

Nov. 18, 1958

C. M. HARDEN ET AL
PATTERN PHOTIC STIMULATOR

2,860,627

Filed March 26, 1953

4 Sheets-Sheet 1

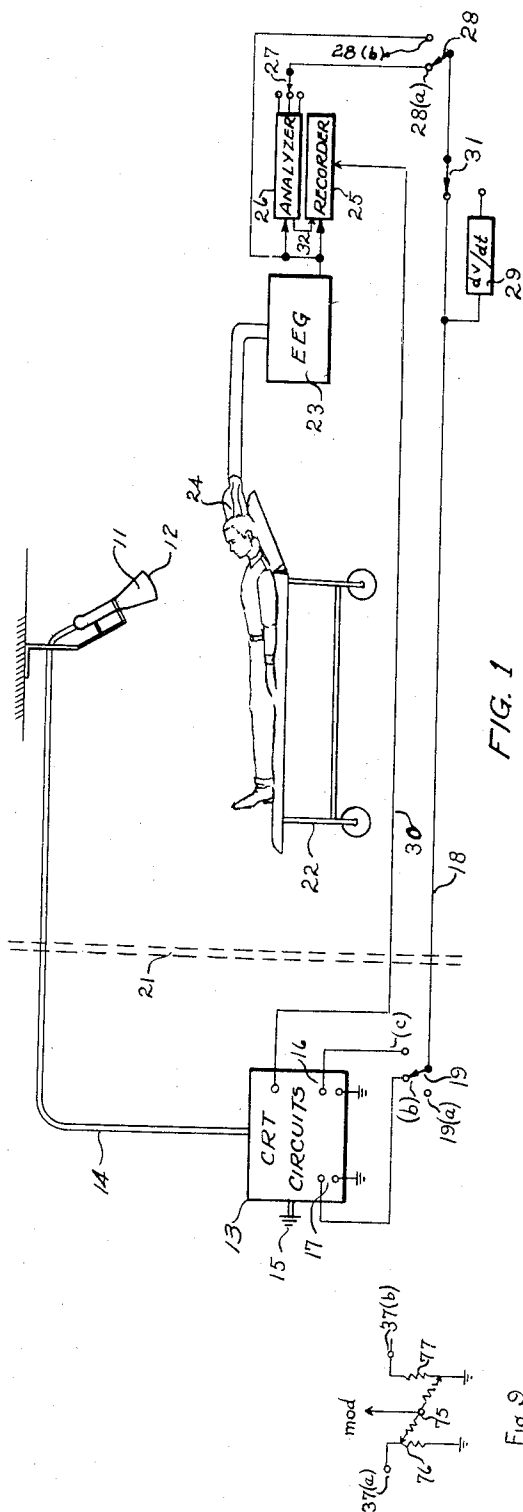


FIG. 1

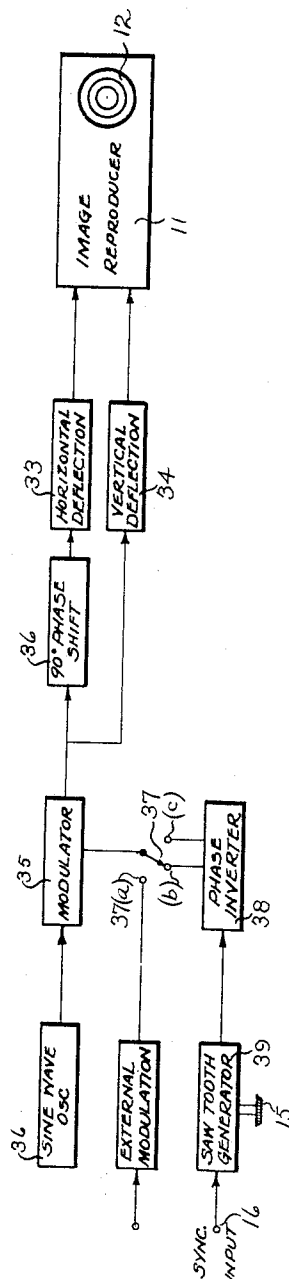


FIG. 2

INVENTOR.
CHARLES M. HARDEN
BY CURTIS MARSHALL.

