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(54) **Title**: SYSTEMS AND METHOD FOR EYESIGHT REHABILITATION

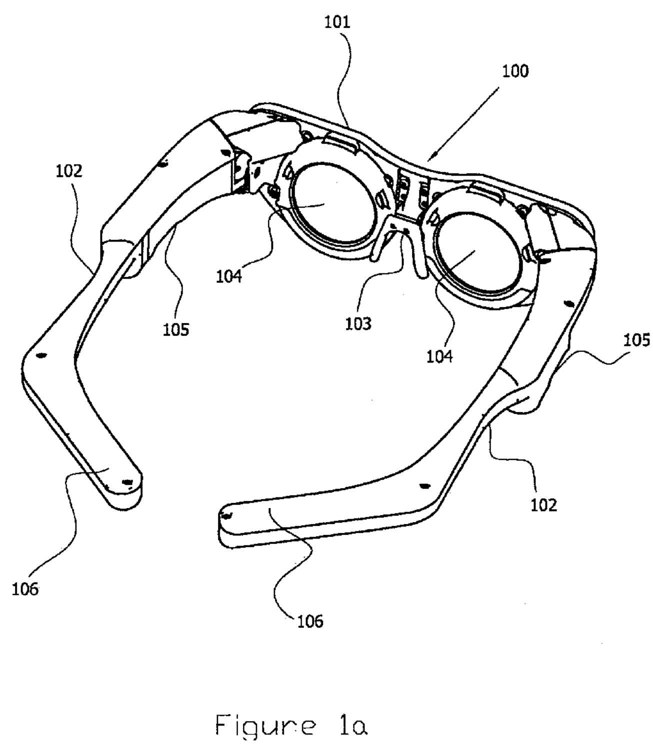

Figure 1a

(57) Abstract: An eye-rehabilitation system and method is disclosed for training and supporting combined action of accommodation and convergence of the brain-eye system of a subject. Eye simulation spectacles, having dynamic lens with variable optical power, are used in combination with a brain stimulation device to train the eye accommodation of the subject. Various embodiments of the eye simulation spectacles are disclosed along with a mnemonic device for use as a brain stimulation device.

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SYSTEMS AND METHOD FOR EYESIGHT REHABILITATION

FIELD OF THE INVENTION

The present invention relates to systems and methods for improving eyesight. More particularly, the present invention relates to training spectacles and exercises for eye-rehabilitation.

BACKGROUND

In the modern world about 80% of population suffers from different vision impairments. Besides disorders such as myopic eye, hyperopic eye or lens astigmatism, 90% of the population suffers from presbyopia, which is a loss of focusing ability with age, after the age of 40. Vision impairments of children and adults are often related to failure in the accommodation function of the eyes. These types of impairments are typically induced by overstrain of the intraocular muscles while performing simple chores, such as reading or working on a computer.

A simple and immediate solution for correction of visual disorders is spectacles (eyeglasses) or contact lenses. Eyeglasses help in the correction of the error in the focal features of the eye lens, and are usually aimed towards compensation of accommodation defects.

A combination of disorders may complicate the use of spectacles or contact lenses because different lenses have to be used to correct different vision impairments. Users wearing spectacles are able to use lenses that are bifocal, trifocal or even multifocal. These solutions are not satisfying to people who need to quickly shift their visual attention from objects near them to objects far away from them (for instance, while driving a car). In addition, bifocal, trifocal and even multifocal eyeglasses have dead-zones and limited field of vision for some distances. Users still have a feeling of permanent discomfort.

Moreover, spectacles can only serve as a temporary solution as they do not fix the underlying problems of accommodation. All conventional spectacles have the disadvantage – the lenses are static. Conventional spectacles only correct the symptom of poor vision, but stop the natural accommodation of the eyes: oculomotor functions go through muscular dystrophy and the accommodation features progressively fails.

In addition to spectacles, there are numerous therapeutic methods for vision therapy or vision training. A broad group of techniques is used in the attempt to improve visual processing and correct binocular, oculomotor, and perceptual disorders. Vision training encompasses a wide variety of non-surgical methods which are commonly divided into two broad categories:

- Orthoptic vision training (orthoptics) - a medical term for eye muscle training procedures which address eye teaming and visual clarity (acuity) only. Orthoptics regard strabismus as an eye muscle problem and treatment is directed toward muscle strength. This training is provided by orthoptists and/or optometrists, who look at the neurological control system of the eyes and thus treat the whole visual system.
- Behavioral vision therapy - a clinical approach for correcting and ameliorating the effects of eye movement disorders, non-strabismic binocular dysfunctions, focusing disorders, strabismus, amblyopia, nystagmus, and certain visual perceptual (information processing) disorders.

Vision therapy programs are individually prescribed to the patient and monitored by an optometrist. These programs involve different exercises and use a combination of training tools such as lenses, prisms, computer programs, and vision training instruments. Through a series of progressive procedures (eye exercises), patients develop and gradually improve their vision abilities. Vision training is remarkably successful in rehabilitating all types of binocular vision impairments including amblyopia (lazy eye), strabismus, esotropia, exotropia or loss of binocular fusion due to hyperopia (farsightedness), myopia (nearsightedness) or astigmatism in one eye.

The major disadvantage of these programs is cost: they require a long training period supervised by a skilled ophthalmologist with suitable medical equipment.

Various devices and methodologies aimed towards the correction, improvement and rehabilitation of binocular vision disorder are used both in the intensive office-based orthoptic therapy and in individual home-based vision therapy programs. Among these are instruments for enhancement of monocular or binocular eye movement control and biofeedback (BF) techniques used to obtain control of involuntary functions.

Other solutions suggest using lens filled with liquid. Some even propose use of liquid lens with non constant or variable focus. Variable focus in prior art publications is achieved by using liquid with different density, a pump that supplies changing amount of liquid to the lens, or a finger operated actuation.

The solutions mentioned above are complicated and expensive. The need remains, therefore, for a simple and affordable system and method for eyesight rehabilitation. The present invention addresses this need.

SUMMARY OF THE INVENTION

Embodiments described herein relate to an eye-rehabilitation system for training and supporting combined action of accommodation and convergence of the brain-eye system of a subject, the system comprising: eye simulation spectacles comprising at least one dynamic lens having a variable optical power; and a brain stimulation device for training the subject to accommodate at least one eye.

According to selected embodiments, the eye simulation spectacles comprise: at least one dynamic lens configured to receive variable quantities of liquid; at least one reservoir in fluid communication with the dynamic lens, the reservoir configured to contain the liquid; and a control unit for controlling the flow of liquid into the dynamic lens.

Optionally, the eye simulation spectacles further comprise at least one foldable side-arm capable of being in a closed or an open configuration.

Typically, the eye simulation spectacles further comprise at least one switching mechanism for switching between modes of operation.

Advantageously, the eye simulation spectacles may further comprise tubing configured to convey the liquid from the dynamic lens and the reservoir. Optionally, the eye simulation spectacles may further comprise at least one tubing adapter connecting the dynamic lens with the reservoir. According to some embodiments the eye simulation spectacles further comprise a blocking mechanism for controlling flow of the liquid between the reservoir and the dynamic lens.

According to other embodiments, the eye simulation spectacles further comprise a flexible control unit configured to adjust flow of the liquid between the reservoir and the dynamic lens. Optionally, the flexible control unit comprises a flexible pipe within a flexible protective sheath.

Where appropriate, the eye simulation spectacles may further comprise receptacles for receiving inserts configured to adapt the optical effect of the dynamic lens.

According to still other embodiments the brain stimulation device comprises a mnemonic device comprising: a chart comprising a plurality of signs; and a mnemonic aid associated with the chart. Optionally, the mnemonic aid comprises a poem. Typically, the mnemonic aid is descriptive of the signs.

Advantageously, the chart comprises at least one row, the row comprising at least one sign. Generally, each row comprises a plurality of the signs of common size. Where the chart comprises a plurality of rows the signs of each row are usually of different sizes. Typically, the signs increase in size from a topmost row to a bottommost row.

Optionally, the mnemonic aid associates data of the mnemonic aid and the signs using easy-to-remember constructs. Accordingly the mnemonic aid may comprise descriptions associated with the chart. Where appropriate, the mnemonic aid comprises a set of rhyming verses.

Another embodiment described herein teaches a method for improving the eyesight using a mnemonic device comprising: step (i) - providing a mnemonic aid associated with a plurality of signs; step (ii) - memorizing the mnemonic aid while associating the mnemonic aid with the plurality of signs; step (iii) - reciting the mnemonic aid with eyes focused on the signs. Optionally, the mnemonic aid comprises a poem. Typically, the plurality of signs have a plurality of sizes and are arranged in a chart having a plurality of rows.

Still another embodiment described herein teaches a method for training and supporting combined action of accommodation and convergence of the brain-eye system of a subject, the method comprising: step (a) – providing an eye-rehabilitation system configured to encourage a user to exercise accommodation of at least one eye; step (b) – presenting the eye-rehabilitation system to a subject; step (c) – the subject using the eye-rehabilitation system to focus the at least one eye upon a plurality of objects thereby exercising accommodation muscles of the eye. Optionally, The method further comprises: step (d) – providing at least one dynamic lens configured to change optical power; and step (e) – the optical power of the dynamic lens changing according to head-inclination of the subject.

Typically, the eye-rehabilitation system comprises: at least one dynamic lens configured to receive variable quantities of liquid; at least one reservoir in fluid communication with the dynamic lens, the reservoir configured to contain the liquid; and a control unit for controlling the flow of liquid into the dynamic lens.

Optionally, the eye-rehabilitation system comprises: a mnemonic device comprising: a chart comprising a plurality of signs; and a mnemonic aid associated with the chart.

BRIEF DESCRIPTION OF T HE FIGURES

For a better understanding of the invention and to show how it may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings.

With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention; the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice. In the accompanying drawings:

Figs. 1a and 1b schematically represent an embodiment of rehabilitation spectacles;

Fig. 2 is a schematic representation of an embodiment of the rehabilitation spectacles integrated into a system for mimicking and supporting the natural function of the eye-brain system;

Figs. 3a and 3b illustrate a cross sectional view of another embodiment of the rehabilitation spectacles;

Fig. 4 illustrates an an embodiment of an elastic liquid-filled lens;

Fig. 5 is a graph showing how the optical power of the liquid filled lens varies with the inclination angle α of the spectacles;

Figs. 6a and 6b are a table and graph respectively illustrating the variation of optical power addition of various embodiments of the lenses having various liquid fillings;

Fig. 7 is a graph showing the variation of optical power addition of embodiments of the multifocal lens having different thickness of polycarbonate membrane;

Fig. 8 illustrates a cut-away isometric view of Automatic Eye Simulator (AES) eyeglasses;

Figs. 9a and 9b show an eyepiece of an embodiment of the rehabilitation spectacles in exploded isometric view (Fig. 9a) and cross-section view (Fig. 9b);

Figs. 10a and 10b show cross sections of an embodiment of a mode selector configured for dynamic mode (Fig. 10a) and static mode (Fig. 10b);

Fig. 11a-e show schematic representations of various embodiments of the control unit in various configurations;

Figs. 12a and 12b illustrate an embodiment of a package-case for use with embodiments of the rehabilitation spectacles;

Figs. 13a-c illustrate an embodiment of the rehabilitation spectacles in three orientations;

Fig. 14 is a graph illustrating the relationship between inclination angle and both the viewing distance and the dependency of optical power;

Figs. 15a and 15b show cut-away isometric and side views respectively of another embodiment of the Automatic Eye Simulator;

Fig. 16 schematically represents the main elements of an embodiment of the rehabilitation spectacles including a liquid reservoir;

Fig. 17 schematically represents the main elements of an embodiment of the rehabilitation spectacles comprising a power supply source, and electroactive lens.

Figs. 18a and 18b illustrate an embodiment of a mnemonic device for use in exercises for improving eyesight.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The various embodiments described hereinbelow relate to eyesight rehabilitation systems and their usage to improve eyesight. In particular, various eye-rehabilitation systems are presented which may be used in combination or separately to encourage a user to exercise ocular accommodation. In other embodiments, training methods are presented for eye-rehabilitation using eye-rehabilitation systems such as eye-rehabilitation spectacles, eye simulators, mnemonic aid devices and the like as described below. It will be appreciated that such eye-rehabilitation devices may be of significant benefit to the visually impaired and may further benefit the health of the well-sighted.

EYE-REHABILITATION SPECTACLES

Reference is now made to Figs. 1a and 1b representing an embodiment of a pair of rehabilitation spectacles 100. Fig. 1a illuminates the components of the embodiment the rehabilitation spectacles 100 and Fig. 1b shows how the rehabilitation spectacles 100 are typically worn by a user 10.

When worn, the rehabilitation spectacles 100 may be used to help the eye-brain system of the user to naturally improve visual ability. Accordingly, various embodiments of the rehabilitation spectacles 100 may serve as a training device for the ocular muscles thereby improving oculomotor function and accommodation in the user's eyes.

The rehabilitation spectacles 100 include a rim 101, two side-arms 102, two dynamic lenses 104, two earpieces 106, a bridge 103 and two mode selector switches 105. The rim 101 serves as a frame for holding the dynamic lenses in place. The side-arms 102 are configured to align the lenses 104 opposite to the user's eyes. The dynamic lens 104 according to an exemplary embodiment of the rehabilitation spectacles may be liquid lenses as are disclosed in Israel Patent No. 151592, which is incorporated herein by reference. Accordingly, two elastic transparent membranes (not shown) are provided, forming a cavity therebetween and a transparent liquid may be introduced into the cavity to produce the liquid lens. The elastic membranes are adapted to change their curvature such that the optical power of the dynamic lens 104 is adjustable.

EYE-BRAIN SIMULATION CONTROL

Reference is now made to the schematic diagram of Fig. 2 illustrating how embodiments of the rehabilitation spectacles 100 (Fig. 1a) may be used to mimic and support the natural function of the eye-brain system. A dynamic lens 201 is positioned in front of a user's eye 208 and works in conjunction with the intraocular lens 202 to form a dynamic optical system focusing light onto the retina 203. Neural signals passed from the retina 203 to the brain 204 via the optic nerve bundle are typically interpreted by the brain 204 as an image. The brain 204 may also provide reflex feedback to the ciliary muscles (not shown) thereby controlling shape of the intraocular lens 202 and consequently, the accommodation of the eye 208.

It is a particular feature of embodiments of the rehabilitation spectacles 100 that a control unit 205 is provided which mimics the feedback function of the brain 204. Furthermore, various methods are disclosed hereinbelow by which embodiments of the rehabilitation spectacles 100 may be used to train brain-eye system to improve the efficiency occular accommodation. Such methods include the use of mnemonics to assist a user to remember a series of symbols presented upon a chart such that the brain may anticipate the symbol being viewed by a user and to accommodate accordingly.

Alongside accommodating the eye 208, a viewer generally responds to the brain's interpretation of an image by a head-tilt motion. It is noted that this head-tilt need not be a voluntary response and viewers often continue to tilt their heads by reflex until the sharpest image is interpreted by the brain 204. The control unit 205 of the rehabilitation spectacles 100 may be configured to detect the head-tilt motion of the user and to adapt the optical power of the dynamic lens 201 accordingly.

The head-tilt reflex is a complex vestibulo-ocular reflex which may be responsive to the human visual system. Combination of a dynamic lens 201 and the natural biological human eye-brain system compose a dynamic optical system, which is controlled by these native vestibulo-ocular reflexes. Reflex coupling between human visual system and the control system of embodiments of the rehabilitation spectacles may provide continuous feedback for adjusting the optical power of the dynamic lens according to the sharpness of image on the retina. Such feedback may mimic the natural accommodation of the eye and may therefore be perceived by the brain as a native.

It will be appreciated that the optical power of the dynamic lens 201 is influenced by a plurality of factors such as lens dimensions, lens shape, refractive index of its material and the like. The dynamic lens 201 is selected such that at least one of these factors may be adjusted by the control unit 205 in response to the head-tilt motion. Accordingly, in one embodiment, the control unit 205 may be configured to control the flow of liquid between a fluid reservoir 206 and a dynamic lens 201. In this way, the control unit 205 may adjust the shape and therefore the optical power of the dynamic lens.

According to selected embodiments of the dynamic lens 201 the adjustment response time of the optical power of the dynamic lens 201 is greater than the response time of the natural accommodation of the eye 208. Using such embodiments forces the eyes to make additional stretches to achieve a better focus on the retina, while the optical power of the dynamic lens 201 is changing. The resulting continuous actuation of the eyes may provide a training effect for the oculomotor system. In addition, a person wearing an embodiment of the rehabilitation spectacles 100 may gradually and unconsciously develop dynamic visual reflexes for automatic focusing of the eyes at different distances rather than the inactive behavior encouraged by spectacles of the prior art. In certain embodiments the response time for the dynamic lens 201 may itself be adjustable to suit the needs of the user.

