



Wissenschaftliche Vereinigung für Augenoptik und Optometrie

Online-Veranstaltung am 14.03.2022, 20.00 Uhr



Welche visuelle Information benutzt das Auge zur Emmetropisierung?

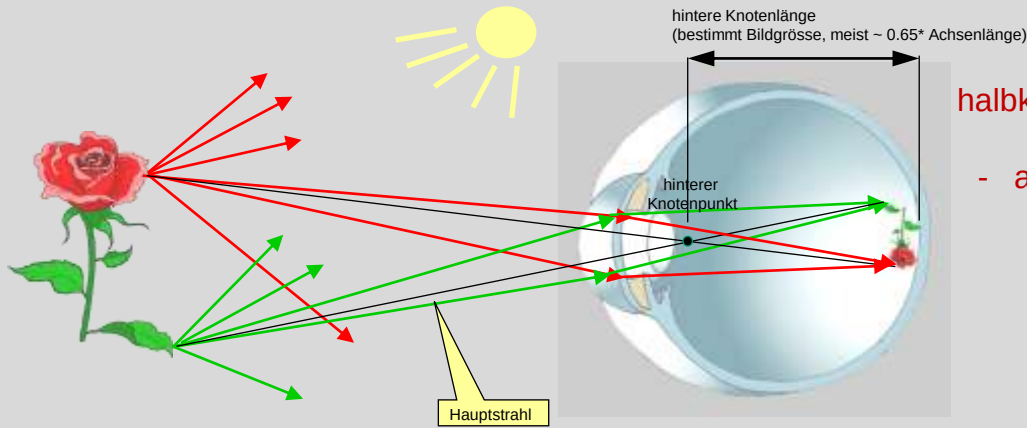
Frank Schaeffel



Tuebingen 2019



Basel 2021



halbkugelförmige Bildschale

- anders als bei Kamera mit flachem Bildaufnahmechip

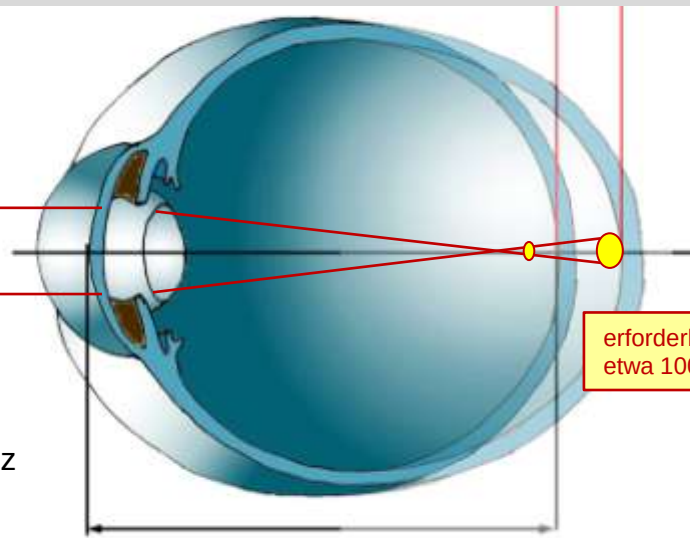


gekrümmter Horizont bei Weitwinkelkamera (copyright RedBull)

Myopie:
Auge wächst zu lang, "Lichtscheiben" anstelle von Lichtpunkten

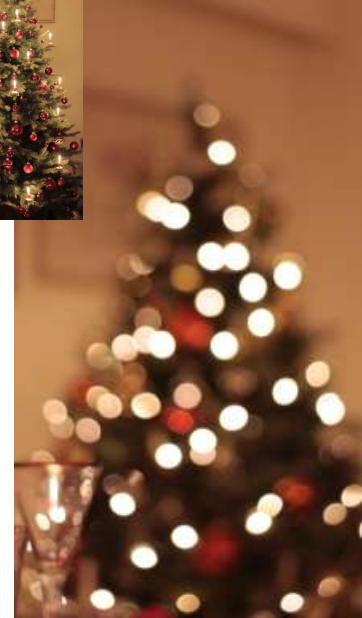
1 mm zu lang = 2.7 dpt Myopie

mit einer Tiefenschärfe von 0.25 dpt muss die Augenlänge mit einer Toleranz von 100 μm auf die Brennweite abgestimmt werden



erforderliche Genauigkeit: etwa 100 μm (0.1 mm)

normale Achsenlänge ca. 24 mm



Die biologischen Mechanismen der Myopie

Experimente an Tiermodellen

Ein neue Aera begann Ende der 1970er Jahre

ein schlechtes Bild auf der Netzhaut stimuliert das Augenlängenwachstum - zuerst entdeckt am Rhesusaffen 1977, kurz darauf am Huhn **Deprivationsmyopie**

TORSTEN N. WIESEL
ELIO RAVIOLA
Nature Vol. 266 3 March 1977
Departments of Neurobiology and Anatomy,
Harvard Medical School,
Boston, Massachusetts 02115



Myopia and eye enlargement after neonatal lid fusion in monkeys

THE aetiology of myopia has been studied mainly by investigating the distribution of refractive errors in human populations¹. No clear conclusion has emerged, however, so the prevailing clinical attitude is that myopia can neither be prevented nor cured, but only corrected with appropriate

