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# **Analysis of the Disturbances Caused by Intraocular Forced Convection Mechanism Failure**

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Additional information is available at the end of the chapter

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## **Abstract**

In this chapter, we show the refractive error treatment result of a patient, the first author, who restarted in 2000, after a 4-year break, at the study start. According to previous publications, the treatment consists of rehydration and elimination of agglutinated, dehydrated and deposited metabolic residues in the cornea, the trabecular meshwork, the crystalline lens and the retina, as a consequence of the failure in the mechanism of intraocular mass transfer by forced convection. However, the forced movement of the metabolic mass to rehydrate one region can cause dehydration in another region. Therefore, the patient developed posterior and capsular cataract in their respective eyes, right and left. This dehydration, during the treatment, increases the difficulties for the success of the treatment. The first part is a chronological record of the most important components of the treatment. Then, the research method and the material used are discussed. The main symptoms and signs are analyzed and correlated with the failure of the mass transfer process and the accumulation of metabolic residues. The anatomy of binocular vision is analyzed as a part of the forced convection mechanism, and in conclusion, the report shows the main oculomotor functions, topographic mapping of corneas over an interval of 17 months.

**Keywords:** cataract, glaucoma, saccadic movement, torsional movement, refractive error, uveitis, floaters

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## **1. Introduction**

The research began in 1996 when the first author (will be called the patient) realized that after 4 h of working on a computer, his vision was blurred and, after performing other activities,

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the view was retrieved. Then, the patient realized the possibility of regaining his vision, which was showing the beginning of the symptoms of presbyopia. The patient presented visual acuity OD 6/10 and OS 9/10 and corrective lenses NV, OD +0.25 and OS +0.75. Work interruption occurred in the same year due to anterior recurrent uveitis of unknown cause in the left eye, which increased the intraocular pressure to 40 mmHg in the first crisis. Two years before the start on this study, the patient had his first two cases of uveitis, but the most important crisis occurred after the study began and the patient took a few days to get medical help. To control intraocular pressure, the patient received three intraocular injection on alternate days. Even with the patient's narrative that he did not feel well, the doctor reduced the dosage of medications. The patient still felt pain when pressing the left eye in the superior nasal position through the superior eyelid. The patient returned to the doctor after 2 days, having noticed the blurred image in the left eye. The physician diagnosed the recurrence of uveitis and intraocular pressure at 40 mmHg. At the end of treatment, the pain in the sclera did not exist. Many other painful inflammations had occurred in the left eye, but at this early stage, physicians consulted in Brazil and France did not prescribe any treatment. Treatment was started the next day after uveitis was diagnosed. At that time when the pain symptom occurred in the sclera, the patient used a medication eye-drop prescribed for the treatment of uveitis to impede damage progression. A single drop once was sufficient to eliminate the symptom and avoid uveitis, but when the symptom did not go away, the patient used another dose the next day. On June 15, 1998, the patient had visual acuity 8/10, with corrective lenses. The research for vision recovery was restarted in the year 2000 after an oculomotor relaxation procedure, advised by the patient's brother, who had read in a self-help book on eyesight.

After 2009, the same ophthalmologist periodically examines the patient, but sometimes the patient looks for another professional in order to obtain information from the doctor when he first examines the patient. A posterior cataract had developed in the right eye and capsular in the left eye. **Table 1** shows the lenses prescribed by doctors. The prescribed lenses do not change the direction of the elimination treatment of the intraocular metabolic residues. In 2012, ophthalmologists informed the patient that, without surgical intervention in the left eye, the patient would have great difficulty in passing the eye examination to renew his driver's license, scheduled for 2014. So, 15 days before the date of renewal, the patient underwent 12 sessions of 30-min exercise on different days with occlusion of the right eye and added 2 days without exercises. The patient was approved in the exam.

Although the patient perceived changes in visual perception during treatment progress, however, it was not possible to establish treatment phases through these changes. The changes in visual perception depend on the element being observed. The observed element can be an object, a light source or an image, with or without letters, that is near or far, in a certain environment. The environment can be dark, or light, with or without diffused light, under the influence of various luminous intensities. In addition to the environment, visual perception is severely influenced by dehydration, agglutination and the amount of metabolic residues accumulated.

The physical characteristics of the residue disposed orally vary with the progress of the treatment of recovery of sight. Eliminated residue is the one with the least resistance to movement. The movement resistance depends on the location of the accumulation region and the

Calendar date	Rx		Spherical	Cylindrical	Axis
1975	D.V.	O.D.	—	—	—
		O.S.	—	—	—
	N.V.	O.D.	+0.25	—	—
		O.S.	+0.25	—	—
1994	D.V.	O.D.	—	—	—
		O.S.	—	—	—
	N.V.	O.D.	+2.50	0.50	35°
		O.S.	+2.50	0.50	155°
December 02, 1996	D.V.	O.D.	—	—	—
		O.S.	—	—	—
	N.V.	O.D.	+0.50	—	—
		O.S.	+0.75	—	—
1997	D.V.	O.D.	+1.50	0.50	30°
		O.S.	+1.50	0.25	140°
	N.V.	O.D.	+2.50	0.50	30°
		O.S.	+2.50	0.25	140°
1999	D.V.	O.D.	+1.50	0.50	35°
		O.S.	+1.50	0.50	140°
	N.V.	O.D.	+3.50	0.50	35°
		O.S.	+3.50	0.50	140°
July 18, 2003	D.V.	O.D.	+1.50	0.50	180°
		O.S.	1.25	—	—
	N.V.	O.D.	+2.50	0.50	180°
		O.S.	+2.50	—	—
June 20, 2006	D.V.	O.D.	+1.25	0.50	65°
		O.S.	+1.00	0.50	125°
	N.V.	O.D.	+2.75	0.50	65°
		O.S.	+2.75	0.50	125°
June 30, 2006	D.V.	O.D.	+1.25	−0.50	30°
		O.S.	+1.00	−0.50	155°
	N.V.	O.D.	+2.75	−0.50	30°
		O.S.	+2.75	−0.50	155°
March 19, 2007	D.V.	O.D.	+1.00	−0.50	35°
		O.S.	+1.00	−0.50	120°
	N.V.	O.D.	+2.25	—	—
		O.S.	−2.25	—	—

Calendar date	Rx		Spherical	Cylindrical	Axis
October 01, 2012	D.V.	O.D.	—	−0.50	100°
		O.S.	−0.50	−1.50	100°
	N.V.	O.D.	+2.50	add	—
		O.S.	+2.50	add	—
November 12, 2012	D.V.	O.D.	+0.50	−0.75	90°
		O.S.	−1.00	−0.75	105°
	N.V.	O.D.	+3.25	−0.75	90°
		O.S.	+1.75	−0.75	105°
February 07, 2013	D.V.	O.D.	−0.75	—	—
		O.S.	−2.00	—	—
	N.V.	O.D.	+2.25	add	—
		O.S.	+2.25	add	—
July 22, 2013	D.V.	O.D.	+0.50	−1.25	85°
		O.S.	−1.50	−1.00	105°
	N.V.	O.D.	+2.75	add	—
		O.S.	+2.75	add	—

**Table 1.** Lenses prescribed by doctors.

physical and biochemical characteristics. These characteristics are mainly associated with the compositions of their components, viscosity, dehydration, color, transparency and acidity. Some of these characteristics can be observed in oral elimination.

