Human Performance in Adverse Environments

Progress report on
NASA Research Grant, NSG-718/22-07-020

by

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Contents

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Background of the Research Program

At the present time there is great interest in the performance of our astronauts in space missions. Every possible attempt is being made to ensure that nothing in his environment will influence adversely his expected achievements. Great care is needed to provide atmospheres within the capsules which are as close as possible to the optimum. There is some evidence that the existing working environment is quite marginal from this point of view. It is important, therefore, to study human thinking and seeing in aritificial atmospheres in an attempt to discover the factors that are likely to limit the abilities of even the best of men despite careful training. Subtle impairments of cerebral speed and accuracy may not always be obvious. Much experimental effort will be required to devise sensitive and reliable measures of seeing and thinking despite such difficulties. Some of the procedures being devised in this research program at the Harvard School of Public Health may be of assistance in appraising the efficiency of astronaut performance in space flights. We are working in close collaboration with representatives from NASA Headquarters in Washington and also NASA scientists from the new Electronic Research Center in Boston in regard to possible in-flight recording of changes in alertness and proficiency.

1. Statement of Problems under Investigation

This research program is attempting to develop techniques that will appraise the capabilities of astronauts in situations resembling space flight. A search is being made for ways of measuring slight impairments in human performance due to atmospheric conditions. Recent discoveries in information processing within electronic systems are well known. This better understanding of data handling in electronic situations has been partly responsible for improvements in the human sciences. Great progress has recently been achieved in general in the measurement of basic human functions as they relate to the handling of information. During the last few years more precise measurements have become feasible in studies of seeing, thinking, and the making of visual judgments.

The present researches have devised a series of tests in the areas of peripheral and prolonged seeing, as well as in forms of thinking involving the detection of trends in evidence presented as either verbal or spatial patterns. In such situations the subjects must maintain a certain degree of alertness and a high level of accuracy. Simplified procedures have been developed which can eventually be used in actual space flights, as well as in other research institutes in the NASA program.

Some of the environmental variables can be introduced during the development of these sensitive procedures for appraising human performance. Even moderate changes in altitude or atmospheric temperatures within the space capsules can then be effectively measured in terms of the influence of single or combined stresses. Few studies are quite so readily able to bridge the gap between scientific evidence and mission effectiveness. The alertness and other changes are often expressed in terms of failure to respond or the wrong responses are given in human situations which clearly resemble the work involved during ciritcal states of possible space flight missions.

2. Accomplishments during the First Year

First of all an appraisal was made of the published literature in the fields of peripheral viewing, vigilance, the perception of form and texture, information handling and short-time memory. A bibliography and card index was prepared of the live items in this material with the help of Mr. John Loring of the Guggenheim Center for Aerospace Health and Safety. Some of the more promising test procedures could then be selected for the problems outlined above from this background of knowledge. Along with the selection and standardization of these procedures, it was also necessary to obtain and modify suitable equipment for these measurements. One of the more exacting requirements in this research has been the devising of suitable visual situations and displays. Much has been done by recording the line of sight, by photographing position of the eye relative to the scene in front of the experimental subject. Two different procedures have been followed. The first used a fixed head and second permitted the subjects to turn their heads. The latter procedure depended on the use of fiber optics cables to register the coordinates of the eye position as well as to record a picture of the scene in front of the experimental subject. The most difficult technical problem has been the devising of procedures to analyze these eye movement records entirely automatically. Much help is being given here by other groups in Harvard such as the Harvard Center for Cognitive Studies and the Computation Laboratory of Harvard University. Highly elaborate computer programs have been devised and have now been written in the form of the required machine language. The extensive efforts in this direction are clearly justified in view of the enormous saving in the labor involved in the routine analysis of data. Such arrangements also bring new experimental techniques into the realm of feasible procedures. With similar ideas in mind, an equipment has also been produced for use in studies of peripheral attention and decision making. Visual stimuli here are automatically presented by a punched tape program.

Experimental work has been conducted with the above equipment; the research has also included studies in the altitude chamber as one of the more basic environmental variables. The details on the achievements to date have been outlined in Section IV.

3. Experimental Program for Second Year

Similarly the outline in Section V gives the program for the second year. Briefly, the emphasis is mostly on prolonged and peripheral seeing. The maintenance of alertness in vigilance-type situations describe environmental difficulties as becoming of greater importance with the increasing length of space flights. This essentially requires methods for the continuous recording of moment by moment changes in the eye movements and perceptual processes. The possible effects of even relatively small environmental changes may prove to be of greater importance than was originally anticipated especially when several potential sources of impairment of human ability occur at the same time.

In planning this research program with several technical specialists of NASA it was assumed that the most productive results would be forthcoming during the second and third years of a three-year program.

4. Expected Outcome

The main emphasis in the research program has been on the discovery of basic procedures to measure human performance under laboratory conditions. But there might also be clear, practical implications for space flight itself. For example, it is reasonable to expect that simple forms of these procedures may help to monitor the human performance of astronauts during prolonged flights. This is all the more likely as experimental tasks have been chosen that are related to the kind of work undertaken during vital aspects of space flight. A constant watch is being kept for possible ways in which ground-control staff could detect that astronauts in actual flight were not at their normal level of ability. Space flights lasting several days highlight the need to know whether astronauts are at the top of their form when they are trying to solve difficult problems in navigation. The atmospheres in the space capsules must be such that they leave the astronauts with a clear head and an alert eye for the unexpected.

I. Introduction

This research program involves the study of a number of human performance tests that are sensitive and reliable in measuring the effects of adverse environmental situations. Altogether nine such experimental tasks have been developed and these are now being studied under conditions related to a reduction in the amount of oxygen reaching the central nervous system.

Two basic principles or general ideas are being analyzed in this research program. The first is to discover tests which measure minimal changes in human performance rather than those that assess the effects of very severe environmental conditions. The target here is to discover the beginnings of impairment since such changes in ability can be quite insidious; the astronaut may be quite unaware that any such change is taking place. The second point is that it appears to be especially important to try a wide range of different psychological tasks on a few environmental conditions. This approach has been adopted in preference to the alternative of trying a few performance tasks on many different environmental situations. The reason for this approach is that these inquiries can then produce standard human performance situations which can be tried in a wider range of other environments in subsequent studies.

The objective is, therefore, to discover methods of measurement and test procedures which are very reliable ones and which can be studied under a wide variety of environmental conditions. One of the primary objectives is to develop tests which can be used in actual space flight experiments. To obtain satisfactory results, tests should possess certain features, including: (a) a high degree of sensitivity, so that small changes can be readily measured; (b) precision of the physical measurements involved in the test; (c) independence of the results from the degree of conscious or unconscious effort which may be exerted; and (d) stability of the function during control experiments when the physiological stresses are not applied.