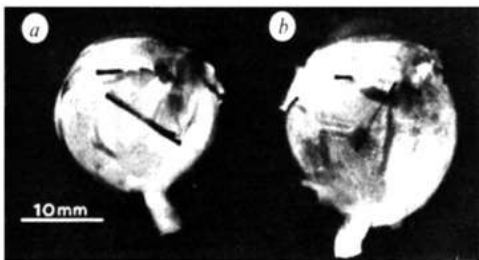


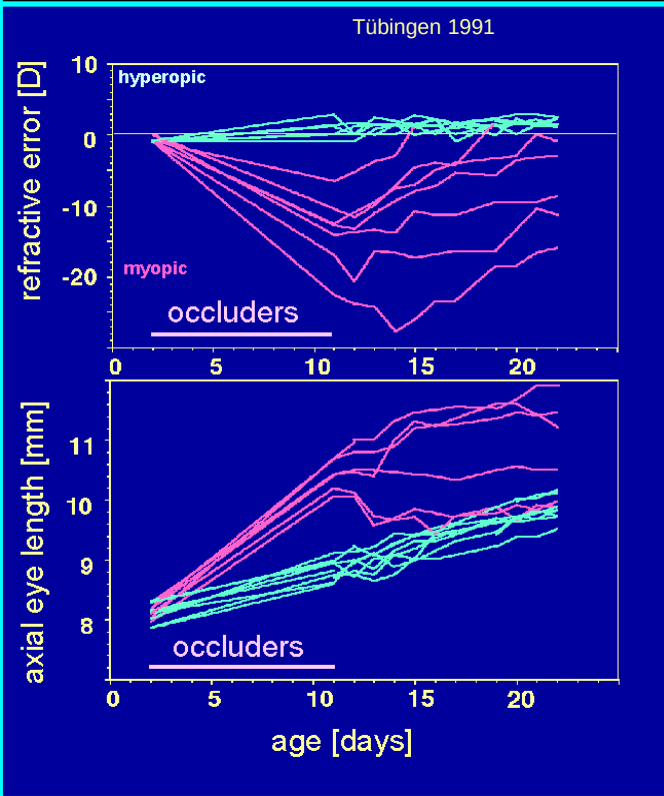
Fig. 1 Eyes of a rhesus monkey in which the lids on the right (b) were fused at the age of 2 weeks and opened 18 months later (experiment 5 in Table 1). Suture threads mark the insertions of the extrinsic ocular muscles. The left eye (a) was normal.

of a 1% solution of homatropine and the refraction of both eyes determined by using a streak retinoscope and hand-held trial case lenses. The corneal curvature was measured with a keratometer and the fundus was examined. At various times after lid opening, animals were refracted again, used for electrophysiological studies on the visual pathways and finally perfused through the heart with 10%



Josh Wallman
Science 1978

Der biologische Sinn der „**Deprivationsmyopie**“
Ist nicht klar -
(aber bei allen Wirbeltieren)

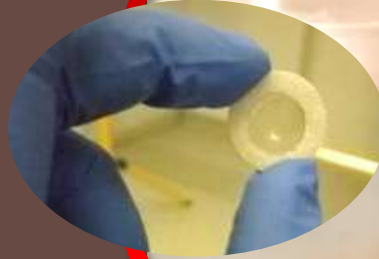


Deprivationsmyopie kann in jedem Auge getrennt induziert werden und:

Augenwachstum findet hier ohne Rückkoppelungskontrolle statt – ein **"offener Regelkreis"**

Mattgläser verringern Bildkontrast
und wirken als Tiefpassfilter

es werden weniger räumliche Details
gesehen

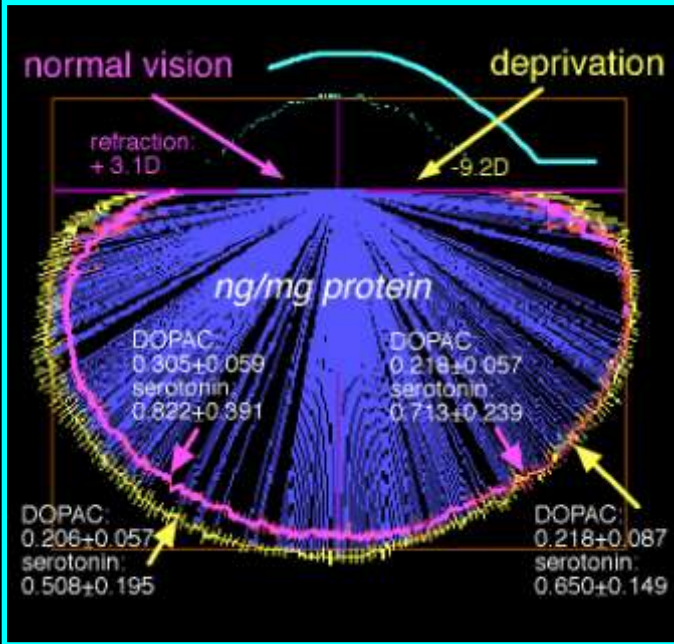
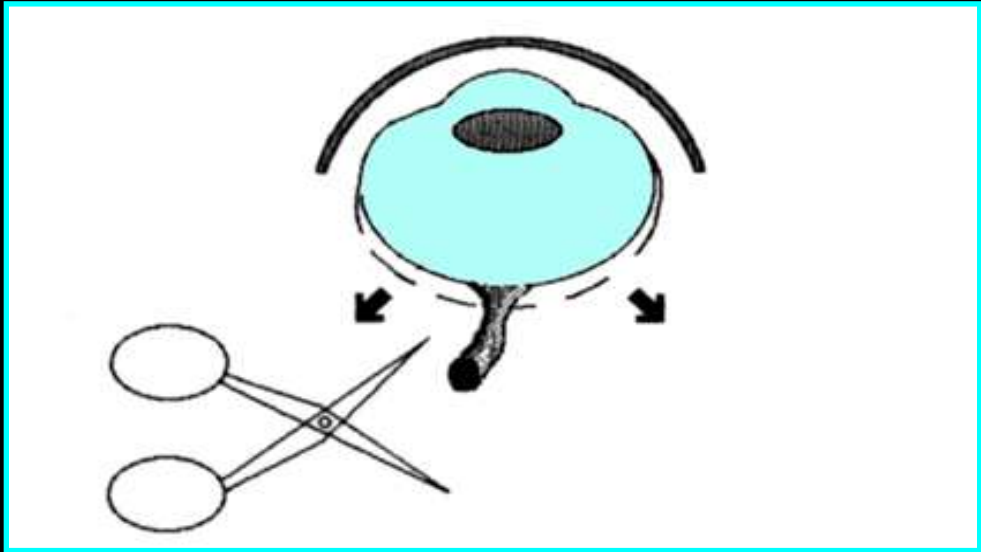


unerwartet: intakter Sehnerv nicht nötig und lokale visuelle Kontrolle des Augenwachstums