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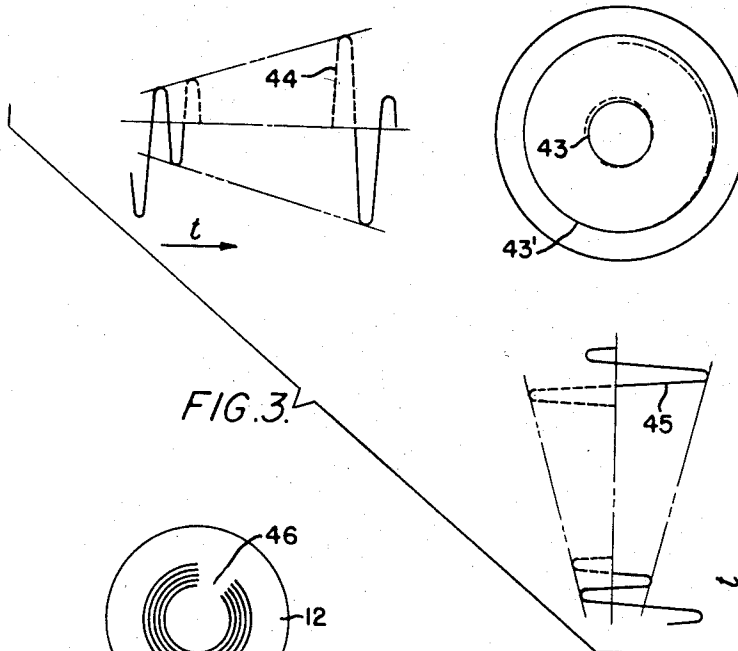


FIG. 3.

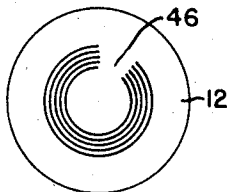


FIG. 4.

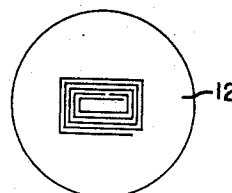


FIG. 5.

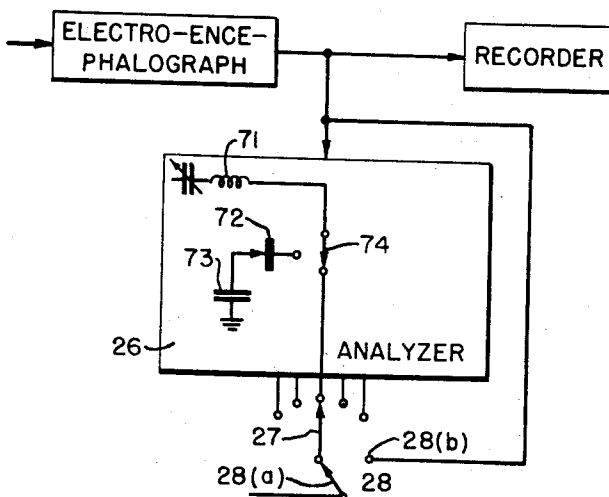


FIG. 8.

INVENTORS
CHARLES M. HARDEN
CURTIS MARSHALL

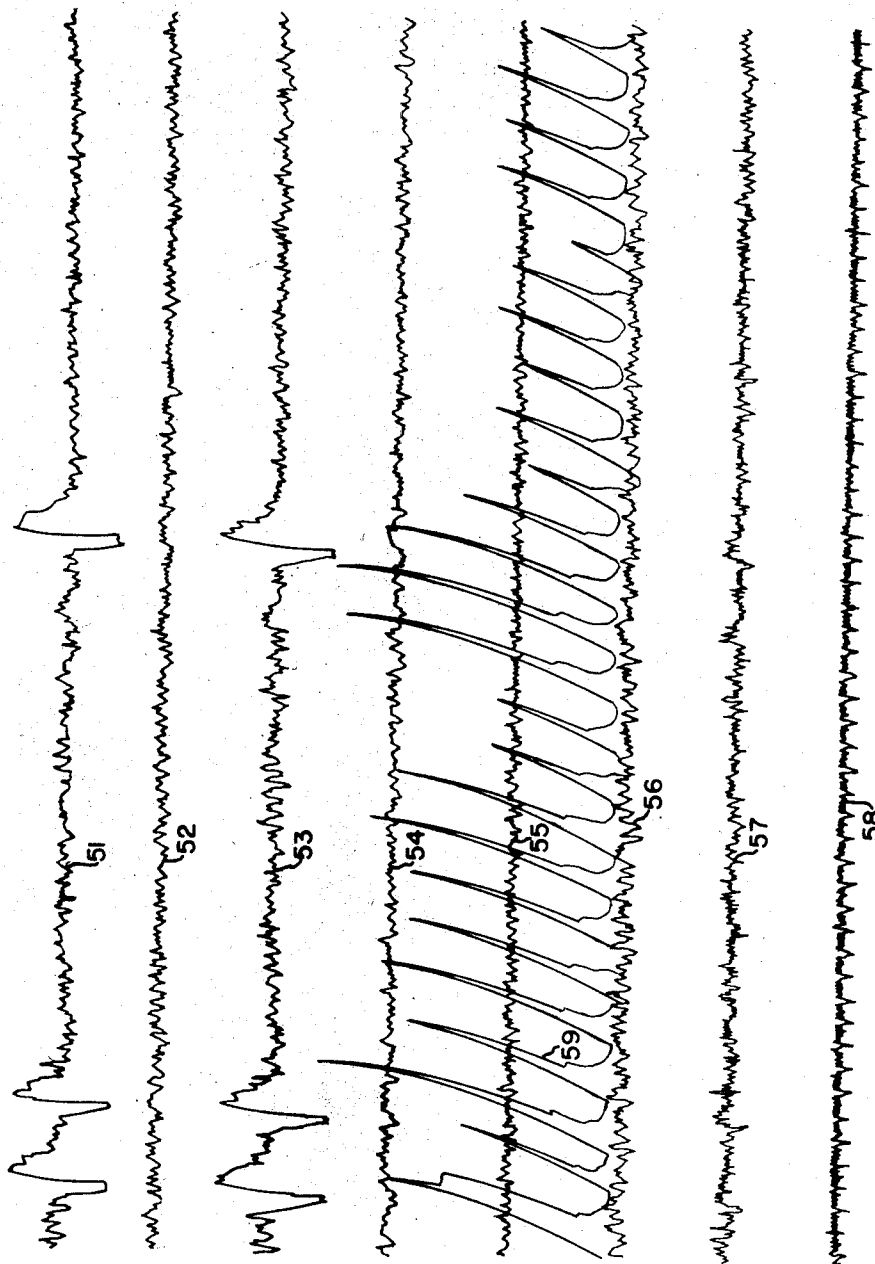
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INVENTORS
CHARLES M. HARDEN
CURTIS MARSHALL