II. Summary of Present Research Program

This work has been aimed at devising and obtaining new research procedures under NASA Grant NSG-718/22-07-020 to measure impairment of human performance due to unusual atmospheres. These various methods each estimate ability in a different way. The sensitivity of these new visual or cognitive tasks is now being evaluated. Recordings of the changes in human performance are being taken, in turn, for each task under moderate oxygen lack, equivalent to 8000 feet.

Six tasks have been devised for the two main research areas initially outlined for study at the start of the research program. These broad areas for investigation are: 1. Peripheral Seeing, 2. Prolonged Seeing.

Most of the investigations have so far been directed at the topics of peripheral seeing and prolonged seeing. Experimental work has been undertaken in both of these areas. The studies of peripheral seeing have also been undertaken in a low pressure chamber which reduced the oxygen content of the atmosphere to a level equivalent of 8000 feet. Additional studies have been run with low oxygen content in atmospheres breathed through a diving mask at normal atmospheric pressures.

NASA has granted further support for this program and to extend the work for a second year on the two topics of 1) peripheral seeing and 2) prolonged seeing.

III. Practical Implications

As the work has proceeded it has also become increasingly clear that some of the main practical applications of the work on seeing lie in the recognition of visual patterns on the moon surface in connection with the detection of suitable landing areas. Much more needs to be known about the nature of visual scanning especially under the circumstances where the main outlines of a pattern must be detected despite a large number of confusing visual details. The distractions may well be entirely irrelevant, but they are also quite unavoidable due to the very visible microstructure of the textures on the moon surface.

These performance aspects of thinking and seeing must be kept at a high level of efficiency - and even slight impairment avoided as far as possible by ensuring a satisfactory atmospheric working environment.

IV. Research during the First Year

The experimental studies to date have been considered below under the heading of the research proposal upon which NASA Grant NSG-718/22-07-020 was awarded:

1. Peripheral Seeing

   a. Peripheral seeing and the scanning of visual details
   b. Peripheral seeing and pattern matching
   c. Peripheral seeing of flashing lights

2. Prolonged Seeing

   a. Prolonged seeing of flashing lights
   b. Prolonged seeing and eye track coverage
   c. Prolonged seeing and detection of texture changes.

1. Peripheral Seeing

a. Peripheral seeing and the scanning of visual details

Displays and procedures have been prepared to record, by means of an eye camera, the tracks made by the line of sight during the search of a detailed display for some small target objects. The active input area around the line of sight is known to be surprisingly small when subjects are scanning the visual world for fine details. This area, termed the useful field of view, is found to be even smaller when more confusing details per unit area have to be disregarded in the display. Under these circumstances, the visual steps between the visual fixation points become shorter. This change is believed to represent a human adjustment to prevent overloading of the visual mechanism. It is expected that lack of oxygen could also shorten the visual steps made during scanning in much

the same way. Once more, visual overload could be avoided by processing the visual material in smaller packages, since eye fixations seldom seem to be made at a reduced rate. The work of Bills on lack of oxygen would suggest that this overloading would be intermittent because the gaps in attention that Bills found under these circumstances took this general form. Therefore, it would seem likely that the size of these successive visual steps would aslo become more irregular as well as shorter.
/_ Ledwith and Denison, 1964_/

Thirty-two subjects have been tested in the standardization runs. A further ten subjects have been examined so far in the altitude chamber at a simulated altitude of 8000 feet. Eye tracks were taken from these subjects while they scanned along a test strip of visual material looking for a very small square amongst a whole series of equivalent sized small black circles seen on a white ground. The variation in the eye tracks from person to person makes it necessary to test more subjects before definite conclusions can be drawn about the atmospheric effects.

Magnetic tape recordings suitable for computer analysis have been taken from eye tracks. A general purpose program for the PDP-4 digital computer has been prepared in flow diagram form. This data bank program for eye track analysis is now being written in specific computer language. This program should prove of the greatest possible value in analyzing visual step size and direction and measuring any changes in visual track arising from lack of oxygen. For example, it may well be that the concentrations of visual fixations so often found normally on certain key areas of a display (such as the larger craters in the moon surface) may become flattened out by lack of oxygen. This effect is known to occur in children, and could arise whenever selective visual attention is slightly impaired. Computer analysis could also discover whether repeat runs on the same picture under anoxic conditions gave the same similarity and consistency usually found with normal adults in a normal environment. Statistical procedures have been devised to analyze this test-retest consistency. Such concentrations of fixations whereby tracks on successive runs reenter the same areas do in fact also entail good peripheral vision on where not to look, i.e., the subjects eliminate some blank areas without visual exploration.

Recent work has emphasized that visual concentration (as measured by noting any small areas of the scene receiving many fixations) must be assessed from averages taken from individual eye track patterns; superimposed individual tracks forming group patterns greatly reduce the chances of detecting even quite marked visual concentrations.

b. Peripheral seeing and pattern matching.

A new test of pattern recognition is now in use in normal atmospheres to measure the width of the field of view. A row of letters is flashed on for one-tenth of a second. The subject has to say whether or not the central letter is repeated in the row. When it is repeated, the two other identical letters are placed symmetrically at varying distances from the central letter. The identification of similarity between the three letters is easy

Figure 1.