It is noted that the psychological aspect of vision deterioration typically causes the person having vision problems to suffer from psychological vision strain. This may present as continual psychological discomfort as a result of overstraining the eyes in an attempt to discern objects sharply. Such a strained psychological state may lead to uniform or non-uniform strain of near-eye muscles. Embodiments of the rehabilitation spectacles 201 may provide comfortable viewing of objects at any distance without psychological strain. The lack of psychological strain may provide motivation to the brain 204 to activate all physiological processes in the biological system of vision. Where the response time for the dynamic lens 201 is adjustable, the rehabilitation spectacles 100 may be adjusted to selectively comfort and challenge the eyes as required. Thus, users may gradually rehabilitate their eyesight.

MULTIPLE MODE DYNAMIC LENSES

Typically, a mode selector 105 is provided upon at least one of the side arms 102 and may be configured to switch the rehabilitation spectacles 100 between static mode and dynamic mode. In static mode the rehabilitation spectacles 100 may behave as standard fixed lens eye glasses. It is noted that the dynamic lenses may be fixed at a plurality of settings and that the mode selector may further provide controls for achieving the desired optical power during static mode.

In dynamic mode, the rehabilitation spectacles 100 may support and train the user's eye-brain function as described hereinabove. The control unit 205 is therefore typically configured to sense head-tilt motion and provide feedback to the dynamic lenses 104. Optionally the response time of the dynamic lenses 104 may be selected via a user interface.

Thus the rehabilitation spectacles 100 may serve as a device for training, correction, improvement and rehabilitation of binocular vision disorders. Among others, such disorders may relate to amblyopia (lazy eye), strabismus, extraocular muscle balance, refractive errors and accommodative insufficiency. Additionally, the rehabilitation spectacles 100 can be used for improvement of stereoscopic vision. The rehabilitation spectacles 100 allow exercise of native accommodation reserve in a wide range of eyes refractive errors.

It is noted that embodiments of the rehabilitation spectacles 100 may be provided for home-based training of users. Because the overall shape and appearance of the rehabilitation spectacles 100 is not dissimilar to that of conventional eyeglasses, they may be comfortable for the wearer. Furthermore, vision training using the device may be undertaken by a novice with no specialist knowledge or skills.

DYNAMIC LENS ADJUSTMENT

Reference is now made to Figs. 3a and 3b illustrating a cross sectional view of another embodiment of the rehabilitation spectacles 300. The spectacles comprise a lens cavity 322, tube adapters 324, 325 a reservoir 316, a control unit 318. The lens 322 is formed by a rigid ring 313 formed by the lens rim 101 (Fig. 1) and two transparent elastic membranes 320. A first tubing adapter 324 maintains fluid communication between the lens cavity 322 and the liquid reservoir 316, which runs the length of the side arms eyeglasses shaft 102 (Fig. 1). A second tubing adaptor 325 maintains fluid communication between the liquid reservoir 316 and the control unit 318.

The control unit 318, adapters 324, 325, reservoir 316 and lens cavity 322 typically form a closed, leak-proof system filled by a transparent liquid 314. It is noted that, in preferred embodiments, the refractive index of the transparent liquid is substantially similar or identical to that of the containing membranes. Matched refractive indices may provide a lens having substantially constant index of refraction at any location along the membrane thickness thereby reducing refraction distortions.

The control unit 318 may of embodiment of Figs. 3a and 3b includes a fluid filled flexible bladder 328 configured to allow liquid 314 to flow therefrom when tilted as shown in Fig. 3b. Alternatively, a control unit may be hydraulically connected to the reservoir via the compact adjustment valve. Such adjustment valves may further provide one-way communication with the atmosphere.

Whilst not wishing to be bound by theory an analysis of the optical system is presented hereinbelow. Variation in the optical power is optional. Optical power of a liquid-filled elastic lens depends on the radius curvature of thin membranes. The elastic membranes 320 may be stretched by the liquid pushed inside the lens cavity 322 and as it can be assumed have approximately spherical shape with radius of curvature R. The optical power D (expressed in diopters) of such a symmetrical convexo-convex thin lens is:

$$D = \frac{2(n-1)}{R} \qquad (1)$$

where n - is the relative refractive index of the lens.

The degree of stretching of membranes and corresponding optical power of lens depends on the amount of liquid introduced into the lens cavity, which may be determined by the pressure of liquid in the lens. Adjustment of the elastic lenses may be provided by a simple tilt of the eyeglasses rim, i.e. by means inclination of head downward and forward with the respect to the horizontal plane as illustrated in Fig. 3b.

In the initial state as shown in Fig. 3a, the optical axis of the device 330 is parallel to a horizontal plane. This is typical of the case when the user is observing distant objects. The lens optical power is determined by some initial amount of liquid inside the lens cavity. This initial amount of liquid is determined by initial stretch forces of elastic membranes equilibrated by external atmospheric pressure P_o and initial pressure ΔP generated by adjusting a valve. Thus, the initial internal pressure inside the lens in the horizontal position is equal to:

$$(P_o + \Delta P)$$

When the eyeglasses shaft with overall length L is tilted on the angle α to the horizontal plane 320, the pressure inside the lens cavity 322 increases due to the increase in the liquid column height in accordance with the following relation:

$$P = (P_o + \Delta P) + \rho g L \sin\alpha \qquad (2)$$

where ρ - is the density of liquid, g - acceleration of free fall.

In other words, under influence of gravity an extra amount of liquid is forced into the lens. As a result, the radius of curvature of the elastic lens increases. According to Pascal's principle - any externally applied pressure is transmitted to all parts of the enclosed fluid, i.e. the additional pressure P_L inside the lens cavity 322 is equal to gravity pressure:

$$P_g = \rho g L \sin\alpha = P_L \qquad (3)$$

In the closed hydrostatic system of embodiments of the rehabilitation spectacles an amplification of gravitational force F_g may be achieved. Indeed, if the cross-sectional area of the shaft 102 is S_1 and the cross-sectional area of the membrane is S_2, the additional force F_L applied to the lens membrane is:

$$F_L = \frac{S_2}{S_1} F_g = \frac{D_2}{D_1} F_g \qquad (4)$$

where D_1 is the diameter of the channel 405 and D_2 is the effective diameter of the membrane.

In one experimental model of the rehabilitation spectacles 100, the values of D_1 and D_2 were 3 millimeters and 39 millimeters respectively. Thus a force amplification factor of thirteen might be achieved. For example: a liquid column of silicone oil having a density of $\rho = 0.986$ kg/m^3 and a mass of about 3.2 grams will act on the membrane with the force of 42 grams.

The degree of stretching of membranes and corresponding optical power of the lens depends on two main parameters: (i) the amount of liquid inside the lens cavity 322, which is determined by additional pressure of liquid P_L and (ii) the mechanical properties of the elastic membranes 320 (tensile modulus ε).

$$R = f(P_L, \varepsilon) \qquad (4)$$

The shape of a lens filled with refractive liquid may be calculated according to Sugiura and Morita calculation and by Knollman et al. calculation. Such calculations are based on the assumption that an elastic lens takes the form of a paraboloid and deflection of a point of elastic film located at the distance x from the optical axis can be described as:

$$y = \frac{P}{4T} \cdot (r^2 - x^2) \qquad (5)$$

where T is the absolute value of the tension in the film per unit length, r is the lens radius of curvature, and P is the pressure inside the lens (see Fig. 5).

Reference is now made to Fig. 4 illustrating an optical medium of the elastic liquid-filled lens. The shape of the lens is a sphere at the central area, and the curvature depends on the liquid pressure and the tension of the film as:

$$R = \frac{2T}{P} \qquad (6)$$

Equation (5) was obtained by assuming that the effect of gravity is negligible and that the elastic film is thin. Therefore the absolute value of tension T in the film is the same across the film. The tension T of the film can be evaluated if appropriate equations containing this parameter are known. According to the theory of elasticity we can write:

$$\varepsilon b = \frac{T}{h} - m \cdot \left[P + \frac{T}{h}\right] \qquad (7)$$

where h is the thickness of the film, m is Poisson's ratio of the film, b is the strain along the film, and ε is Young's modulus of elasticity of the film.

With the approach developed by Sugiura and Morita the strain in the film can be found as:

$$b = \frac{(S - 2r)}{2r} \qquad (8)$$

where S is the length of the diametric arc ABC of the elastic film under pressure P inside the lens and r is the radius of the lens rim.

Length S can be evaluated from:

$$S = 2\int_0^r \{\cos[\arctan(Px/2T]\}^{-1} dx \qquad (9)$$

The equation for the tension T can be found from Eqs. 7 - 9:

$$T^3(\frac{m}{h}-\frac{1}{h})+T^2mP+0.04167P^2r^2=0 \qquad (10)$$

From this equation the dependence of $T = f(P,h,r)$ was numerically calculated and fitted by polynomial function:

$$T = 400.002 + 1.38\cdot10^{-2}\cdot X - 1.46\cdot10^{-3}\cdot X^2 + 1.36\cdot10^{-6}\cdot X^3 \qquad (11)$$

where $X = P(\alpha)$.

Using equations (1), (5) and (11) the optical power $D(\alpha)$ of elastic liquid filled lens can be found.

$$D(\alpha) = \frac{(n-1)}{T(P,h,r)}\cdot(\rho g L \sin\alpha) \qquad (12)$$

Reference is now made to the graph of Fig. 5 showing how the optical power of the liquid filled lens varies with the inclination angle α of the spectacles 100 with respect to the horizontal axis. The dependence of optical power addition of the liquid filled lens as a function of inclination angle α, calculated according to equation (12), is presented. Experiments used rehabilitation spectacles having the next technical specification:

- membrane radius r .... 19.5 mm
- membrane thickness h ....0.2 mm
- shaft length L .... 15 mm
- density of optical liquid ρ.............. 968 kg/m^3 (silicone oil DC200)
- refractive index n......................... 1.405 (silicone oil DC200)
- membrane tensile modulus ε .... 2.35 GPa (polycarbonate foil)

It is noted that up to an inclination of 45 degrees there is a good matching between calculation and experimental data. Deviation from experimental points for large inclinations (angles >45 degrees) may relate to some model simplification. It is noted that the calculations presented here do not take into account changes of the liquid column height over time during the inclination of the spectacles, the nonlinear membrane tensions or the frictional force acting between the liquid and the internal walls of the shafts. The graph of Fig. 5 shows that from a horizontal position (α=0°)

to inclined position of about 45°, the optical power of lenses is changed in the range of 0 to 1.75 diopters.

From equation (12) it follows that the range of optical power variation of the rehabilitation spectacles depends on three main parameters: (i) the density of the liquid ρ, (ii) the refractive index of the liquid and (iii) the mechanical properties of the elastic membrane. The transparent optical liquids may therefore be selected for high density and a refractive index close to the refractive index of elastic membranes such as polycarbonate foil which has a refractive index of 1.58. The refractive index matching is also important for reduction of possible optical distortions of the lenses.

Reference is now made to the table and graph of Figs. 6a and 6b illustrating the variation of optical power addition of various embodiments of the lenses having various liquid fillings. The liquid for filling the lenses is preferably a transparent substance with a high refractive index close to the refractive index of the selected elastic membranes. Organic oils, high hydroxyl group, viscous organic liquids such as glycerol and immersion oils for regular microscopy may be used as filling liquids as required. In the table of Fig. 6a, a list of optical liquids is presented that may be used as a filling agent for lenses of the rehabilitation spectacles. The list which is not intended as exhaustive includes optical liquids such as: low, middle and high viscosity silicone oil DC-200, various concentrations of glycerine ranging from 30% solutions to 100%, paraffin oil, and various viscosities of immersion oil for light microscopy.

Fig. 6b indicates a possible liquid-selection strategy for obtaining various ranges of optical power addition. For example paraffin oil, having relatively low density, may be used for small (from 0 to 1.5 diopters) variation of optical power. For variation of optical power addition in the range of 0 to 3 diopters, the immersion oils having higher density and high refractive index may be used.

Reference is now made to the graph of Fig. 7 showing the variation of optical power addition of multifocal lens for different thickness of polycarbonate membrane. The elastic membrane is an important element of the liquid filled lenses. It has been found that LEXAN polycarbonate films have unique features making it particularly well suited for this application. It is noted, however, that other types of elastomers may be preferred as suit requirements.

Elastomers in general and polycarbonate in particular may sustain relatively large strains within their elasticity ranges. Moreover, polycarbonate also has a large "Hookean" range within which the stress/strain curve is proportional. In this range of small deformation forces, the polycarbonate foil is elastic and restores its original form upon release of stress. Polycarbonate foils have optical properties, heat resistance, dimensional and ultraviolet stability suitable for use in multifocal lenses, which have the required range in optical power and which do not require excessive force to operate. Polycarbonate films are available having various thicknesses, high-gloss surface-finishes and masking materials preventing surface damage and contamination during shipment and processing. The graph of Fig. 7 illustrates the variation of optical power addition for different thickness of polycarbonate films. Polycarbonate film of thickness 0.2 mm was used in the prototype. A simple variation of thickness of the elastic membrane can provide the variation of optical power additions for the lenses in a wide range of practically important cases.

AUTOMATIC EYE SIMULATOR

Reference is now made to Fig. 8 illustrating a cut-away isometric view of Automatic Eye Simulator (AES) eyeglasses 800 including a hydrostatic system in accordance with another embodiment of the rehabilitation spectacles. The hydrostatic system of AES represents leak-proofed system filled by transparent liquid. This system includes a flexible lens cavity 805 flexible tubing 804 hermetically connected to the lens cavity through adapter 803 from one side and to a control unit 808 from the other one. The flexible pipe 804 passes through a mode selector 806 enabling the Automatic Eye Simulator to be switched from dynamic to static mode. These components may be placed within a foldable side-arm, temple 802 and closed at the top by a protective cover 809.

EYEPIECES

Reference is now made to Figs. 9a and 9b showing an eyepiece 900 of an embodiment of the rehabilitation spectacles in exploded isometric view (Fig. 9a) and cross-section view (Fig. 9b). The right eyepiece 900 shown includes a bridge 904 for affixing to a matching provides left eyepiece. The bridge 904 further provides a mounting for nose pads. A liquid lens is formed by two juxtaposed membranes 905 that are spaced about their circumference by main frame body 901 so as to define an internal lens cavity 916 between the membranes. Optionally, the membranes 905 may be cemented or welded to the frame body 901 so as to establish a leak-proof connection. Typically, the lens cavity 916 is filled with transparent liquid fluidically connected through hollow channel 907 and adaptor 903 to the rest hydrostatic system of lens placed in the foldable temple. A ring 906 made from light metal, such as aluminium, titanium or the like, typically provides additional rigidity to the frame 901. An external frame casing 902 is placed in front of spectacles frame hiding the front mounting parts such as fasteners, inserts, screws and the like.

Thus, the body of the elastic liquid-filled lens consists of a rigid ring sandwiched between two transparent elastic membranes to form a lens cavity. A leak-proof connection is provided between the rigid ring and the thin elastic membrane.

OPTICAL ADJUSTMENT INSERTS

According to selected embodiments, optical inserts may be mounted in front of the elastic lens. For example, referring particularly to Fig. 9b, a constant optical power lens 909 may be introduced into a lens holder 910 to provide additional functionality including: (i) the protection of the external membrane from mechanical damages, and (ii) the provision of a shift in the adjustable range of elastic lenses for a specific wearer requiring a high initial positive (presbyopia) or negative (myopia) diopter numbers.

It is noted that, for many exercises using the AES, particularly with the head inclined downwards and forwards with respect to horizontal plane, the liquid lenses are configured convexo-convex lenses having a certain range variation of positive optical power addition. For different cases of presbiopia, when for specific user requires the specific lenses (high positive dioptre for distanced seeing), an adjustable range of optical power addition of ASE can be shifted by using of additional constant lens 909. This additional lens is positioned adjacent to liquid lens. The constant lenses 909 are prescribed for individual user optical lenses that are adapted to increase or decrease the optical power of the liquid lens or may be a zero dioptres lens that is adapted solely to protect the membranes of the liquid lens. For example, if the user for training procedures needs in glasses with variation of optical power in the range of $+1 \div +2.5$ the constant optical power lens of +1 dioptry must be mounted. For the most important practical cases of myopia a constant convexo-concave lens must be mounted adjacent to elastic liquid lens. For example, if the user needs in glasses with variation of optical power in the range of -2.5 ÷ -1 dioptres the constant optical power lens of -2.5 dioptry must be mounted. The lens 909 by means of ring 911 tightly placed inside the lens holder 910 providing protection of lens from mechanical damages. Holder 910 has some special recesses and ledges providing fast and comfortable mounting and replacement of lens on the AES spectacles frame.

