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Prevention of MYOPIA: the eye ought to exercise the use of the 3rd dimension of the visible at an early age

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Abstract:-Myopia is increasing worldwide; its cause is not well understood. A new interpretation of the relationship between the optical imaging equation and the ocular mechanism of fixation and accommodation shows that the eye can choose between three options when dealing with the 3rd dimension of the visible world. The three possible solutions are analyzed. A first solution would differentiate the 3rd dimension only in focal space and image all objects at different distances into only one image plane, the solution adopted by photographic optics. A second solution would differentiate the 3rd dimension only in image space, but makes the ciliary body apparatus of accommodation dispensable. The 3rd solution relies on a 3D-processing in the focal and in the image space and the coordination of both parts through the adoption of an accommodation resting position, determined by the early vision experience with the 3rd dimension. Myopia results, if there is early in life only a training of vision with objects at short distances. Prevention of myopia therefore not only should enhance the time spent in fresh air, however, the training of fixation and accommodation should also be included in monocular and binocular vision to objects at different distances in the real 3D world.

***Index terms:*-Human vision, Monocular 3D vision, Prevention of Myopia, Object fixation and accommodation in human vision.**

I. INTRODUCTION

A child ought to be permitted to experience at an early age that the visible world is further than one's own four walls…The correct way of learning to see succeeds if the eye not only learns the plain optical imaging of the visible as such, but also if it is able to actively use and successfully exercise the mechanism of fixation and focussing of visual objects inherent at birth and the accommodation to the distances of objects in three-dimensional space [7]. This is according to the principle: 'Whatever it is that you have inherited from your fathers, make it your own in order to possess it'. The gaze saccades into the depth of the three-dimensional space, the leaping of the view to objects at different distances are of decisive importance for the early development and life-long fitness of the visual organ. Therefore, the eye requires using the 3rd dimension of the world at an early age. A myopic person sees far-away objects indistinctly; the objects close to him he sees with normal acuteness [8]. The occurrence of myopia (short-sightedness) has still not been resolved sufficiently. The extent, to which myopia is increasing worldwide, is terrifying. "According to estimates made by the World health Organization (WHO) in the next 10 years 2.5 billion people will be affected by myopia" [3, p.16]. In searching for a remedy, "large-scale studies undertaken during the last few years have shown that children, who spend more time in the fresh air will develop myopia less often or will see it progress more slowly " [1, 4]. The hypothesis that "bright daylight will increase the deep focus, which results in a more acute image and that by means of daylight more dopamine is released on the retina, which has an inhibitory effect on the growth of the length of the eye" is not sufficient for a successful counter measure. Scientists have proven that the daily time of reading, the distance of the text and intensive near-work facilitate the progression of myopia" and that "persons in urban regions are affected by myopia more often" [3, p.57]. The more frequent going out into daylight is surely already a step in the right direction. However, the danger continues to persist that more and more people will have to rely on corrective glasses or contact lenses, only because they cannot successfully capture the world in the third dimension. Two axes in each eye are responsible for the fixation of the visual objects. The fixation of objects is related to the alignment of the axes in the eye. Each eye has two axes [6]. In daylight vision it is the visual axis, which connects the fovea being the location with the most acute cone vision in the central area of the retina with the fixation point on the targeted object (Fig. 1, left). In twilight vision, this function is taken over by the mechanical axis of the eye with the ring-zone of the greatest rod density (zone of the most acute rod vision), which orbits the fovea and papilla in the central area of the retina (Fig. 1, right). In fixation, one spot on this ring zone will relate the central retina with the fixation point on the targeted object. In doing so, in comparison to daylight vision, we look slightly to the side of the object, when we target it. The mechanism of accommodation is responsible for providing the acute image of the particular fixated object present at different distances in the central area of the retina in the relevant image plane. The ring muscle of the ciliary body around the lens of the eye regulates the curvature of the eye lens with its holding fibers (Zonula- fibers) and thus also the refraction value of the optic. The fixation of an object and the accommodation at its distance take place under the influence, the stimulation and control of the central area of the retina. Both mechanisms are present in each individual eye and are therefore not only available binocularly, but also monocularly.