At the beginning of treatment, it was very easy to perceive the negative afterimage, but it has not been observed for a long time. This pathology was solved. Initially, the appearance of new floaters was observed. Then, there were floaters that changed their appearance, one divided into two, maintaining a discreet connection. The oldest floater had already added new expansion, but kept its round, black core. Sometimes after the beginning of treatment, the oldest floater changes in appearance and returns to the initial appearance.

When the light source, in a dark environment, is refracted in light rays projected on the retina, it may suggest the beginning of the residue elimination phase; the perception of the colored arc, around the light source, indicates residues with a high index of refraction, very dehydrated, with great viscosity; blurry sight can indicate residues available on the cornea for disposal.

The intraocular process of accumulation of metabolic residues, as well as its intraocular process of elimination of metabolic residues, occurs essentially through the involuntary oculomotor movement that acts with the objective of producing the best projection in the temporal retina. In the process of eliminating the accumulated metabolic residue, the patient voluntarily interferes in the oculomotor movement so that the metabolic residue interferes in the

projected image in the temporal retina, and then, the involuntary movement rehydrates the accumulated residues in the region, reduces its viscosity, and produces the best projection in the temporal retina. Much attention, just as there is anterior ocular torsional movement, due to the difficulty of adaptation of the cornea, a posterior ocular torsional movement can occur, cause physical tension in the optic nerve and cause normal tension glaucoma.

## 2. Method

Teamwork was used to interview professionals and patients. Team studies, based on the interpretation of symptoms, among others, corneal burning, tear production and resistance to visual adaptation to a fixed target, performed through the horizontal periodic movement of the head (the duration of the exercise is within the range of 5-30 min). Studies of anatomy and biophysics of the eyes as a system of dynamic action are made. Simulation of a physical model to reproduce the studies of Scheiner, apud [1], was used to associate the main refractive errors and the patient's symptomatology. Simulation of a hypothetical mathematical model was made to study the daily intraocular pressure variation. As the main form of treatment progress evaluation, a light source, at the same distance, was initially used to measure the diameter of its dispersion, evaluated in the number of adjacent diameters of the source. At the present, a traffic light is used as the light source for measurement. Visual acuity and corrective lens parameters are not used to evaluate the reduction of intraocular metabolic residue.

## 3. Eyesight regeneration and analysis of symptoms and signs

### 3.1. Materials

In this section, the main materials used for vision recovery are listed in alphabetical order, together with a brief description of the use.

**Corrective lenses, +19 D, +10 D, +5 D, +2.5 D, -5D:** Negative lenses were abandoned shortly after starting treatment because they did not present difficulties during exercises. Corrective lenses have been included in vision recovery exercises because anyone, without accumulation of intraocular metabolic residue, can read a text with any corrective lens.

**Cotton-polyester fabric, nylon mesh:** Light obstruction acts as a load for oculomotor movement. The mesh with thicker wire requires more oculomotor effort. By having a greater aperture in its mesh, the nylon mesh interferes in the elimination of the metabolic residues that are sheltered by the shadow of the light obstructed by its wires. The cotton-polyester fabric, by having a smaller opening in its mesh, can eliminate the residuals left by the nylon mesh.

**Eyewear (temporal):** Occlusion of temporal visual fields to increase the power of the rectus and ciliary muscles without the help of the oblique muscles.

**Eyewear (nasal):** Occlusion of the nasal visual fields to stimulate the movements related to the projection of the image in the nasal retina (needed but with little use).



**Pinhole glasses:** Used only at the beginning of treatment as a test. The use of these glasses can cause patient well-being because it eliminates a small volume of metabolic residue, but the volume eliminated is insufficient to solve the problems of refraction error. In addition, its use is not recommended during activities involving patient control or movement, such as driving a vehicle or walking. The holes in the lenses select the visual axis direction, and Scheiner's experiment apud [1] shows that the selection of the visual direction presents to the patient's target at different distances, making it impossible to evaluate the distance of the target and cause an accident.

**Sun:** Treatment using sunlight has been used several times because it is a source of light with greater intraocular penetration power. It is because of its power that, when looking at the Sun, one or more regions become dark. This strong light causes movements in the dehydrated and viscous metabolic residue that becomes opaque for some time, the accumulation region. Opacity ends due to involuntary intraocular movement. It is the involuntary movement of adaptation to the dark.

**Compact fluorescent lamp:** Used as fixation point.

**Treadmill equipment:** Ocular exercise performed on a treadmill does not cause sleep. Six is a great speed for the exercises. It is necessary that there is ample front and lateral visual space.

### 3.2. Symptoms and signs

During the exercises, there may be, in one or both eyes, fiery sensation along with blood-shot eye. After, there may be itching. Sweat can be severe on one side of the head or on both sides. Exercises can stimulate bruxism, pain in the jaw joint, tongue, and marks on the face. Although there is no direct relationship in many cases, this takes a lot of time and effort to perform the image fusion in a certain direction, or to maintain the fusion of images during the movement of the fixation point. By carrying out the exertion for a long time, it can divert the attention of the patient and it passes on to transmit force to these other parts of the body. After the exercises, sight may become blurry or there may be some other painless modification. For a short time, there may be a foreign body sensation in the cornea or intraocular. There may be acute pain of short duration.

**Auditory perception:** In 2003, on routine examination, the patient became aware of the absence of 6 kHz frequency perception and the presence of permanent noise, only in the left ear. In the analysis performed by an otorhinolaryngologist, no other pathology was found. In subsequent years, the patient was evaluated to verify the evolution of auditory perception. The patient began to perceive small hearing in the frequency of 6 kHz and reduced the perception in the adjacent frequencies, including in the right ear. Currently, the patient has noticed some relationship between the exercises for recovery of sight and the perceived noise, because the noise in the right ear stops and the amplitude of the remaining noise varies with the direction of the exercise. Then, among the criteria of choice of exercises are the direction of greater variation in the amplitude of the noise and displacement of fixed images. Thus, the variation in noise should be considered, in the choice of the exercise for the eyesight recovery.