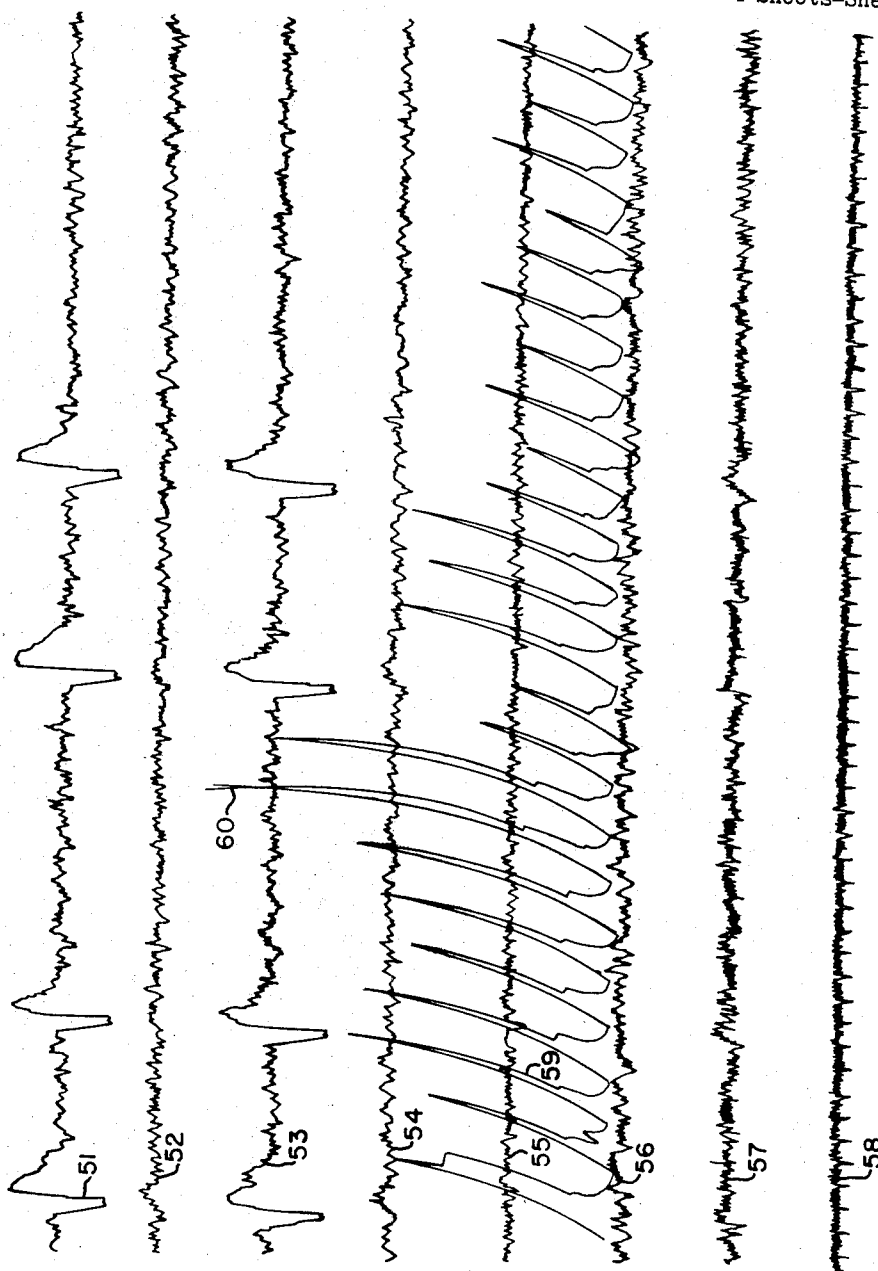
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INVENTORS
CHARLES M. HARDEN
CURTIS MARSHALL

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PATTERN PHOTIC STIMULATOR

Charles M. Harden, Natick, Mass., and Curtis Marshall,
Baltimore, Md.