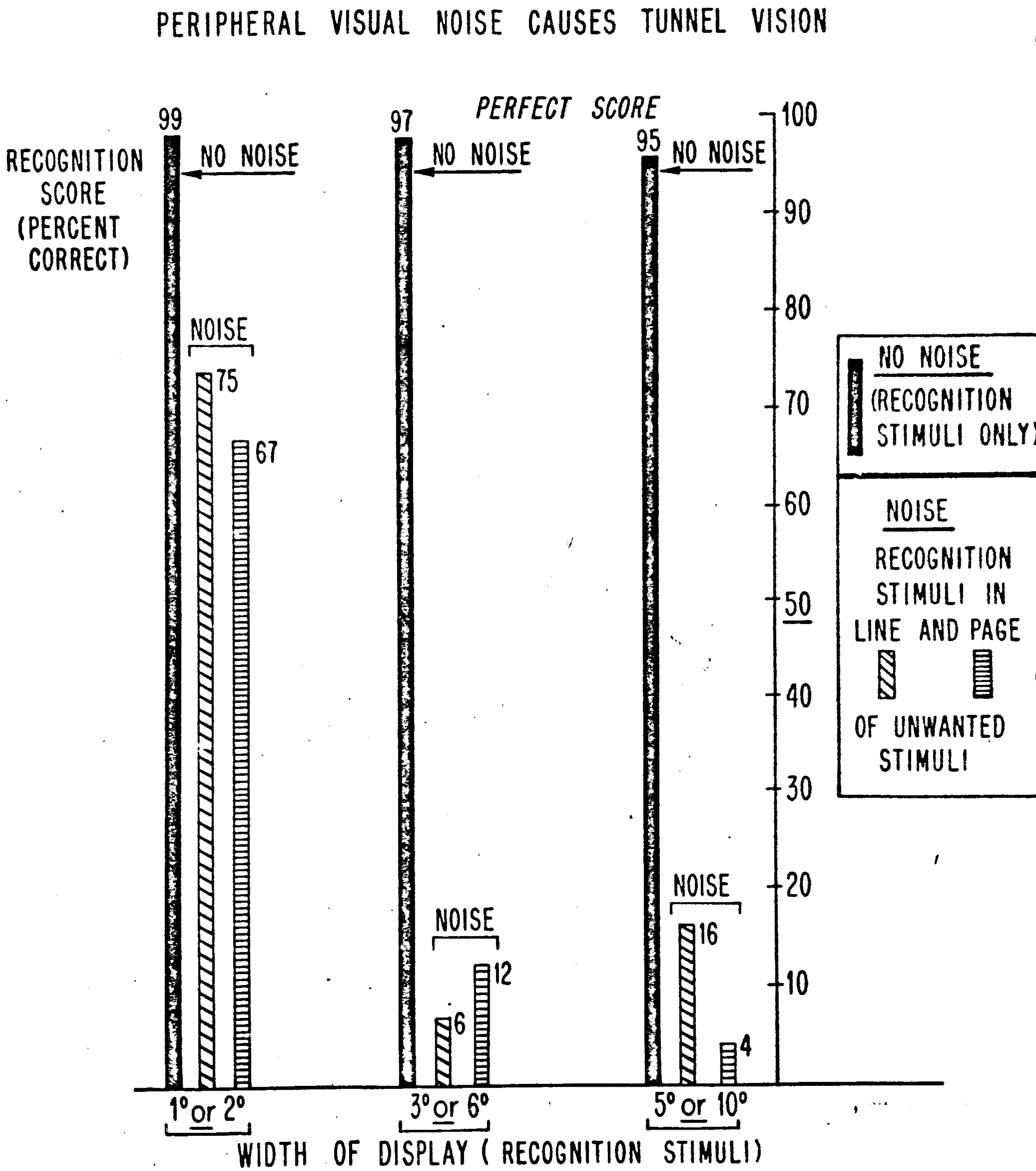
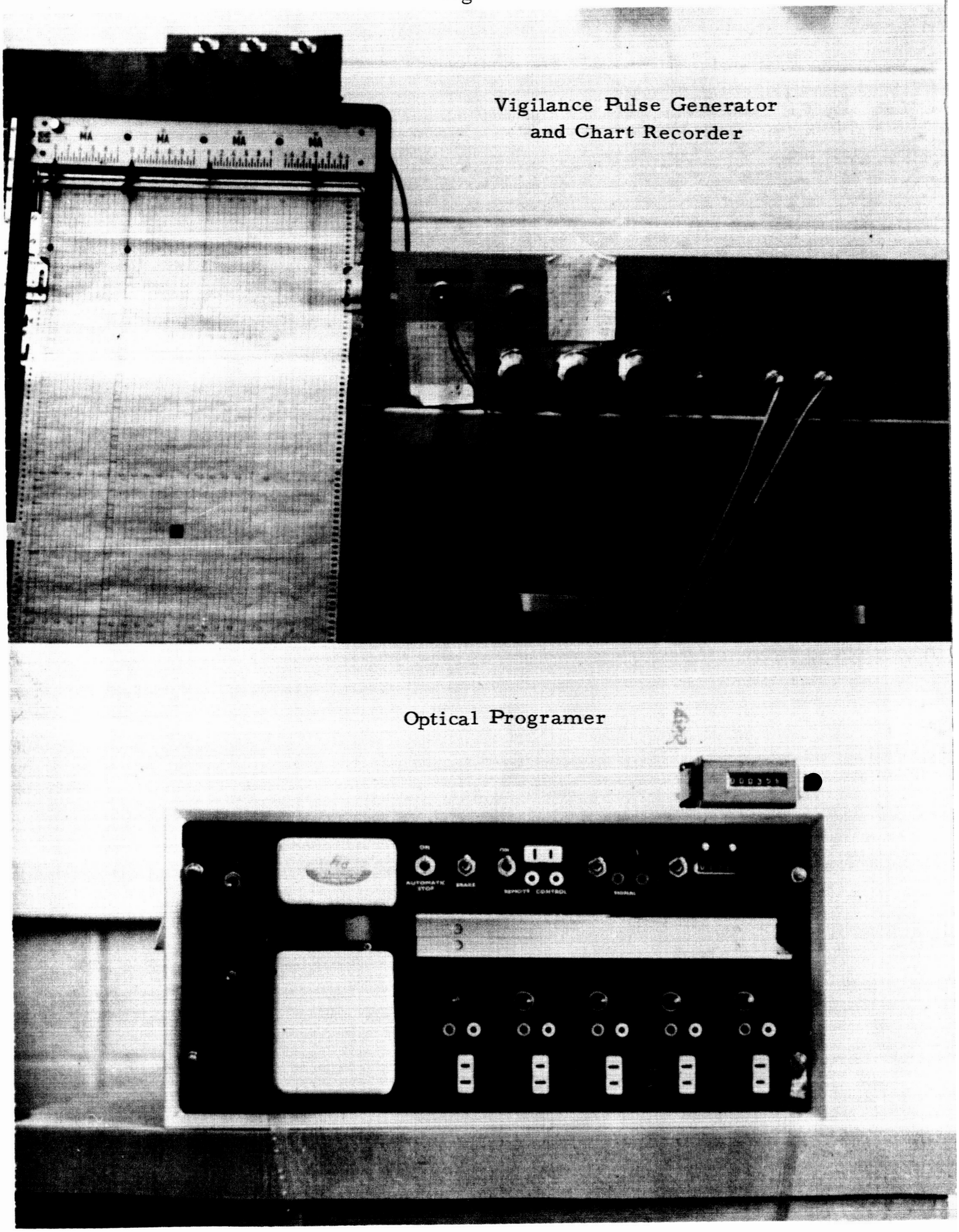

PERIPHERAL VISUAL NOISE CAUSES TUNNEL VISION
PERFECT SCORE
RECOGNITION SCORE (PERCENT CORRECT)
99
97
95
NO NOISE
NO NOISE
NO NOISE
NOISE
75
67
NOISE
6
12
NOISE
16
4
100
90
80
70
60
50
40
30
20
10
1° or 2°
3° or 6°
5° or 10°
WIDTH OF DISPLAY (RECOGNITION STIMULI)
NO NOISE
(RECOGNITION STIMULI ONLY)
NOISE
RECOGNITION STIMULI IN LINE AND PAGE
OF UNWANTED STIMULI

Fig 2



Vigilance Pulse Generator and Chart Recorder

Optical Programer

up to the maximum width tested so far, at least over ten degrees. However, when there are seventeen letters in the row, the match can only be made when the three letters are contiguous. In other words, with the extra visual input, the useful field of view has contracted from at least ten degrees down to two degrees, from five inches on the display to two inches. Figure 1. The next step is to separate the effects of the visual spacing of the letters and the number of unwanted letters between the outlying and central wanted letters. By adjusting the number of unwanted letters between the outlying and central wanted letters, it should be possible to obtain finely-graded levels of difficulty in the task, so that small changes due to oxygen lack can be detected.