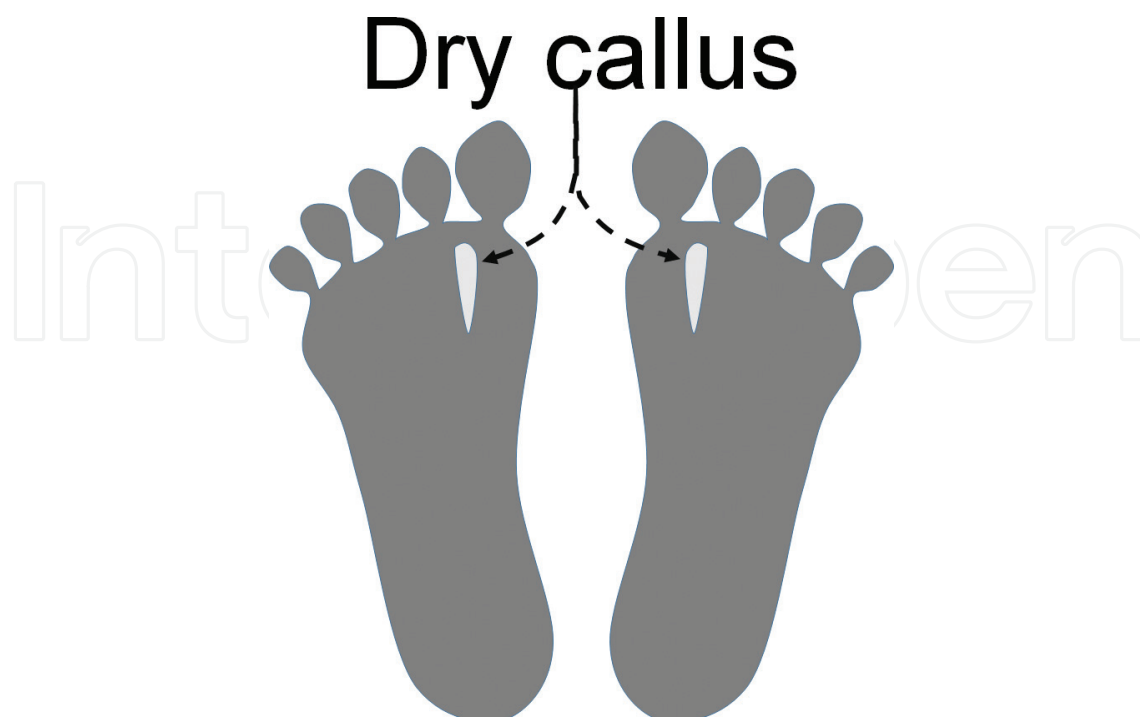
**Dizziness:** Exercising may cause dizziness, and in this way, the patient should hold onto the equipment support during the exercises.

**Imbalance:** May be perceptible or imperceptible. The imperceptible can cause the patient to knock down nearby objects, can in certain situations move one or more steps, as if drunk, for a short time, can cause pain in the sciatic nerve, and can produce dry callus on the bottom of the feet (**Figure 1**). Sometime later, they suffered fatigue in the right leg. Tiredness settled in the upper posterior region of the knee and then settled in the upper posterior region of the thigh, and the same symptom started in the left leg. This caused a great deal of suffering. It was not thought to be due to muscle strain. The hypothesis was that there was a problem of balance, since the dry callus had already been treated, and balance requires many activities of the lower limbs. Early in the morning, when the patient was seated, he began the eye exercise with eyewear (temporal), to strengthen and straighten the muscles, the symptoms immediately disappeared. The patient worked all day with the symptom of one who had walked for a long time. Two days later, the patient spent a lot of time with the symptom of muscle relaxation in both legs.

**Torticollis:** The most common signs are the sensation of contraction and pain on one side of the neck that can radiate to the back. It can be caused by stimuli of recurring displacement of the projected image on the retina.

### 3.3. Analysis of some ocular pathologies

The analysis was based on the progress of the recovery of the patient's vision, in addition to the conclusions reached in our other publications. The ocular refractive error has its origin in the accumulation, dehydration and agglutination of the intraocular metabolic residue [2] caused by the defect in the mechanical system of mass transfer in the cornea (between the corneal layers) [2–4], trabecular meshwork [5], lens [6] and retina [7, 8]. Congenital and acquired pathologies increased the mass transfer deficiency.



**Figure 1.** Diagram showing the dry callus location.



**Cataract:** It is the accumulation of dehydrated metabolic residue in the lens. As the residue is translucent, its dehydration is opaque.

*Because it is an accumulation, it is natural to increase the volume and rigidity of the lens, as well as to associate the age of the person with its consequences, among them visual acuity. During the exercises, there may be an intraocular foreign body sensation as well as a small, rapid and uncomfortable intraocular pain because of cataracts.*

**Dark adaptation:** The eye takes longer than 20 min to fully adapt from bright sunlight to dark [9].

*The eyes are organs of the visual system. The eye transmits the luminous image to the retina that, through electrochemical impulses, transmits to the brain. The image interpretation can trigger a physical protection action, that is, the person through the image can move the hand or foot to perform a body protection action. The hand and foot take well less than 20 min to make the maximum displacement. So "the eye is a radar that spends 20 minutes to identify an attack, and in defence, it can trigger a missile attacking the target in a minute, so this radar is not for this operation." This means a serious visual impairment. A person without accumulated intraocular metabolic residue can look at the sun and then read a text written in black ink on white paper. In the appendix, it is shown that the adaptation time to the dark is not greater than 0.24 s (Eq. 7).*

#### **Glaucoma:**

- **Open-angle:** It is caused by slow obstruction of the trabecular meshwork, resulting in increased eye pressure.

*In Ref. [5], it shows how the metabolic residues coming from the cornea can slowly obstruct the trabecular meshwork, increasing the resistance of the aqueous humor and, consequently, increasing the intraocular pressure.*

- **Angle-closure:** It is the result of the closing of the angle between the iris and the cornea.

*The accumulation of dehydrated metabolic residue causes formation of a large refractive error and may cause defective coordination between the movement of the lens and the movement of the oculomotor muscles. See in keratoconus analysis.*

- **Normal-tension:** The optic nerve is damaged without the eye pressure being too high [5].

*The accumulation of intraocular metabolic residue modifies the shape, volume and mass of the eye, and as a result, the oculomotor muscles move out of their ergonomic movement and change the position of the eye in the ocular cavity. These changes can strain the optic nerve.*

Eye movements [10]:

- **Conjugate:** They are those that preserve the angular relationship between the right and left eyes.
- **Saccadic:** They are very fast jumps from one eye position to another.