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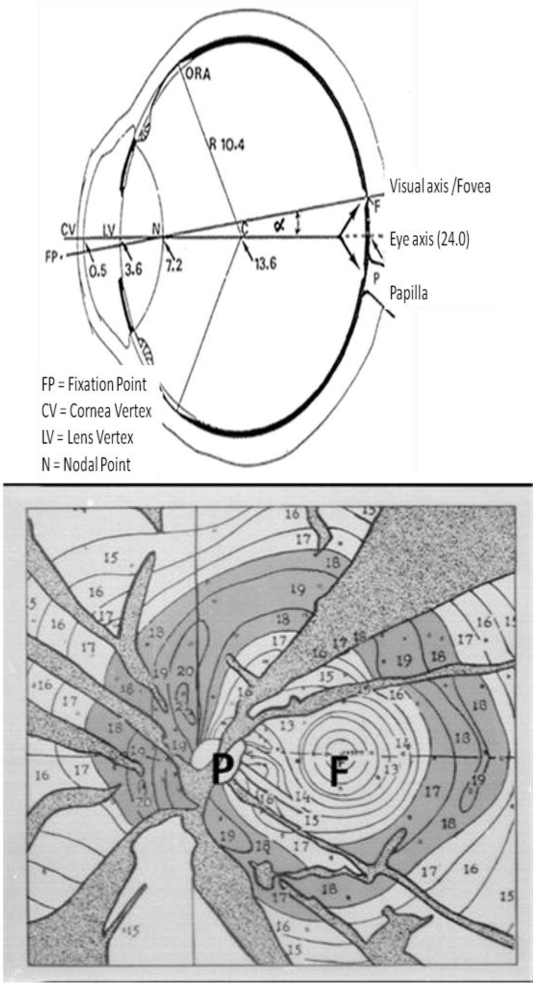

Fig. 1: (left) the two axes of each eye: the visual axis and the mechanical eye axis with angle α between the two axes. (right) The central area of the retina with the Fovea (F), the location of sharpest daylight vision, which has the greatest density of cones [5], and the papilla (P), the place of exit of the optic nerve from the eye, which makes up the 'blind spot' in the eye and causes its lack of photoreceptors (right eye). The ring zone of the highest density of rods orbits both poles of the central retina [9, ring zone was marked by the author. The gray segments in the image are missing pieces of the retina preparation].

II. THE IMAGING EQUATION OF OPTICS

An object, which is approaching from a great distance, pushes the image plane in the eye further backwards… The imaging equation of optics in Fig. 2 describes the regular connection between the object distance g and image distance b depending on the anterior focal length f and the posterior focal length f'. In this simple form, it applies to a thin lens. With low modifications however it also applies to composite optical imaging systems such as the human eye. For the human eye, the equation generally describes the fact that, if g decreases, f' decreases and b increases. As well as the fact, that in the case of approach of an object fixated by the eye from a distance of e.g. 100m to 25 cm, the focal length f' will decrease due to a stronger curvature of the lens and thus the image distance b in the eye will increase. If the imaging equation is extended by the refraction indices of the optical media, this process is described more precisely:

$$\frac{fn_2}{g} + \frac{f'n_1}{b} = 1 \text{ and } b = \frac{gf'n_1}{(g - fn_2)}$$

In the imaging equation the object distance g and the image distance b now depend on the optical focal lengths and the refractive indices, on fn_2 and $f'n_1$. The refraction index anterior to the eye corresponds to the one in air with n_1 = 1; in the inner eye the overall refraction index is n_2 = 1.336 [10, 11]. Therefore f/f'= n_1 / n_2 with $n_1 < n_2$ holds. It means that in the case of a fixation of e.g. an object at a distance of 5 m, with f'= 22.785mm and f = 17.055 n_2 = 22.785mm. (f = 17.055mm is the anterior focal length of the eye), both relations become equal (f'/f = n_2 / n_1 = 1.336). The object distance of g = 5m corresponds (with f' = 22,785mm) to an image distance b = 22.889mm and the imaging equation thus results as follows f n_2/g + f' n_1/b = 22.785/5000 + 22.785/22.889 = 0.004557 + 0.995443 = 1. This corresponds to an equilibrium state in the 'optical swing' of the accommodation, comparable to a balance with arms of different lengths and with unequal weights. The ‚optical swing', as illustrated in Fig. 3 represents an elongated rotational ellipsoid, whose focal points are the points F and F' of optics; the object lies in the anterior pole, the subject – the fovea of the observer in daylight vision - in the posterior pole. It guarantees the balance between outer and inner optical events. The equilibrium state always occurs when the eye has successfully adjusted to a particular object distance. The object thereby is imaged acutely in an image plane at the central retina place of the most acute vision.