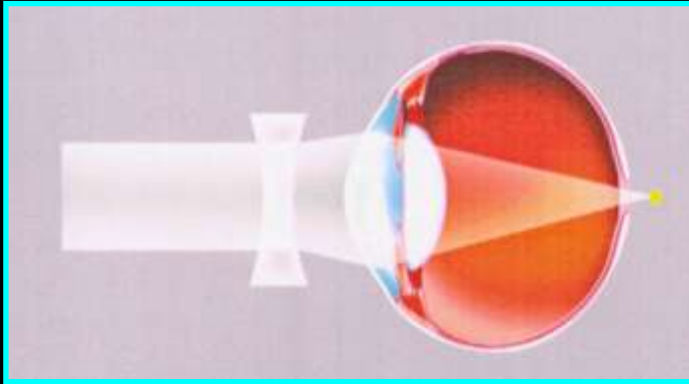
Ohngemach et al,
Vis Neurosci 1997

auch lokale Änderungen des
retinalen Dopaminstoffwechsels

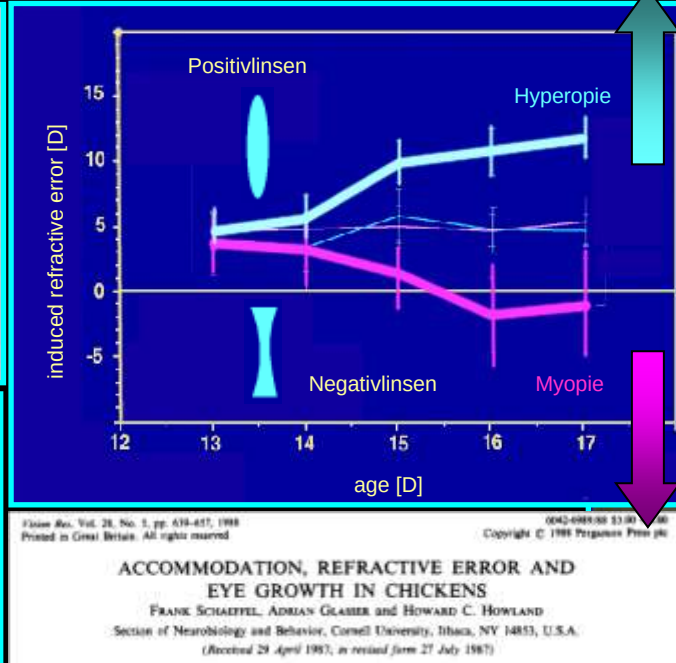


aber es gibt auch noch einen „geschlossenen Regelkreis“ für die Emmetropisierung

Verschiebung der Schärfenebene erzeugt kompensatorisches Augenwachstum



(Bilder von Earl Smith III, Houston)



funktioniert auch bei Affen, Tupeias, Meerschweinchen, Fischen, Mäusen --- und Kindern

3D Drucker Helme mit Brillengläsern (Smith et al, ARVO 1999)

