movie made by Dr. Bela Julesz. (Figures on page 17 show patterns which are random except for certain symmetries. Some of the most striking effects were the motion of one random pattern of dots past or through another. In this case it is impossible to illustrate the effect in still pictures. Each frame looks randomly speckled. The illusion of motion is achieved by displacing the random patterns from frame to frame.) Another movie illustrates a strange sequence of tones that Dr. Roger Shepard, a psychologist at the Bell Telephone Laboratories, produced using the computer. A succession of tones appears to rise endlessly in pitch—yet the tones never escape the octave.



A third brief movie shows a computer-produced design, first in fine detail, and then at such a distance that the detail merges into an overall pattern. (The effect was obtained by zooming away from the picture shown above. Viewed very close, the computer processed figure is a collection of electronic symbols. At an intermediate distance it is a pattern of dark and light. Only at a considerable distance does a gestalt emerge.)

In a world of computers and TV, I do not see how anyone can doubt the importance of technology to the arts.

Some areas of science can be useful to the artist in coping with and taking advantage of our advancing technology and our changing environment. But science is no source of philosophical order and ultimate aim for the artist. Science teaches us how great and complicated the world is. Science and technology teach us how great the impact of even partial knowledge can be.

It seems to me that the message of science and technology to the arts is: use us opportunistically, however you can, keep the successful, and turn away from blind alleys before you get lost!

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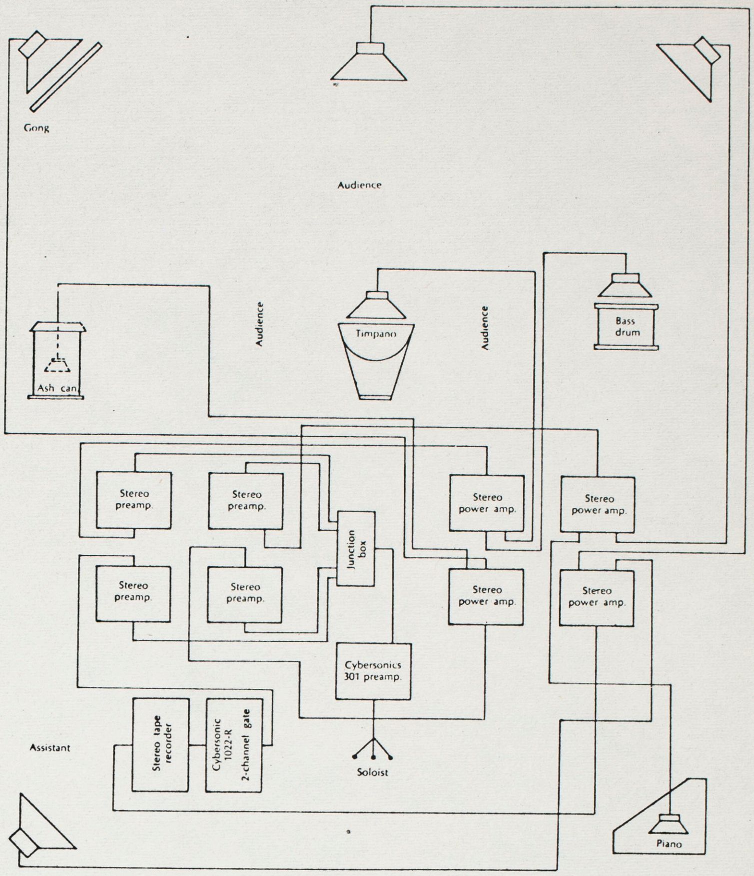
UMMA

sic for Solo Performer 1965

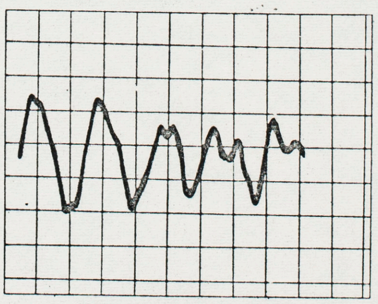


Typical configuration of equipment and speakers including extra equipment for special tape-storage version.