The options the eye has for the ‚proper' processing of the third dimension…

The 'optical swing' in each eye has to provide for the correct depth position of the acute image of the particular fixated object at the central retina location… Within the framework of the imaging laws, from the very beginning, the eye basically has a choice between three different solutions for the processing of the third dimension of the visible. However, while learning to see, it has to choose between these at an early stage. In this, consequences for the imaging of the particular fixated object result as well as for the imaging of the non-fixated objects in the neighborhood of the fixated object.

- **3D-information exclusively in focal space**. By choosing the first solution, the eye could place value on the fact that the visual objects at different distances would always provide their acute image into one and the same image plane if they are fixated alternately. The image distance b would become a constant and the focal distance f' would become a variable in the image equation. The possible result is

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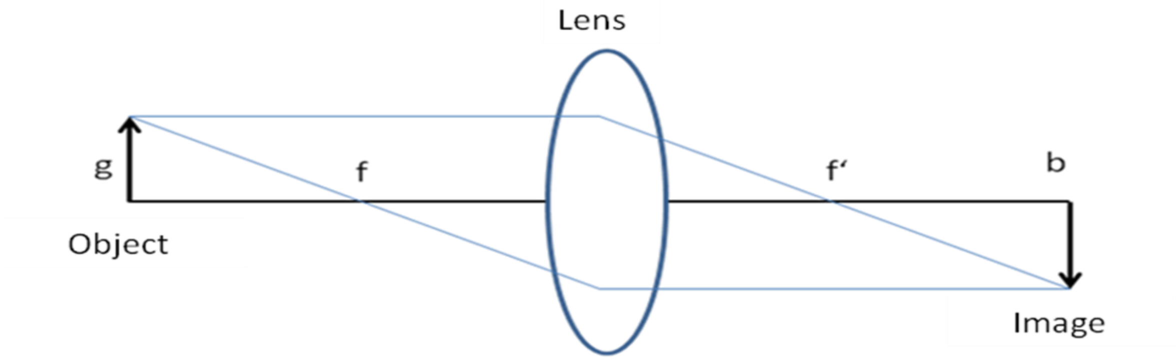
illustrated in Table 1. The image distance b would be the same at 22.889mm for all object distances, whereas the focal distance f' would be specific for the distance g of the particular fixated object. As the data demonstrate, f' would decrease in the case of fixation of increasingly approaching objects, between 1000m and 25cm by 1.92mm in total.

The accommodation mechanism would all the time be strongly challenged, because with every change in fixation it would have to implement an erratic readjustment of the optics and it would never settle down. If this were the solution for the eye, it would only have information about the third dimension of the visible in focal space, however not in image space where the photoreceptors are located.



Optical imaging equation for a thin lens

$$\frac{1}{g}+\frac{1}{b}=\frac{1}{f'};b=\frac{f'g}{g-f'};f'=\frac{bg}{b+g}$$

Fig. 2: The optical imaging equation describes the relationship between object distance (g) and image distance (b) depending on the anterior focal length (f) and the posterior focal length (f') of a lens.