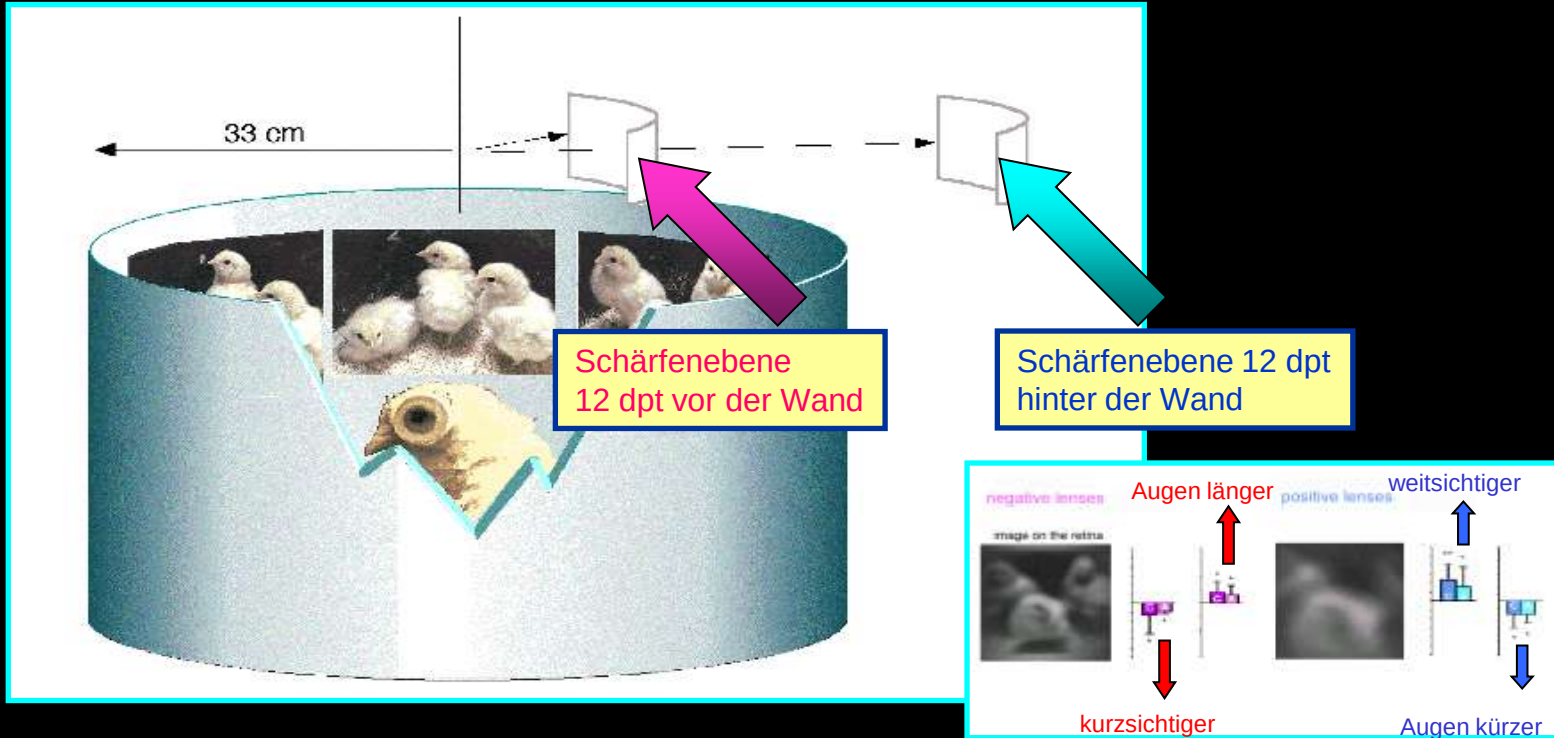


und die Retina kann positive und negative Defokussierung unterscheiden – auch in sehr schlechten Bildern

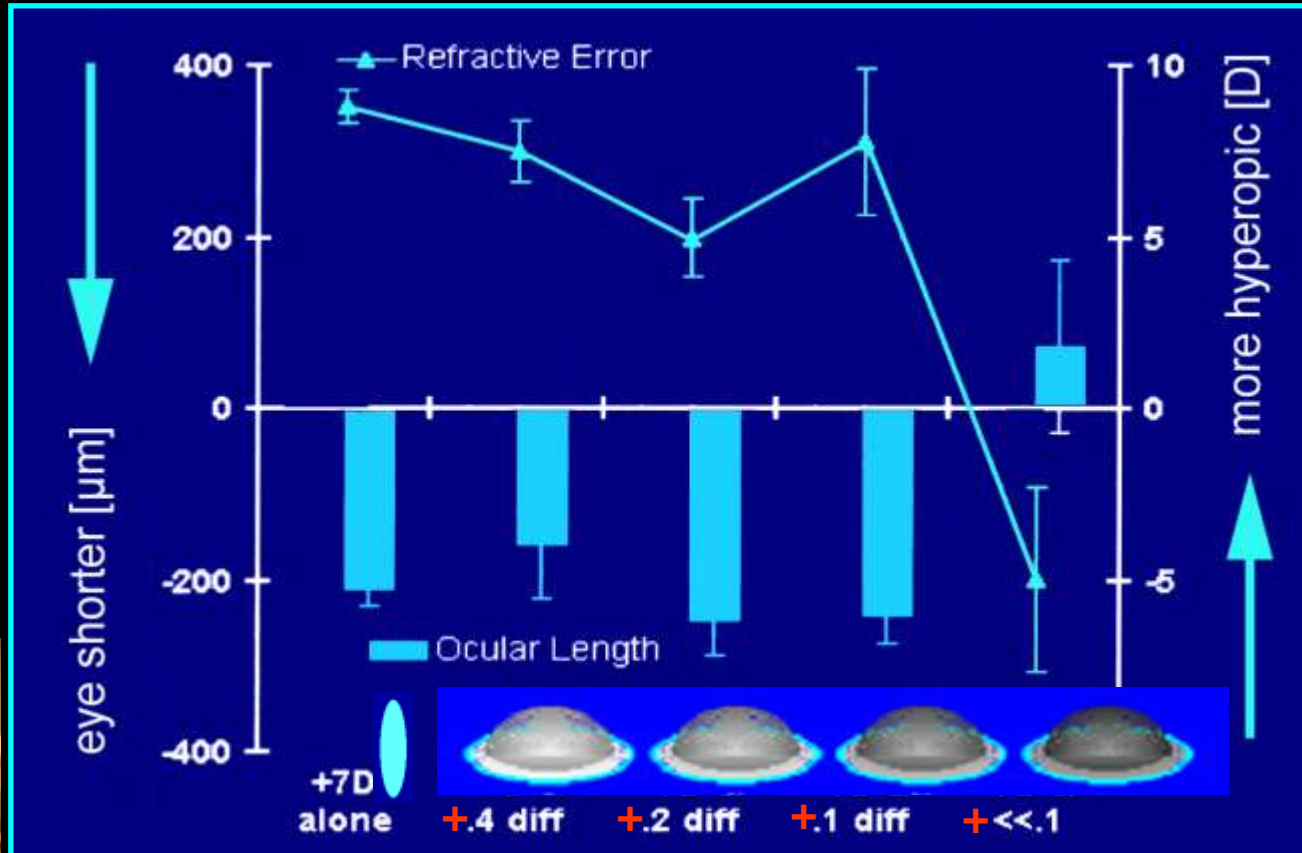
- Huhn im Zentrum einer Trommel - nur **eine** Sehentfernung
- **Linse** verschieben den Fernpunkt entweder 12 dpt vor oder hinter die Wand
- Zykloplegie – Netzhautbilder immer ganz schlecht



Sigrid Diether, 1999



sehr stabile Erkennung einer Defokussierung durch +7D Pluslinsen,
selbst in Kombination mit zunehmend vernebelnden Bangerterfolien



→ Bangerterfolien mit zunehmender Stärke

und wissen wir jetzt, wie die Emmetropisierung funktioniert?