Application March 26, 1953, Serial No. 344,853

12 Claims. (Cl. 128—2.1)

This invention relates generally to photo-stimulation and more particularly to methods and means for effecting photo-stimulation with relatively low intensity variable light patterns.

Photo-stimulation may be considered as that branch of neurological diagnosis and analysis or treatment which involves presenting to the visual sense of a subject a non-constant source of illumination and observing the influence of the change in such illumination upon the neurological activity of the subject. In general, neurological activity may best be observed and indicated by means of electroencephalographic (EEG) apparatus which is well known in the art.

The EEG response to intermittent photic stimulation is well known and has been used to a limited extent heretofore for the treatment of patients having certain neurological abnormalities and for obtaining data related to the activity of the human brain and visual apparatus in general. These prior arrangements have suffered from certain shortcomings including a low sensitivity of overall response. In attempting to produce an adequate response by increasing the intensity of the light source, the subject rapidly became fatigued and the possibility of injury to the retina arose before significant improvement in the EEG response was obtained. In addition, such intense light sources were either unduly cumbersome to work with or involved the use of large transient electromagnetic fields, causing interference with the delicate potentials measured at the surface of the scalp which was difficult to eliminate.

Certain other attempts to obtain EEG response to low level intermittent or undulatory light sources have been satisfactory for certain studies but have been incapable of presenting spatial modulation to the eye.

The foregoing disadvantages of prior art arrangements and methods have been largely overcome by the methods and apparatus of the present invention which, in addition to providing improved response from a low intensity source of light, permits quantitative studies to be conducted between the characteristics of the light source and the brain activity influenced thereby.

Accordingly it is an object of this invention to provide new and improved methods and apparatus for photo-stimulation.

A further object of this invention is to provide arrangements for photo-stimulation in which a variable light pattern is employed.

Another object is to provide method and means which are readily applied to experimental procedures and in which controlled conditions may be introduced as required during the course of the diagnosis.

A further object is to provide photo-stimulation arrangements which produce improved results without danger of injury to the subject and which may be carried on for extended periods of time without undue fatigue.

A further object is to provide apparatus which will present to the subject a light pattern of variable size or shape which has an intensity which is not offensive to

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the subject and which may be spatially modulated at will to product the most desired results.

A further object of the invention is to provide photo-stimulation methods and apparatus in which the EEG response may be utilized to control or modulate the source of the visual stimulation.

A still further object is to provide improved arrangements for comparing normal optical unstimulated and controlled photo-stimulated EEG responses.

These and other objects of the present invention are obtained by means of the present preferred embodiment of apparatus and employment of techniques which are more fully set forth in the detailed description and the accompanying drawings. Essentially the invention requires a visual pattern source which can be spatially and intensity modulated over wide ranges, such as the cathode ray oscilloscope tube. By generating suitable light patterns on the fluorescent screen of the tube which are observed by the subject being analyzed, the EEG response influenced thereby may be readily sensed by means of conventional EEG equipment. These EEG responses may be recorded and analyzed for various frequency components to determine correlation between the visual pattern modulation and the EEG response in a manner set forth in an article entitled Use of Rhythmically Varying Patterns for Photic Stimulation published in The EEG Journal for August 1952. By means of suitable feedback networks the EEG potentials or frequency components thereof may be employed to synchronize or modulate the visual pattern.

Further advantages and equivalent modifications of the method and apparatus claimed herein will become apparent from the following detailed description taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a diagrammatic view of the preferred embodiment of the system of the present invention as arranged for practicing the method of the invention;

Fig. 2 is a block diagram of oscilloscope circuits as employed in Fig. 1;

Fig. 3 is a view of a preferred luminous pattern on the fluorescent screen of the oscilloscope of Fig. 1 with representations of the horizontal and vertical deflecting forces applied to the cathode-ray;

Figs. 4 and 5 are views representative of modified luminous patterns which may be used;

Fig. 6 is a graph showing a composite record of EEG potentials and the analyzed frequency components thereof for a subject who was staring at a maze;

Fig. 7 is a graph showing a composite record similar to Fig. 6 for the same subject who was observing a varying light pattern in accordance with the invention;

Fig. 8 is a partial diagram of a modified connection of a portion of the apparatus of Fig. 1; and

Fig. 9 is a schematic diagram of a differential attenuator.