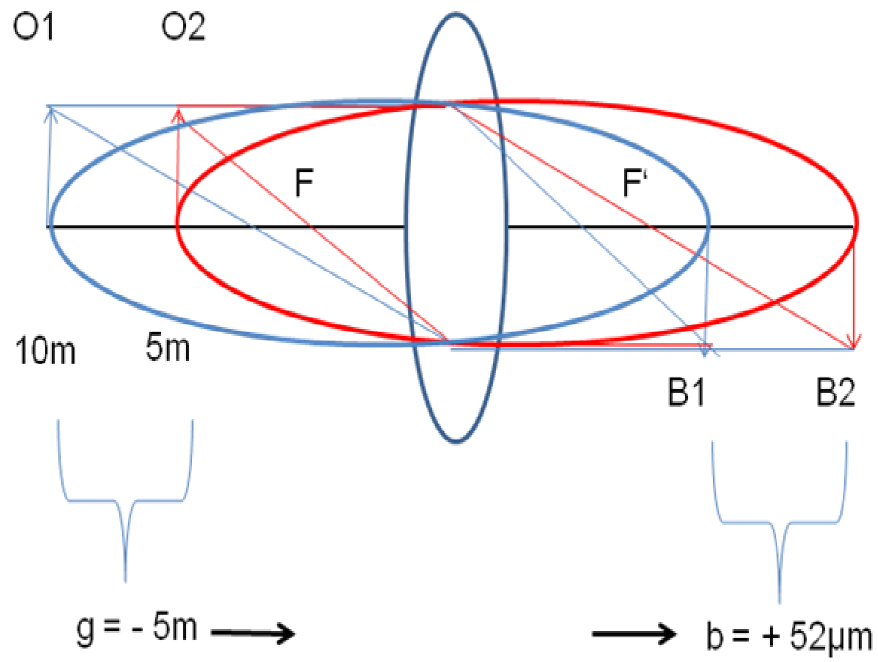


Fig. 3: The optical swing of the object fixation and accommodation in the eye in the case of an eye saccade from an object at a distance of 10m to one at a distance of 5m (O1 and O2 = objects at different distances, B1 and B2 = their particular image locations in the case of a successful accommodation. F and F‘ = focal points of the imaging optics). Exterior measurements are in meters, interior ones in micrometers. A leap in fixation from 10m to 5m in object space results in a shift of the image distance by +52µm backwards (the difference between b = 22.837mm and 22.889mm), a leap in fixation from 5m to 2m results in a shift of the image distance by +158µm (the difference between b = 22.734 and 22.892mm in Table 3, Col.5).

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Table 1: variable focal distance f' and constant image distance b.

Object Distance g	Focal distance f' variable	Image distance b constant
1000m	22.888mm	22.889mm
100m	22.884mm	22.889mm
10m	22.837mm	22.889mm
5m	22.785mm	22.889mm
2m	22.630mm	22.889mm
1m	22,377mm	22.889mm
0.5m	21.887mm	22.889mm
0.25m	20.969mm	22.889mm

The complete waiver of the 3D-information in image space corresponds to the solution chosen by photographic optics in order to be able to image everything visible on to a plane surface (film or CCD). Then, the distance adjustment takes place exclusively by means of the lens optics, which has been calculated especially for this case, namely the reduction of the 3D-world down to two dimensions in image space. In the case of such a solution a connection of the central retina and the circular muscle around the lens would be dispensable for the eye.

- **3D-information exclusively in image space.** In the case of a second solution, the eye could place emphasis on the fact that all visible objects would provide their acute images in each case into an image plane specific for the distance of the objects. This could succeed if f' became a constant and b became a variable. The possible result is demonstrated in Table 2.

Table 2: constant focal distance f‘ and variable image distance b.

Object Distance g	Focal Distance f' constant	Image Distance b variable
1000m	22.785mm	22.785mm
100m	22.785mm	22.790mm
10m	22.785mm	22.837mm
5m	22.785mm	22.889mm
2m	22.785mm	23.048mm
1m	22.785mm	23.316mm
0.5m	22.785mm	23.873mm
0.25m	22.785mm	25.070mm

To each object distance now would correspond a specific image plane in image space. The closer an object comes to the eye, regardless of whether it is fixated or not, the further back its acute image plane would shift. The acute image of an object at a distance of 10m would be located 52µm anterior to that of an object at a distance of 5m; the acute image of an object at a distance of 2 m would be located +159mm posterior to the acute image of an object at a distance of 5m. Altogether the image planes would take up a space depth of 2.285mm. This is regardless of the fact that the retina itself only has an average thickness of approximately 0.25mm. The complete 3D information about the visible would in this case at least be available where the photoreceptors are located in the eye. However, in this solution any accommodation mechanism in the lens or in the optical apparatus would be dispensable. The eye could do without the complete apparatus around the ciliary muscle. However, since the accommodation mechanism is already developed before birth and is thus available at an early stage, there must still be a third solution, which the eye preferred to the two solutions so far.