Probleme:

Myopie hemmt sich nicht selbst

(wie man es von einem Regelkreis erwarten würde)

Unterkorrektur funktioniert kaum

(obwohl Unterkorrektur wie eine Pluslinse wirkt)

Warum soll Lesen kurzsichtig machen, wenn die Netzhaut ein scharfes Bild bekommt?

(vielleicht ist es nicht scharf oder Bildinhalt wichtig?)

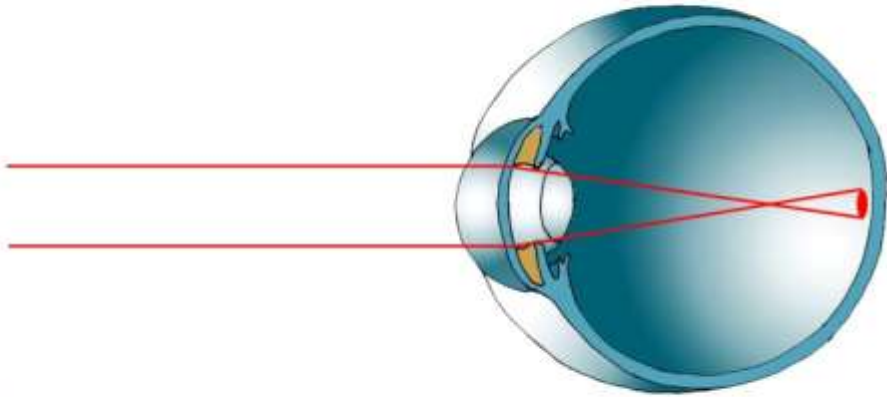
Wird positive Defokussierung von der menschlichen
Retina überhaupt zuverlässig erkannt?

(... beim Akkommodieren brauchen wir es ja nicht !)

Wie kann man das beim Menschen untersuchen? Wir zeigen dem Auge "echte" und berechnete Defokussierung

Ein Bildpunkt (oder Pixel) wird in eine Scheibe überführt

(sofern die Optik halbwegs gut ist, ansonsten wird die "Punktverwaschungsfunktion" (point spread function, PSF) komplizierter)



Wie kann man die Bildschärfe überprüfen? Die Modulationsübertragungsfunktion
Ortsfrequenzen [Zyklen/Grad] (Jean Baptiste Fourier, geb 1768)
anschaulich:

Breite des Daumennagels in Grad:
 $\arctan(1.3 \text{ cm} / 65 \text{ cm}) = \text{ca. } 1.1 \text{ Grad}$

Daumen in Armlänge
ca. 1 Grad

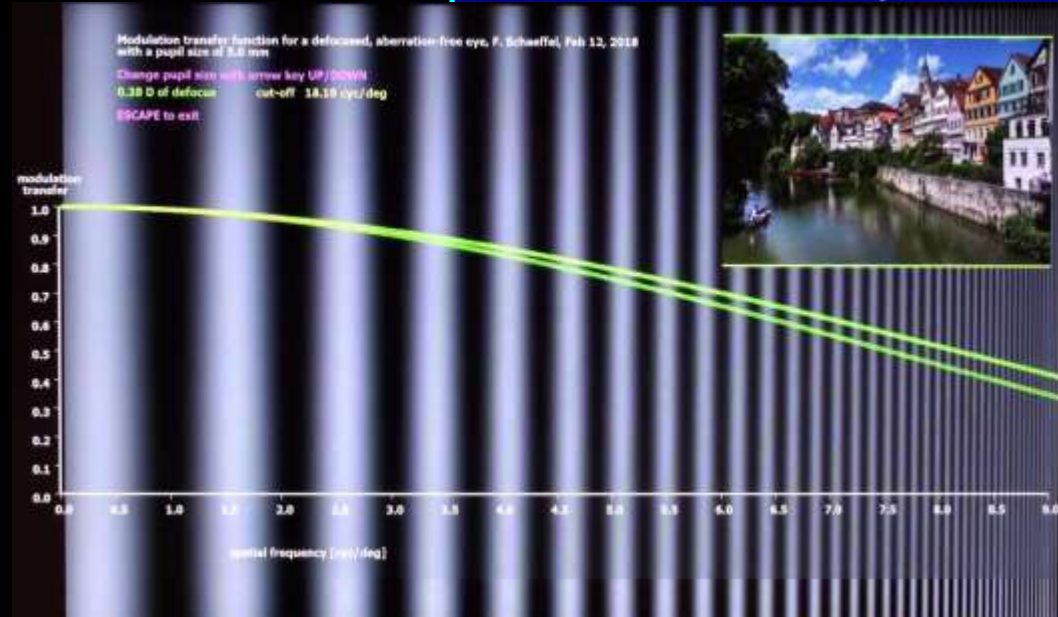
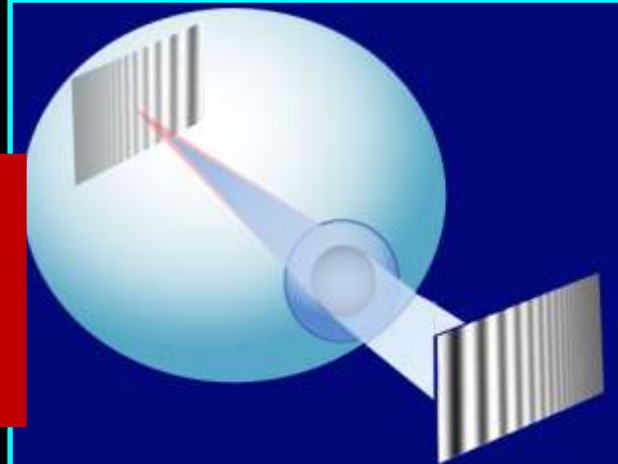
7 Zyklen/Grad