Optionally the AES may include a set of one or more replaceable insert slides 913 may be sandwiched between two thin frames 912 to provide desired optical results. Such inserts may be opaque, semi-transparent, polarized, colored, transparent colored films or the like.

Optionally, replaceable inserts may be provided for various types of vision training. For example, non transparent inserts may be used for exercising the left or right eye individually while colored inserts may be used for exercising improvements in stereoscopic vision. Accordingly, a slide holder 914 is mounted on the internal face of the spectacles frame having a slot providing ready access for inserting of slides into the spectacle frame. Inserted slides may be fixed in place by springing ball 915.

MODE SELECTOR

Reference is now made to Figs. 10a and 10b showing cross sections of a mode selector 1000 configured for dynamic mode (Fig. 10a) and static mode (Fig. 10b). The mode selector 1000 includes a blocking mechanism 1040, a guide-track 1030, a flexible tube 1020 and a backing wall 1010.

With particular reference to Fig.10a, showing the mode selector 1000 configured for dynamic mode, the flexible tube 1020 is unobstructed allowing fluid communication therethrough. Thus, in dynamic mode, liquid may pass through the mode selector 1000 in order to change the optical power of dynamic lenses (not shown).

With reference to Fig. 10b, the mode selector 1000 may be adjusted to static mode by moving the blocking mechanism 1040 along the track 1030 such that the flexible tube 1020 is squeezed against the backing wall 1010. It will be appreciated that in this configuration liquid may not readily pass through the flexible tubing 1020. Thus in static mode, the quantity of liquid in the dynamic lens which consequently maintains a fixed optical power. According to various embodiments, the blocking mechanism 1040 may be configured as a grooved wheel protruding from the side-arm of the rehabilitation spectacles. Other blocking mechanisms may occur to suit requirements

Optionally, the spectacles are provided a mode selector for adjusting and blocking the liquid flow between the liquid lenses and the reservoir.

DYNAMIC MODE APPLICATIONS

Reference is now made to Fig. 11a showing a schematic representation of the external features of an embodiment of a control unit 808 for use with embodiments of the rehabilitation spectacles. The control unit 808 of the embodiment includes a body 2010, a connector 2020, a cover 2040 and an inlet 2060.

Referring back to Fig. 8. The control unit 808 may be incorporated into the side-arms 802 of the spectacles 800 to the control the flow of liquid into the dynamic lenses according to the tilt of the head of the user. Accordingly, the connector 2020 is provided for connecting the control unit 808 to tubing 804 within the side-arms 802 of the spectacles 800.

Cross sections of two alternative embodiments of the control unit 2000, 2000′ are represented in Fig. 11b and Fig. 11c. With particular reference to Fig. 11b, the housing 2010 of the control unit 2000 contains an air cavity 2012 and a flexible bladder 2070. The pressure of the air cavity 2012 is maintained at atmospheric pressure by the provision of air-holes 2050 within the cap 2030. The flexible bladder 2070 may be filled with liquid via the inlet 2060 which may be sealed by a sealing member such as a screw-cap 2030, a valve or the like.

The flexible bladder 2070 serves as a tilt-sensitive liquid dispensing mechanism configured to dispense liquid into the dynamic lens according to the tilt-angle of the spectacles. A second tilt-sensitive liquid dispensing mechanism is represented in the alternative embodiment 2000′ of Fig. 11c. The flexible bladder 2070 of the first embodiment 2000 is replaced with a flexible bellow 2080 having a concertina style.

The functionality of the control unit 2000, 2000′ is outlined with reference to Figs 11d and 11e respectively. According to the examples presented, when in a horizontal orientation, the control unit 2000, 2000′ dispenses liquid to the dynamic lens such that it adopts a neutral configuration. When the head is tilted upwards the control unit 2000, 2000′ dispenses liquid from the dynamic lens such that it adopts a concave configuration and are adjusted to function as myopic lenses. When the head is tilted downwards the control unit 2000, 2000′ dispenses liquid to the dynamic lens such that it adopts a convex configuration and are adjusted to function as presbyopic lenses.

FOLDABLE SPECTACLES

Reference is now made to Figs. 12a illustrating an embodiment of foldable rehabilitation spectacles 3000 in their folded configuration. In contradistinction to prior art spectacles having liquid lenses, the embodiment of the foldable rehabilitation spectacles 3000 includes a hinged connection 3020 between the adaptor and the side-arms 3060. Flexible tubing is provided which passes through the adaptor and side-arms 3060 for conveying the fluid from the liquid lenses in rim and the reservoir at the end of side-arm 3060.

In order for the folded spectacles to be easily stowed, the side-arms 3060 may be folded as shown in Figure 12b such that the side-arms do not overlap. The side-arms 3060, when folded, are on the same surface relative to rim 3080 thereby reducing stowage volume.

Reference is now made to Fig. 12b illustrating an embodiment of a package-case for use with embodiments of the rehabilitation spectacles. The package-case 3010 is configured such that a user can insert the spectacles 3000 in a specific orientation. The whole package-case is configured to be placed on a surface when the spectacles are not in use preventing or reducing movement of the liquids inside the spectacles. It will be appreciated that limiting movement of liquid within the lenses, may reduce deformation of the liquid lens membranes. The package-case 3010 may protect the spectacles and the other components of a simulator system placed therewithin. The internal part of package-case 3010 includes a housing 3030 for the spectacles and additional docks 3040, 3050 for holding additional components for use with the simulator such as additional inserts, lenses, filters or the like.

STATIC MODE APPLICATIONS

Reference is now made to Figs. 13a-c illustrating a further use of an embodiment of the rehabilitation spectacles. The rehabilitation spectacles act as universal eyeglasses that can be used for correction of visual defects such as presbiopya and myopia. Dynamic lenses used in the rehabilitation spectacles may have a wide range of variation of optical power addition for example from +2.5 D to -2.0 D and may be suited for the most practical cases. As required by the user, the rehabilitation spectacles may be easily configured to function as conventional eyeglasses having fixed optical power.

For example, as illustrated in Fig. 13c, in the case of presbiopia (far-sightedness) users looking through dynamic lenses at reading material (book or magazine), may incline the head down until the image and text is sharp. The mode selector, as described above, may be used to switch the spectacles from dynamic to static mode. In static mode, the optical power of the spectacles is fixed. Thus a presbiopic (farsighted) user may obtain the reading glasses required. In the case of myopia (nearsightedness) switching to the static mode is realized similarly. As shown in Fig. 13a, the user raises the head up to look at distant objects such as clouds, the tops of trees, buildings or the like. Furthermore, embodiments of the rehabilitation spectacles may function as multifocal eyeglasses.

Thus embodiments of the rehabilitation spectacles provide the user with a device for comfortable and unstrained viewing of objects at many distances. In part this is due to the dynamic optical system controlled by native vestibulo-ocular reflexes which works similar to the natural accommodation of the eyes and may therefore be perceived by the user as native.

Reference is now made to the graph of Fig. 14 illustrating the relationship between inclination angle and both the viewing distance and the dependency of optical power. The multifocal functionality of the spectacles is also illustrated on the same graph. The dependence of optical power of dynamic lenses as a function of inclination angle α is calculated for the myopic and presbyopic cases. Accordingly, the two solid lines present two important applications of the spectacles functioning as multifocal eyeglasses correction of presbyopia and myopia.

HEAD-TILT INDEPENDENCE AND FINE ADJUSTMENT

Reference is now made to Figs. 15a and 15b showing cut-away isometric and side views respectively of another embodiment of the Automatic Eye Simulator (AES) eyeglasses 3100. The AES 3100 includes a liquid lens cavity 3105, flexible pipe 3104, mode selector 3106 and flexible control unit 3116. The flexible control unit 3116 is affixed to the end of a flexible metal tube 3112 mounted upon the foldable side-arm 3102. Foldable side-arm includes a separate ear duck 3110 for comfortable wearing of glasses on the head. A flexible pipe 3104 passes through the flexible metal tube 3112 and is hermetically connected to the adjusting valve placed inside of control unit member 3116. The flexible metallic tube 3112 serves as a protective sheath and is selected such that it provides allows the control unit 3116 to bend freely in any direction without damaging of internal flexible pipe 3104. This technical solution provides additional fine control of optical power of liquid filled lenses by the bending of the tube 3112 upwards or downwards.

According to embodiments described hereinabove, the optical power may be controlled by tilting the entire side-arm of the eyeglasses, typically by means inclination of head downwardly and forwardly in the respect to horizontal plane. It will be appreciated that such an embodiment may not always be appropriate, for example where the user is unable to make a sufficient head-tilt motion or when additional adjustment of optical power may be inconvenient or uncomfortable.

The flexible control unit 3116 allows such adjustment to be made independently from the head-tilt. With particular reference to Fig. 15b, the flexible control unit 3116 is shown in three possible configurations. The AES for the specific user may initially adjust the spectacles for viewing of distant objects when the head is not inclined, for example. However, when the user is looking horizontally at a close computer display the spectacles fail to produce a clear image. In this situation the fine adjustment of lenses may be effected by bending the flexible tube 3112 upwards or downwards leading to corresponding variation of pressure of liquid inside the lens cavity 3105 resulting in a variation of optical power. Optionally, a fine adjustment member may provide variation of optical power typically in the range of -1 to +1 dioptres.

It is further noted that embodiments of the fine adjustment member enable adjustment of optical power for left and right eye independently. It is thus a feature of such embodiments of the AES that they can be used to correct the initial adjustment of the AES for a specific user with differing focal features of left and right eyesigh.

LIQUID LENS OPTICAL POWER CONTROL

Reference is now made to the block diagram of Fig. 16 schematically representing the main elements of an embodiment of the rehabilitation spectacles comprising a liquid reservoir. A lens 4010 is attached to the side-arms of the spectacles. It is a feature of the specific embodiment that the spectacles include a liquid reservoir 4040 containing the liquid to be transferred to the lenses. The reservoir may be an integral part of the spectacles or an external unit that can connect to the spectacles for filling it with the liquid. The spectacles may include a liquid flow actuator 4030 that controls the two directional flow of the liquids as well as a blocking member 4050, such as a mode selector or the like, used for controlling the liquid flow. Liquid flow actuator 4030 is configured and operable to connect to an actuator control unit 4070 that controls the amount of liquid to be flown. The information regarding the requested flow is received from inclination sensor 4060 that senses the movement of the head as well as from an Accommodation Time Control Unit (ATCU) 4080. The ATCU may adjust the response time for the optical power of the dynamic lens.

METHOD FOR CONTROL OF VARIABLE OPTICAL POWER LENS

Reference is now made to the block diagram of Fig. 17 schematically representing the main elements of an embodiment of the rehabilitation spectacles comprising a power supply source. It is a feature of this embodiment that an adjustable voltage or current power supply unit 5040 is provided to control the optical power of lens 5010. In a preferred embodiment of the present invention, the lens 5010 is electroactive. The lenses optical power is changed due to change in the voltage or current that supplied to lens. The lens 5010 may be any lens having variable optical power. For example it may be lenses that are made from liquid crystal that responds to electric field so that the area of the lens is broken up into many small pixels and a different voltage is applied to each pixel. It may be also electroactive optical polymers or thin organic and inorganic layers with variable refractive index and also microlens matrix.

A power supply unit 5040 receives input from a switch member 5060 and from a microprocessor 5030. The switch member 5060 is configured and operable to switch the mode between dynamic or static mode. The switch member 5060 provides a signal to the power supply unit 5040 and to a microprocessor 5030. The microprocessor 5030 may comprise an integrated ATCU and is configured to receive input from an inclination sensor 5050 that senses the movement of the head. When the power supply unit 5040 receives the input from the switch member 5060 and from the microprocessor 5030, an adjusted amount of voltage or current is supplied to electroactive lens resulting to corresponding changes in optical power.

EYE-REHABILITATION METHODS

Referring now back to Fig. 2, it is noted that accommodation of the eye 208 involves the brain 204 and the ciliary muscles controlling shape of the intraocular lens 202. Exercise may be most effective when performed while using the eyes to focus in as natural manner as possible. Consequently, eyesight rehabilitation may be assisted by exercising the ciliary muscles as well as training the brain 204 to respond effectively. The rehabilitation methods disclosed hereinbelow are directed towards training the brain-eye system to accommodate the eye effectively and may therefore be used to improve the eyesight of an exerciser.

DYNAMIC LENS AIDED REHABILITATION EXCERCISES

For visual training the rehabilitation spectacles may be worn about the head of the user much as conventional eyeglasses may be. Typically, the rehabilitation spectacles are initially adjusted to suit the specific wearer for example requiring an initial high positive (presbyopia) or negative (myopia) diopter numbers. The procedure of adjustment may include the selection of appropriate optical inserts for each eye. Appropriate optical inserts may provide a clear view of distant objects when the user's head is not inclined. Such a procedure may provide clear vision of objects at different distances.

One possible training exercise may be based upon repeated viewing by the user of far and near objects alternately. During the exercises the optical axis of each elastic lens must coincide with optical axis of the corresponding eye. For viewing distant objects (distances of more than 10 m) a user generally raises the head in order to direct the optical axis onto the viewing objects. Thus the axis of the lens-eye optical system lies approximately in the horizontal plane.

Embodiments of the rehabilitation spectacles may be configured to automatically adjust the optical power of the lenses to allow a user to focus clearly upon distant objects. In order to view near objects, for example when reading a book, a user typically inclines the head to an appropriate angle α, which is generally less than 45 degrees. Embodiments of the dynamic lens are configured to change and adapt automatically in response to such an incline so that the optical power allows a user to see sharply. The relationship between an optical power of the lens and the angle of inclination of head α is explained hereinabove. Accordingly, embodiments of the rehabilitation spectacles allow the user to focus upon intermediate objects under transition from position of far viewing ($\alpha = 0$ degrees) to a reading position ($\alpha \approx 45$ degrees).

As outlined hereinabove, the response time of the dynamic lenses may be determined to be greater than that of natural accommodation of eye. Thus, while the optical power of the dynamic lenses changes, the eyes are encouraged to make additional stretches to achieve a better focus. Repeated movements of the head continuously activate the auto-focus mechanism of the dynamic lenses. These, in turn, activate the oculomotor accommodative system of eyes, thus providing them with training. For example, a user may exercise for 25 – 30 minutes a day and may gradually form a dynamic visual reflex of automatic focusing of eyes on objects at various distances. In this manner the user's eyesight may be improved and rehabilitated.

Another possible training exercise disclosed here involves the use of a novel mnemonic device to assist in the rehabilitation of eyesight and vision improvement by exercising the ocular muscles.

Correct functioning of eyes depends on joint action of accommodation and convergence. Failure in accommodation or convergence leads to binocular disbalance and as the result to vision disorders. As noted herein above, the use of conventional spectacles for correction of users' ability to view clear does not improve their eyesight. Moreover, long (durable) wearing of such eyeglasses leads to forgetting and as the result to lose the skill of normal visual work of eyes. Because, improving and rehabilitating of eyesight itself must include both exercises aimed to strengthening the ciliary muscles and exercises aimed to training (regaining) of users to normal visual work of eyes. For purpose of developments and restoration of coordinated functioning of accommodation and convergence of eyes a novel mnemonic device may be used in conjunction with rehabilitation spectacles. Mnemonic devices (auxiliary tables filled by special visual symbols with variable size and form) aid the user in associative memorizing and control of changes in visual perceptions. When user looks through rehabilitation spectacles at the symbols his head is inclined down. Rehabilitation spectacles allow to user to clearly see and recognize the visual symbols and accordingly easy memorize them. The training exercise with using of mnemonic devise may be based upon repeated viewing of mnemonic symbols and far objects alternately. During such exercises the user subconsciously sets (controls) accommodation and convergence and subconsciously perceives feed back between operation of intraocular muscles and sharpness of image of symbols. Such associative memorizing of symbols and continuously perceived feedback provides training of users normal works of visual system of eyes and as a result, the user may gradually improve their eyesight.

Accordingly a mnemonic device is disclosed herein for use in improving the focusing capabilities of the eyes and to improve the eyesight. Furthermore a method is taught for using the mnemonic device in order to improve the eyesight of the user.

MNEMONIC-AIDED REHABILITATION EXERCISE

Reference is now made to Figs. 18a and 18b which illustrate an embodiment of the mnemonic device for improving eyesight. Fig. 18a shows a mnemonic chart 10 provided with a plurality of rows, each row has a plurality of symbols or signs. The size of the symbols displayed in each row is similar, but the size of the symbols changes from row to row. Preferably, the top row of mnemonic chart 10 is provided with signs that are sized to be relatively large at the top of the device while the size of the signs is gradually decreased from line to line downwardly. Thus symbols in the line in the top row are typically largest and the signs in the bottom row are smallest.

Reference is now made to Fig. 18b illustrating a mnemonic aid for use in conjunction with the mnemonic chart 10 of Fig. 18a. Mnemonics are often verbal, typically a poem or a word used to help a person remember an item, sign or action.