Referring now to Fig. 1 the system of the present invention will be described together with the novel methods of the present teaching. The system includes a cathode-ray tube 11 having a fluorescent screen 12 which provides localized visible light energy upon energization thereof by a focused electron beam of predetermined energy level. In accordance with the present invention a desired light pattern is produced on the screen 12 by suitably deflecting the electron beam and controlling the intensity thereof. The control of the electron beam may be effected by circuits 13 which are of a type generally well known in the oscilloscope art and which will be described more fully hereinafter. Operation of the tube 11 to energize the screen 12 in a desired manner from the circuits 13 is achieved by an energy and signal cable 14 providing the necessary connections therebetween.

As will be further described, a desired light pattern is

produced on the screen 12 by the generation and utilization of waveforms of current or voltage which vary with time. These waveforms will, in general, be synthesized from more basic waveforms which are of two types. First, a carrier or super-visible-rate waveform will generate a basic shape light pattern such as, for example, a circle. Second, a quasi-visible-rate waveform will, by modulating the carrier or otherwise, vary the size, shape, position or other characteristic of the light pattern. It will be understood that this technique is but a means to an end and any other means for producing light patterns, of which those herein disclosed are exemplary, are equally satisfactory for the purposes of this invention. The light pattern produced by the first and second above described waveforms is such that the basic shape generated by the super-visible-rate waveform appears as a continuous image in which the human eye is unable to discern any appreciable motion. The modulation of this basic continuous image produced by the quasi-visible-rate waveform is carried on at speeds including those at which the human eye is able to perceive the motion so produced. An important feature of the apparatus of the present invention and a step in the method thereof is the adjustment of the recurrence frequency or the speed of transition of the quasi visible rate waveform. To achieve this result a sweep frequency adjustment control 15 is provided.

The oscilloscope circuits are provided with synchronizing signal terminals 16 and modulation signal terminals 17 which may be selectively connected to a signal line 18 via a switch 19 having contact points 19(a), 19(b), 19(c). The oscilloscope apparatus is preferably separated by a partition 21 from the room containing the subject for the purpose of reducing the artifactual influence of fields associated with the generating apparatus and avoiding the possibility of any conscious effort to affect correlation.

Disposed in a suitable position adjacent the cathode-ray tube 12 is a support such as table 22 upon which the subject may be positioned. The support 22 may be any convenient arrangement which is comfortable for the subject and which positions his eyes preferably directly in front of the screen 12 at a suitable distance, for example twelve inches. A standard electroencephalograph (EEG) 23 is arranged with the sensing leads 24 thereof preferably directly connected to the subject's scalp at the points the physiological potential of which is to be investigated. Inasmuch as photic stimulation is to be investigated, the scalp connections of primary interest will be those associated with the visual portion of the neurological system, such as, for example, the low central to homolateral occipital connection.

The outputs of the EEG may be recorded by means of the individual channel pens and a moving chart in a conventional manner by a recorder 25. The output of a selected one of the EEG channels is supplied to an analyzer 26 which may be an Offner automatic low frequency analyzer. The Offner automatic low frequency analyzer receives the selected EEG potential and by means of adjacent tuned band pass circuits separates the frequency components of the input wave from $1\frac{1}{2}$ cycles per second (C. P. S.) to 30 C. P. S. These frequency components are individually rectified and accumulated during the EEG recording epoch so that the relative magnitude of the stored frequency components is available for operating a suitable recorder. The recording in sequence of the stored frequency components produces a frequency component curve for the EEG input wave. A switch 27 is arranged for selecting one of the frequency component outputs of the analyzer 26 as will be more fully described hereinafter. Another switch 28 is arranged to connect the frequency component from the switch 27 via contact 28(a) to the line 18 or via contact 28(b) one of the channel outputs of the EEG may be connected to the line 18. The line 18 may run directly to the switch 19 or may include any desired operational circuit, for

example a time derivative circuit 29 selectively inserted by a switch 31. The analyzed output of a selected channel may be supplied to the recorder 25 by a connection 32 as will appear hereinafter. If desired, timing markers of the periodicity of the quasi-visible rate sweep may be recorded by means of a signal via lead 30.

In Fig. 2 suitable arrangements are shown for operating an image producer 11 having means for producing a controlled image on the image screen 12. Included are a horizontal deflection force generator 33 and a vertical deflection force generator 34, both supplied from a modulator 35 with a 90° phase shift unit 36 interposed between the modulator and one of the generators 33, 34. The modulator 35 is supplied with a super-visible rate sine wave carrier from an oscillator 36 and amplitude modulation signals therefor selectively by means of a switch 37. The switch 37 provides at a contact 37(a) external modulation of any desired character and at contacts 37(b) and 37(c) saw-tooth modulation of a rising or falling character as derived by phase inversion in a phase inverter 38 of the saw-tooth wave generated by a saw-tooth generator 39. The generator 39 has a frequency adjustment 15 and a synchronizing signal terminal 16. An elementary schematic diagram of a circuit suitable for performing the oscillation generation and mixing functions of the system of Fig. 2 is shown in Fig. 1 of the previously referenced article. It will be understood that these circuits are exemplary only and that many arrangements will be apparent to those skilled in the electronic and allied arts for producing the desired visual effects taught by the present invention.