*Saccadic and vergence movements are acquired pathologies associated with agglutinated metabolic residues. These clusters form intraocular lenses, which project images into the retina, in different places.*

In 1619, Scheiner described these images apud [1]. Then, when the visual axis changes agglutination, the image of interest jumps from the fovea to another location. This jump causes a rapid movement of the eye in the opposite direction (saccadic movement) to transfer the image to fovea. If the jump of the eye causes the return of the visual axis to the anterior agglutination in order to cause recurrent periodic movement, then it can cause photosensitive epilepsy [2].

- **Vergence:** Eye movement for fusion of retinal images and obtaining binocular vision.

**Floater:** These are deposits of metabolic residue, in the cornea or lens, with various sizes, shape, consistency and refractive index and can be transparent, translucent or opaque.

During treatment, the oldest floater is opaque, but on many days, it presents itself in different forms and opacity. Another floater was divided in two and maintained connection between both.

**Headache:** This is a warning symptom of a greater problem that is occurring in the body.

You should not take medicine and you should do exercises. If you delay in taking action, the treatment is much longer. Precisely, on the day that the writing of this work is being finalized, the right eyeball of the patient presented a pain sensation, similar to the occurrence, shortly after the injection in the left eye of the same patient. It is probable that the right eye has performed movements that cause mechanical tension in the optic nerve. If immediate corrective action is not provided, it can cause glaucoma with normal pressure. In both cases, the treatment is the same given in relation to the imperceptible imbalance of the body, motor coordination and increase of the power of the rectus muscles.

**Keratoconus:** Changes of the cornea to a cone-like shape and its thickness reduction.

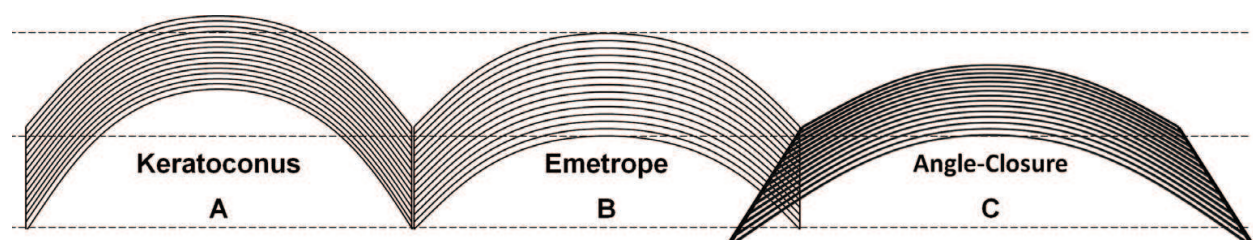
The torsional accommodation of the cornea is a movement of variation of the radius of its curvature. This may be caused by personal habits and ocular structure, which can progressively increase the radius of curvature, causing keratoconus, or by modifying its cylindrical periphery to the conical shape, blocking the drainage of the aqueous humor, causing angle-closure glaucoma. **Figure 2** shows the two possibilities.

**Ocular dominance:** This is the fixation of the eye with less movement (called the dominant eye) on the target and the adjustment of the contralateral one.

In Ref. [4], it is treated as visual impairment.

**Phosphene:** This can be directly induced by retina mechanical stimulation. It is easy to check when rubbing or applying pressure to closed eyes.

In Ref. [7], it is written without naming the acquired pathology. "The metabolic secretions are accumulated in the retina forming clusters without any regularity therefore when the eyes are pressed on



**Figure 2.** Scheme of the formation of keratoconus, and the angular closure.

*by the hands, the photoreceptors are also pressed, and the process affects its biochemical transduction that produces an electrical signal to the brain which interprets it as a light signal.” At the present, only, some blue dots are still perceived.*

**Photophobia:** It is a symptom of abnormal light sensitivity.

*When the iris fails to reduce interference from the brightness of the incident light to improve the sharpness of the temporal retinal projection. This is one of the effects of accumulation of intraocular metabolic residue. If the physician needs to use different corrective lenses between the exams with and without dilated pupils, it is necessary to verify the need to eliminate the stagnant metabolic residues in regions that are not usually used to design images in the retina.*

Refractive error

- **Myopia:** When there is a need for the use of concave lens, to correct the convergence of light rays.
- **Hyperopia:** When there is a need for the use of convective lens, to correct the convergence of light rays.
- **Presbyopia:** When there is a need for the use of bifocal or progressive lens, to correct the convergence of light rays.
- **Astigmatism:** When there is a need for the use of cylindrical lens, to correct the convergence of light rays.

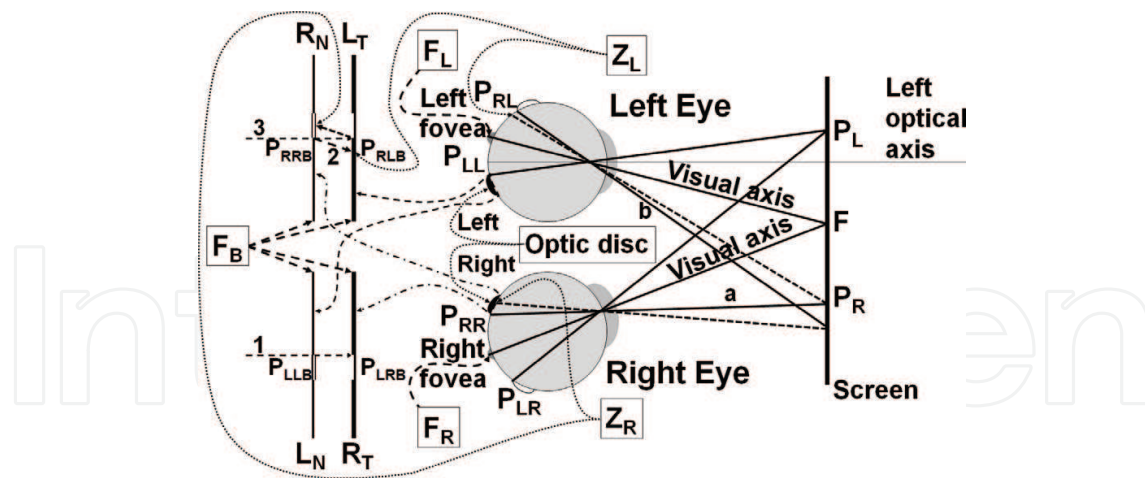
*In Ref. [2], it is shown that refractive error causing myopia, hyperopia, presbyopia and astigmatism has the same origin: dehydration and agglutination, intraocular, of accumulated metabolic residues.*

## 4. Binocular vision anatomy

Binocular eyesight uses the image fusion for greater visual accuracy. **Figure 3** shows, schematically, the main elements to explain the oculomotor control mechanism, obtained from the images projected on the retina.