Mnemonics rely not only on repetition to remember facts, but also on associations between easy-to-remember constructs and data, for example the rows of symbols in the mnemonic chart 10 are selected according to the principle that the human mind remembers insignificant data attached to spatial, personal, or otherwise meaningful information than that occurring in meaningless sequences.

Using the mnemonic device presented in Figs. 18a and 18b, a method may be used for improving eyesight by exercising the eyes. The method involves exercising the eyes by repeatedly reading the poem 20 and associating the words in the poem with the signs in the mnemonic chart 10. The poem 20 comprises a description or a logical story. A graphic representation of a portion of the words of poem 20 is found in mnemonic chart 10. The step of the reading poem 20 is repeated, and the user is encouraged to memorize the logic and associations of the story described. As the poem 20 is memorized, the exerciser may look at the mnemonic chart 10 and use the associative information he memorized to recognize the signs appearing on the mnemonic chart 10. Since the poem 20 is memorized, the brain can expect what the next words should be and the user recites the poem while looking at the signs on the mnemonic chart 10. Therefore, when looking at the mnemonic chart 10, the eye recognizes the sign that represents the word and the user may succeed in focusing his eyes. By repeating these steps, the user may improve his focusing capabilities and his eyesight. As he proceeds through the rows and the size of the rows is decreased, the user has to focus his eyesight in order to recognize the smaller signs and the recognition of the smaller signs is facilitated by the poem that the user memorized.

Thus various embodiments described hereinabove provide effective techniques for rehabilitating the eye using systems and methods directed towards training the eyes to accommodate on both distant and near objects. The scope of the present invention is defined by the appended claims and includes both combinations and sub combinations of the various features described hereinabove as well as variations and modifications thereof, which would occur to persons skilled in the art upon reading the foregoing description.

In the claims, the word “comprise”, and variations thereof such as “comprises”, “comprising” and the like indicate that the components listed are included, but not generally to the exclusion of other components.

CLAIMS

1. An eye-rehabilitation system for training and supporting combined action of accommodation and convergence of the brain-eye system of a subject, said system comprising:
eye simulation spectacles comprising at least one dynamic lens having a variable optical power; and
a brain stimulation device for training the subject to accommodate at least one eye.
2. The eye-rehabilitation system of claim 1 wherein said eye simulation spectacles comprise:
at least one dynamic lens configured to receive variable quantities of liquid;
at least one reservoir in fluid communication with said dynamic lens, said reservoir configured to contain said liquid; and
a control unit for controlling the flow of liquid into said dynamic lens.
3. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise at least one foldable side-arm capable of being in a closed or an open configuration.
4. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise at least one switching mechanism for switching between modes of operation.
5. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise tubing configured to convey said liquid from said dynamic lens and said reservoir.
6. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise at least one tubing adapter connecting said dynamic lens with the reservoir;
7. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise receptacles for receiving inserts configured to adapt the optical effect of the dynamic lens.
8. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise a blocking mechanism for controlling flow of said liquid between said reservoir and said dynamic lens.

9. The eye-rehabilitation system of claim 2 wherein said eye simulation spectacles further comprise a flexible control unit configured to adjust flow of said liquid between said reservoir and said dynamic lens.
10. The eye-rehabilitation system of claim 9 wherein said flexible control unit comprises a flexible pipe within a flexible protective sheath.
11. The eye-rehabilitation system of claim 1 wherein said brain stimulation device comprises a mnemonic device comprising:
a chart comprising a plurality of signs; and
a mnemonic aid associated with said chart.
12. The eye-rehabilitation system of claim 11 wherein said mnemonic aid comprises a poem.
13. The eye-rehabilitation system of claim 11 wherein said mnemonic aid is descriptive of the signs.
14. The eye-rehabilitation system of claim 11 wherein said chart comprises at least one row, said row comprising at least one sign.
15. The eye-rehabilitation system of claim 16 wherein said row comprises a plurality of said signs of common size.
16. The eye-rehabilitation system of claim 16 wherein said chart comprises a plurality of said rows and said signs of each row are of different sizes.
17. The eye-rehabilitation system of claim 16 wherein said signs increase in size from a topmost row to a bottommost row.
18. The eye-rehabilitation system of claim 16, wherein said mnemonic aid associates data of said mnemonic aid and the signs using easy-to-remember constructs.
19. The eye-rehabilitation system of claim 16, wherein said mnemonic aid comprises descriptions associated with said chart.
20. The eye-rehabilitation system of claim 16, wherein said mnemonic aid comprises a set of rhyming verses.
21. A method for improving the eyesight using a mnemonic device comprising:
step (i) - providing a mnemonic aid associated with a plurality of signs;
step (ii) - memorizing said mnemonic aid while associating the mnemonic aid with said plurality of signs;
step (iii) - reciting said mnemonic aid with eyes focused on the signs.
22. The method of claim 21 wherein said mnemonic aid comprises a poem.

23. The method of claim 21 wherein said plurality of signs have a plurality of sizes.
24. The method of claim 21 wherein said plurality of signs are arranged in a chart having a plurality of rows.
25. A method for supporting combined action of accommodation and convergence of the brain-eye system of a subject, said method comprising:
step (a) – providing an eye-rehabilitation system configured to encourage a user to exercise accommodation of at least one eye;
step (b) – presenting said eye-rehabilitation system to a subject;
step (c) – said subject using said eye-rehabilitation system to focus said at least one eye upon a plurality of objects thereby exercising accommodation muscles of said eye.
26. The method of claim 25 further comprising:
step (d) – providing at least one dynamic lens configured to change optical power;
step (e) – the optical power of said dynamic lens changing according to head-inclination of said subject.
27. The method of claim 25 wherein said eye-rehabilitation system comprises:
at least one dynamic lens configured to receive variable quantities of liquid;
at least one reservoir in fluid communication with said dynamic lens, said reservoir configured to contain said liquid; and
a control unit for controlling the flow of liquid into said dynamic lens.
28. The method of claim 25 wherein said eye-rehabilitation system comprises:
a mnemonic device comprising:
a chart comprising a plurality of signs; and
a mnemonic aid associated with said chart.