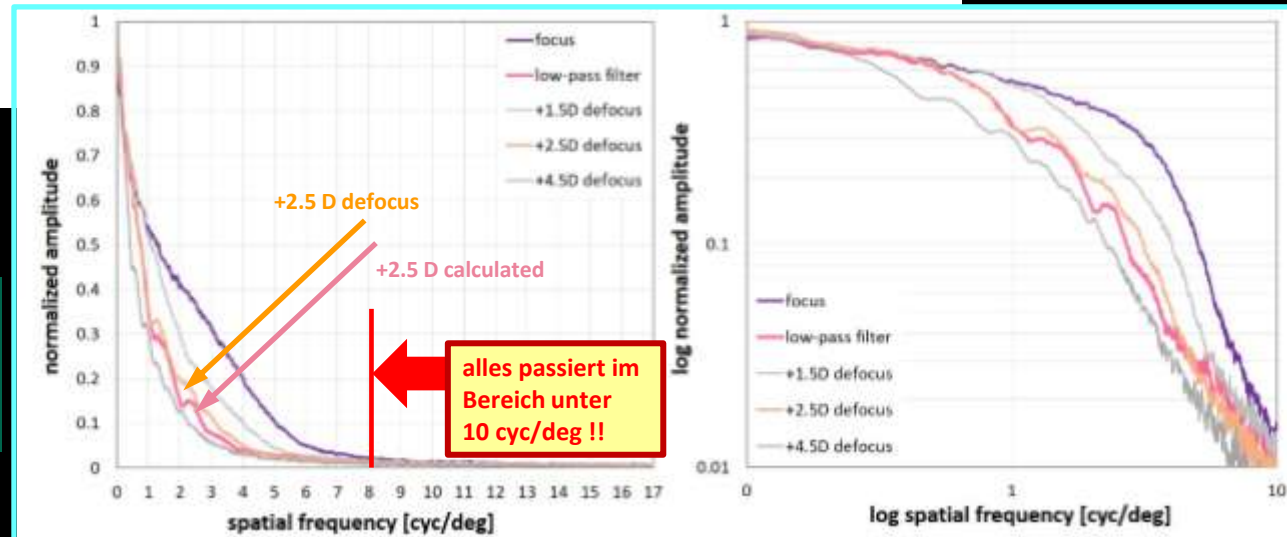
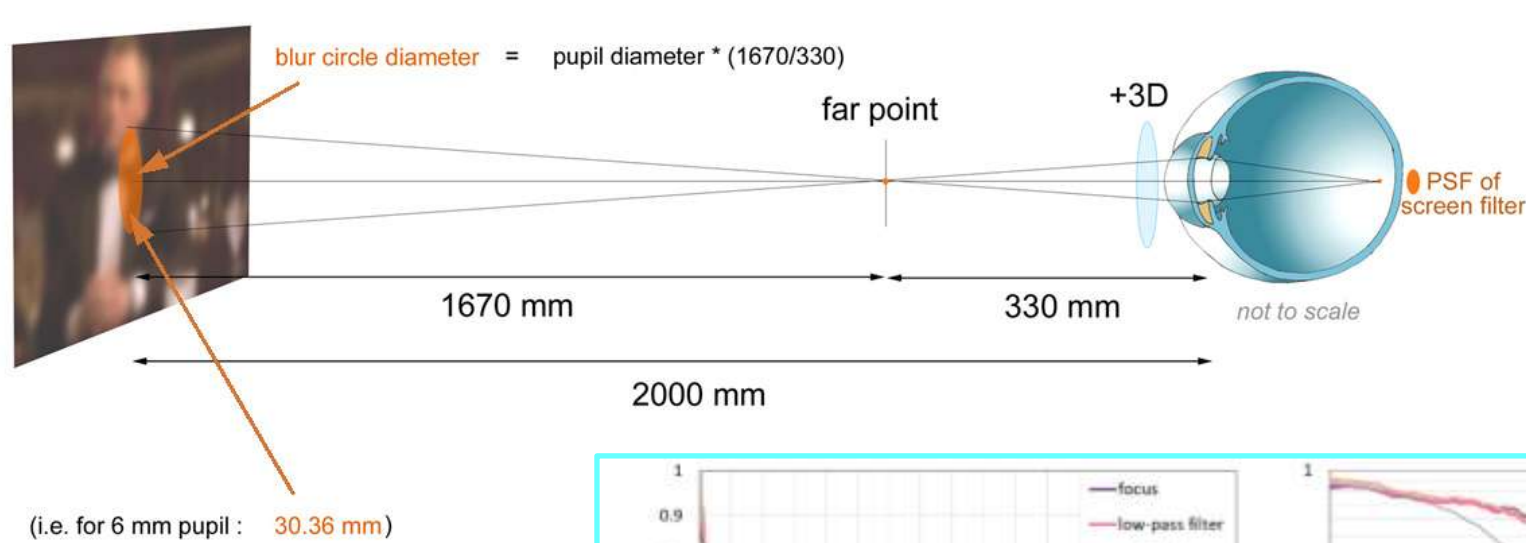
19 Zyklen/Grad

die Optik des Auges ist nicht perfekt
und deshalb von Anfang an ein Tiefpassfilter
für Ortsfrequenzen