Binocular vision of the fixation point on a screen (F in **Figure 3**) occurs when the visual axes of the eyes converge at this point. The F-point protrudes into the central fovea at points  $F_R$  and  $F_L$  (**Figure 3**), respectively, in the right and left eyes. The two visual axes define the visual plane. The visual plane intercepts the retina in both eyes on two anatomical horizontal meridians, in the right and left eyes. Each anatomical horizontal meridian has two sides, the temporal and the nasal. The nasal anatomical horizontal meridian includes a segment, corresponding to the optic disc, which does not send an image to the brain.

The nasal anatomical horizontal meridian intercepts the neural communication periphery of the optic nerve, closer to the left fovea, at the  $P_{LL}$  point (**Figure 3**). In the right eye, the  $P_{LR}$  retinal point is the closest to the fovea, obtained by the interception of the temporal anatomical horizontal meridian with the corresponding neural communication periphery of the



**Figure 3.** Binocular vision representation scheme.

contralateral optic disc (projection of the contralateral blind spot periphery). If the  $P_{LL}$  and  $P_{LR}$  retinal points are the neurologically corresponding signals to the  $P_L$  screen point retinal projections, the image fusion is perfect. The projection on the right temporal anatomical horizontal meridian, containing the  $P_{LR}$  point, sends the visual signals to the ipsilateral cerebral hemisphere in the  $R_T$  line (right temporal side), shown in **Figure 3**. The projection on the left nasal anatomical horizontal meridian, containing the  $P_{LL}$  point, sends the visual signals to the contralateral cerebral hemisphere, in the  $L_N$  line (left nasal side), shown in **Figure 3**. In the  $L_N$  line, there is a small segment for the optic disc representation. The arrow "1" locates in the brain at the intersection with the  $L_N$  line and the neural point  $P_{LLB}$  (left horizontal nasal anatomical meridian) corresponding to the signal received from  $P_{LL}$  retinal point and reaches the  $R_T$  line at the neural point  $P_{LRB}$  (right horizontal temporal anatomical meridian) corresponding to the signal received from  $P_{LR}$  retinal point. If the  $P_{LLB}$  and  $P_{LRB}$  neural points are the neurologically corresponding signals to the  $P_L$  screen point retinal projections, the images fusion is perfect, that is, the horizontal diameter of the contralateral blind spot is projected on the  $R_T$  line white highlight, indicated by "1" arrow.

The nasal anatomical horizontal meridian intercepts the neural communication periphery of the optic nerve, closer to the right fovea, at the  $P_{RR}$  point (**Figure 3**). In the left eye, the  $P_{RL}$  retinal point is the closest point of the fovea, obtained by the interception of the temporal anatomical horizontal meridian with the neural corresponding of communication periphery of the contralateral optic disc (projection of the contralateral blind spot periphery). If the  $P_{RR}$  and  $P_{RL}$  retinal points are the neurologically corresponding signals to the  $P_R$  screen point retinal projections, the image fusion is perfect. In this case, retinal points are not the neurologically corresponding signals to the  $P_R$  screen point retinal projections; therefore, there is no fusion of images, and there is binocular diplopia. The projection on the left temporal anatomical horizontal meridian, containing the  $P_{RL}$  point, sends the visual signals to the ipsilateral cerebral hemisphere in the  $L_T$  line (left temporal side) shown in **Figure 3** diagram. The projection on the right nasal anatomical horizontal meridian, containing the  $P_{RR}$  point, sends the visual signals to the contralateral cerebral hemisphere in the  $R_N$  line (right nasal side) shown in **Figure 3** diagram. In the  $R_N$  line, there is a small segment for the optic disc representation. Arrow "2"



locates in the brain at the intersection with the  $R_N$  line and the neural point  $P_{RRB}$  (right horizontal nasal anatomical meridian) corresponding to the signal received from  $P_{RR}$  retinal point and reaches the  $L_T$  line at the neural point  $P_{RLB}$  (left horizontal temporal anatomical meridian) corresponding to the signal received from  $P_{RL}$  retinal point. If the  $P_{RRB}$  and  $P_{RLB}$  neural points are the neurologically corresponding signals to the  $P_R$  screen point retinal projections, the image fusion is perfect. The image fusion follows the neural correspondence shown by the “3” arrow, which does not correspond to the respective  $P_R$  screen point retinal projections; thus, there is binocular diplopia. The right superior oblique muscle action can accommodate the cornea to perform the angular displacement of “2” arrow until reaching “3” arrow (make the  $Z_L$  point coincide with  $P_{RL}$  point corresponding to  $P_{RLB}$  point in brain). That is, intersect “a” line (**Figure 3**) with the “b” line on the screen, or move the  $Z_R$  point (**Figure 3**), projected on the optic disc of the right eye, to overlap the  $P_{RR}$  point or  $P_{RRB}$  in brain. As the control is contralateral, the right superior oblique muscle action moves the  $Z_L$  point until it coincides with the  $P_{RL}$  point, that is, the horizontal diameter of the contralateral blind spot is projected on the LT line white highlight, indicated by “3” arrow.

## 5. Conclusion

As is well known, the brain is “cross-wired” with body movement control and superior oblique muscle but is ipsilateral to the other oculomotor muscles. For the reception of visual signals, the brain is ipsilateral to the projection in the temporal retina and contralateral to the projection in the nasal retina. In the binocular limit of lateral vision, the nose contralateral shadow is the contralateral temporal projection, so that the ipsilateral nasal projection is the only contralateral control signal of the third and sixth cranial nerve functions. Therefore, contralateral ocular movement occurs only under the influence of the projections in the ipsilateral eye. The image fusion influences only the contralateral movement of the superior oblique muscle to avoid binocular diplopia. In summary, the ipsilateral and contralateral nasal projections form the contralateral oculomotor control signals, and the ipsilateral temporal projection transmits, for the brain, the reference signal in motor control of the contralateral superior oblique muscle. In addition, the inferior oblique muscle can correct some angular deviation of ipsilateral temporal projection, without any influence of control of the superior oblique ipsilateral muscle (it does not have a reference image for motor control). In this way, it is easy to understand the contralateral influence resulting from a monocular stimulus.

**Rectus muscles:** Its main function is to maintain the designed fixation point in the fovea centralis. The superior and inferior rectus muscles avoid and stabilize the vertical displacement of the ipsilateral retinal projection, and the lateral and medial rectus muscles avoid and stabilize the horizontal displacement of the ipsilateral retinal projection. Maintaining eyesight at a fixation point is extremely important for proper accommodation of the crystalline lens and cornea. The fixation point can be a light source or not, and it can be fixed or movable and can be in an ambience with or without changing the lighting level. Vision may be with or without ocular occlusion, may be with or without corrective lenses and may or may not be through a mesh. The head may have a rotating, extension and flexing motion, or it may

remain motionless. These are possible combinations that depend on the goal to be achieved. Exercise can cause itching in the sclera nasal region.