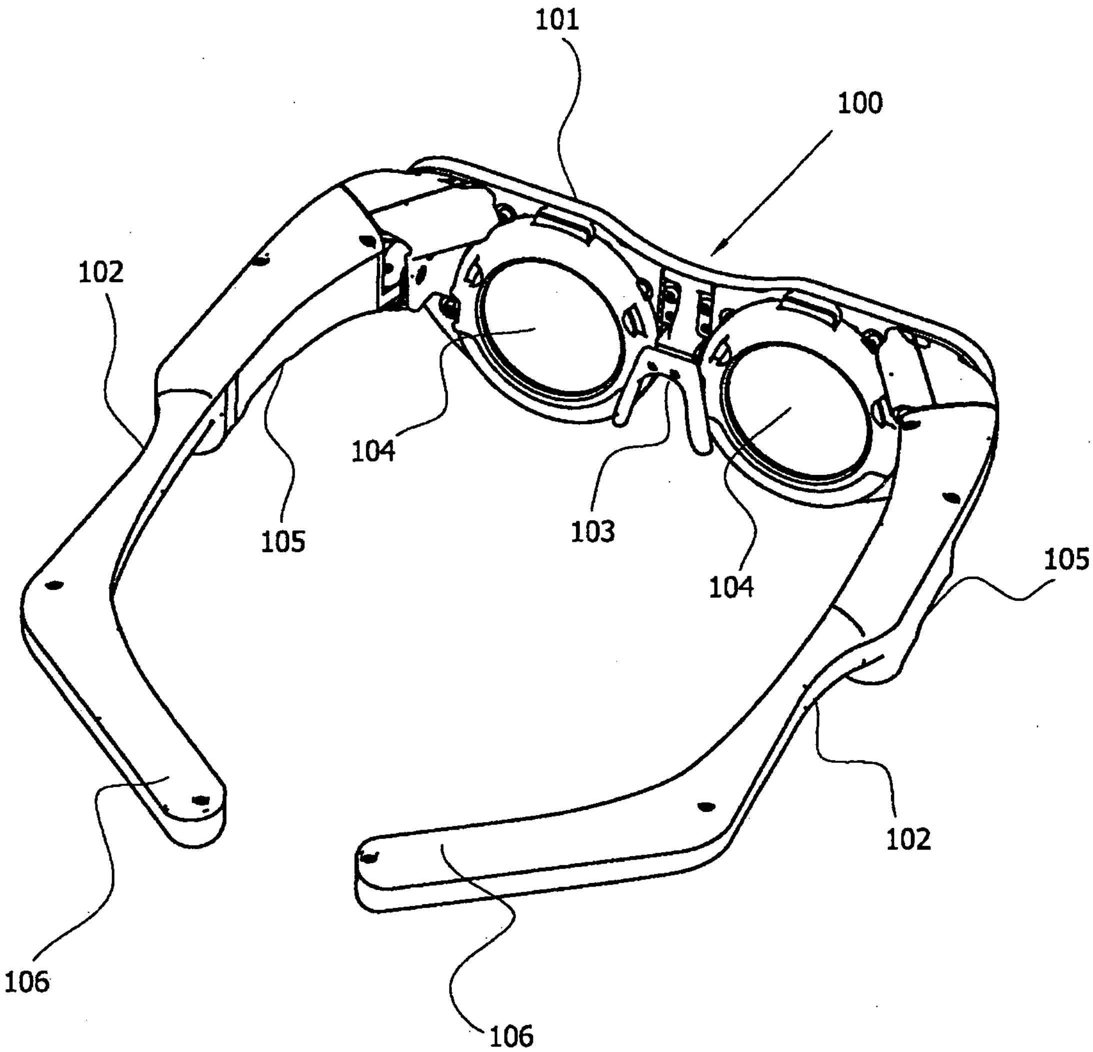

Figure 1a

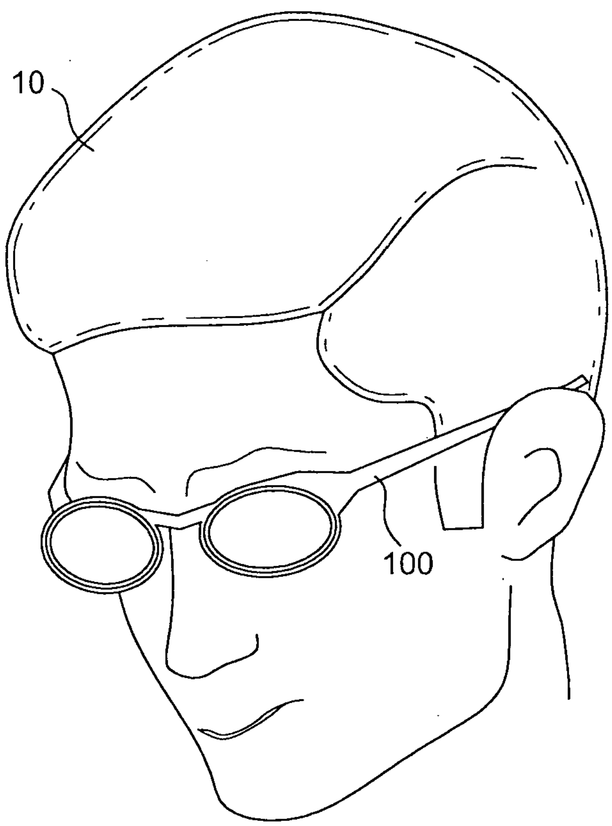

Fig. 1b

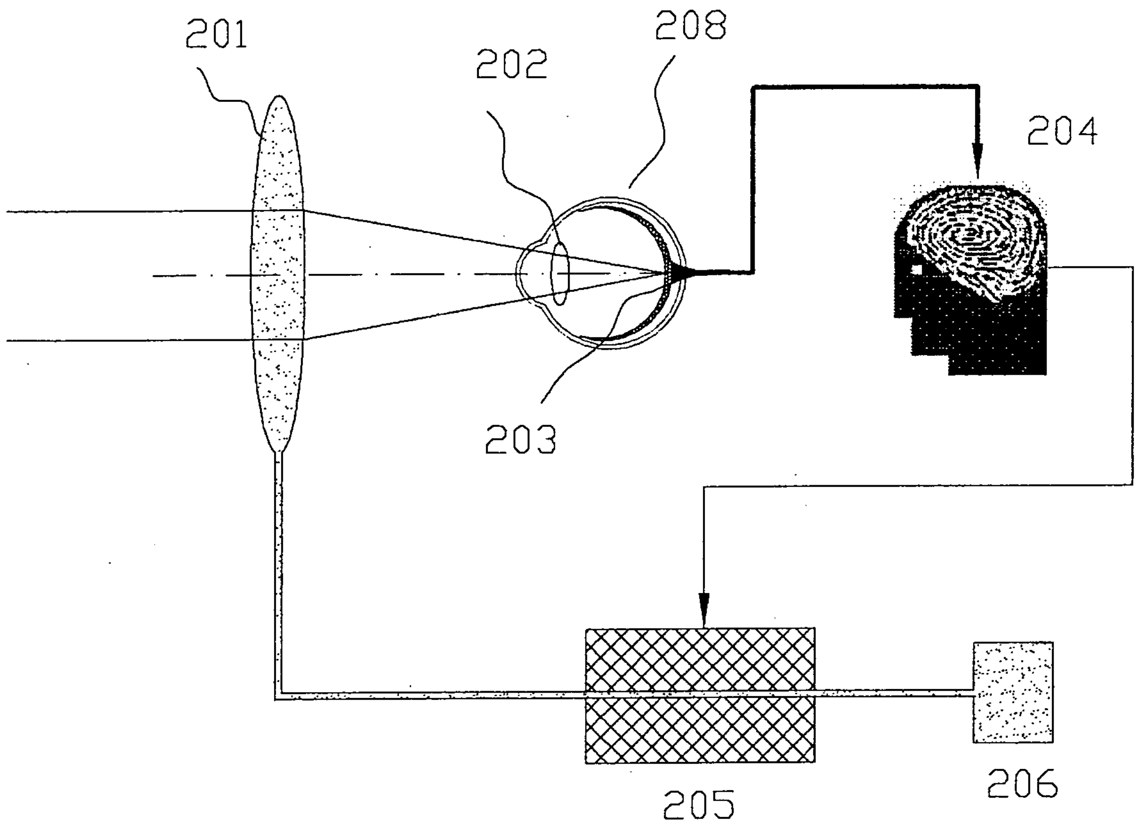

Figure 2

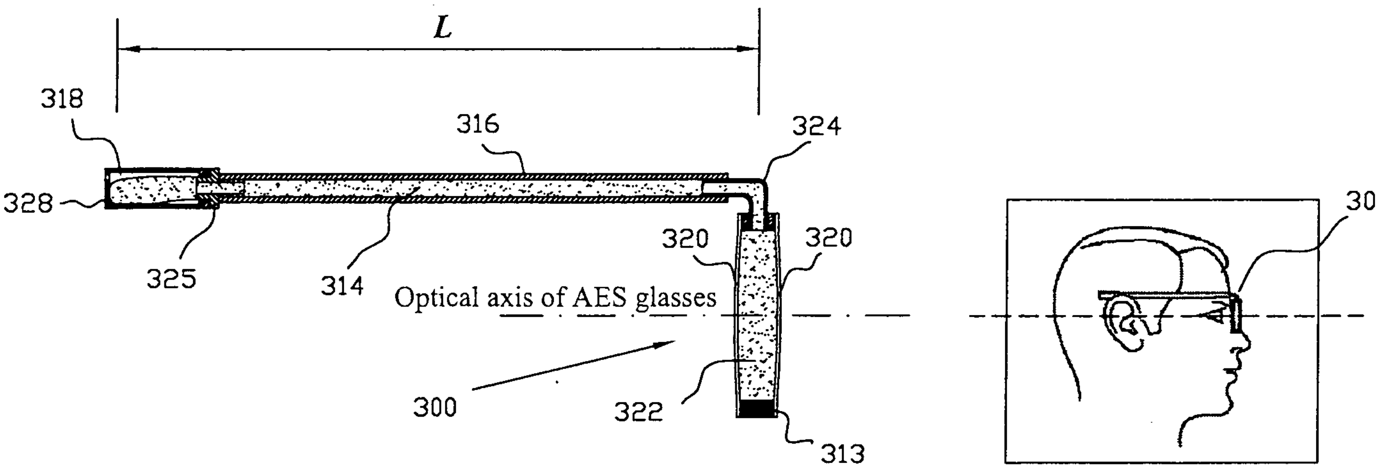

Figure 3a

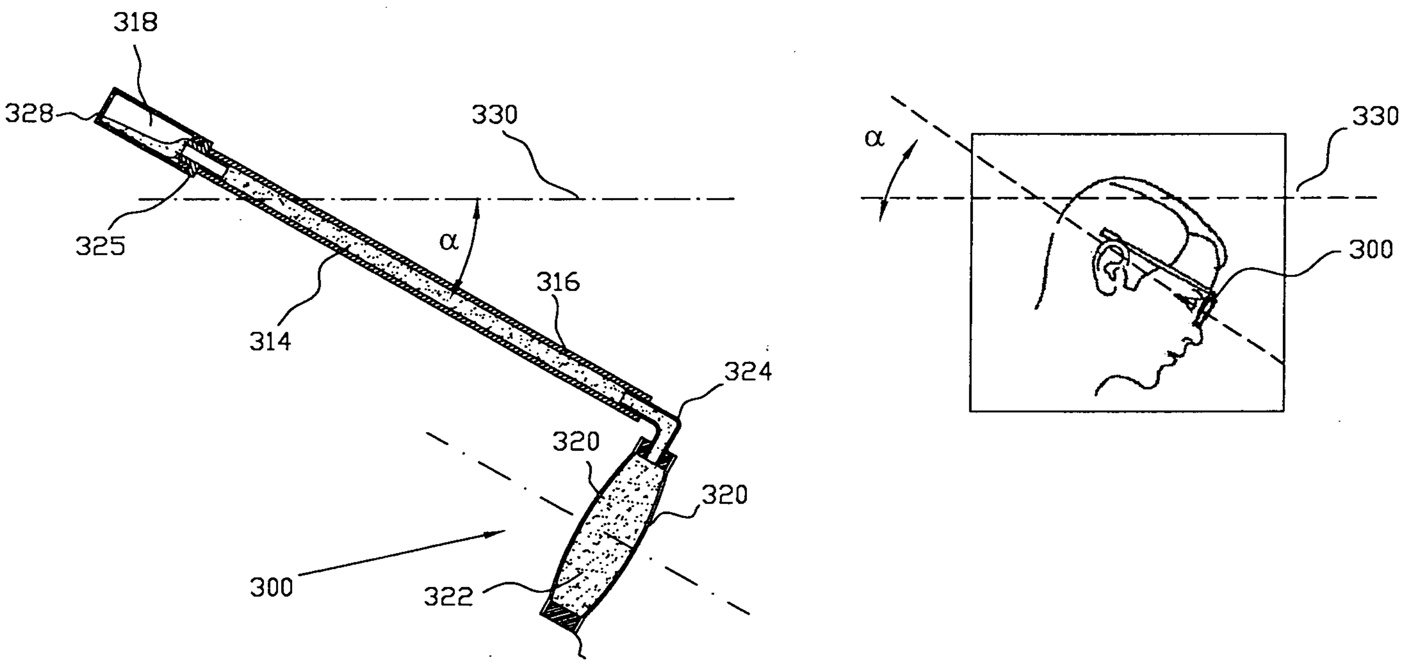

Figure 3b

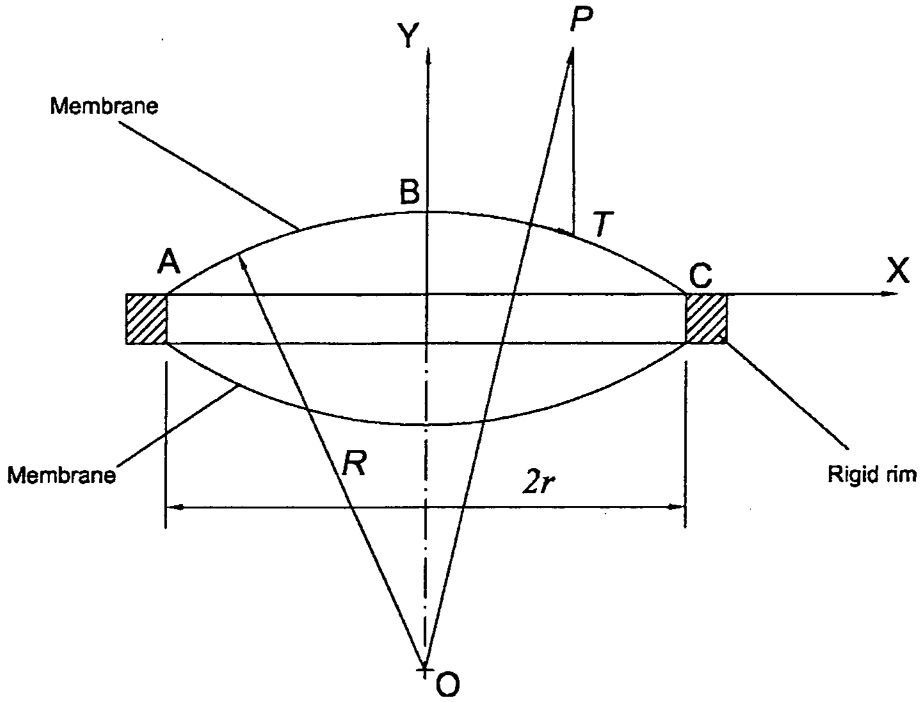

Figure 4

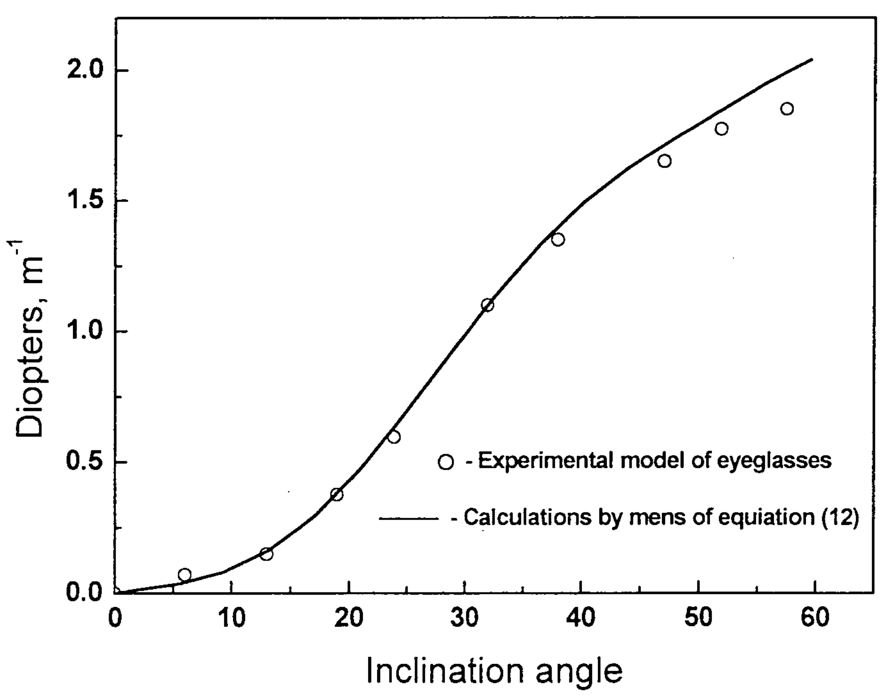

Figure 5

	OPTICAL LIQUIDS	DENSITY (KG/M^3)	REFRACTIVE INDEX
1	LOW VISCOSITY SILICONE OIL DC-200 FROM SIGMA ALDRICH #85411	937	1.401
2	MIDDLE VISCOSITY SILICONE OIL DC-200 FROM SIGMA ALDRICH #85414	968	1.405
3	HIGH VISCOSITY SILICONE OIL DC-200 FROM SIGMA ALDRICH #85424	1090	1.406
4	GLYCERIN 100%	1260	1.482
5	GLYCERIN –WATER SOLUTION 75%	1195	1.435
6	GLYCERIN -WATER SOLUTION 50%	1126	1.398
7	GLYCERIN -WATER SOLUTION 40%	1099	1.384
8	GLYCERIN -WATER SOLUTION 30%	1073	1.371
9	PARAFFIN OIL	800	1.412
10	LOW VISCOSITY IMMERSION OIL FOR LIGHT MICROSCOPY (TYPE A) FROM SPI #04105	923	1.52
11	IMMERSION OIL FOR LIGHT MICROSCOPY (TYPE FF) FROM SPI #04108	877	1.481
12	IMMERSION OIL FOR LIGHT MICROSCOPY (TYPE DF) FROM SPI #04109	1225	1.518