- **3D-information in image space, related to the accommodation resting position.** The eye has decided to comprehend the refraction n_2 and the focal distance f' as variables for the determination of the image distance b. In order for this double dependency not to bring random chaos in its wake, the accommodation resting position of the 'optical swing' is of vital importance. The result is illustrated in Table 3 for an accommodation resting position at an object distance of 5m (columns 2+3), of 2m (columns 4+5) and of 1m (columns 6+7).

Table 3: Determination of focal distance f' and image distance b for an accommodation resting position at g = 5m, 2m, or 1m (lines in bold print).

1	2	3	4	5	6	7
Object-Distance g (m)	Focal Distance f' (mm)	Image Distance b (mm)	Focal Distance f‘ (mm)	Image Distance b (mm)	Focal Distance f‘ (mm)	Image Distance b (mm)
1000m	22.785	22.785	22.630	22.631	22.377	22.378
100m	22.785	22.790	22.630	22.635	22.377	22,382
10m	22.785	22.837	22.630	22.682	22.377	22.428
5m	**22.785**	**22.889**	22.630	22.734	22.377	22.480
2m	22.785	23.048	**22.630**	**22.892**	22.377	22.637
1m	22.785	23.316	22.630	23.159	**22.377**	**22.902**
0.5m	22.785	23.873	22.630	23.714	22.377	23.453
0.25m	22.785	25.070	22.630	24.907	22.377	24.638

If the eye adapts to an accommodation resting position for objects fixated at 5m distance (columns 2+3 in Table 3), then the acute image, due to f' =22.785, will lie at the central retina at a depth of b = 22.889mm, as was already demonstrated in the previous Tables 1 and 2. If, however, the eye chooses an accommodation resting position for fixated objects at 2m distance, then it has decided in favour of a stronger refraction (e.g. n_2 = 1.34) and a shorter focal distance f' (f‘ = 22.630mm). The image of the object fixated in this resting position will lie at b =

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22.892mm (Table 3, col. 4+5). With a resting position set at g = 1m, again n_2 increases (e.g. n_2 = 1.345) and f‟ decreases (f‟ = 22.377mm). The image distance will then be at b = 22.902mm (Table 3, col. 6+7). If the eye chooses an accommodation resting position at object distances < 5m, then always f' decreases, and n_2 as well as b increase. In every case, with these values for the resting position the equilibrium state of the 'optical swing' (fn_2 /g + f‟ n_1 /b = 1) results. A change in fixation from the particular resting position to objects at a greater distance will then result in shorter image distances, in the case of objects more close the result will be larger image distances. The depth distance in image space covered by all image planes would have a length of 2.285mm with a resting position at 5m; at 2m it would be = 2.28mm and at 1m = 2.26mm. In all cases, the image planes b for objects fixated at a distance g greater than the resting position, will always be shifted forward more closely to the focal distance. In the proximity the differentiation of object distances increases. After an initial decision in favour of an accommodation resting position at a particular object distance, thus in favour of this third solution, its image distance b becomes the reference image plan, upon which the image planes of all other objects at different distances, which together with the fixated object are optically imaged, are related. If one closes one eye in vision, the world does not shrink into a plane. The introduction of an accommodation resting position, in favour of which the eye in fact decided, shows that the 3D-information in vision always is present in focal space and in image space. The work of the accommodation, which leads to the determination of an accommodation resting position, is taken on by the ciliary body in close harmony with the central retina. It is thus in a considerably simplified manner placed on a secure reference basis, the accommodation resting position of the 'optical swing' in the eye. This also applies to the subsequent accommodation work, which becomes necessary in the case of a fixation leap from the already found resting position to an object in another distance. However this work decreases because the distances from the resting position to the extreme object positions are now shorter. The adjustments of n_2 , f‟ and b are now easier.