In Fig. 3 the viewing screen 12 has displayed thereon an expanding spiral 43—43' as the preferred visual pattern which may be generated by the saw tooth modulated sine wave deflection forces 44, 45. The maximum diameter of the outer spiral boundary 43' is made adjustable as well as the inner boundary 43 which may be reduced to a point or substantially zero diameter. As has been explained, the spiral 43—43' is preferably so tight that the visual pattern appears as an expanding circle. For the purpose of illustration in Fig. 3 the sine waves 44, 45 and the spiral 43—43' are shown on coarse scale.

Other expansion or contraction configurations for the light pattern may be used in a particular examination. For example, if photic stimulation in response to light patterns having diverse extensions or rates of motion with respect to two axes is desired, an ellipse may be used instead of a circle. The figure need not be curved but may be square or rectangular as shown in Fig. 5 or some other regular shape which can be readily generated. For certain controlled investigations a fragmentary figure may be employed. Thus in Fig. 4 by blanking the cathode-ray over a predetermined sector 46 or masking a portion of the tube face 12, area selective sector energization of the retina may be obtained. By controlling the inner and outer diameters of a circular pattern, any desired distribution of energy between the macular and peripheral areas of the retina is possible.

The diagnosis of a patient with the apparatus of the present invention may be made in accordance with the novel methods now to be described. In an arrangement such as shown in Fig. 1 a patient is placed in position comfortably to view the screen 12 of the tube 11 at a suitable distance, say 12 inches. The normal scalp-to-scalp connections are made with the leads 24 to sense the physiological potentials which are generated between various points on the scalp of the patient. One signal-pair is selected for analysis, for example the connections to the low central and homolateral occipital regions which provide response related to the subjects visual system. Switch 19 is positioned at contact 19(a), interrupting the feed-back circuit and making the expansion or contraction rate for the pattern controlled as to periodicity by means of the control 15. The amplifier channel of the EEG 23 to which the selected signal-pair of

leads 24 supplies the input signal has the output signal thereof applied to the analyzer 26. The output of the analyzer 26 produces the relative amplitudes of the frequency components of the EEG potential which was applied to the input of the analyzer 26. To record these frequency components they may be applied to a pen of the recorder 25 via lead 32 in such a manner that the analyzed response is super-posed upon the EEG potential recordings which have been analyzed to produce the response. One suitable arrangement is provided by ten seconds (one epoch) recording of EEG potentials with the analyzer response pen spatially displaced a distance along the path of the record chart corresponding to a predetermined time after the epoch. This spacing of the pens is made to correspond to the time taken for the analyzer 26 to determine the frequency components of the signal within the epoch and the magnitudes of these components are then recorded successively within the chart space of the epoch.

In order to establish a datum reference for each patient, at least one set of data is recorded with the view of screen 12 obscured from the patient. Preferably several sets of data are recorded with each patient, both for observing the variable pattern and with the screen 12 obscured, and these sets will ordinarily be recorded in alternation. During the control epochs or sets the patient may run a maze with his eyes by allowing his eyes to follow the pattern of the maze or stare into the distance or at a blank card, in which event the alpha rhythm will be recorded as for a normal subject; alternate epochs during which the pattern is observed produce definite peaks of EEG response at the pattern expansion or modulation frequency for normal subjects.

Representative data obtained by the instant method are shown in Figs. 6 and 7. These figures are recordings of successive 10 second epochs during which seven EEG potentials 51-57 were recorded. The recorded traces 51-57 respectively are the EEG potentials existing between the following scalp-to-scalp connections: 51 left-frontal to left central; 52 left-central to left occipital; 53 right-frontal to right central; 54 right-central to right occipital; 55 left occipital to right occipital; 56 left-central to right-central; 57 left-frontal to right frontal. Marker pulses synchronized with the pattern expansion and received via line 30 are recorded at trace 58. Superposed on the EEG traces of Fig. 6 is an analyzer trace 59 giving the relative amplitudes of the frequency components between 1½ and 30 C. P. S. for the wave 54 while the subject was running a maze. The succeeding epoch of Fig. 7 represents conditions identical with those of Fig. 6 except that the subject was observing an expanding circle having periodicity of five per second. The accentuated response 60 of the pattern frequency component of five C. P. S. is apparent.

The foregoing method provides by comparison technique information relative to the normal functioning of the neurological system associated with the subject's visual apparatus. The experimental conditions such as expansion or contraction, frequency, phase, modulation waveform and the like are all readily available for selection in wide variety by well known circuit techniques or equivalent apparatus. An examination over a substantial range of any one of these variables is a time consuming process, however, during which the patient is likely to become fatigued with a concomitant loss of sensitivity of EEG response to photic stimulation. Furthermore, due to the vague nature of the relation between EEG potentials and the entire neurological system, conditions may change during an experimental procedure which would influence the conclusions obtained from the data.