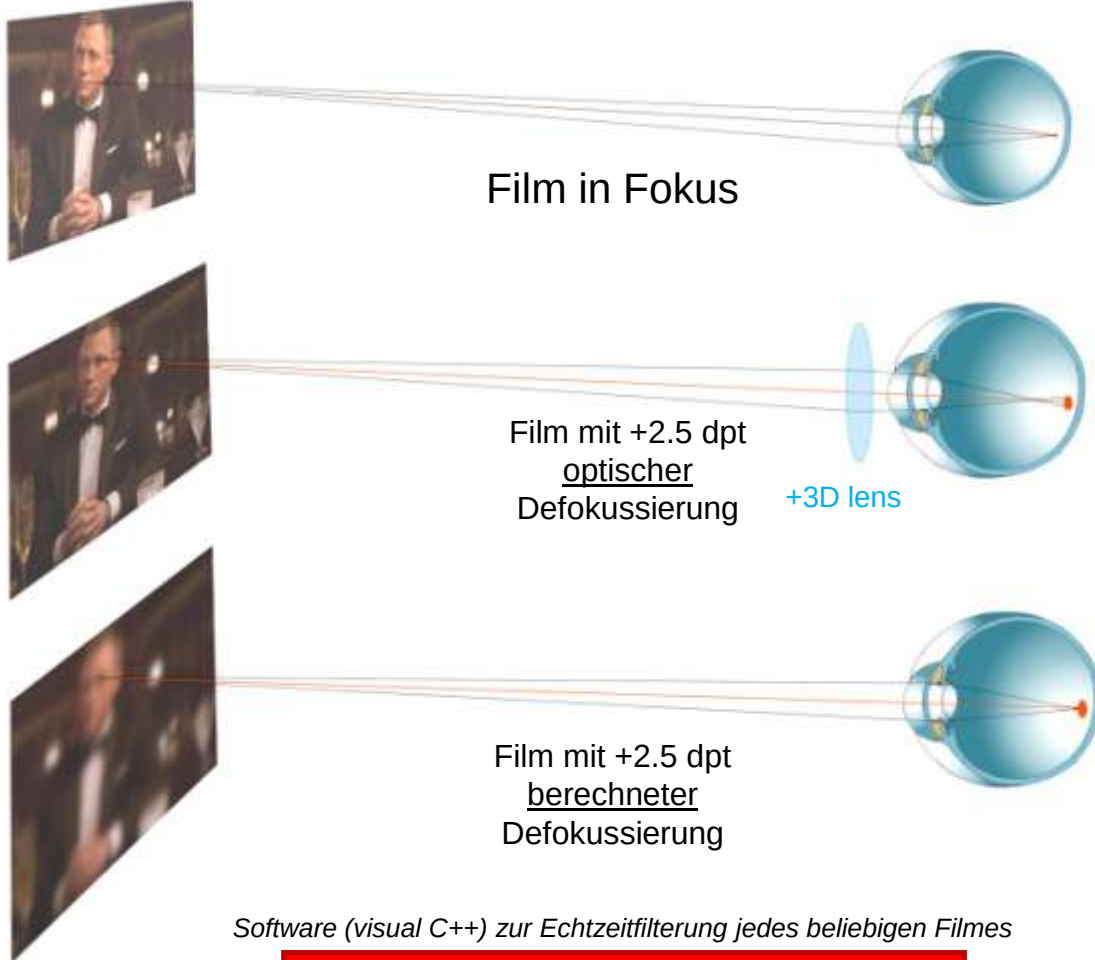
Defokussierung verstärkt die Tiefpassfilterung
nach einer genau festgelegten Funktion
(der „ersten Besselfunktion“)



Prüfung der Berechnung der Defokussierung (nachdem die Pixel in einem kreisförmigen Bereich um jedes Pixel gemittelt wurden)



... führt zu guter Übereinstimmung der Kontrastübertragungsfunktion für echte und berechnete Defokussierung



Probanden betrachteten die Filme 30 Minuten lang



Wie können wir die Antwort der Netzhaut messen?



Hühner: schnelle Zunahme der Aderhautdicke, wenn die Schärfenebene vor der Netzhaut liegt, und Abnahme, wenn Myopie induziert wird
(bei Hühnern, Mäusen, Meerschweinchen, Affen ändert sich die Aderhautdicke innerhalb von Stunden, wenn die Position der Schärfenebene verschoben wird)

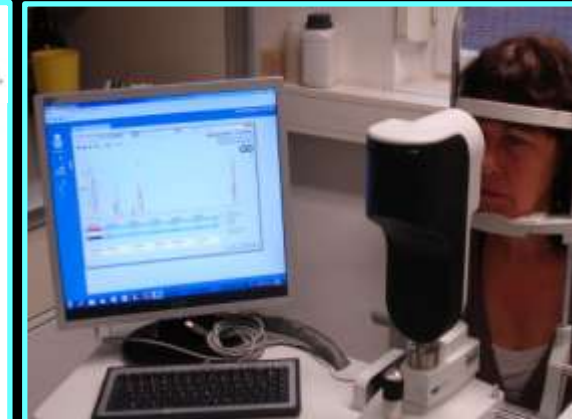
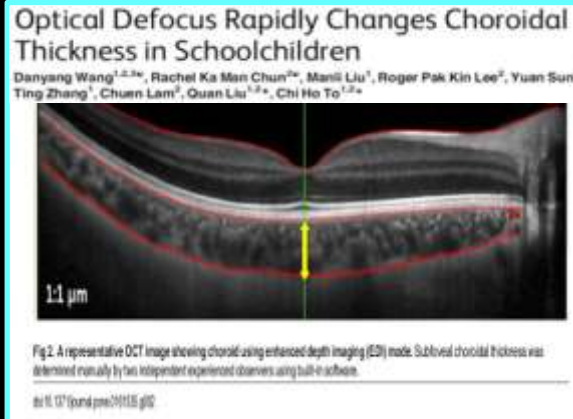
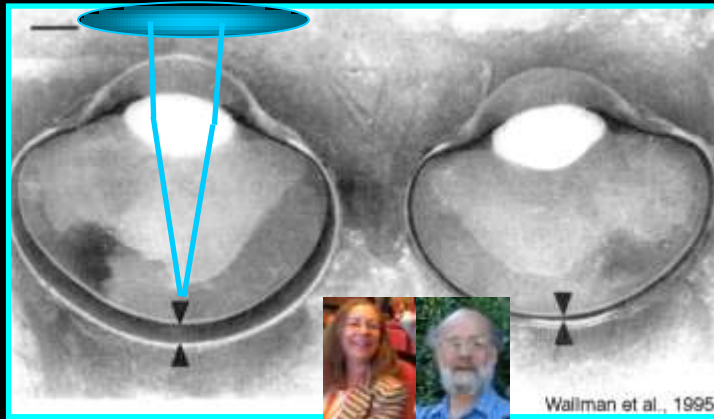