III. HOW DOES THE EYE FIND AN ACCOMMODATION RESTING POSITION IN VISION?

The trick, with which the eye engages in statistics while learning to see,: adaptivity to the real world is required. The accommodation resting position corresponds to an equilibrium state of tension and relaxation in the ciliary body or in the inner eye in the 'optical swing'. The search and final finding of it is the relevant factor, which decides over the axis length of the eye and in doing so, over the location of the correct image distance in the central retina for objects fixated at any distances. Thus the decision regarding emmetropia, myopia and hypermetropia (short-sightedness and far-sightedness) is linked to this resting position. Therefore, vision at a very early stage has to rely on determining such an accommodation resting position from the visible in object space by means of actively fixating. In order to do so, it engages in statistics. The statistics works similar to the calculation of the Gaussian distribution of random events and their probabilities. Fig. 4 illustrates the calculation of the mean value. If one throws balls into a multi-layer grating of rods, then these finally land via different ways and detours at different places behind the grating with the frequency shown in the normal curve. Already 40 to 50 balls are sufficient for calculating a normal curve. The mean value (M) is located in the peak of the curve; it shows that those balls which chose the shortest way in the grating, are registered most frequently at the exit. The full width half maximum (HW) shows the range of the remaining frequencies to both sides.

The eye does not gamble for very long…This is how one has to imagine the work of fixation and accommodation in early vision during the adaption to the real world. The place of the balls falling into the grating is taken by the objects, which are fixated at different distances by the eye. On average, approximately 20,000 eye movements per day are executed to visual objects at different distances [7. p.88]. "Even infants at the age of only a few months show evidence that they can fixate their view" [7. p.90]. Fig. 5 demonstrates the result if the eye is regularly offered different object distances for fixation and if these are used by it; if it experiences the mean value e.g. at an object distance of 5m, the equilibrium state of the accommodation resting position will become located there. However, if the eye is regularly only offered short object distances for fixation or if it only uses these, then in consequence, it will locate the equilibrium state of the accommodation resting position at a lower mean object distance, e.g. at 2m.

Once a resting position has been chosen, then this is not determined for eternity. Early experiences can be corrected by further learning and re-learning. Normally the accommodation resting positions for adults come out at medium object distances (2-5m). Since the ocular bulbs, which are already very large at birth, nevertheless continue to grow, this process must always be readjusted. Here, everything finally depends on the life-long experiences of the eye in dealing with the 3rd dimension.

How the range of the calculated image planes of approximately 2mm in the depth expansion can be reduced even further down to the length of the photoreceptor outer segments in the central area of the retina, consequently down to approximately 70µm-100µm, has been discussed and illustrated in [5].

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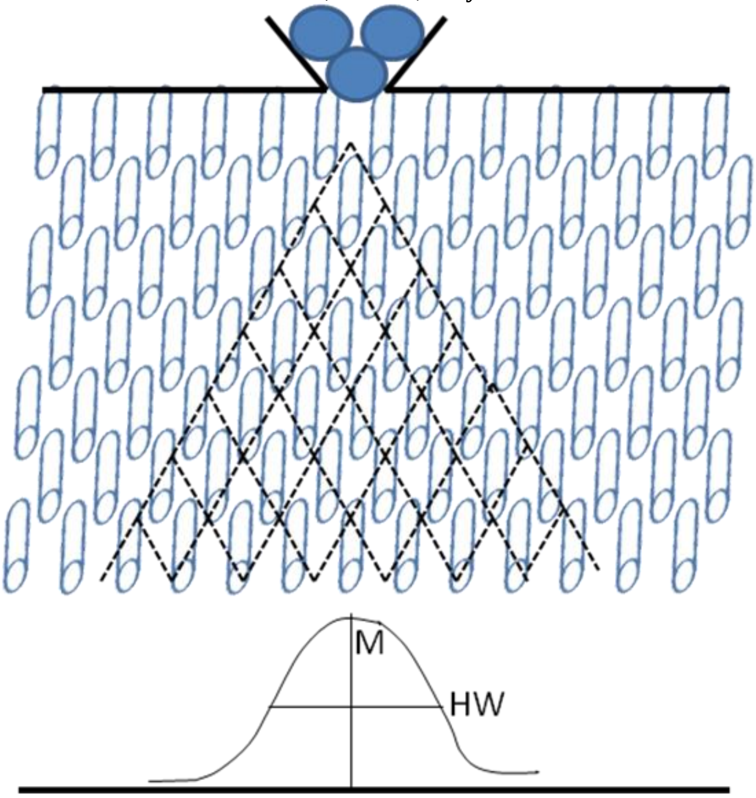

Fig. 4: The Gaussian distribution of random events in a normal curve. An experiment at the Museum of Science in Boston/Mass.