A paper entitled Visual Noise causes Tunnel Vision has been published by Psychonomic Science, 1965, 3, 67-68, and a draft paper on Estimating the Useful Field of View is being extended and rewritten.

c. Peripheral seeing of flashing lights.

Recent work has led to a simple but an important device which has become available to the NASA project. This vigilance pulse generator seen in Figure 2* repeatedly flashes two lights at intervals of a second. About six times a minute the light placed in the peripheral field of view becomes dimmer than the other central light. This change in the peripheral light has to be reported by the subject. The McFarland, et al., tests of foveal sensitivity to light have so far been the most reliable measures of decrement due to lack of oxygen. It is, therefore, logical to discover

*See Fig 2 - top.

whether simultaneous foveal plus peripheral viewing is even more sensitive to oxygen lack. The peripheral detection of flashing marker lights is clearly of importance in many aspects of space navigation, including console monitoring, rendezvous and landing.

2. Prolonged Seeing

a. Prolonged seeing of flashing lights.

The flashing light equipment was originally designed to investigate the 'vigilance' decrement in detection that occurs over prolonged periods. By increasing the flash rate to three a second, the decrement over time can be increased. Thus it is possible to investigate the immediate effect of oxygen lack on the ability to detect small changes in the flash, and also to determine whether oxygen lack increases the customary decrement due to prolonged watching. This method of examining the vigilance decrement gives considerable sensitivity, since 180 readings can be obtained in a half-hour test of each individual. As many as six subjects have been tested simultaneously from the one display when subjects were wearing face masks in some oxygen lack studies by the Institute of Aviation Medicine in Canada.

b. Prolonged seeing and eye track coverage.

It is necessary to measure whether the extent of the eye track pattern becomes smaller than the required coverage in the visual world during prolonged visual work over a period of half an hour. The flashing light situation described above could readily detect whether there was any reduced coverage by the visual pattern. Again, one of the lights would be dimmed at a rate of six times per minute; these visual incidents would have to be detected by scanning back and forth between two such lights placed 20 degrees apart and separated horizontally. Automatic analysis by the X-Y plotter in the Harvard Center for Cognitive Studies would be quite feasible if the movie record from the head-mounted camera showed changes in eye-spot positions due only to eye movement. This can readily be achieved by projecting the two stimulus lights from a head-mounted device attached to the head camera. By these means the two lights on the screen in front of the subject would always be 10 degrees on either side of a line drawn along the sagittal plane of his skull. Then an automatic X-Y reader can be given these filmed records from which head movements have been removed. Indeed the center of the film frame and the automatic recording matrix will always be centered wherever the head is pointing at the time. The desire position of the eye spot would be always $\pm 10^{\circ}$ on either side of this cross wire in the middle of this matrix. The PDP-4 computer can readily be provided with a program to calculate the extent to which the eye track fell short or overshoots this point. These inaccuracies of aim will be measured over five-minute intervals to discover any progressive trends within the half hour. The need for this automatic X-Y analysis becomes clear when one calculates that one subject produces about 5400 readings from every half-hour test, and at least 20 subjects would need to be investigated. More than 1000 hours of programming time

Fig 3 - Projection and Recording Equipment is required for this and related research in the Center for Cognitive Studies. This work has now been completed.

c. Prolonged seeing and the detection of texture changes.

Standard visual patterns can now be generated by computer methods. It is, therefore, quite straightforward to produce a series of visual textures which occasionally vary rather more than usual. The visual detection of subtle texture differences may be of great importance to the astronaut travelling at 80 miles per second in orbit around the moon. For example, he may have to cancel one of several suggested landing areas from the list of possible areas by visual judgments of this kind. Dr. Pickett has considerable experience of these computer generated textures and has a projection equipment to change these quickly.* Therefore it seems vital to discover whether lack of oxygen impairs the subjective judgment in detecting slight variations in textures by visual methods. It is important again to know whether this is an intermittent impairment. For example, the judgment time in comparing patterns may occasionally be much longer than usual and the number of such occasions may increase with prolonged work even during half-hour spells.

We are also studying the detection of contours and beacons in simulated terrain. The detection of contours formed by disjunctive shifts in the statistical structure of simulated terrain can be studied as a function of the degree of contrast in the structure. For this purpose artificial patterns generated by a computer and automatically drawn by an electronic device

*See Fig 3.

MARKOV TEXTURE

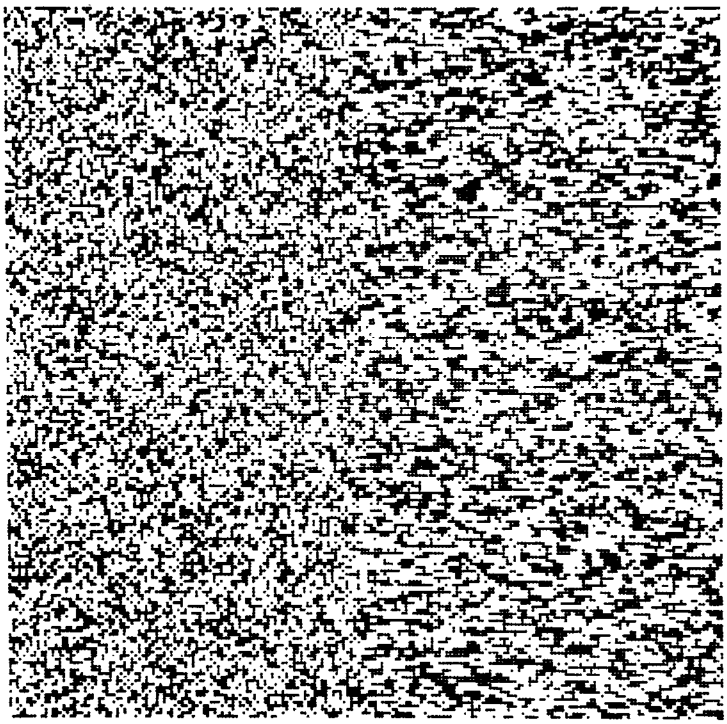


Fig. 4. Markov texture

Dots are assigned to the rows of a square matrix according to a 2-state Markov process. By shifting the transition probability of the Markov process, a discriminable shift in the texture of the dot matrix can be seen. The transition probability could be shifted continuously to create a texture gradient, or disjunctively as in the present example.

