(12) UK Patent Application (19) GB (11) 2 129 963 A

(21) Application No **8328671**
(22) Date of filing **27 Oct 1983**
(30) Priority data
(31) **437558**
(32) **29 Oct 1982**
(33) **United States of America (US)**
(43) Application published **23 May 1984**
(51) **INT CL³ A61B 3/00**
(52) Domestic classification **G2J** 13AX 13B3
(56) Documents cited **GB 1479568**
Specification WO 81/00197
(58) Field of search **G2J**
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(54) **Visual acuity tester**

(57) A spot of light e.g. from source 20 and aperture, plate 22 may be scanned across the eye by mirror 24 and is increased in intensity (by 56) until observed by the eye. The intensity at which this occurs is a measure of visual acuity. The subject operates a switch 66 when the spot is observed or the operator watches the subject's eye with television camera 58 to detect the commencement of tracking when switch 68 is operated.

Before the acuity measurement an automatic measurement of refractive error may be made by pattern generator and detector 44 coupled to computer 46 and a cylindrical lens 26 and focussing lens 42 are adjusted for 20/20 vision. Target 30 is also adjusted to relax accommodation of the eye.

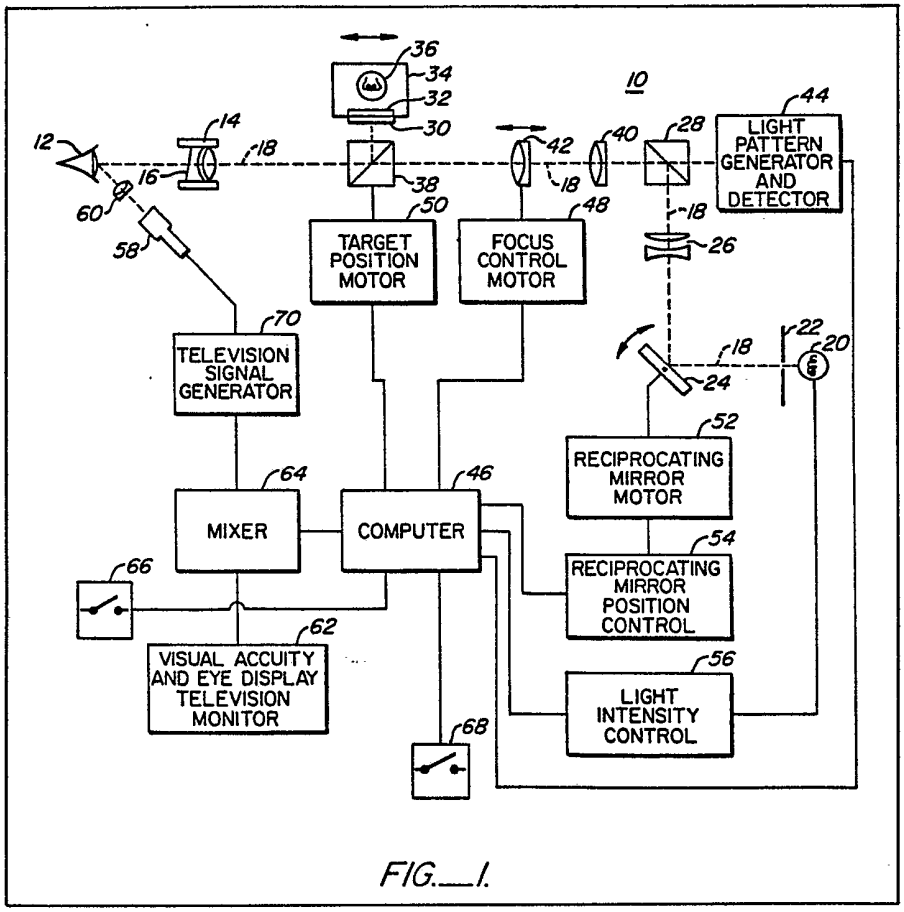

FIG. 1.