Alvin Lucier's *Music for Solo Performer 1965* is a live-performance work employing electronic equipment. An assisting technician attaches three small Grass Instrument silver electrodes to the scalp of the solo performer to obtain the alpha current. The alpha current is a low-voltage brain-wave signal of approximately 10 Hz which appears at the scalp surface during the non-visualizing times of human mental activity. These alpha currents, on the order of 25 microvolts signal strength, are increased by means of a Cybersonics differential amplifier which contains a 14 Hz low-pass filter (to remove extraneous signals) and are amplified by standard high-fidelity power amplification to several wide-range loudspeakers.

The loudspeakers are deployed throughout the performance area in order to activate the sympathetic resonance of nearby percussion instruments. The musical continuity of Lucier's *Music for Solo Performer 1965* is determined both by the solo performer and his assistant. The alpha current is triggered on and off when the soloist's eyes are closed (with non-visualizing mental activity) and opened, and selectively directed to the various loudspeakers with their corresponding resonant percussion instruments by the technical assistant.

Only two types of sound occur in the performance of Lucier's *Music for Solo Performer 1965:* the 10 Hz alpha and the various sympathetically resonant percussion instruments. With one exception, sound modification does not occur. The 10 Hz alpha is essentially a sine wave. Any harmonics of the 10 Hz signal are suppressed by the 14 Hz low-pass filter and the subsequent amplification is nearly linear. The only sound modification is that which happens in the loudspeakers, which Lucier likes to operate to maximum cone excursion at 10 Hz. Lucier's preference is for the large acoustic suspension type speakers, which, operated in this manner, produce a very clean and rebound-free 10 Hz pulse waveform. This waveform, of course, contains harmonics; and this is the only sense in which sound "modification" occurs in *Music for Solo Performer 1965*.



Oscilloscope tracings of amplifier output before filtering (1 volt per Abscissa Division and 50 milliseconds per Ordinate Division).

Oscilloscope tracings of amplifier output after filtering (1 volt per Abscissa Division and 50 milliseconds per Ordinate Division)

Perhaps the most significant electronic-music aspect of this work is that the loudspeakers are not the final part of the system. Generally, the loudspeaker is the ultimate sound-producer in an electronic-music system. It is the final object from which the sound emanates, ready for the ears of the audience. Instead, Lucier has extended this system-concept and uses the loudspeakers as transducers or triggers for the natural, resonant sounds of percussion instruments.

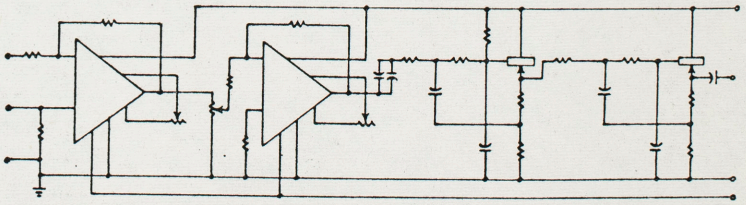
It might seem that Lucier's use of a performer's brain-waves as sound material in a piece of music is an innovation in itself, and this may well be the case. It is no longer an isolated example, however. Works using brain-waves have been made since *Music for Solo Performer 1965* (e.g., Alex Hay's *Grass Field,* which was premiered in October, 1966, at the Nine Evenings of Theatre and Technology in New York City).