DOT DENSITY TEXTURE

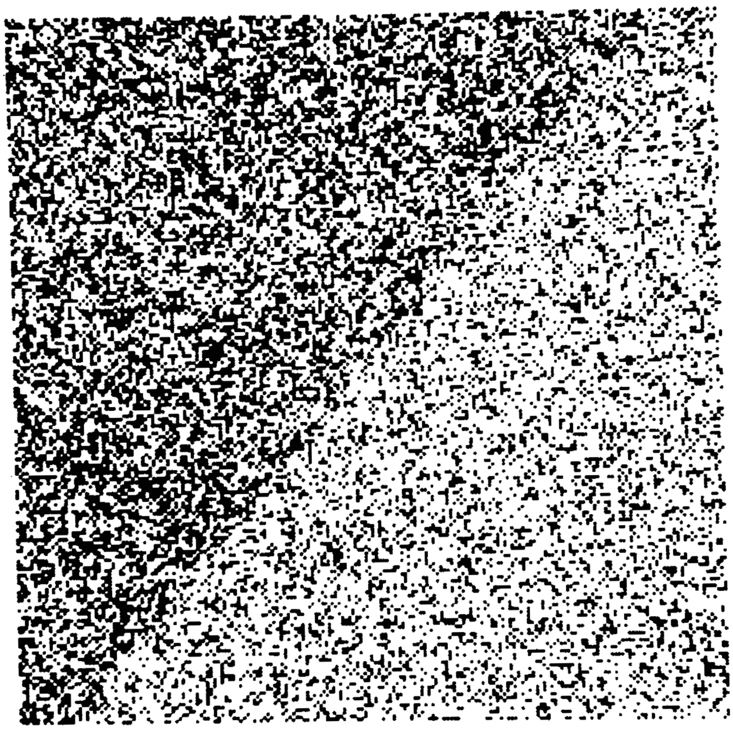


Fig. 5. Dot density texture

Dots are randomly assigned to the cells of a square matrix. Dot probability can be continuously varied over the matrix to create gradients of dot density, or it can be shifted disjunctively as in the example to create a subregion of contrasting dot density. The number, size and shape of such subregions can also be controlled.

have been developed and produced in quantity. Such displays can take on the appearance of terrain seen from high altitude particularly if defocused. Since the contrast can be precisely specified and systematically manipulated in a number of ways, a new area of contour perception can be studied. This area of study has not only practical implications but theoretical ones as well. Figures 4 and 5 provide some dramatic examples of contours formed by shifting statistical structure.

The study of beacon detection also employs simulated terrain displays. In these studies a point of light, the brightness of which can be controlled, is presented in an unknown location in the simulated terrain background. The effects of variations in the statistics of the terrain on the detection of the beacon can be studied. Speed of detection, consistency of attention (looking without seeing) and patterns of eye scan can be studied. The findings from studies of beacon detection are expected to contribute to an understanding of how qualities of terrain, like roughness, may affect the search for targets.

3. Rules Recognition

a. Rules recognition for patterns and textures.

The most important starting point in studies of rules recognition is the extent to which subjects can categorize visual information. Proposed is a continued effort at studying man's ability to identify the statistical structure of very complex visual patterns. This work has a dual purpose (1) to develop sensitive perceptual tests of general intellectual functioning