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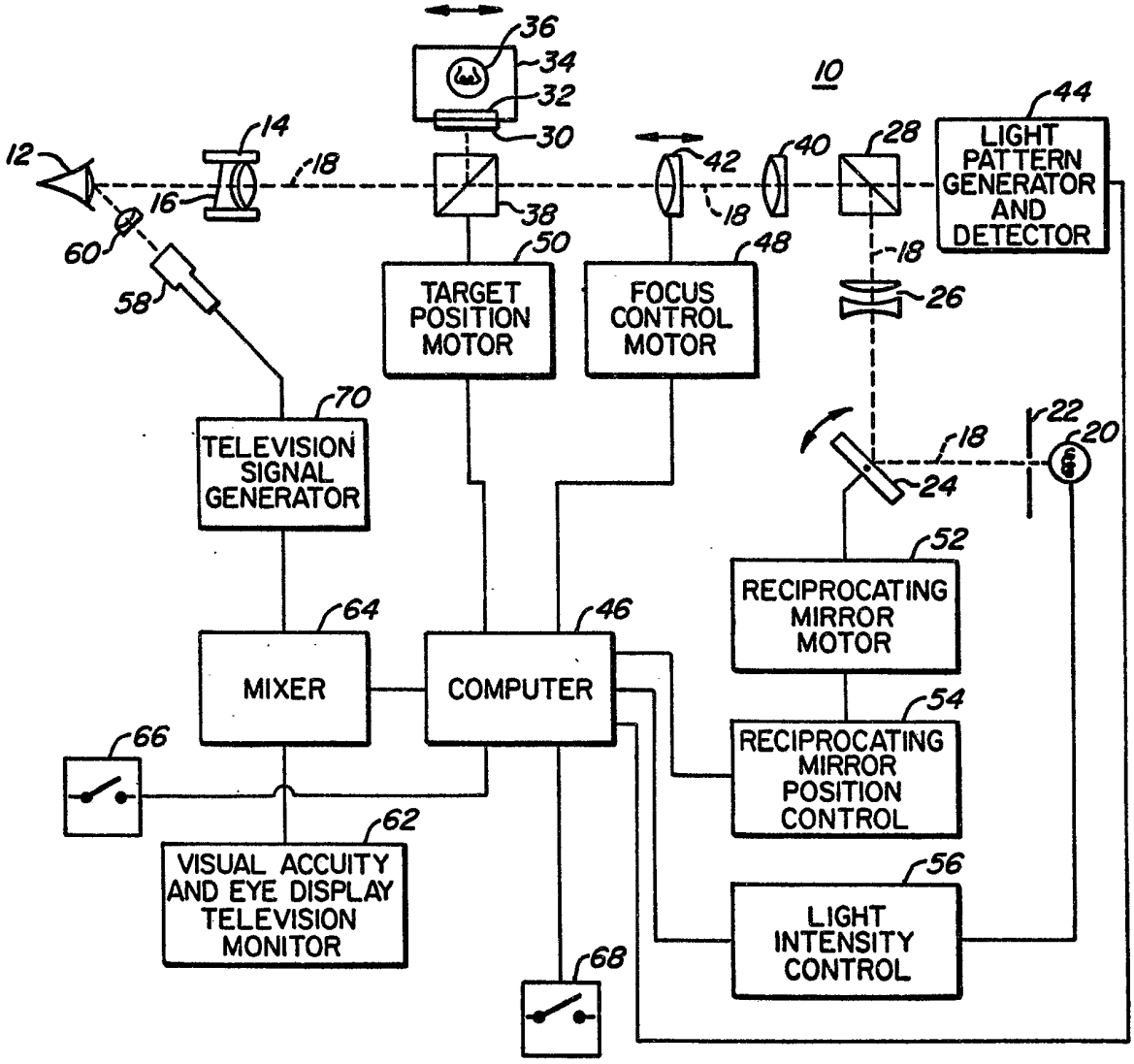
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TARGET POSITION MOTOR
FOCUS CONTROL MOTOR
LIGHT PATTERN GENERATOR AND DETECTOR
TELEVISION SIGNAL GENERATOR
RECIPROCATING MIRROR MOTOR
MIXER
COMPUTER
RECIPROCATING MIRROR POSITION CONTROL
VISUAL ACCUITY AND EYE DISPLAY TELEVISION MONITOR
LIGHT INTENSITY CONTROL

FIG. 1.

SPECIFICATION

Visual acuity tester

Technical Field

This invention relates to visual acuity testers, and in particular, to visual acuity testers for use with automatic refractors.

Background Art

A visual acuity tester, to be effective, should be objective. Goldmann, in 1943, developed a target with pendular motion, for visual acuity testing. He obtained high correlation to standard visual acuity tests by observing the motion of the eye and noting the distance at which the target could be followed. Subsequent techniques involved evoking or arresting an optokinetic nystagmus or a pendular eye movement for various targets including gratings, black dots, or illuminated holes.