The foregoing difficulties may be largely obviated and significant additional data, further indicating characteristics of the visual-neurological system, obtained by means of modified apparatus and methods now to be described.

With these arrangements all of the techniques and advantages of closed loop systems become applicable to neurological diagnosis and studies. Closed-loop systems may be broadly classified as those systems having an input control signal and an output response dependant in part on the input control signal and in which the output response is utilized to modify the effective input control signal. Closed loop systems which include a human operator as a link in the feedback path are well known and countless examples of this arrangement for control purposes are apparent every day. However, the use of a portion of the human system in a closed loop arrangement for determining involuntary characteristics of the human system has not heretofore been proposed.

In the arrangement of Fig. 1 the switch 19 may be moved to the contact 19c and switch 28 may be connected to the contact 28(a). The switch 27, in selecting particular frequency components of an EEG wave, preferably is provided the direct magnitude of the component as indicated in Fig. 8. In Fig. 8 a frequency selection circuit 71 is indicated together with a rectifier 72 and a storage capacitor 73 which normally accumulates a charge proportional to the frequency component selected by the circuit 71 and stores this charge until the component is plotted, such as the relative magnitude of the individual frequency components 59 heretofore described. For supplying an instantaneous magnitude of the frequency component of the EEG potential selected by the circuit 71 to the switch 27, a switch 74 is provided to disconnect the rectifier 72 and capacitor 73. The frequency component selected by the circuit 71 is thus connected directly to the output of the switch 27.

The voltage from the switch 27 is applied to the terminals 16 to synchronize the expansion or contraction of the luminous pattern with or without being modified by the operator 29, as desired. For precise synchronization the operator 29 may include clipping and shaping circuits before differentiation to provide well defined synchronizing signals.

For complete feedback control of the system of Fig. 1 the switch 19 may be moved to the contact 19(b). For this connection the switch 37 of Fig. 2 should be moved to the contact 37(a). With these connections and the switch 28 at contact 28(a), the expansion or contraction modulation of the luminous pattern is directly under control of the frequency component selected by the switch 27. For ease in transition between selected modulation and feedback controlled modulation it may be desirable to provide a differential attenuator between the contacts 37(a) and 37(b). One form of such attenuator suitable for this purpose is indicated in Fig. 9. In Fig. 9 an arm 75 moves differentially over a pair of potentiometers 76, 77 which have the signals from the terminals 37(a) and 37(b) respectively impressed thereacross. The arm 75 supplies the input signal to the modulator. With this arrangement a response can be initiated by manual control of the expansion frequency with the control 15. At any desired point a selection of frequency component can be made with the switch 27 and the control of the expansion gradually transferred to full feedback control by shifting the arm 75.

In this specification and claims the light pattern generated by the periodic predetermined motion of an elemental area of light shall be defined as a "scansion light pattern."

Obviously, many arrangements and procedures will be apparent to those skilled in the art in the light of the above teachings which are understood to be descriptive only and not in limitation. The invention therefore may be practiced in other than those manners herein specifically described without departing from the scope of the appended claims.

We claim:

1. The method of comparative photostimulation of a living organism having a visual sense comprising the

steps of recording electroencephalographic potentials of said organism while said sense is subject to a control condition, recording electroencephalographic potentials of said organism while said sense is stimulated by a predetermined repetitive scansion light pattern, and comparing said recordings for the influence of said stimulation on said potentials.

2. Photo stimulation apparatus comprising, means for generating a quasi-visible rate scansion light pattern substantially in the form of an expanding or contracting ring, means for varying said scansion rate, electroencephalographic means for sensing brain wave potentials influenced by said light pattern, means for developing modulation signals in accordance with said potentials, means for differentially selecting control signals from said varying means and said modulation signals, and means for controlling said scansion in accordance with said control signals.

3. Photostimulation apparatus comprising oscillographic means for generating and exhibiting to the patient a quasi-visible rate scansion light pattern substantially in the form of an expanding or contracting ring, an electroencephalograph connected to said patient for sensing brain wave potentials of the patient influenced by said light pattern, a recorder connected to said electroencephalograph for recording said potentials and connections from said oscillographic means to said recorder for supplying timing signals related to said scansion to said recorder to record timing marks whereby the record of said recorder correlates the record of said brain wave potentials with the frequency of said expanding or contracting ring indicated by said timing marks.

4. Photostimulation apparatus comprising a light pattern generator having a viewing screen for displaying said pattern, means for controlling said generator to display a selectable quasi-visible rate scansion light pattern on said screen, an electroencephalograph for connecting to a patient viewing said screen to detect brain wave potentials influenced by said light pattern, a recorder connected to said electroencephalograph for recording said potentials, and means for correlating the record of said potentials with the frequency of said quasi visible rate light pattern whereby the influence of said frequency on said patient can be determined.