**Ciliary muscle:** It has the main function of maintaining and stabilizing the projection in the ipsilateral temporal fovea and giving it the same dimension as in the contralateral nasal fovea image. These muscles also have the ability to correct the distance from the fixation point, which may be invisible to the eye and act as a mass transfer mechanism by forced convection in the lens.

**Superior oblique muscle:** It has the main function of enlarging or reducing the projection in the horizontal nasal anatomical meridian, so that the same projected image in the periphery of the optical disc is the same projected image in the corresponding neural region of the periphery of this optic disc, in the contralateral temporal retina. The deviation in the ipsilateral temporal projection causes a force antagonistic to the superior obliquus muscle movement.

**Inferior oblique muscle:** It has the main function of correcting the angular deviation of the projection in the temporal retina in relation to the projected image in the contralateral nasal retina. The torsional accommodation of the cornea is a joint action of the oculomotor muscles to obtain fusion of the temporal and contralateral nasal images, in addition to varying the intraocular pressure. This accommodation is the mechanism of forced convective mass transfer on the cornea and retina, and it may be inferior, cylindrical or superior, but the difficulty in twisting the cornea may cause twisting of the eyes. Because of the cornea torsional accommodation, a circle in the binocular view can project with the same radius in the retinas of the eyes, with duplication of the monocular vision information, adjustable, and able to obtain a much greater mathematical precision than the accuracy of monocular vision, in accordance with human perception.

**Iris:** It is a thin circular structure with the main function of reducing incident light when this brightness interferes with the sharpness of the temporal retinal projection as well as diaphragmatic action, to avoid the aqueous humor return, when the pressure in the anterior chamber is greater than the pressure in the posterior chamber due to corneal accommodation.

**Eyelid movement:** It has the main function of mechanical transport of nutrients and metabolic residues, in addition to being able to reduce the ocular opening voluntarily or involuntarily, when the iris reaches the minimum limit of its opening. The eyelid, on a regular basis, spreads tears, for rehydration and entrainment of the metabolic residue throughout the anterior ocular surface. Tears and metabolic residues are drawn into the puncta (an opening near the nasal bridge) by capillary action and conducted to lacrimal sac through the lacrimal canaliculi and then to the nasal cavity through the nasolacrimal duct. In the nasal cavity, the tear goes out through the nose or the metabolic residue can dehydrate; the resulting mucus accumulates in the nasal cavity; or the viscous residue passes through the throat and is eliminated orally or through the digestive tract. Elimination of the metabolic residue during sleep can cause a very inflamed throat, which may be accompanied by hoarseness for a few days. Cough and sneezing may occur with the expulsion of metabolic residue. Shedding of tears (or eye discharge) of one or both eyes may occur in response to the elimination of metabolic residue from the corneal epithelium, and it can last more than a day. The elimination of metabolic residue in the cornea can be accompanied by the sensation of foreign body in the eye.



Because of the personal habits, the mobile intraocular mass may remain stagnant for a long time, so the metabolic secretions of this medium can dehydrate by decantation, increasing its viscosity and, consequently, increasing the absorption and refraction of light penetrating the eyes. This is the process of accumulation of metabolic residues in the cornea, the trabecular meshwork, the lens and the retina, causing the most known intraocular problems such as refractive errors, keratoconus, glaucoma, cataract, retinal detachment, retinitis pigmentosa and macular degeneration among other problems, which may be added with other factors. Involuntary oculomotor movement exists to reduce the refractive error of the projected image in the temporal retina. However, this involuntary movement can add other problems such as change in the volume and shape of the eyeball, cornea and lens. However, this same involuntary movement can be used to rehydrate and remove the intraocular metabolic residue, in the form of solution or suspension.