Fig. 6a

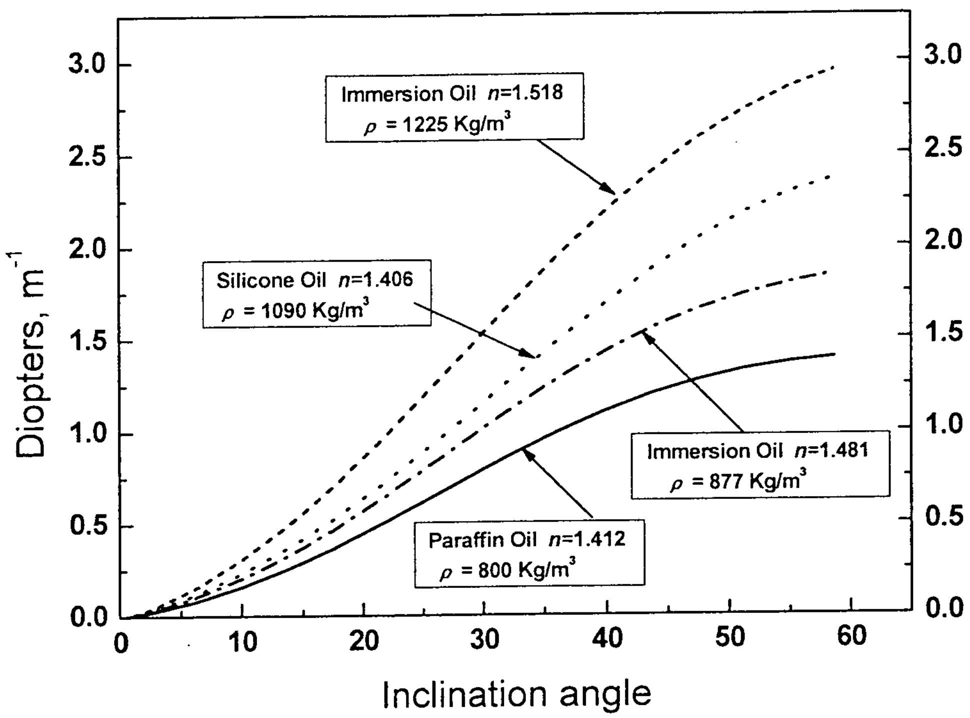

Figure 6b

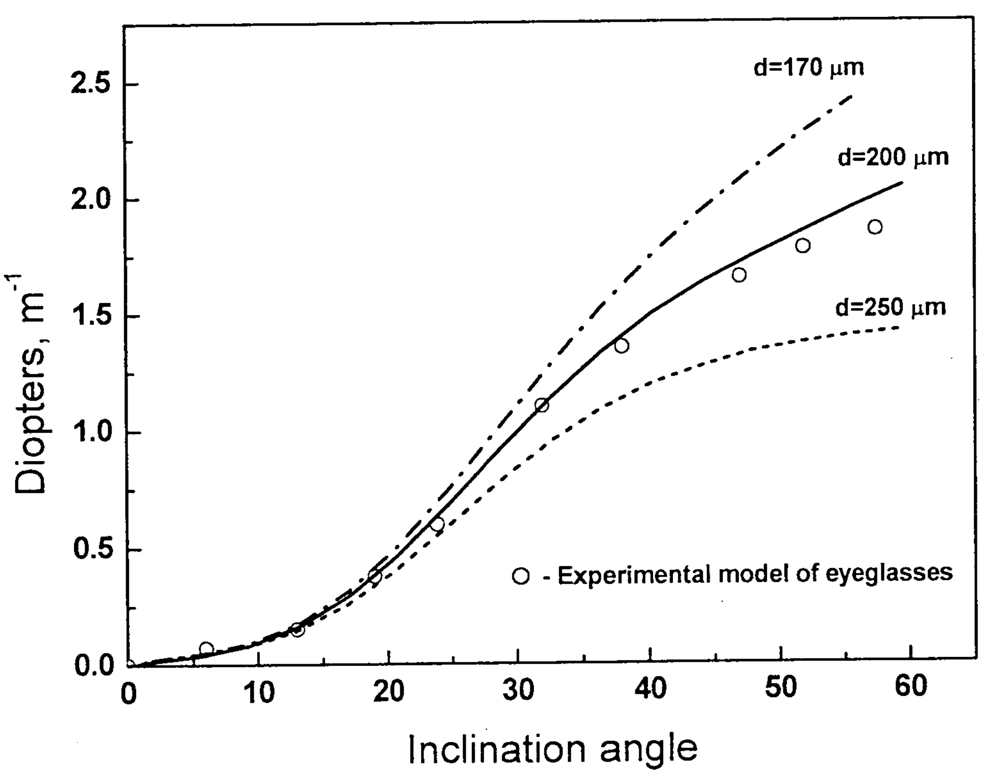

Figure 7

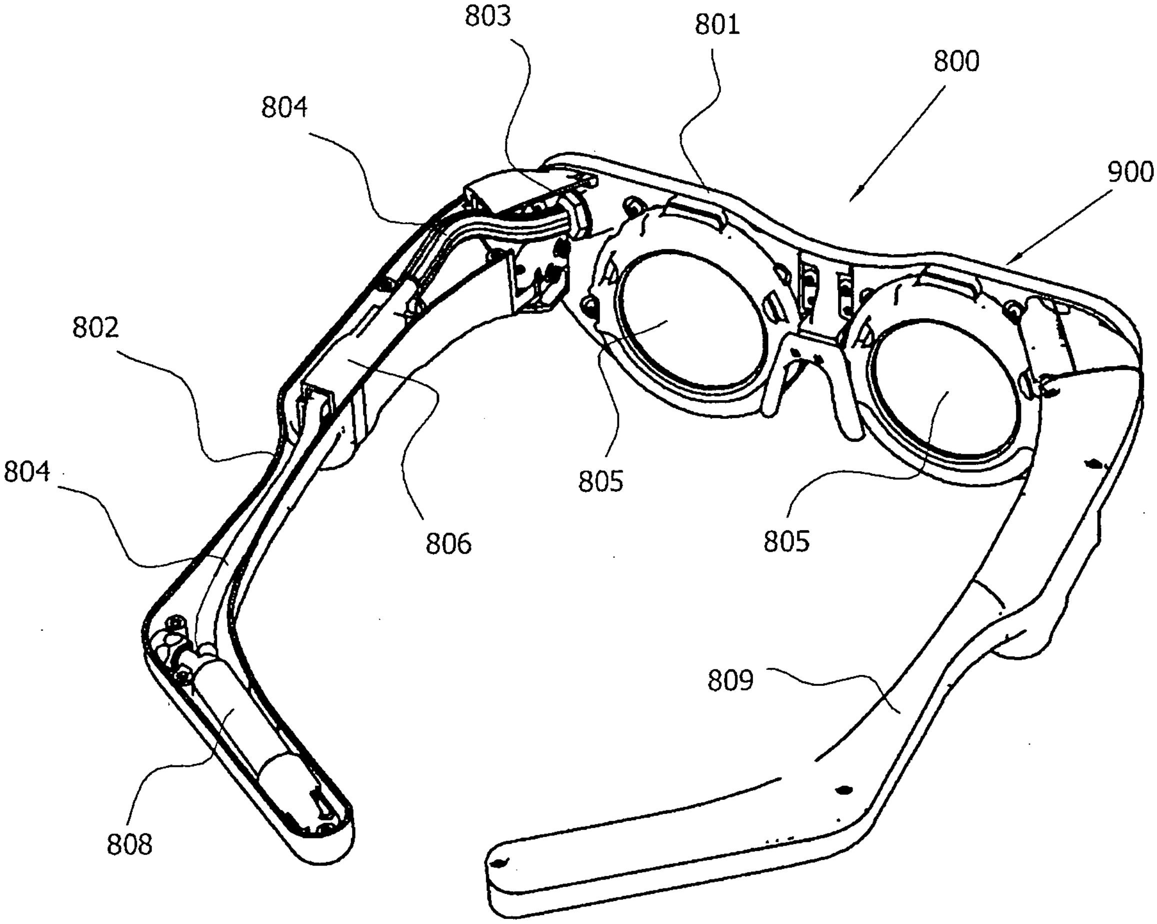

Figure 8

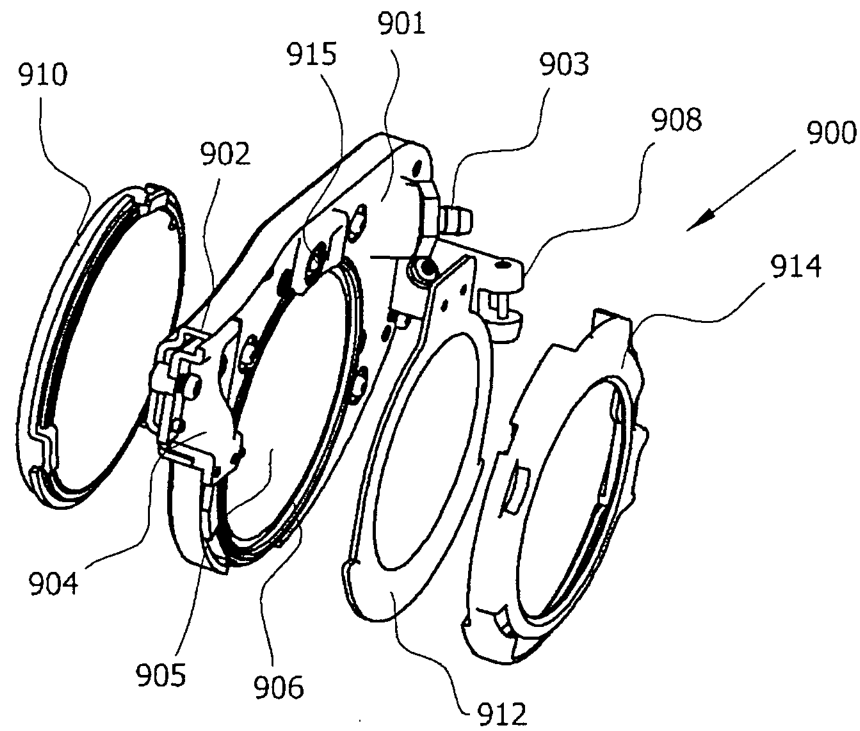

Figure 9a

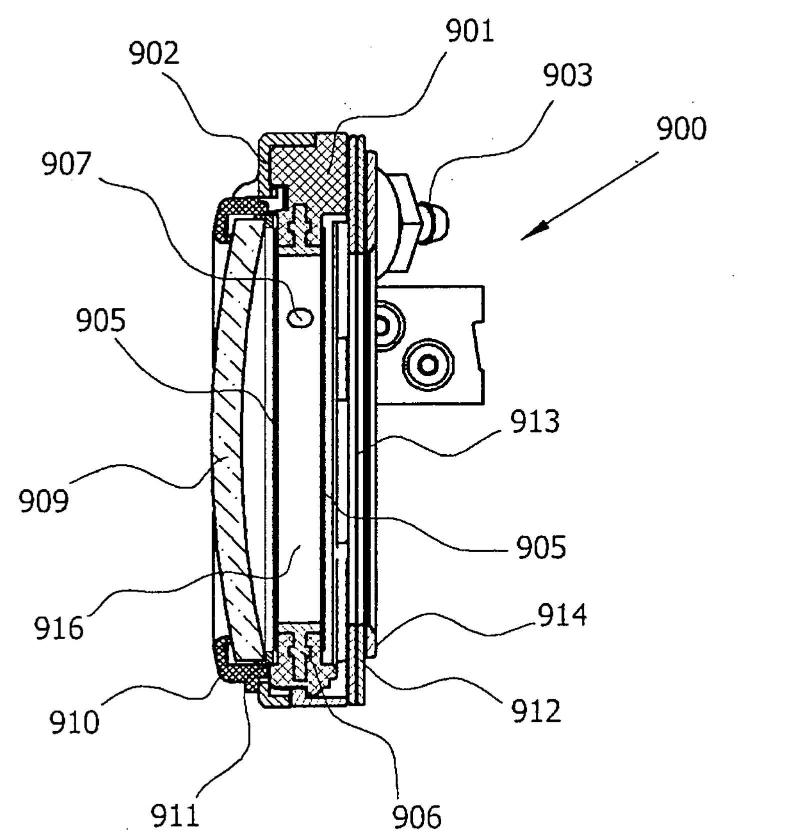

Figure 9b

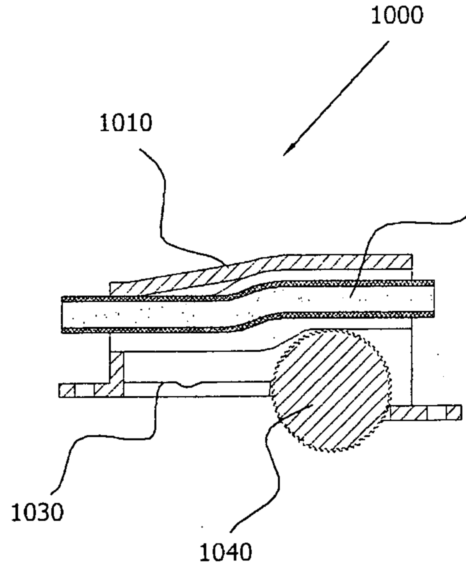

Figure 10a

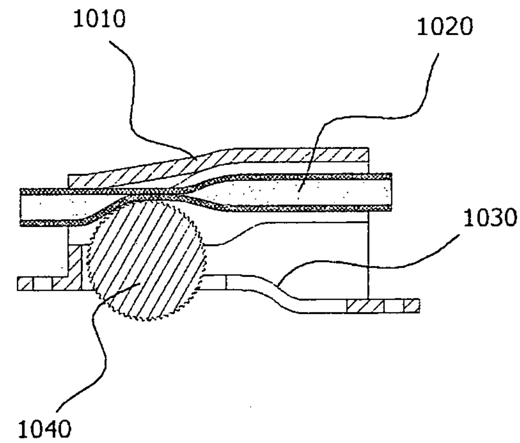

Figure 10b

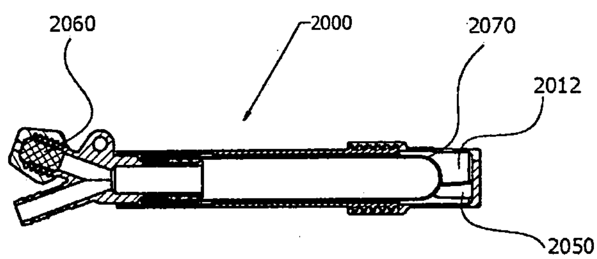

Figure 11b

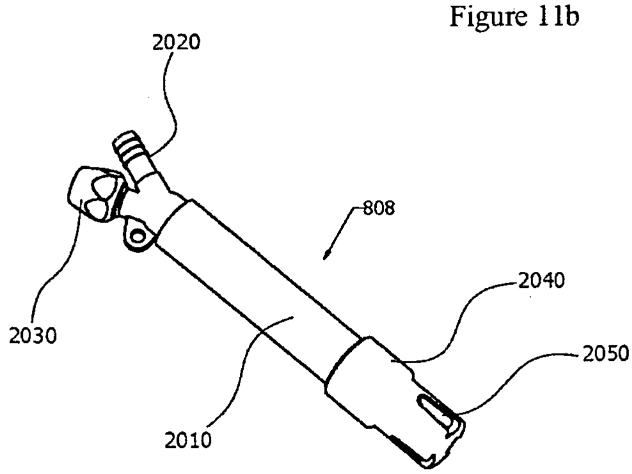

Figure 11a

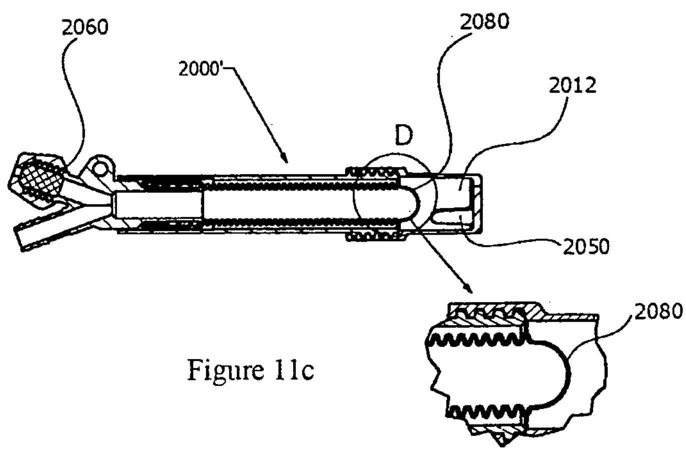

Figure 11c

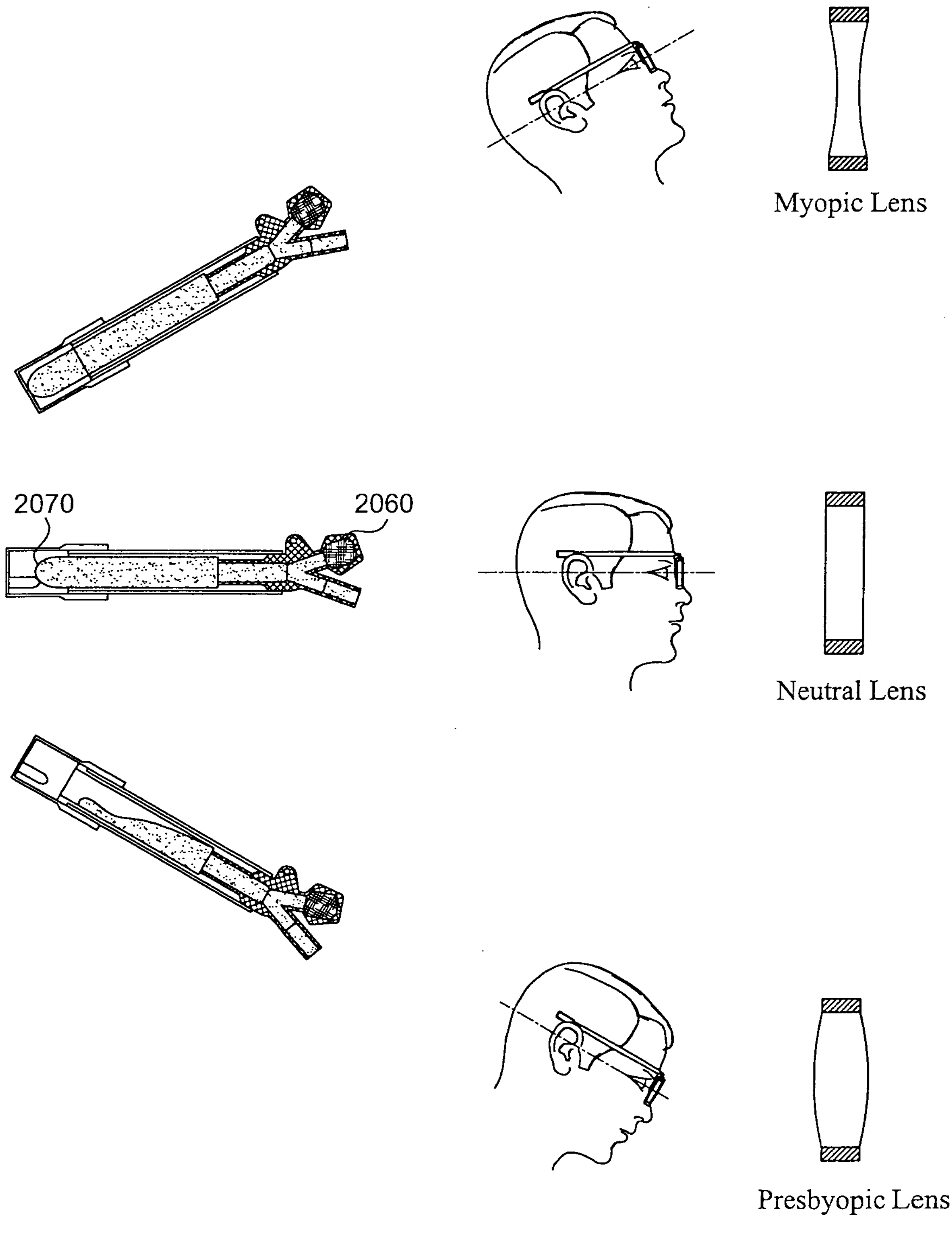

Fig. 11d

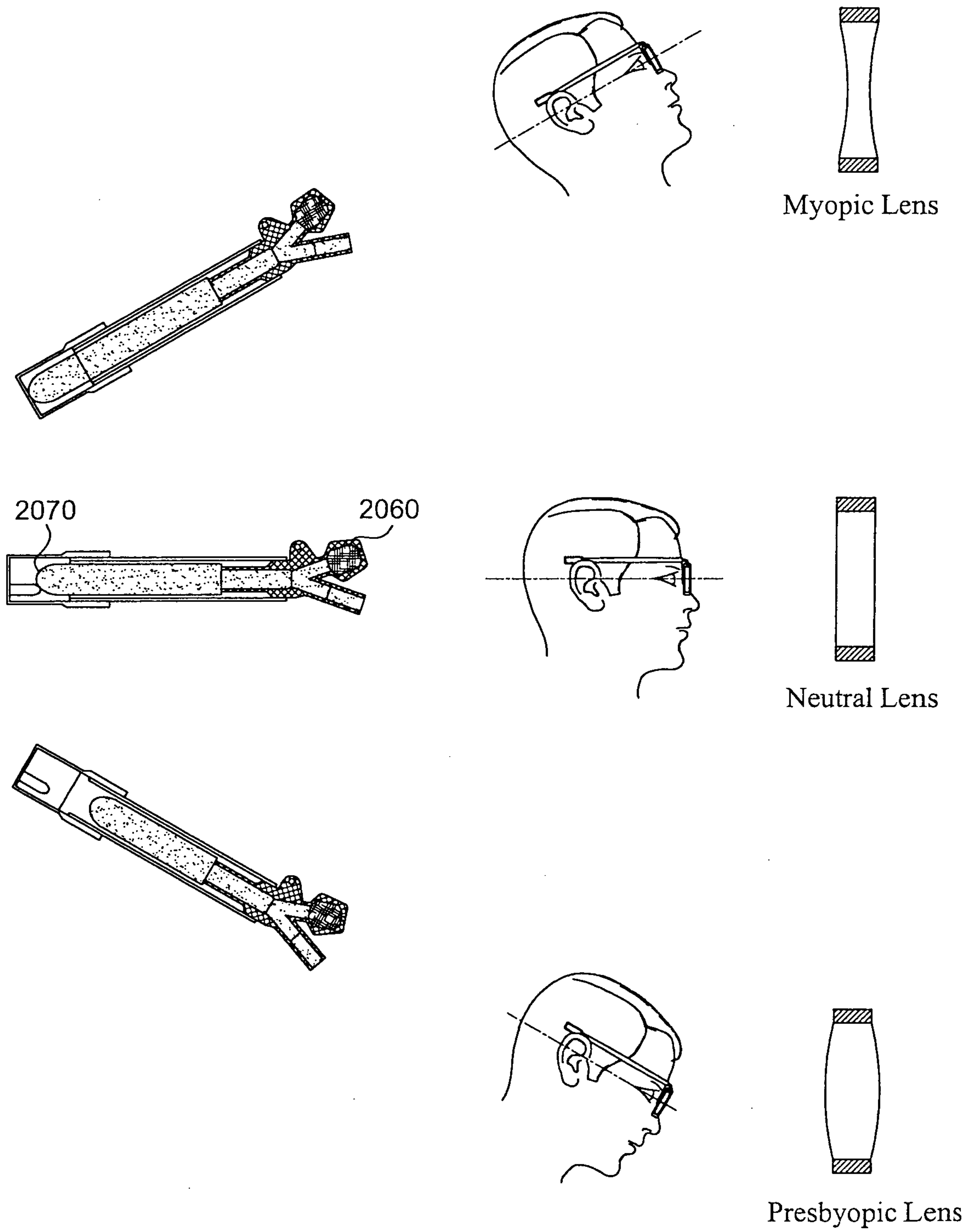

Fig. 11e

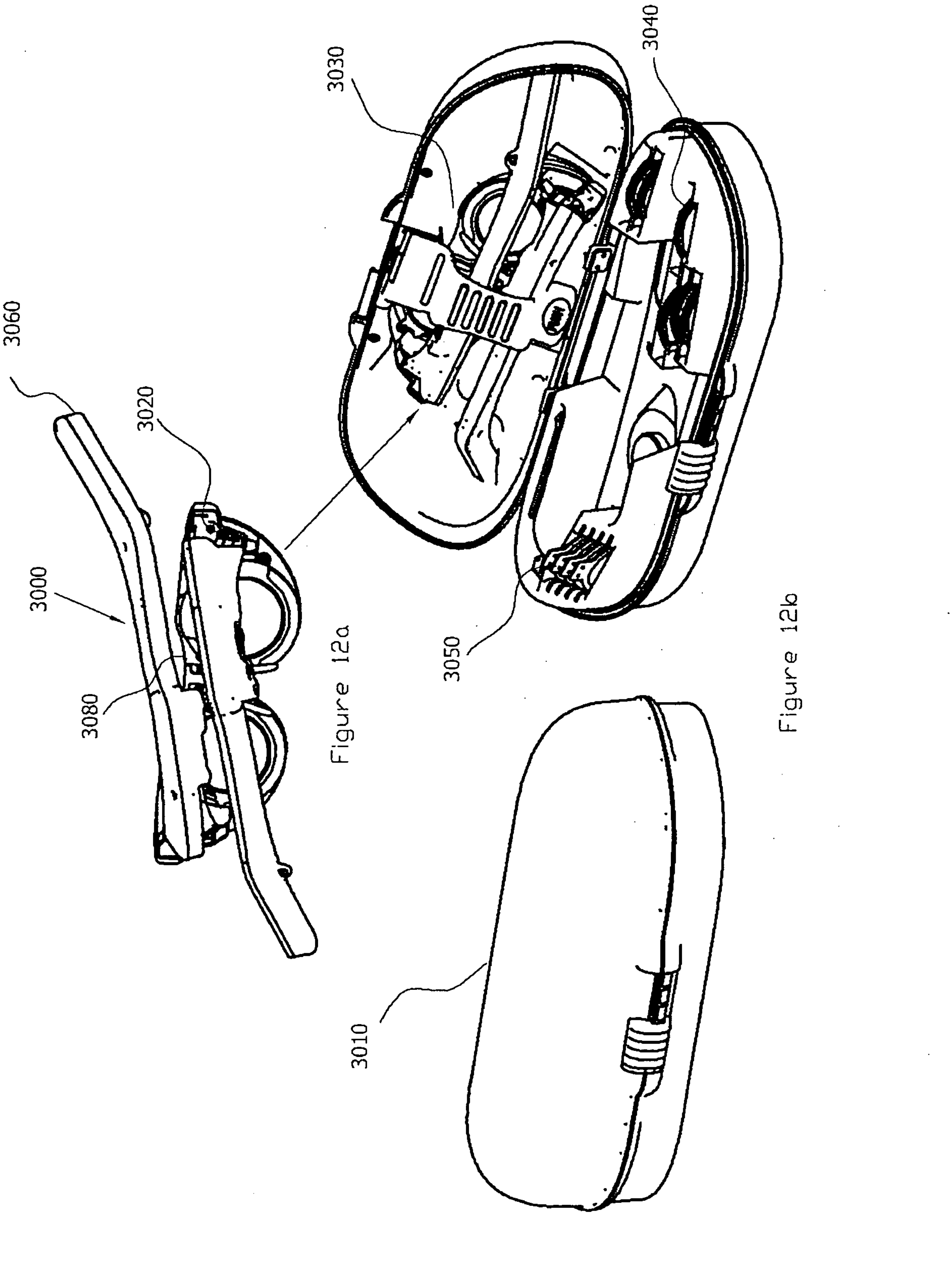

Figure 12a

Figure 12b

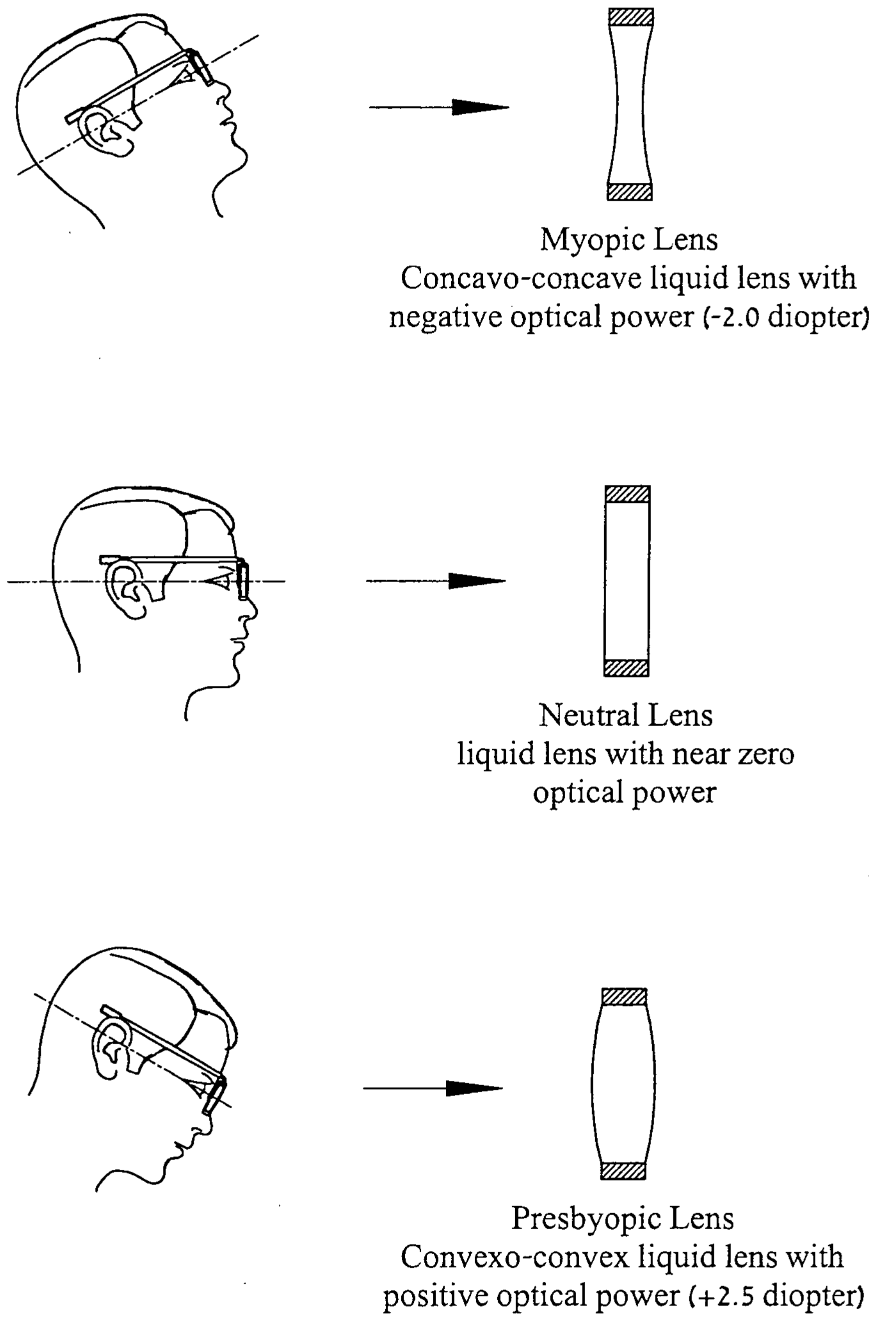
Myopic Lens
Concavo-concave liquid lens with