Studies relating to visual fields testing have established a relationship between foveal threshold level and diopters of ametropia. See, for example, "Visual Acuity," by Dr. Kenneth N. Ogle, U.C.L.A. Forum Med. Sci., 1969 pp. 443—83. U.S. Patent 3,992,087 describes an instrument in which a decrease in contrast of a spot is used to determine threshold with a corresponding assignment of visual acuity. The spot is moved in a pendular motion and loss of tracking is an indication of threshold.

A device for automatically measuring the refractive error of a subject's eye is described in U.S. Patent 3,888,569. While such a device generally provides accurate results, in a certain percentage of cases the results are not accurate. Thus, it is desirable to provide a visual acuity test following the refractive error determination, to verify, and if necessary, alter the calculated correction.

Incorporating a visual acuity tester in an automatic refractor, such as that described in U.S. Patent 3,992,087, would have important disadvantages. First, the decreasing light intensity approach requires a significantly longer testing time. With the accuracy of the automatic refractor, most subject's eyes are correctly, or nearly correctly diagnosed as to refractive error. Therefore, when the visual acuity test is made, after appropriate corrective lenses are interposed within the optical path of the subject's eye, most subjects will have 20/20 or nearly 20/20 vision. But a certain percentage will have incorrectly diagnosed refractive error. Thus to accommodate these subjects, the intensity of the light spot must be sufficiently large to insure it is seen initially by subjects still having poor vision. This means the light intensity will have to diminish significantly before it disappears, for most patients. Thus, this takes an unnecessarily long time for most subjects.

A second problem concerns eye accommodation. One of the major concerns in using an instrument to perform a vision test is whether or not the patient is accommodating, thus indicating a more myopic reading than actual. The Dioptron™ automatic refractor was the first objective instrument to incorporate a computerized accommodation control system to ensure that the patient is presented a target which is optically positioned to form an image in front of the retina, independent of the patient's state of refraction. Since the target image is in front of the retina, the patient must relax accommodation in order to make the target sharper on the retina. U.S. Patent No. 3,836,238 describes such an accommodation control arrangement.

If one desires to obtain a visual acuity test with a target within an automatic refractor, one is faced with the problem of accommodation. The problem is made most difficult if the subject is given a control to adjust the focus. In general, the subject will set the focus control more myopic than his far point.

Automatic refractors are available which provide visual acuity testing. Typically, these include the use of visual charts or symbols provided within the visual path of the subject. However, these require communication between the subject and the operator, which increases the possibility of error in the test results.

Disclosure of the Invention

It is therefore an object of the invention to provide an improved visual acuity tester.

Another object of the invention is to provide an improved visual acuity tester for use with and as a part of an automatic refractor.

Another object of the invention is to provide an improved visual acuity tester which is both accurate and completes a test within a short period of time.

In accordance with the invention a visual acuity tester is provided with means for providing a spot of light, preferably moving, in the view of the subject being tested, initially at an intensity below the subject's visual threshold. Thereafter the intensity of the moving spot is increased until it is observed by the subject. A signal is provided when the subject first observes the moving spot and, based upon the intensity of the light when it is first observed, the subject's visual acuity is determined and displayed. Additionally, means are provided for controlling accommodation of the eye being tested.

A determination of when the subject first observes the moving light spot can be made by either of two means, or both. First, the subject is provided with a button or switch. When he first sees the moving spot he activates the switch and the intensity of the spot of light is then determined. The second way is to provide a video camera which is focused on the subject's eye and observed by an operator. Until the intensity of the moving light spot reaches the visual threshold of the subject, the movement of the eye will be saccadic. When the subject's eye first sees the dot, the eye will then track the moving dot. This is easily observed by the operator who activates a switch and the light intensity is determined.

A visual acuity tester in accordance with the present invention which is incorporated into an automatic refractor, has several advantages over prior visual acuity testers, such as that described in U.S. Patent 3,992,087. Unlike the case of a decreasing-intensity light visual acuity tester described therein, the amount of time required to make the visual acuity test in an automatic refractor is significantly reduced for the majority of patients. This is because the intensity of the light is selected initially to be sufficiently low so that it can only be observed, for example, by one having 20/15 vision. But since the use of the automatic refractor ensures that most of the patients being tested for visual acuity will have corrective lenses in the path of their eyes, most will have 20/20 vision or close to that. Thus, the intensity of the light only has to be increased slightly before it will first be observed by the majority of subjects.