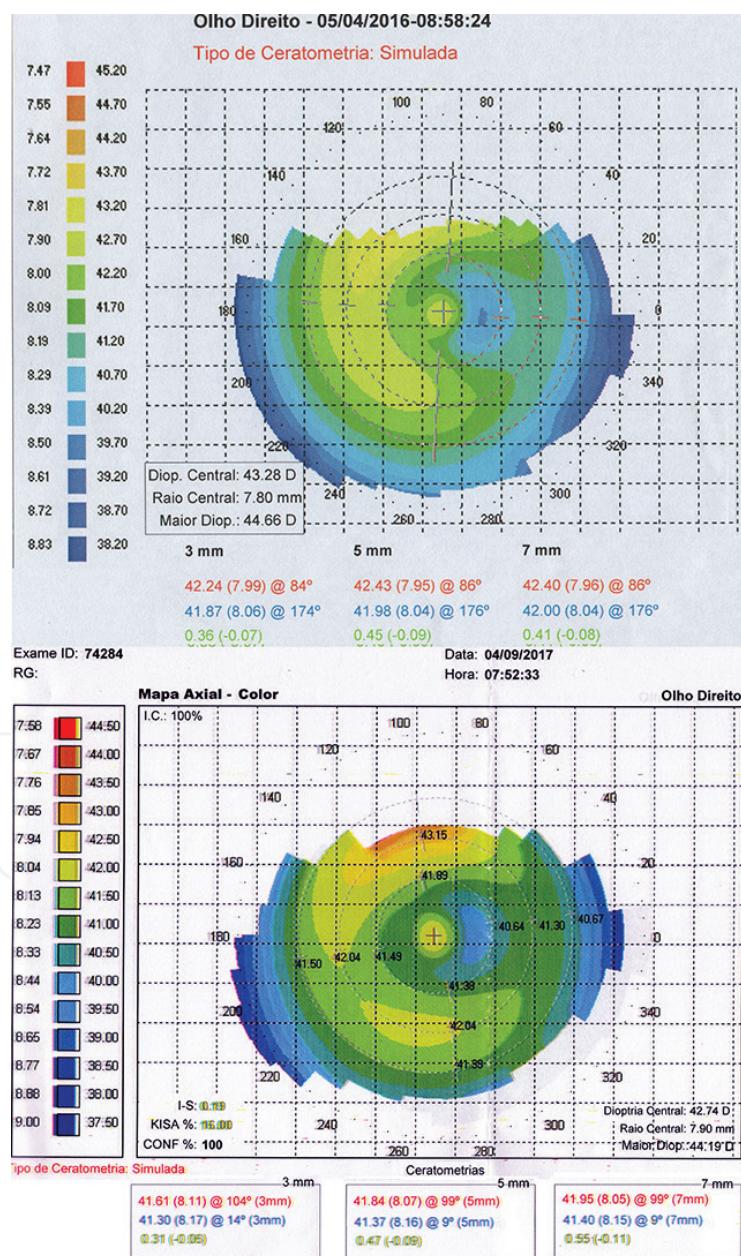
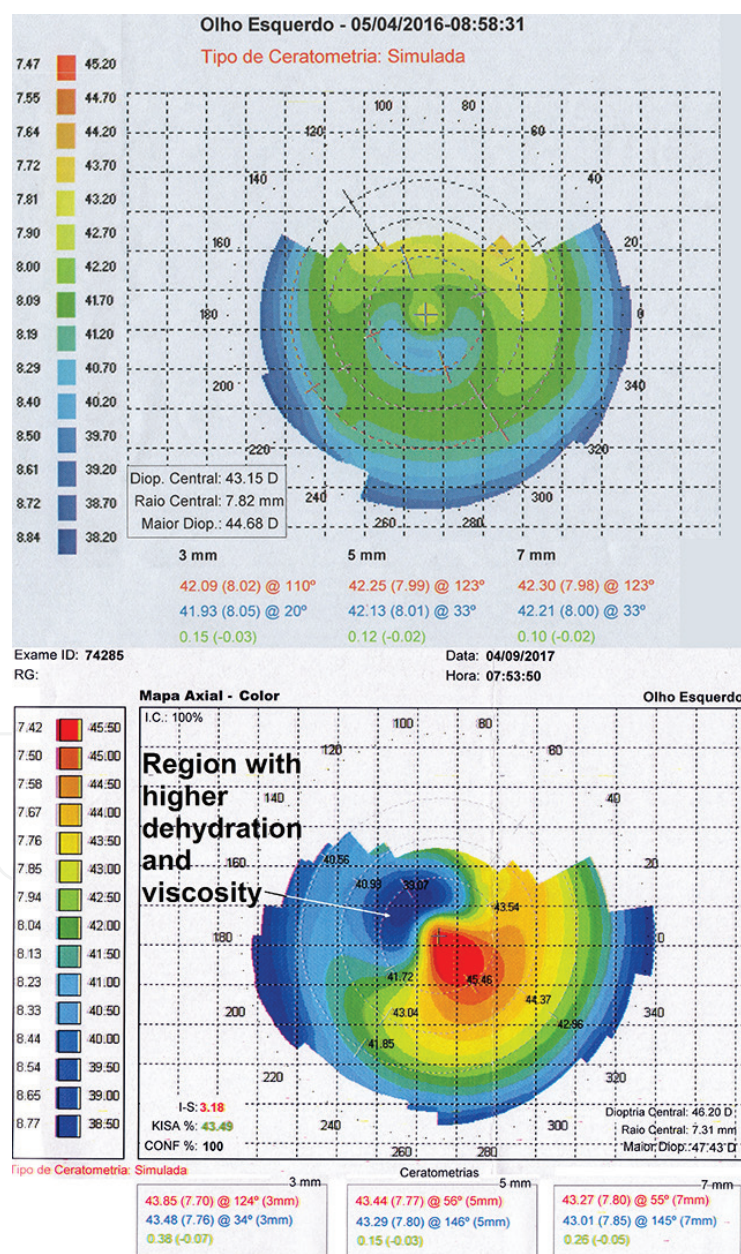


Figure 4. Corneal topography of the right eye performed on April 04, 2016, and September 05, 2017.

From the examinations performed on the patient, only a computerized corneal topography could provide some information to evaluate the progress of the treatment. For each eye and in both, it was necessary to add, on examination, the complementary volume, surplus volume and volume to be distributed, to obtain a uniform corneal lens. At the end of the work, these volumes will be null. **Figure 4** shows the corneal topography of the right eye performed on April 04, 2016, and September 05, 2017, and **Figure 5** shows the result of the same exam for the left eye. Visually, it is possible to verify the progress of the work performed, but there is no measure that can evaluate the volume of metabolic mass moved in the cornea, during 17 months. The region of the left cornea, with the most dehydrated metabolic mass, is indicated in the last examination, shown in **Figure 5**. This region has lower diopter and higher viscosity. Its rehydration causes a foreign body sensation in the cornea, but because of cataract, it can cause foreign body sensation intraocular.



**Figure 5.** Corneal topography of the left eye performed on April 04, 2016, and September 05, 2017.



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## A. Appendix

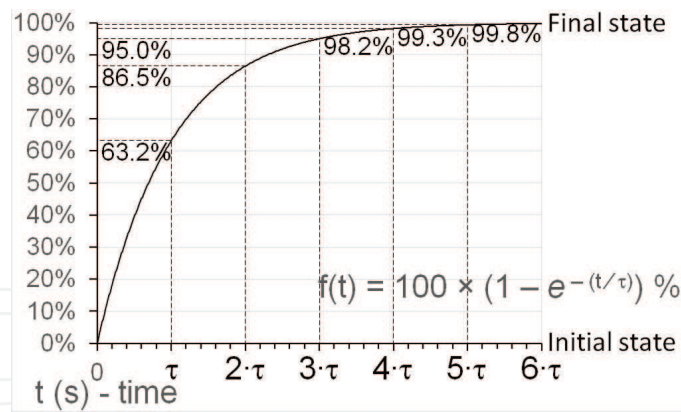
### A.1. Dynamic comparison of the agility of change of state among different activities of the body, eyesight adaptation to dark and movements of the limbs and superior eyelids

In Ref. [5], it was shown that in a first-order system, the percentage change of the final state from an initial state is given by Eq. (1) (see the graphic in **Figure 6**), where  $e = 2.71828$ ,  $t$  is the time and  $\tau$  is the time constant. In the human body, the eye movement has less constant time than the arm movement, that is, the eye movement is faster than the arm movement.

$$f(t) = 100 \cdot (1 - e^{-t/\tau}) \quad (1)$$

In this appendix, a first-order linear mathematical model is used to determine the time constant (numerical value of agility evaluation of a system) to find the maximum displacement time of the upper limbs in personal defense, considering concepts exposed and the maximum time with eyes closed, due to the movement of the eyelid with 287 winks per minute [5]. The result is compared to the value obtained, considering the adaptation to dark with 20 min. With the data obtained, it is verified that the time of 20 min for the adaptation to the dark is unacceptable, because it would have to admit the agility of the superior members much greater than the one of the vision.

The verification of the speed between two systems is performed through the percentage execution of the activity for multiple values of the time constant. If two systems named "A" and "B" with  $\tau_A$  and  $\tau_B$  their respective time constants and have the relation  $\tau_A = 2\tau_B$ , then, when time is equal to  $\tau_A$ , "A" system performed 63.2% of its final state; however, "B" system has



**Figure 6.** Graph of the function  $f(t) = 100 \cdot (1 - e^{-t/\tau})$ .

already achieved 86.5%. Therefore, the system with the shortest time constant is the fastest, in this case the "B" system.