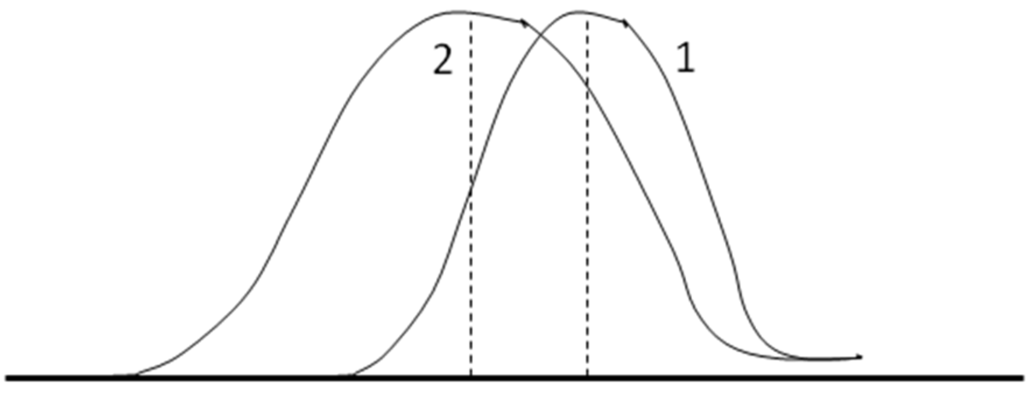

Fig. 5: Experiences with the object distances (scale below) result in different accommodation resting positions (curve 1 at 2m, curve 2 at 5m).

Getting glasses too early results in irreversible disabilities…In the course of the early experiences with the third dimension of the visible, while searching for the accommodation resting position, consequently also the length of the axis of the inner eye is determined and its growth is stopped. If after an insufficient early learning effect - the choice of a resting position determined on object distances which are too close -, the eye is offered objects at a greater distance, then the acute imaging of these objects will fail because the axis in the inner eye turns out to be too long. Their images are than supplied in front of the retina and become blurred. Then the eye has already adapted itself onto a world which is reduced in the 3rd dimension. Vision becomes short-sighted and myopia is acquired. Correction can only be effected by means of glasses or other visual aids. If the first pair of glasses has been acquired, the natural stimulus and the chance for exercising proper vision in the 3rd dimension are lost. This early experience can only be avoided or changed if the eye is regularly offered the opportunity by means of gaze saccades in the depth of space to explore a greater environment than its own four walls and investigate it actively by means of fixation. In environments such as maternity wards, in play rooms and children's rooms, in the computer and mobile phone display world, in learning materials in schools, in city environments, etc. there is usually a lack of the possibility of a corresponding regular experience. At the school age the so-called school myopia often occurs due to learning materials at short distances. This can only be influenced to a limited extent by further growth of the body. Also later in life, there is nothing as relaxing as a walk in the wood, in the park or in an object world scaled in depth. In this the eye can and has to busy itself with the third dimension and all of its scope. Finally, due to the basically central perspective manner of spatial vision, the differences in the individual accommodation resting positions only result in minimal deviations in the three-dimensional space perception.