Secondly, in the absence of means for controlling accommodation of the eye, the eye can accommodate up to two diopters. In this accommodated state, the minimum intensity spot would not be seen until its brightness had increased to make up for the amount of accommodation. With accommodation control this problem is overcome. The accommodation control feature draws the eye to its far focus point. Here, the small light spot is in focus on the retina, thus allowing it to be seen at the lowest possible intensity.

Brief Description of the Drawings

Figure 1 is a block schematic diagram of an automatic refractor having the improved visual acuity tester of the present invention.

Best Mode for Carrying Out the Invention

Figure 1 is a schematic block diagram 10 of an automatic refractor which includes a visual acuity tester for testing an eye 12. The subject is positioned so that his eye 12 is placed at an eye piece 14 which includes a quarter-wave plate 16. The purpose of the quarter-wave plate 16 is described in U.S. Patent 3,888,569. A spot of light is directed along a path 18 to the subject's eye 12 by a light source 20, such as a light-emitting diode, and then directed through an aperture plate 22. The light spot is caused to scan the subject's eye 12 by means of a reciprocating mirror 24 whose operation will be described in greater detail subsequently. The moving spot of light passes through variable cylindrical lenses 26 which are set to eliminate refractive error after the operation of the automatic refractor. The moving spot of light is introduced into the path of the eye by means of a beam splitter 28.

Also in the field of view of the eye 12 is a target 30 which is used to control accommodation by "fogging" the subject's eye 12 being tested. The target is supported by a plate 32 of ground glass which is mounted in a wall of an enclosure 34. A suitable light source 36 is provided within the enclosure 34 for projecting light through the ground glass plate 32 and target 30. The target is provided to the path of the eye 12 by means of a beam splitter 38.

During the operation of the automatic refractor, a pattern of light from a light pattern generator is projected through the beam splitter 28, a collimating lense 40, a focusing lense 42, beam splitter 38, and eye piece 14 to the eye 12. The refracted light from the eye 12 passes back through those same optical components to a detector. This operation is described in detail in U.S. Patent 3,888,569. The light pattern generator and detector is shown schematically as block 44 in Figure 1. As explained in U.S. Patent 3,888,569, the signal from the detector 44 is sent to a computer 46 where the signal is stored and analyzed to calculate the refractive error of the subject's eye 12. As a part of the operation of the automatic refractor, computer 46 controls the focus control motor 48 which controls the position of the focus lense 42 during the operation of the automatic refractor, as explained in U.S. Patent 3,992,087.

Computer 46 also controls a target position motor 50 which in turn moves the target 30 relative to the eye 12. The target 30 is first put in a focused position relative to the eye 12. The target 30 is then moved so as to appear slightly blurred to eye 12. This has the effect of relaxing accommodation of the eye 12. This is explained in greater detail in U.S. Patent 3,836,238.

Reciprocating mirror 24 is driven by motor 52 which is controlled by a position control circuit 54 under the control of computer 46. Similarly, computer 46 controls the intensity of the light source 20 through a light intensity control circuit 56.

Movement of the subject's eye 12 is observed by means of a television camera 58 which is directed at the eye 12 through a focusing lense 60. A televison signal is sent from generator 70 to a television monitor 62 via a video mixer 64. The video mixer 64 enables the computer 46 to display alphanumeric and other graphical information on television monitor 62.

The operation of the improved visual acuity tester of the present invention will now be explained. The visual acuity test begins at the completion of the objective test of the automatic refractor. The automatic refractor sets the sphere, cylinder, and axis of the cylindrical lense 26 and focusing lense 42 in accordance with the determination made for the refractive error of the patient's eye 12. With most patients the lense setting will give the subject 20/20 vision, but as explained above, statistically there will be cases when this is not the case.

Target 30 is set at 1.5 diopters more positive than the most positive axis setting determined by the automatic refractor. This will cause the subject's eye 12 to relax accommodation. The patient is then told to look at the center of the target and when he sees a small dot of light moving across the target, he is to follow the dot back and forth with his eye.