**a. Eyelid—287 flashes per min [5]**

To simulate the movement of the eyelid, you should consider the maximum distance traveled by the eyelid should be considered as 100%. In the initial state, the eyelid is closed (or open) when the instantaneous time is equal to zero and, in the final state, the eyelid is open (or closed) when the instantaneous time is equal to  $\tau$ ,  $2\tau$ ,  $3\tau$ ,  $4\tau$ ,  $5\tau$ ,  $6\tau$  or more, depending on the accuracy.

When  $t$  is equal to  $\tau$ , the system executes 63% of the activity. When  $t$  is equal to  $2\tau$ , the system executes 86% of the activity. When  $t$  is equal to  $3\tau$ ,  $4\tau$  or  $5\tau$ , the system executes 95, 98 or 99% of the activity, respectively.

Eq. (2) gives the time  $t_{oc}$  that the eyelid passes to open or close the eye, in seconds.

$$t_{oc} = 60 / (2 \cdot 287) = 0.10453 \text{ s} \quad (2)$$

If **0.10453** represents 99% of the opened or closed eyelid, then the minimum time constant is  $\tau_i = 0.10453 / 5 = 0.02091 \text{ s}$  and, if 95% of the maximum time constant is  $\tau_a = 0.10453 / 3 = 0.03484 \text{ s}$ , then the eyelid time constant  $\tau_e$  is in the range  $0.02091 \text{ s} \leq \tau_e \leq 0.03484 \text{ s}$ . Eq. (3) gives the eyelid mean time constant  $\tau_{em}$ .

$$\tau_{em} = (0.02091 + 0.03484) / 2 = 0.02788 \text{ s} \quad (3)$$

Thus, the eyelid system completes its activity between  $3\tau_{em}$  and  $5\tau_{em}$ , so its average time is  $4\tau_{em}$ , and the eyelid opens or closes the eye with time  $t_e$  given by Eq. (4), which is considered the transition time for the state change (from opened or closed eye to closed or opened eye or from light to dark).

$$t_e = 4 \cdot 0.02788 = 0.1115 \text{ s} \quad (4)$$

The neural system of reception and comprehension of the retinal image spends the same eyelid time  $t_e$ , to complete the whole process, after the conclusion of the eyelid movement, so that the total processing time  $t_{na}$  is given by Eq. (5), for the situation **a** (eyelid—287 flashes per minute).

$$t_{na} = (1 + 1) \cdot t_e = 2 \cdot 0.1115 = 0.223 \text{ s} \quad (5)$$

If the neural system has the completion time  $t_{na}$ , its time constant varies between  $\tau_{nia} = 0.223/5 = 0.0446 \text{ s}$  and  $\tau_{naa} = 0.223/3 = 0.07433 \text{ s}$  and then the neural time constant  $\tau_{na}$  is in the range  $0.0446 \text{ s} \leq \tau_{na} \leq 0.07433 \text{ s}$ . Eq. (6) gives the neural mean time constant  $\tau_{nma}$  for the situation **a** (eyelid—287 flashes per minute).

$$\tau_{nma} = (0.0446 + 0.07433)/2 = 0.05947 \text{ s} \quad (6)$$

The neural system completes its activity between  $3\tau_{nma}$  and  $5\tau_{nma}$ , so its average time is  $4\tau_{nma}$ , and the image interpretation occurs with time  $t_{na}$  given by Eq. (7), which is considered the transition time for the state change (the time of interpretation of the retinal image).

$$t_{na} = 4 \cdot 0.05947 = 0.23786 \text{ s} \quad (7)$$

The superior limb movement system, to reach the maximum displacement, takes twice the time  $t_{na}$  of the reception and comprehension of the retinal image process, after its completion, so that Eq. 8 gives the total processing time  $t_{sa}$ , that is, slightly less than one second for superior limb maximal displacement.

$$t_{sa} = (2 + 1) \cdot t_{na} = 3 \cdot 0.23786 = 0.71359 \text{ s} \quad (8)$$

#### **b. Dark adaptation—30 min [9]**

If the neural system has the completion time  $t_{nb} = 20.0 \text{ min}$  (in Ref. [9] cites 30 min), its time constant varies between  $\tau_{nib} = 20/5 = 4.0 \text{ min}$  and  $\tau_{nab} = 20/3 = 6.66667 \text{ min}$ , that is,  $4.0 \text{ min} \leq \tau_{nb} \leq 6.66667 \text{ min}$ . Eq. 9 gives the neural mean time constant  $\tau_{nmb}$  for the situation **b** (dark adaptation—30 min [9]).

$$\tau_{nmb} = (4.0 + 6.666)/2 = 5.33333 \text{ min} \quad (9)$$

The neural system completes its activity between  $3\tau_{nmb}$  and  $5\tau_{nmb}$ , so its average time is  $4\tau_{nmb}$ , and the image interpretation occurs with time Eq. (10), which is considered the transition time for the state change (the time of interpretation of the retinal image).

$$t_{nb} = 4 \cdot 5.33333 = 21.33333 \text{ min} \quad (10)$$

The movement system of the superior limbs takes twice the time,  $t_{nb}$ , to reach the maximum displacement of the reception and comprehension of the retinal image process, after

its completion, so that Eq. 11 gives the total processing time  $t_{sb}$ , that is, slightly more than an hour for superior limb maximal displacement.

$$t_{sb} = (2 + 1) \cdot t_{nb} = 3 \cdot 21.33333 = 64.0 \text{ min} \quad (11)$$

Thus, the mathematical model and its parameters have shown that if the measured eyelid movement, 287 flashes per minute [5], is considered as a reference, it obtains, for the displacement of the upper limbs, the time  $t_{sa} = 0.71359 \text{ s}$ , compatible with the reality. However, if the time of 20 min (30 min [9]) is considered as a reference for adaptation to the dark, it obtains, for the displacement of the upper limbs, the time  $t_{sb} = 64 \text{ min}$ , incompatible with reality.

The exposed model does not consider dead time (the time lag between the beginning of stimulus given to a system and the beginning of resulting response); however, it is possible to adopt  $t_{na} = 0.23786 \text{ s}$  and  $t_{nb} = 21.33333 \text{ min}$  as the dead time in the respective simulations. In this case, the dead time, considering the eyelid movement, is compatible with reality and confirms the simplified representation of the event, whereas for the second case, the waiting time is incompatible for the defense of the body, therefore, or the parameter adopted is incompatible or the model chosen is not applicable. This work adopted the first alternative.

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