RANDOM TREE

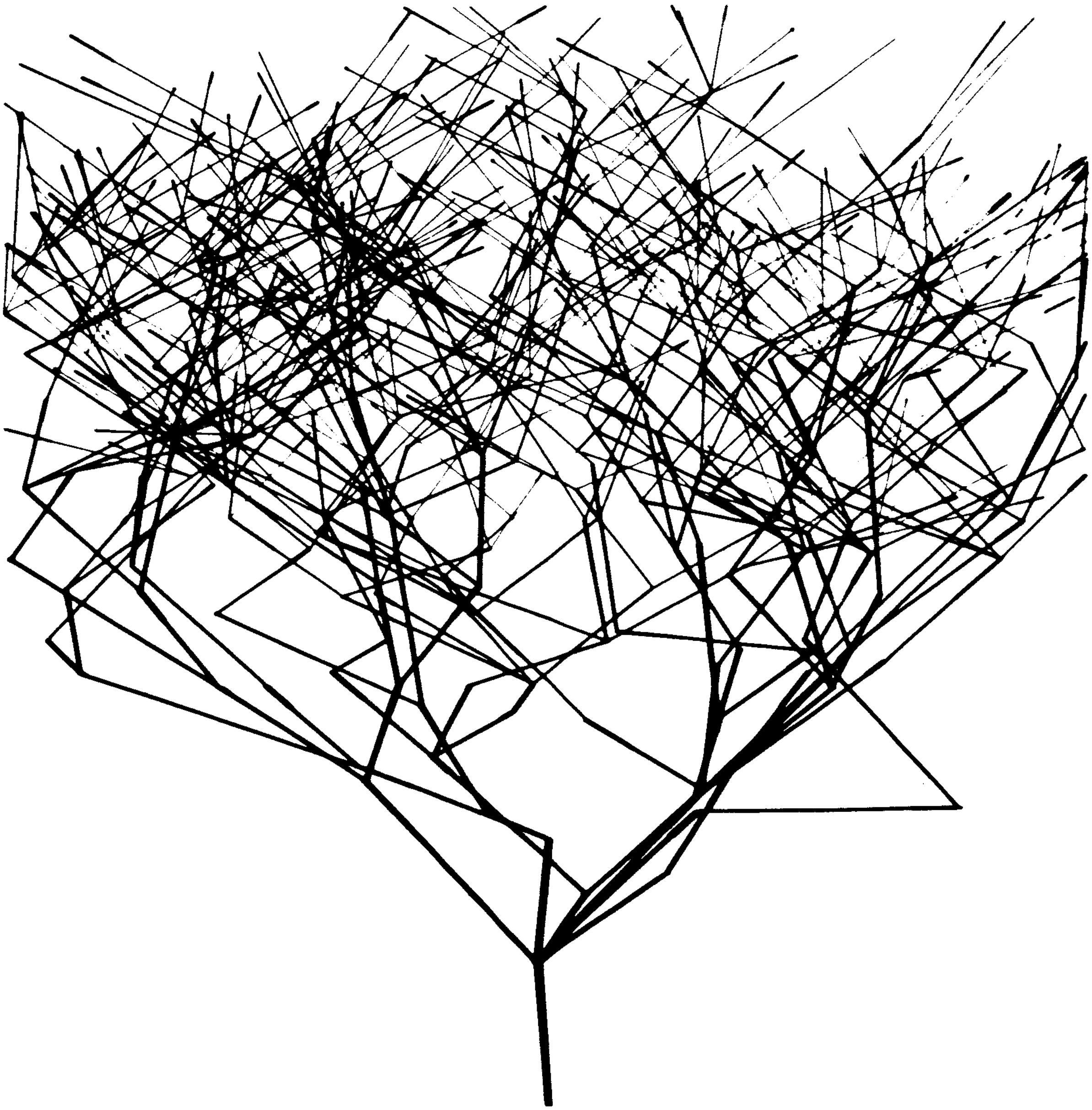


Fig. 7. Random tree

Here a "tree" has been created by overlapping a set of random walks with a common origin. Constraints on the walk can determine, among other characteristics, the thickness of the "trunk," and the number of "branches and twigs." In this example the tree is three-dimensional since branches are allowed to cross. A two-dimensional tree might be easier to specify, but perhaps more difficult to generate.

RANDOM LINE SEGMENTS

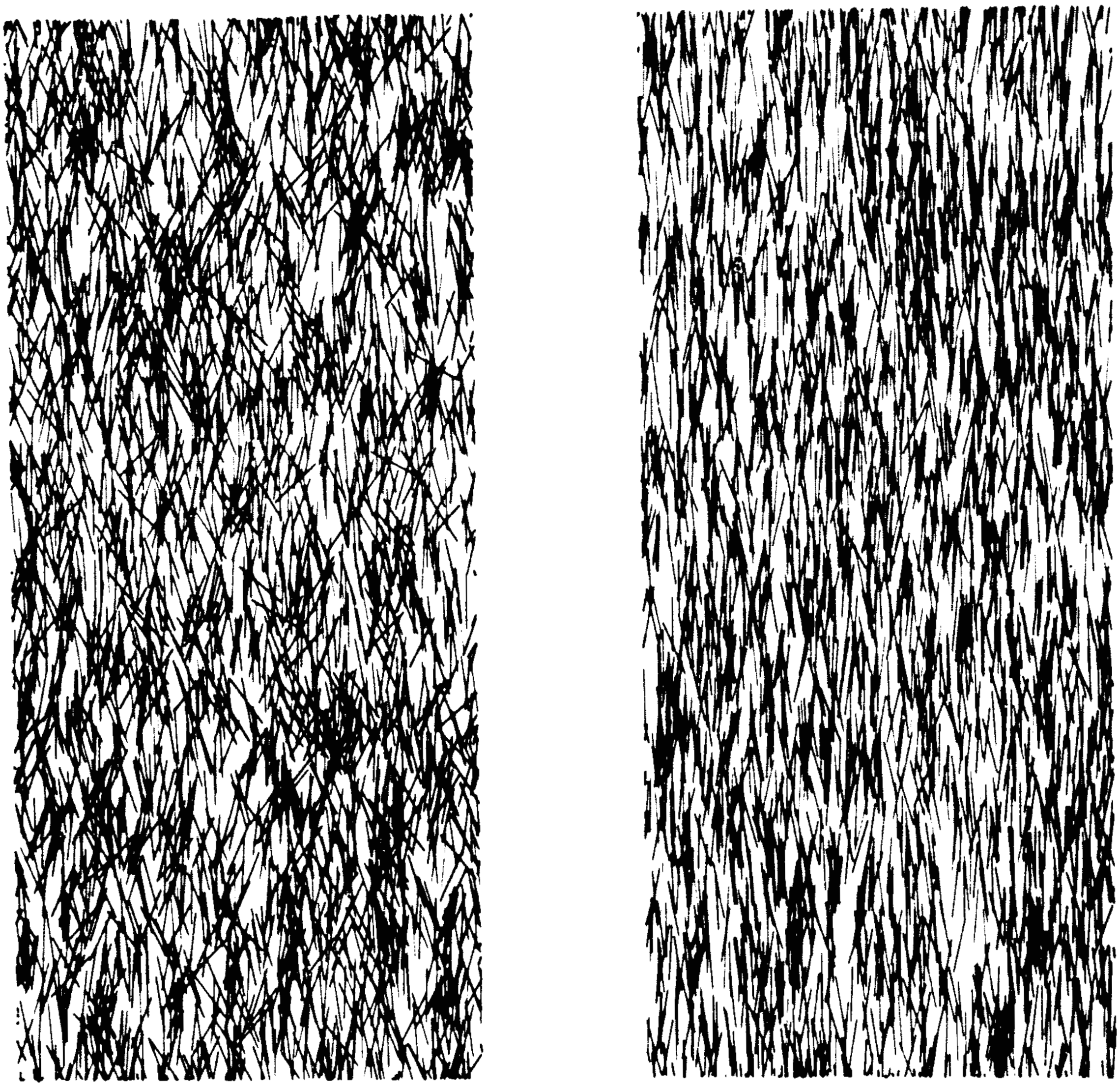


Fig. 6. Random line segments

A straw-like pattern can be created by randomly laying down a large number of short line segments. In the present case the line location is determined by a simple random process. Line orientation and length are both normally distributed. Variance of orientation has been shifted between the two samples. All other parameters were held constant.

under variations in environmental stress and (2) to study man's ability to sense statistical variations in terrain viewed from high altitude. The displays shown above plus other types currently being developed (see Figures 6 and 7) could be used to study the more general perception of statistical structure. In all cases the statistical structure of the displays can be specified in a variety of ways and systematically manipulated, permitting psychophysical studies of terrain or more general structural perception.

b. Rules recognition for serial patterns.

The general approach of this phase of the research program has been expanded from simple rule recognition to the more general problem of complex information processing, although still including the use and recognition of rules as a primary feature. During the first year four basic techniques have been developed.

The first of these employed projected letter sequences developed by Simon and Kotovsky. (cf. Psychol. Rev. Vol 70:534-546, 1963) The sequences were viewed under three experimental conditions: unlimited time, speed stress, and with the projected sequence blurred. While solving the problem, 10-second duration Polaroid photographs were taken by the Eye Camera of the subject's eye positions.