negative optical power (-2.0 diopter)
Neutral Lens
liquid lens with near zero
optical power
Presbyopic Lens
Convexo-convex liquid lens with
positive optical power (+2.5 diopter)

Fig. 13

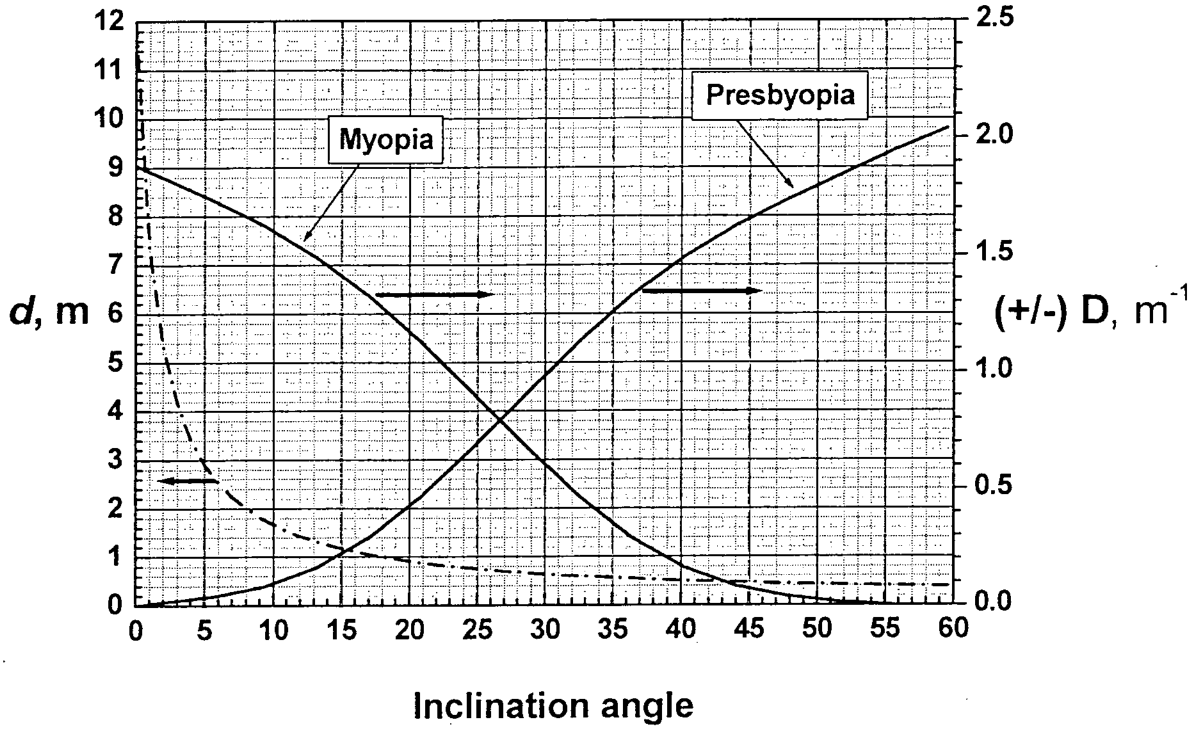
Myopia
Presbyopia
d, m
(+/-) D, m-1
0
1
2
3
4
5
6
7
8
9
10
11
12
0.0
0.5
1.0
1.5
2.0
2.5
0
5
10
15
20
25
30
35
40
45
50
55
60
Inclination angle

Figure 14

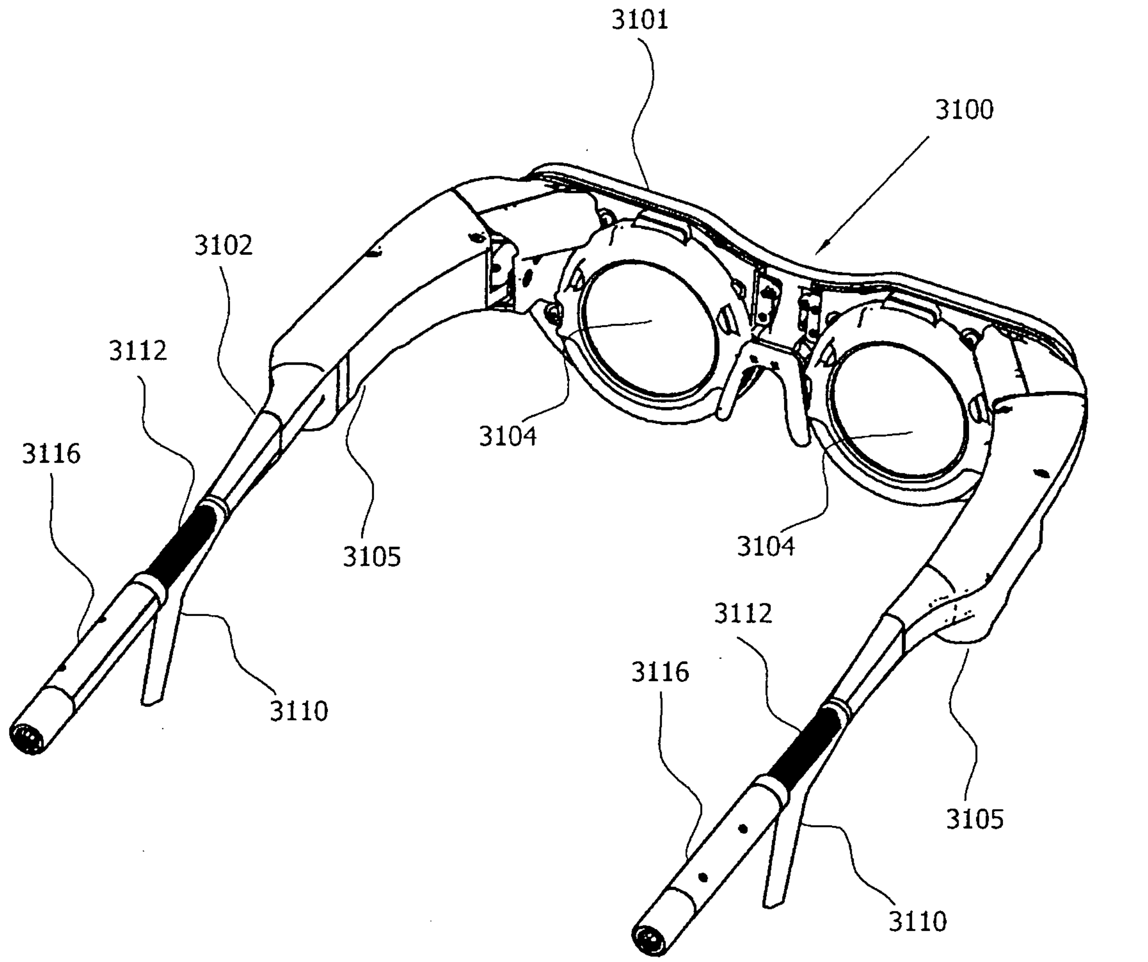
3101
3100
3102
3112
3116
3104
3105
3104
3110
3112
3116
3105
3110

Figure 15a

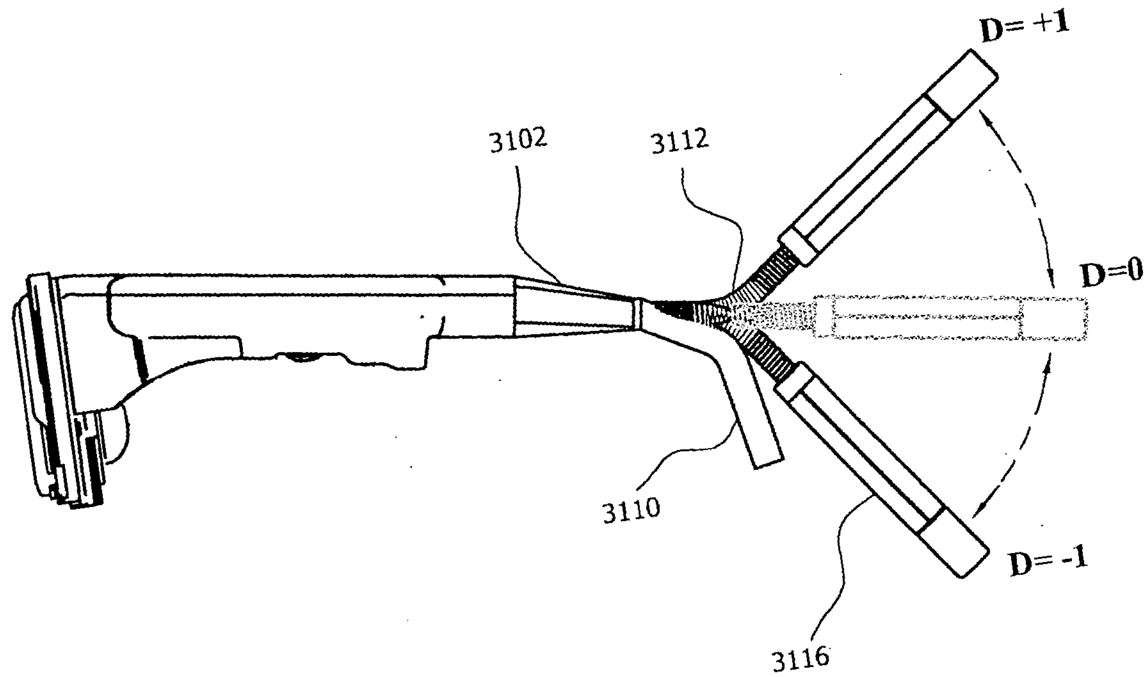

Figure 15b

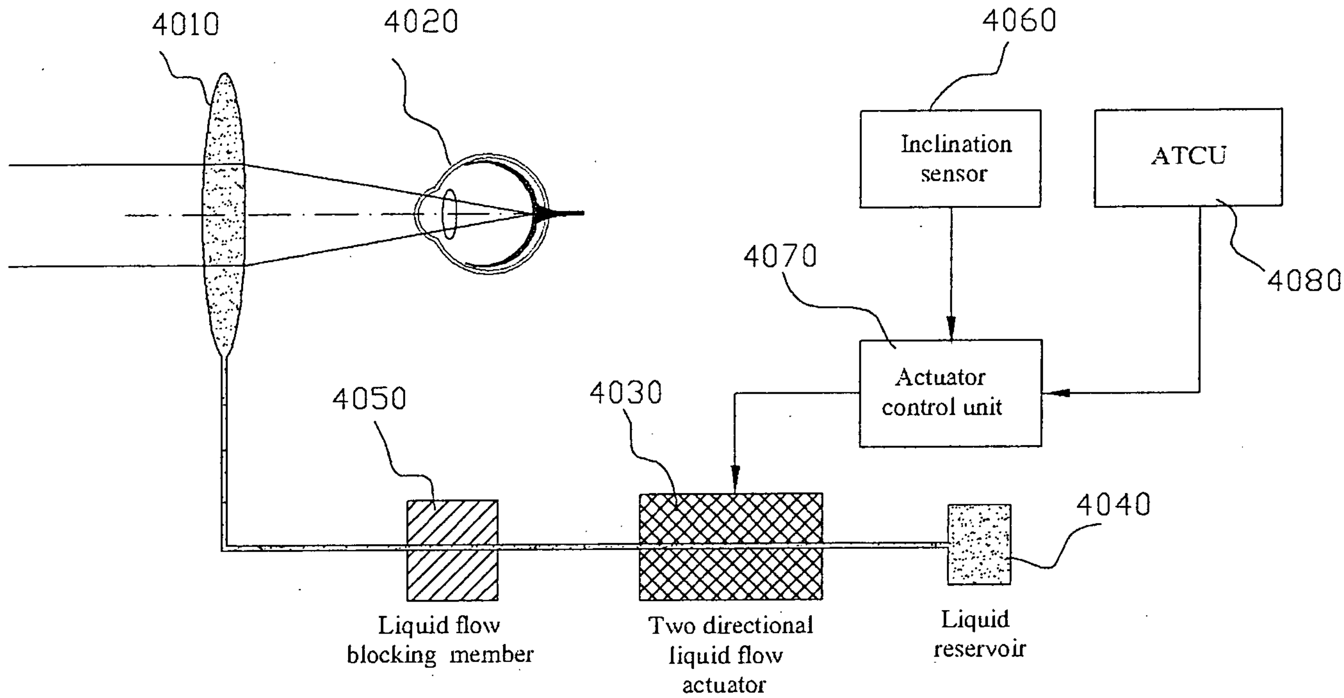
4010
4020
4060
Inclination sensor
ATCU
4080
4070
Actuator control unit
4050
4030
4040
Liquid flow blocking member
Two directional liquid flow actuator
Liquid reservoir