5. Photostimulation apparatus comprising a light pattern generator having a viewing screen for displaying said pattern, means for controlling said generator to display a selectable quasi-visible rate scansion light pattern on said screen, an electroencephalograph for connecting to a patient viewing said screen to detect brain wave potentials influenced by said light pattern, and connections from said electroencephalograph to said generator for modifying said quasi visible rate light pattern responsive to said potentials whereby the response in said brain wave potentials to said photostimulation can be determined.

6. Photostimulation apparatus comprising a light pattern generator having a viewing screen for displaying said pattern, means for controlling said generator to display a selectable quasi-visible rate scansion light pattern on said screen, an electroencephalograph for connecting to a patient viewing said screen to detect brain wave potentials influenced by said light pattern, means for deriving signals having the fundamental frequency of said quasi visible rate from said potentials, and connections from said last named means to said generator for synchronizing the frequency of said scansion in response to said signals whereby the influence of said frequency on said patient can be determined.

7. Photostimulation apparatus comprising a light pattern generator having a viewing screen for displaying said pattern, means for controlling said generator to display a selectable quasi-visible rate scansion light pattern on said screen, an electroencephalograph for connecting to a patient viewing said screen to detect brain wave potentials

influenced by said light pattern, means connected to said electroencephalograph for generating modulation voltage signals in accordance with the wave form of said potentials, and connections from said modulation signal means to said generator for controlling said scansion generator to vary said quasi visible rate pattern in response to said modulation voltage signals whereby the response in said brain wave potentials to said photostimulation can be determined.

8. Apparatus according to claim 7 in which said means for developing modulation signals includes a frequency selective device operable for selecting predetermined frequency components of said potentials.

9. The method of photostimulation of a living organism having a visual sense comprising the steps of exhibiting a predetermined repetitive scansion light pattern and stimulating said visual sense with said light pattern, controlling a repetitive characteristic of said pattern to vary at a frequency below the threshold for persistence of vision, sensing brain wave potentials influenced by the frequency of said light pattern, deriving signals having the fundamental frequency of said repetitive characteristic from said potentials, and synchronizing said repetitive characteristic of said pattern in response to said signals whereby the influence of said frequency of said light pattern on said patient can be determined.

10. The method of photostimulation of a living organism having a visual sense comprising the steps of exhibiting a predetermined repetitive scansion light pattern and stimulating said visual sense with said light pattern, controlling a repetitive characteristic of said pattern to vary at a frequency below the threshold for persistence of vision, sensing brain wave potentials influenced by the frequency of said light pattern, generating modulation voltage signals in accordance with a particular frequency component of said potentials, and applying said signals to vary said repetitive characteristic of said pattern corresponding to the waveform of said modulation voltage signals whereby the response in said brain wave potentials to said photostimulation can be determined.

11. Photostimulation apparatus comprising a cathode-ray oscilloscope having two pairs of deflection plates for deflecting the cathode-ray in two perpendicular directions, a sine wave oscillator for generating a voltage having a frequency much higher than the threshold for persistence of vision, a voltage generator for generating a saw-tooth voltage wave form with a controllable range of fundamental frequencies of substantially zero cycles per second up to the order of thirty cycles per second, a manually operable frequency selector for said saw tooth generator, an amplitude modulator connected to said sine wave oscillator and said saw-tooth generator for combining the voltages from said oscillator and said generator to produce a modulated output voltage of the frequency of said sine wave with amplitude modulation in accordance with said saw-tooth waveform, connections for applying said modulated output to one pair of said deflection plates, a ninety degree phase shift circuit connected to said modulated output and the other pair of said deflection plates whereby a visually continuous circle of light is traced on the screen of said oscilloscope and the diameter of said circle varies directly with the amplitude of said saw-tooth modulation waveform and at the same controllable frequency, means for exhibiting the varying diameter circle on said screen to a patient in a room free of spurious electrical influences, an electroencephalograph connected to the scalp of said patient, a recorder for the brain wave potentials measured by said electroencephalograph, a timing mark pen on said recorder, a circuit for actuating said pen in timed relation with said saw-tooth modulation, and a frequency analyzer connected to said electroencephalograph for determining the magnitude of the particular frequency component of said brain wave potentials which are induced by the frequency of varying said varying diameter circle whereby

the response in said brain waves of various frequencies corresponding to the selected values of said controllable frequency can be determined.

12. The method of photostimulation of a living organism having a visual sense comprising the steps of exhibiting a predetermined repetitive low-level light pattern and stimulating said visual sense with said pattern, controlling a repetitive characteristic of said pattern to vary at a frequency below the threshold for persistence of vision, and indicating the influence of said stimulation with an induced electrophysiological potential of said organism containing frequency components corresponding to said frequency of said light pattern.

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