In general, the results show that in solving problems under the kind of mild stress used, the average subject tends to spend less time scanning and, perhaps, hypothesis-testing, and more time extracting information

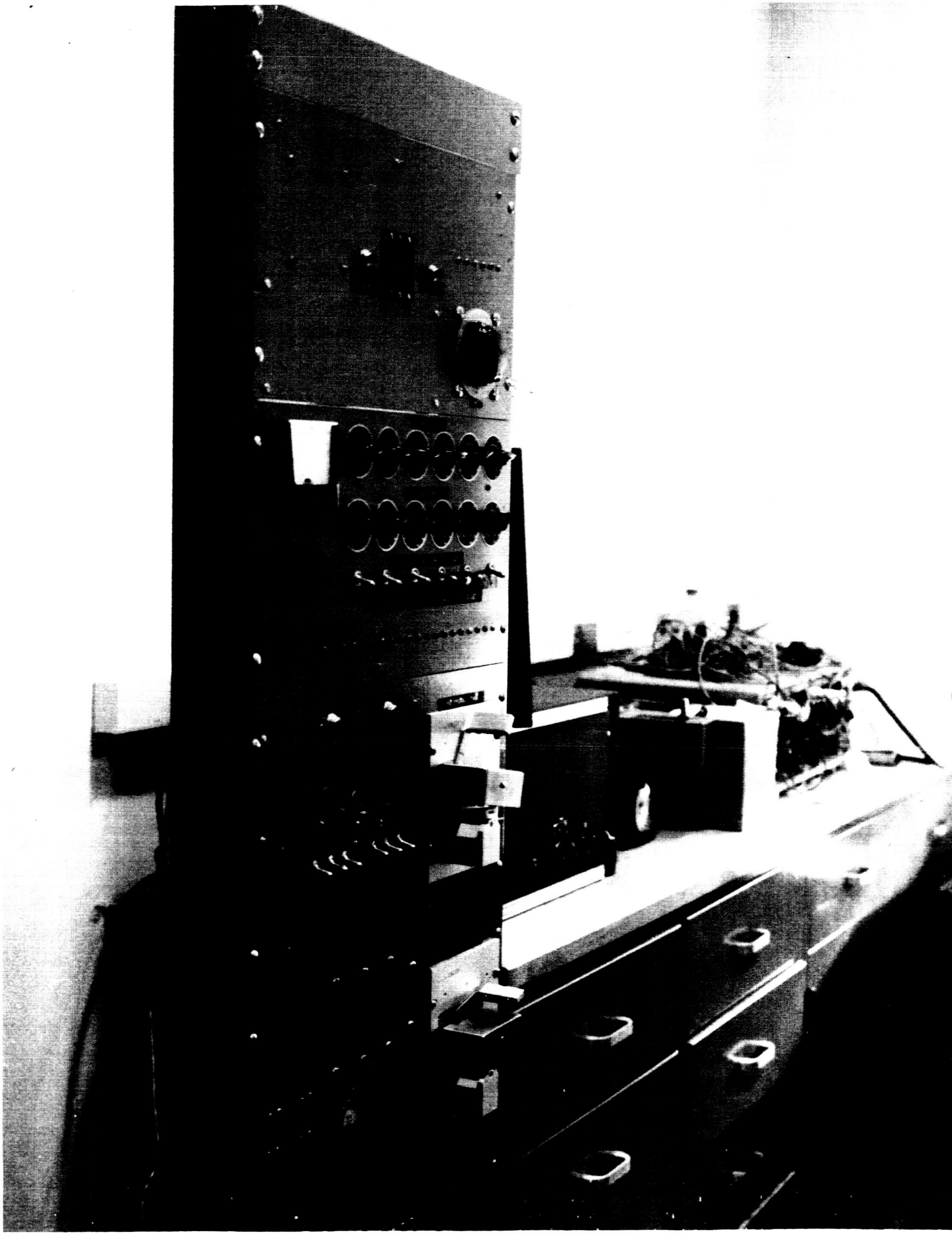


Fig 8 - Equipment to Study Peripheral Detection from each detail of what is seen. That is, a subject's field of attention becomes narrowed and the mode of processing information becomes more systematic. With slight blurring and with mild speed stress, there is heightened attention to detail. This work demonstrates the feasibility of the method and is ready for testing in the altitude chamber.

A second experiment is directed toward the way subjects use coding rules to reduce information and thereby identify patterns.* The use of rules may be thought of as the application of an information coding or classifying system to the reduction of stimulus uncertainty. It is anticipated that under environmental stress it can be determined whether the breakdown in ability lies in using the coding rule or in the actual identification of the patterns. To achieve this, the subject first learns two sets of patterns similar to those used in the task. He then views patterns of lights which have been classified into four numerical groupings. There are two rows of six lights each, of which the end lights in each row are code lights. The patterns are the sixteen possible ones employing four of the middle eight lights at a time. Patterns of lights are flashed once in sequence for the subject to determine the group to which the pattern belongs. There are three experimental groups of subjects, each group viewing the sequences at a different rate. Each group views the patterns containing all six lights. He then views with five lights, having omitted one of the code lights, with both code lights omitted having only the pattern, and with one of the pattern lights missing as well as the code lights.

*See Fig 8.

It is expected, then, by analyzing the percentage of error and the response time in the conditions to determine an effect of mild stress in the reduction of information by the coding process. The absolute ability of the subject to identify is of less interest than the effect of stress on ability to use identifying systems or codes.

The third task permits the separate analysis of whether the loss of ability in a stimulus-response task is due to a loss in stimulus or input processing or to a loss in response or output processing.

Three lights are arranged in series before the subject who is instructed to respond to the middle light with one button and the outside two lights with the other. The reaction time of the subject and his response is then recorded. The experiment is designed so that the percentage of flashes for a given light may be varied to study the stimulus-response process by separate analysis.

In the present experiment the lights are programmed to appear in terms of percentages and presented in patterned and in random order. For four groups of subjects, the lights are programmed to appear with pattern trials, random trials, and again trials of the pattern. The percentages vary with the patterns for each group. For the fifth group the lights appear with random trials of one percentage, followed by trials of another percentage and return to the original trials.

By varying the percentages it is expected that a complete analysis of the stimulus-response problem is possible. Further, a breakdown is expected in the processing of information by the change of pattern and percentage. Under stress, this would be expected to show definite effects.

V. Emphasis during Second Year

This work under the general supervision of Professor Ross McFarland and Dr. Norman Mackworth is being directed on the two main topics of

1. Peripheral Seeing,
2. Prolonged Seeing.

The following account of the arrangements will make it clear how the investigations have been concentrated mostly on these topics. The additional emphasis on the abnormal environmental conditions has also been outlined, especially in connection with the effects of unusual working conditions on prolonged seeing.