IV. THE OPTICAL PARALLEL PROCESSING OF THE VISIBLE IN THE EYE

View saccades explore the third dimension in the complete visual space The eye always fixates only one particular visual object at a specific distance. Other objects - in the near or farther neighbourhood of the fixated object - in optical parallel processing are simultaneously imaged onto the retina. These images are not only seen less precisely (with a lower resolution, a visus of 1.0 – 1.6 in cone vision, and 0.4 in rod vision due to peripherally increasing meshes in the net of the retina), but also imaged diffusely for as long as they are not fixated themselves. At an early stage, the eye collects experiences about whether these objects in space are in a plane in front of or behind the fixated object, on equal or unequal horopter shells. A short gaze cascade to one of these neighbouring objects shows that the distance of an acute image is located relative to the depth position of the image of the previously fixated object in a different image plane. In this way, each eye learns at an early stage to estimate, at which distances other objects in the environment of the particular fixated object are located [7]. With the help of these experiences in a depth map, the orientation in space is developed as a vital ability of self-moving creatures. Wherever the experience with object fixation does not suffice, the eye uses over-lapping and other phenomena to work out the question of distance. With the foveal micro-tremor in the z-axis [8], it can also scan the direction, into which the fixation has to be changed in each case. The depth map is not presented to vision for free since the retina only has a thickness of 0.25mm and the fovea cones only have a length of maximally 0.1mm, the eye has to adapt at an early stage to the optical miniaturization of the third dimension of visual space by means of intensive training of fixation and accommodation. Two dimensions of the visible have been given to each eye as it were; the third dimension it has to work itself both monocularly and binocularly. In this way, vision gains its pre-eminence against the optics of the world of photography and television, which have narrowed down the visual on to a planar world. And this is only because until today there are only flat image receivers such as films or CCD arrays. Their 'flatland' images are well understood in vision only by means of the central-perspectival interpretation of the two-dimensional. However, the eye has high performance nano antennas with its outer segments of cones and rods which are 30-100μm long; these nano antennas are suitable as receivers for three dimensional information. Their technical replica might succeed in future [2]. It would well augment the concept for a later generation of retina implants [5].

V. CONCLUSION

The visible world in monocular human vision does not shrink into a planar image as it does in photography. This is clearly demonstrated when in binocular vision one eye is closed. Prenatal engineering of the human eye is an option for 3D-processing in the image space with a strong reduction or miniaturization of the 3rd dimension. By means of fixation and accommodation of objects in space in a learning procedure, the eye searches to find an accommodation rest state. When trained on a limited 3D space with only near objects this learning will end in a myopic state. Prevention of myopia therefore can be reached by an intensive training of fixation and accommodation to objects in all distances in early vision. This training should not be limited by reaching for spectacles too early.

REFERENCES

[1] J.A. Guggenheim, K. Northstone, G. McMahon, A.R. Ness, K. Deere, C. Mattocks et al., "Time outdoors and physical activity as predictors of incident myopia in childhood: a prospective cohort study". Investigative Ophthalmology & Visual Science, 53 (6), pp. 2856-2865, 2012.

[2] B. Hecht, O. Martin, „Resonant Optical Antennas". Science 308, pp.1607–1609, 2005.

[3] M. Hedrich „Die Myopie gibt weiter Rätsel auf". Part 1 FOCUS 10_2013, pp. 56-57; Part 2 FOCUS 11_2013. pp. 16-18. MediaWelt Services GmbH, Ratingen.

[4] L.A. Jones, L.T. Sinnot, D.O. Mutti, G.L. Mitchell, M.L. Moeschberger & K. Zadnik, „Parental history of myopia. sports and outdoor activities. and future myopia." Investigative Ophthalmology & Visual Science. 48(8), pp.3524-3532, 2007.

[5] N. Lauinger. "The Human Eye: an intelligent optical sensor (The inverted human retina: a diffractive optical Correlator)." Sensors portal. Toronto, Canada,2014. (http://www.sensorsportal.com/HTML/BOOKSTORE/Human_Eye.htm).

[6] N. Lauinger, "The two axes of the Human Eye and Inversion of the retinal layers: the basis for the interpretation of the retina as a phase grating optical cellular 3D chip". Journal of Biological Physics 19, pp. 243 – 257, 1994.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Issue 1, July 2015

[7] K. Lugmair. „Sensorische Integration – Raumwahrnehmung unter besonderer Berücksichtigung des Kindesalters“. Thesis. University of Munich, 2006.

[8] K.L. Mütze, W. Foitzig, G. Krug, G. Schreiber, “ABC der Optik”. Hanau, 1960.

[9] G. Osterberg, “Topography of the layer of rods and cones in the human retina”. Acta Ophthalmological Suppl.VI 13, 3.4, 1935.

[10] H. Schober, „Über die Akkommo-dationsruhelage“. Optik 11. 6, pp. 282 – 290, 1954.

[11] H. Schober, „Das Sehen“. VEB Leipzig, 4/1970.