Figure 16

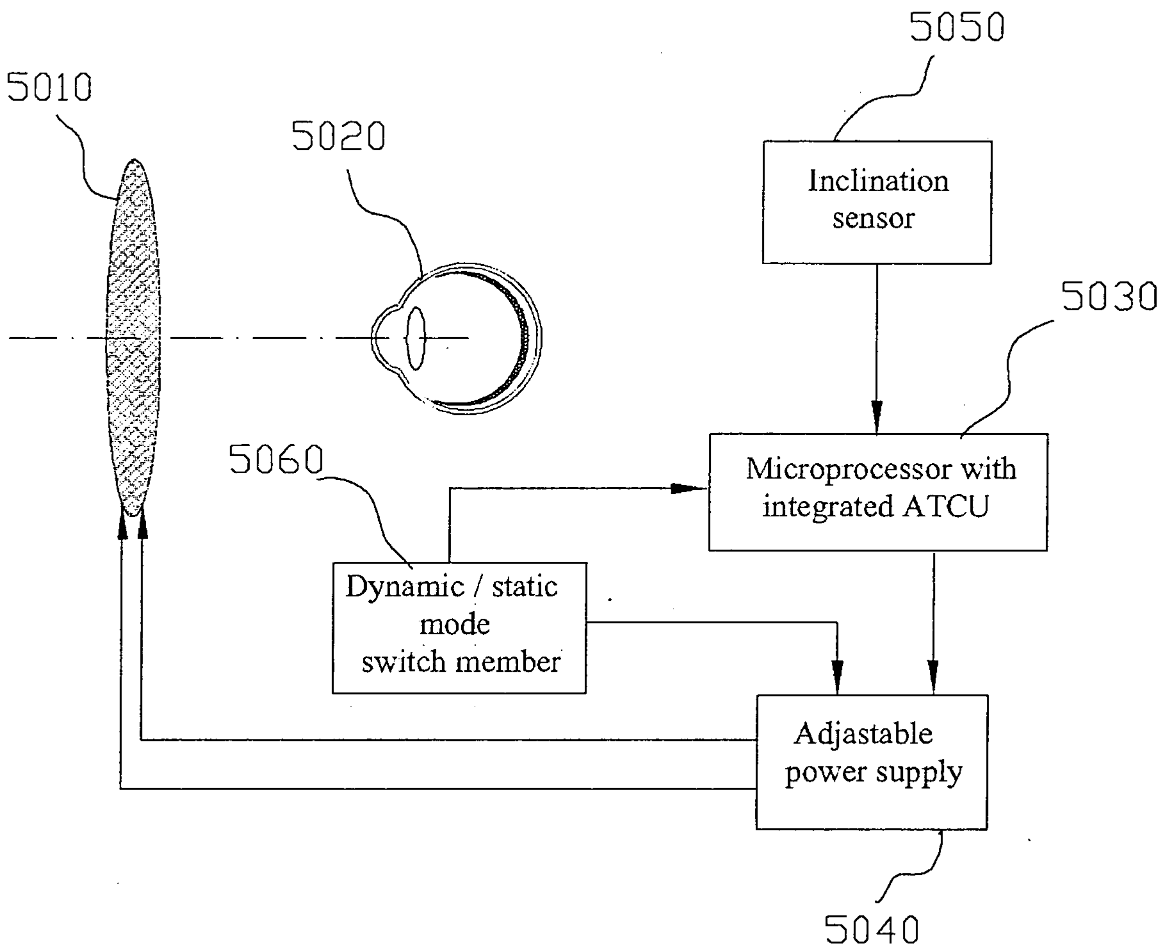
5010
5020
5050
Inclination sensor
5030
Microprocessor with integrated ATCU
5060
Dynamic / static mode switch member
Adjastable power supply
5040

Figure 17

FIGURE 18A

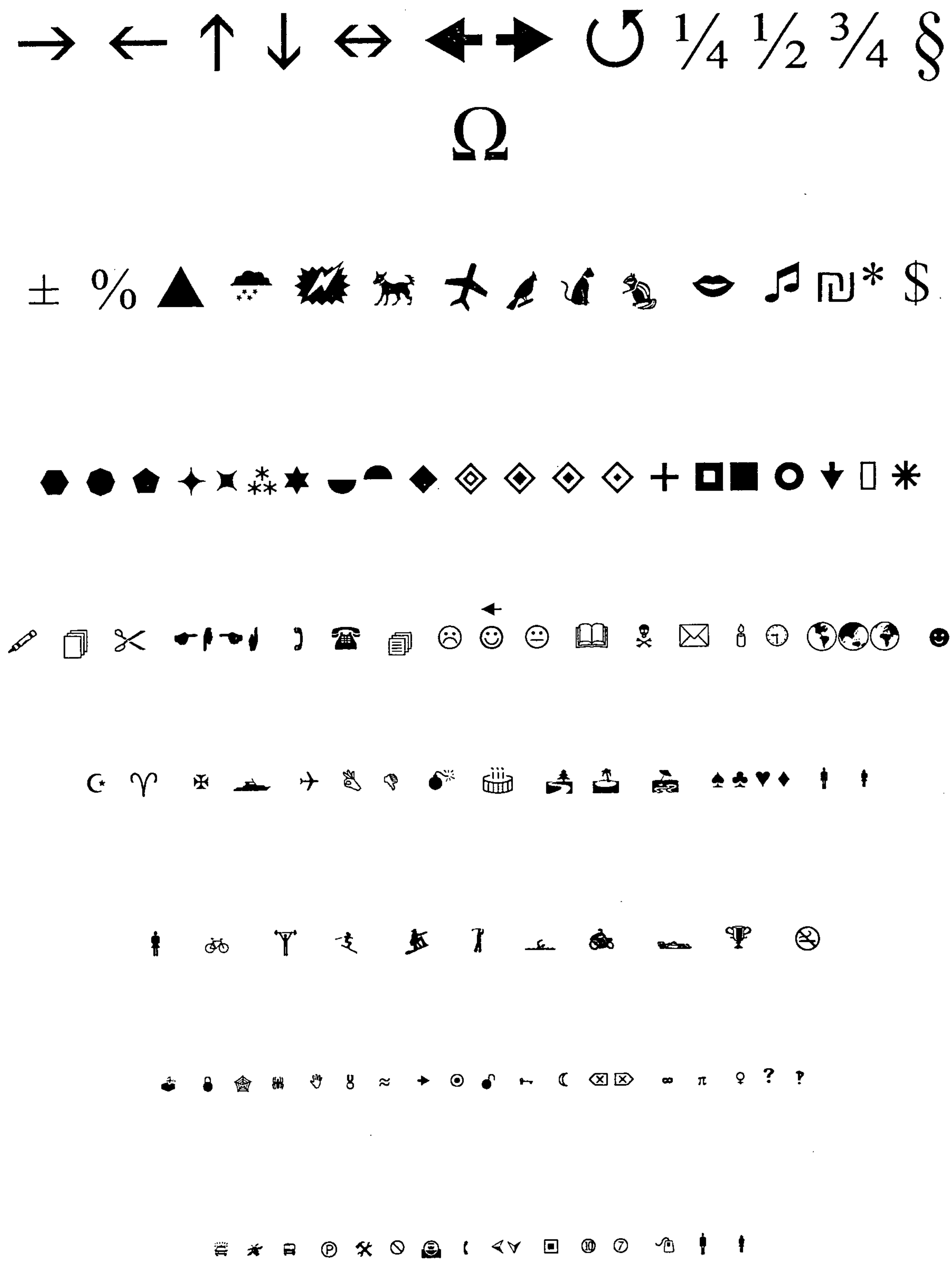

FIGURE 18B

→ ← ↑ ↓ ↔ ◄► ↺ ¼ ½ ¾ § Ω
את דרכנו מוצאים אנו דרך חצים
אשר בחיים כיווננו מראים:
ימינה ושמאלה, אחורה, ישר
אעשה עוד סיבוב ואהיה מאושר.
שברים כמו תיפוף מגיעים לסעיף
הפרסה על הדלת של הסניף תלויה

* $ ₪ ± % ▲ ☔ 🗲 🐈 ✈ 🐦 🐈 🐁 👄 ♫
כוכב עם הדולר ושקל בצל
ואחוז עם פלוס מינוס, הוא על זה מסתכל.
מביאה סערה רעמים וגשמים,
את העיניים שלי הברקים מרפים.
נביחה של כלבים מלווה אווירון,
וטייס מכוון למקום הנכון.
הציפור מאושרת היא עומדת לעוף
החיות מסתכלות על עיצוב של הגוף.
החותם לא יגיד לך לא וגם כן
מסתורין של שפתיי רק בלב מנגן.

⬢ ⬤ ⬟ ✦ ⌘ ⁂ ✶ ◡ ◠ ◆ ◈ ◈ ◈ ◈ + ◘ ■ ○ 🠋 ▯ ✳
משושה בשורה סדר הם מתחילים
ומימלטה צלבים כמו ריבוע עומדים.
הצביר ושמיים ומגן של דוד,
הם סמלים של ארצנו ותקווה יהודית .
הכדור השרוף הוא הזיז חצאים
הריבוע שחור ועוד ארבעה עומדים.
אין טעם לשמירה במקום השרוף
העיגול והריבוע החליטו לעוף.

✎ 🗐 ✂ ☚ ☝ ☛ ☟ ✆ ☎ 🗐 ☹ ☺ 😐 🕮 ☠ ✉ 🕯 🕒 🌎 🌏 🌍 ☻
בוא נכתוב בנייר מיליוני אותיות
לא אכפת לנו מהוראת אצבעות,
ושלא ינדנד כל הזמן טלפון
את הקשר אפסיק דרך הפעמון.
שוב כתבתי אגב סיפורי ארימה

באסון ושמחה שלחג מתאימה.
לי ידוע מי ספר על מתים וחיים
מנורה מאירה מה לראות שכותבים.
על העולם אסתכל פעם ברבע לשש
המפה שתראה לי מה יהיה ומה יש.
אי אפשר להפריד את המים מדג
כל אחד כמו אין-יאן ,כשה בלי זוג, הוא מודאג.

הירח מזוהר הוא שמע באוויר
שמימלטה הגיעה לארצנו אביר
הדורות של הזמן הם מזמן בעבר
הזרים לא יבואו כי בכלל אין דבר.
לכולנו מגיע לאהוב, לטייל,
להגיע לנוף וללכת בצל.
כי יודעים איך לשמוח מחופשה ומפנאי
ליהנות מחיינו כל אחד הוא זכאי .

כל אחד מאיתנו שיהיה מאושר
אופניים ובריאות להפריד אי אפשר.
ובטוח שלא כל אחד ספורטאי
אי אפשר לרפא את הגוף בלי תנאים.
תחרות עם רוחות יעשו מגלשיים
כבר תלמד להפליג על פסגות של גלים.
כמובן שעם קרח אתה לא חבר
תנסה להנות מקיאקים בספר.
יש לך לאופנוע זמן להספיק.
די, תעוף עצלנות, כי נמאס לי, מספיק.
החושים וגופנו סובלים מעישון
יעזרו להפסיק אמונה ואימון.

בקופסונת סודית הוסתרה האמת
והניחו איסור - אם תיפתח, אתה מת.
וסרוג המקום על ידי עכביש
אף אחד לא ימצא את הדרך וכביש.
לכבוד עם מדליות הכוון הוא עקום

לא ניתן להגיע למקום הסתום.
רק האור של ירח את הסוד יגלה
מחוכמות של שכולנו גם הפעם נתפלא.
הכותפת עם צלב והסמל של נצח
אז על מה לסמן על הגב, או על מצח.

חרדה וחשש הם - פיצוץ של חיים
על פיגוע אנחנו כבר כולנו יודעים.
הצפירות ,טלפון ,כבאים ומסוק
שבאוטובוס ילד, מוכרח הוא לשתוק.
באוטובוס ילד ועוד חברים
יודעים שלהם כולם דואגים.
בדרך סודית של רכבת תחתית
הביאו לאוטובוס רובוט-חיפושית.
את כל הממזר כבר הפכו לישן,
הדרך החוצה אף אחד לא ייתן.
הסיפור לילדינו נגמר בשלום
כי אין בארצנו מקרים של פתאום.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 09/01235

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61H 5/00 (2010.01)
USPC - 601/37
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 601/37

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 601/23, 37; 351/41, 177, 200, 222; 359/665, 666 (keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (PGPB, USPT, EPAB, JPAB); Google Scholar
Search terms: flexible, elastic, deform$, lens, lenses, train$, rehabilitat$, treat$, stimulat$, therap$, test$, eye, visual, optic$, accomadat$. adjust$, variable, focus, chart, figure$1, mnemonic$, pattern$, number$, display, drawing$1, construct

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2005/0140922 A1 (BEKERMAN et al.) 30 June 2005 (30.06.2005), Fig 1, 2a-3a, 5-7, para[0010]-[0012], [0014], [0023], [0071]-[0095], [0109], [0112], [0116]-[0122], [0124], [0126], [0127], [0130], [0133]	25-27 ---------------- 1-20 and 28
Y	US 2008/0212032 A1 (SEILLER et al.) 04 September 2008 (04.09.2008), Fig 4, 8a, 8b, para[0033], [0034], [0053], [0054], [0071], [0078], [0085], [0090], [0096]	1-20 and 28
Y	US 6,715,876 B2 (FLOYD) 06 April 2004 (06.04.2004), Fig 5, 10, col 6, ln 66 to col 7, ln 9, col 10, ln 4 to col 11, ln 4	4 and 8
A	US 5,684,637 A (FLOYD) 04 November 1997 (04.11.1997), entire document	1-20 and 25-28

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2010 (22.06.2010)	29 JUN 2010

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer:
Lee W. Young
PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 09/01235

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Group I: claims 1-20, 25-28 directed to an eye rehabilitation system
Group II: claims 21-24 directed to a mnemonic device

The groups of inventions above do not related to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical feature of the Group I claims is a dynamic lens system , which is not present in the claims of Group II.
The special technical feature of the Group II claims is a mnemonic aid, which is not present in the claims of Group I.

Groups I, II share the technical feature of a visual/brain stimulus for testing the eyes. This generic feature does not avoid the prior art, as evinced by US 2007/0200927 A1 to Krenik which teaches an example of a vision measurment and training system that displays images to the eyes (Abstract). Therefore, the listed inventions lack unity of invention under PCT Rule 13 because they do not share a same or corresponding special technical feature.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-20 and 25-28

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.