1. Peripheral Seeing

The lack of oxygen work on searching moon patterns is being completed as also are investigations of visual search amongst fine details despite lack of oxygen. The intention then is to pursue similar studies in the high atmospheric temperature situation. The testing for this work is being undertaken by Mr. Gruber with advice from Dr. Norman Mackworth.

2. Prolonged Seeing

The researches and the prolonged seeing of flashing lights is being undertaken by Dr. Jane Mackworth on a no cost basis. In this she will have the assistance of Mr. Gruber.

3. Rules Recognition

Dr. Pickett will continue to guide the work on rules recognition for patterns and textures with Mrs. Rubin on the actual testing.

The secretarial, report writing and coordination of subject arrangements, is being undertaken as during the first year by Mrs. Tinsley.

Appendix on Technical Procedures

I. Recording of Eye Tracks

a. Stand Eye Camera

The stand eye camera can simultaneously record the visual display on the vertical screen and the eye reflection created by the light source. These composite records can take three forms: 1) the television closed circuit camera which provides a TV monitor picture which serves as a large view-finder for calibration and also for photographic records by 2) a Polaroid Camera; simultaneously, 3) 16mm Bolex movie camera can take continuous motion pictures.

b. Head Camera

A head-mounted form of the eye camera equipment is shown in Figure 3. This creates a beam of light which is reflected from the cornea of the right eye, and the resulting highlight is conveyed by a fiber optics cable to a mixing device so that the scene picture coming from the second fiber optics cable can be combined and shown on the small TV monitor screen. Again, this can be viewed directly as a large view-finder, and 16 mm motion pictures can also be taken at the same time.

c. X-Y Automatic Analyzer

The 16 mm film records from either eye camera and can be projected on to the X-Y automatic analyzer in the Harvard Center for Cognitive Studies. This automatically registers the position of the gaze on a 15x15 matrix so that a picture 10x10 inches can be divided into 225 small squares, 0.6x0.6 inches. The presence of the eye marker in this matrix is determined sixty times a second and its X-Y coordinates recorded in digital form on magnetic tape. An elaborate program is necessary to analyze this series of coordinates automatically by the PDP-4 digital computer. The program will, however, greatly simplify the analysis of quantities of data. For example, the device will then provide tables or graphs of data such as the frequency of visual fixations in the various areas of a scene, the length of visual step and the direction of eye movements. Many other combinations of these yardsticks can also be selected. The result is that many other special analyses can be undertaken automatically by additional programs to rearrange the facts in this initial data bank.

II. Projection Equipments for Visual Displays

Several standard presentation devices are in use such as an ordinary tachistoscope and a presentation drum which revolves the visual material behind a horizontal slot. A somewhat unusual feature of the latter equipment is that it is attached to an optical programmer which automatically records when the subject should have made a response. The flexibility and simplicity with which this 35mm film program can be changed makes this equipment, constructed by Space Mechanisms, Inc., of Cambridge, Massachusetts, a useful general laboratory tool.*

*See Fig 2 - bottom.

The visual perception of random texture is being studied in a series of psychophysical tests. Pictures are generated by computer directly onto 35 mm films and prepared for individual slide projection. From slide to slide, the characteristics of the picture are varied in systematic ways, and the observer is asked to classify the pictures along some subjective dimension. For example, they can be varied along a dimension of roughness. The observer can be shown a series of slides of "medium roughness" then asked to classify the test series as "rougher" or "smoother" than the criteria. The speed and accuracy of his responses are examined as functions of the systematic variations made in the pictures.

Automatic presentation of displays, feedback and response recording is necessary to permit an efficient psychophysical test. Considerable effort has, therefore been directed toward the use of automatic equipment, and a slide projector with large capacity magazines is employed. Appropriate switching circuits have been developed so that when the slide is projected its precoded stimulus class determines the branch of a tree leading to clock and counter for that stimulus class. A gate is also opened to a logic circuit for comparing the observer's response to the "right" response for that class. When the slide is projected the appropriate clock is started. When the observer responds his answer is automatically scored. His cumulative response time and his cumulative correct response score are updated at each response and displayed to him for motivational purposes.

III. Analysis of prolonged and peripheral seeing of flashing lights

The Canadian Defence Research Board constructed some new equipment which has been copied for these NASA investigations. This vigilance pulse generator (shown in Figure 2)* is a flashing light pulse activator specially developed for use in visual detection intensity experiments. The equipment controls the ON and OFF periods and the repetition rate of two simultaneous flashing neon bulbs. The flash repetition period can be varied from 0.15 to 1.5 seconds, and the duration between 0.08 and 0.05 seconds. A circuit is included where one neon will flash at a slightly lower increment of brightness than the other; one of seven different levels can be chosen. The 35mm film programmers mentioned above select the moment at which the peripheral light of the pair of lights becomes slightly dimmer than the central light. The subject presses a response key which can therefore record when he has detected one of these unusual signals.

A new piece of equipment has been built for the study of the effects of environmental and other stresses on pursuit tracking, peripheral detection, attention and decision making (for example, rules recognition). Because of the combining of the two tasks, it can be used to study the process by which subjects compensate for fatigue and stress by reducing the field of concentration.

The experimental situation is one which presents the subject with a primary central task and a peripheral task which must be performed simultaneously. The central task, as presently used, consists of a series

*See Fig 2 - top.

of lights and sensitive corresponding contact points. The lights are programmed in a predetermined manner by an external programming unit. The subject's output is fed through a system which performs the following two functions: 1) The output is fed through a servo which controls the external programming unit in such a way that the rate at which the lights are programmed increases or decreases at the rate at which the subject's tapping speed increases or decreases. The unit provides for control of this feedback rate. Although lights and tapping are being used, any control-display situation can be used instead. 2) The subject's tapping rate is fed through an integrating circuit to a digital-converting unit and thence to an IBM card punch. This permits immediate card punched recordings of the Subject's performances measured as tapping rate and allows for detailed mathematical analysis of his tracking.

The peripheral task consists of six lights, programmed externally, at six peripheral positions in the subject's visual field. The subject's task is to indicate detection of a peripheral light while carrying on the central tapping task. As the central task becomes more demanding or as environmental stress is imposed, peripheral detection becomes impaired. The impairment is shown not only in the number of lights detected, but as a greater reduction of the more periphera lights - the funneling effect.

This apparatus was developed by Warren H. Teichner at the University of Massachusetts. A study of the effects on the tapping response and the peripheral detection of combinations of basic speed and feedback rate has been made, as well as a study of the effects of different kinds of intermittent acoustic exposures on these responses. Both will furnish a background of valuable data for use in this study, including an autocorrelational analysis of the periodicities in individual tapping sequences.

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