"System-concept" thinking is important in the creative process of the composers I have mentioned. (In a sense, composers have always thought in system-concepts, particularly those who write orchestral scores.) The great diversity of equipment-configuration which is possible with recent electronic-music procedures seems to have made systems-analysis essential on a fundamental level of contemporary musical creation. For instance, in a special version of *Music for Solo Performer 1965* Lucier uses magnetic tape storage as an accessory to the alpha-articulated percussion instruments. The tape-stored material consists of continuous pre-recorded alpha signals which have been multiplied in frequency. In this special version the performer releases his 10 Hz alpha signal in bursts, or periodic wave-trains. Following the required differential amplifier and low-pass filter stages, the live soloist's alpha signal is divided and a portion applied to a special circuit which gates the tape-stored material. In performance of this special version of *Music for Solo Performer 1965,* the gated bursts of frequency-multiplied alpha signals sound, like a ghostly *tessitura,* from a loudspeaker at some remote part of the auditorium. The system-concept of this special version treats the original 10 Hz alpha signal with two different functions. On the one hand, directly amplified alpha signals from the loudspeakers produce sound from the sympathetically resonant percussion instruments. On the other hand, a sub-system derives electronic triggering signals from the 10 Hz alpha signal to activate the tape-stored materials.

The theatrical aspects of presentation of the work are simple and dramatic. The indication on the printed program is simply "Alvin Lucier: *Music for Solo Performer 1965,*" with enumeration of the soloist and assistant, and acknowledgement of Dr. Edmand Dewan (of the Air Force Cambridge Research Laboratories) as technical consultant. Performance of the piece begins with the appearance of the soloist and his assistant. The soloist seats himself comfortably near the differential amplifier, and the assistant begins the procedure of applying the electrodes to the soloist's head. This operation involves cleaning the scalp with alcohol, applying special conducting electrode paste and gauze pads to secure the electrodes, measuring the electrical resistance between the electrodes (which should be below 10,000 ohms), and adjusting the gain and DC balance of the differential amplifier. The procedure takes several minutes to complete, generally a time of remarkable effect upon the audience.

Much of the audience does not immediately comprehend that electrodes are being implanted on the soloist's head. Some, perhaps, have never seen nor heard of such a thing, even for non-musical reasons. In any case, the situation is both ambiguous and dynamic. This period of time, before the first tapped brain-waves are directed to their resonant instruments, is really quite mysterious. After the sounds have begun, one comes to recognize the coincidence of the soloist opening his eyes with the stopping of the alpha-articulated sounds. Closing of the eyes will not necessarily start the alpha again. The process of non-visualizing must occur. This is a specially developed skill which the soloist learns with practice; and, no matter how experienced the soloist has become, various conditions of performance intrude upon that skill. A performance of *Music for Solo Performer 1965* by a skilled soloist is a matter of exercising great control over conditions which are hardly ever completely predictable. The soloist who can achieve sustained sequences of rapid alpha bursts, which are distributed from the resonating instruments throughout the audience, creates a *tour-de-force* performance.

To date, three people have served as soloists in performances of *Music for Solo Performer 1965:* Alvin Lucier, David Tudor, and myself. At various times Larry Austin, John Cage, David Behrman, Robert Bernat, and Joel Chadabe have served as the assistant. Both David Tudor and I learned the work directly from the composer. I am impressed with the paradox that, as the musical use of elaborate and sophisticated electronic technology increases, passing works of art on to succeeding generations requires reverting to a kind of ancient oral tradition. The spectacular evolution of new musical notation procedures during the past two decades indicates that this problem extends beyond the electronic music realm. But it is in the area of live-performance electronic music that the problem of notation, communication from composer to performer, is most acute. The efficiency of Lucier's recently prepared "score" for *Music for Solo Performer 1965* (a kit of parts including electrodes, paste, lead-in wires, a differential amplifier and low-pass filter, and an instruction manual) awaits verification in the hands of future solo performers.



CYBERSONICS DIFFERENTIAL AMPLIFIER-LOW PASS FILTER
designed by *Gordon Mumma* and *William Ribbens*
for *Alvin Lucier's* Music for Solo Performer 1965
input signal 10 to 25 microvolts rms output 0.1 to 0.25 volts rms cutoff frequency 14 Hz, 24 db oct