After the operator initiates the test, the target

spot of light begins scanning at an intensity level corresponding to less than 20/20 vision, such as 20/15. This will be at an intensity insufficient to be seen by most subjects. The moving spot sustends an angle of two arc minutes. This angle corresponds the size of the bar and space in the letter E on a Snellen Chart for 20/20 vision. In one actual embodiment it is presented against a background level of 32 apostilbs which corresponds to the background level used in a Goldmann perimeter. This level is considered to be photopic or daylight vision. For a 2 minutes of arc diameter spot, the minimum detectable spot for a normal eye is about 40 apostilbs with a 32 apostilb background.

The intensity of the spot is increased in 0.1 log unit levels until the suject observes the spot and his eye begins to track it. The subject may be asked to press a switch 66 when he first sees the moving spot of light. Based upon this acutation, the intensity of the light is determined by computer 46 and thereafter the visual acuity of the eye is displayed on television monitor 62.

Alternately, the operator of the tester can signal when the subject first sees the moving spot of light. The operator watches the eye of the subject through the television monitor 62. The computer can be programmed to display a oscillating spot on the television monitor through mixer 64. This oscillating spot corresponds to the actual moving spot of light on the subject's eye. As soon as the operator observes the subject's eye 12 tracking the oscillating spot on the monitor he actuates input switch 68. Thereafter, the computer 46 displays the visual acuity of the subject on monitor 62, based upon the intensity of the light spot when it is first observed. This level will typically be 0.1 log units above the threshold. The spot on the eye continues at the same intensity level one half cycle after the switch 66 or 68 is activated. This is to verify reversal of the eye.

If desired, once tracking is established, the intensity can be decreased in 0.1 log unit levels until tracking is lost. The two endpoints should agree within 0.3 log units. If not, the signal can be increased again until the appropriate endpoint is found.

The visual acuity is correlate to the increase in contrast required to see the target spot of light. Each 0.1 log unit corresponds to one-half line or a standard Snellen Chart for lower ranges. For higher ranges, a separate target or larger size automatically comes on. This target has been correlated to visual acuity in the higher ranges.

Computer 4 stores the correlations between the light intensity of the light 20 and visual acuity based upon prior empirical results.

Instead of the television monitor to allow an operator to view the subject's eye to observe when the eye first tracks the spot of light, various automatic eye movement detectors, well known in the art, can be employed for automated operation.

CLAIMS

1. Apparatus for measuring visual acuity of an eye comprising:

means for providing a spot of light in the view of a subject being tested, initially at an intensity below the subject's visual threshold;

means for increasing the intensity of the light spot;

means for indicating when the subject first observes the spot of light; and

means for determining and displaying the subject's visual acuity based upon the intensity of the light when first observed by the subject.

2. Apparatus as in Claim 1 including means for controlling accommodation of the subject's eye prior to the visual acuity test.

3. Apparatus as in Claim 1 wherein said indicating means comprises a switch which is activated by the subject when the spot of light is observed.

4. Apparatus as in Claim 1 wherein said spot of light is a moving spot of light.

5. Apparatus as in Claim 4 wherein said indicating means comprises a video camera directed at the subject's eye, a television monitor for displaying the subject's eye, and a switch which is activated by the operator when the operator observes on said monitor the subject's eye tracking the moving spot of light.

6. In an apparatus for automatically measuring the refractive error of an eye, including improved means for checking the visual acuity of an eye following the initial determination of the refractive error, comprising:

means for interposing corrective lense settings in the path of the eye being tested, based upon the automatic measurement of refractive error of the subject's eye;

means for providing a spot of light in the view of the subject's eye being tested at an intensity below that which can be seen by the subject;

means for increasing the intensity of the light spot;

means for providing a signal when the intensity of the spot of light is sufficiently great to be seen by the subject; and

means responsive to said signal to determine and display the visual acuity of the subject's eye.

7. Apparatus as in Claim 6 including means for controlling accommodating the subject's eye prior to the visual acuity test.

8. Apparatus as in Claim 6 wherein said signal providing means comprises a switch which is activated by the subject when the spot of light is first seen.

9. Apparatus as in Claim 6 wherein said spot of light is a moving spot of light.

10. Apparatus as in Claim 9 wherein said signal

providing means comprises a video camera directed at the subject's eye, a television monitor for displaying the subject's eye, and a switch which is activated by the operator when the operator observes on said monitor the subject's eye tracking the moving spot of light.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1984. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.