Auch bei Kindern ändert sich die Aderhautdicke in verschiedene Richtungen, je nach Vorzeichen der Defokussierung mit Linsen



Aderhautdickenänderungen können mit OCT gemessen werden, oder indirekt mit hochauflösender Achsenlängenmessung, z.B. mit Niederkohärenzinterferometrie (wie Lenstar LS 900)

eine Verdickung der Aderhaut geht langfristig mit weniger Augenwachstum einher



Ergebnisse (Entwicklung der Augenlängen in 30 min)



UNFILTERED MOVIE

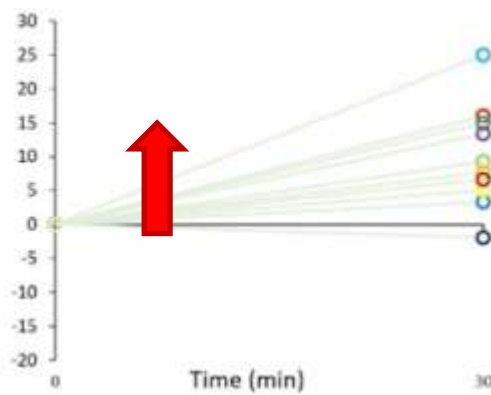
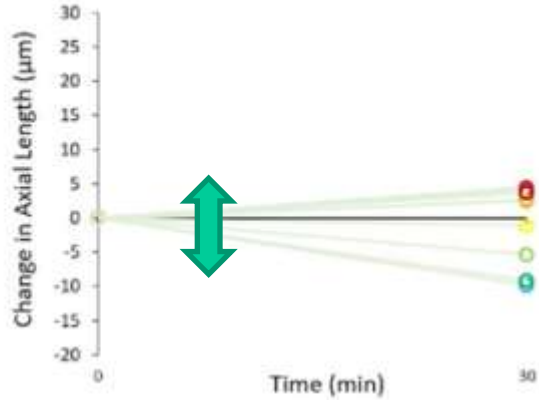


LOW-PASS FILTER



+2.5D DEFOCUS

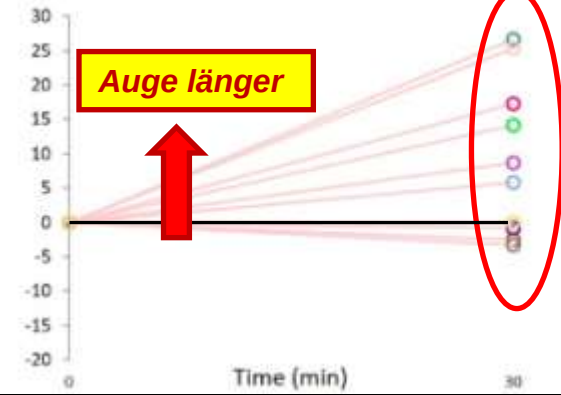
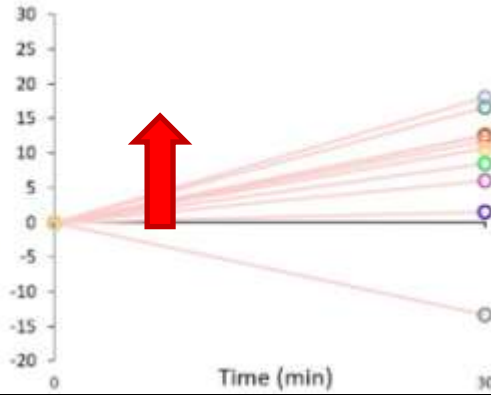
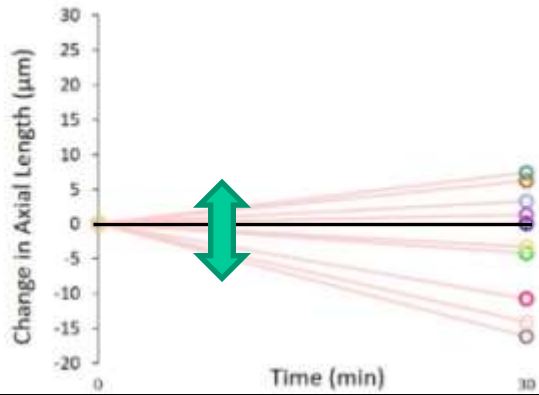
EMMETROPES



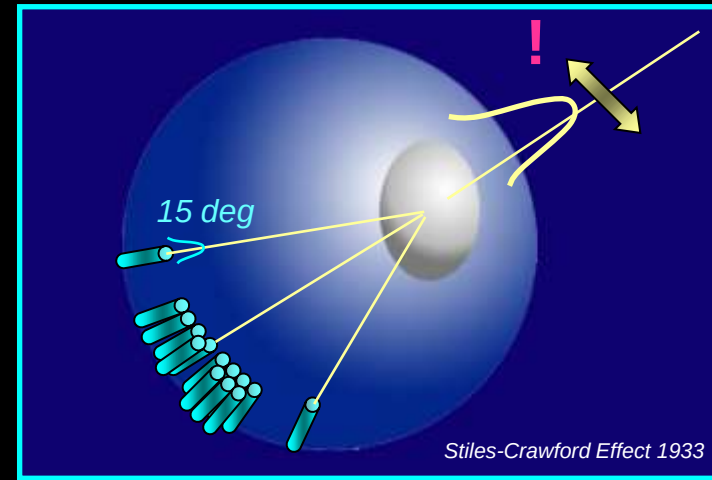
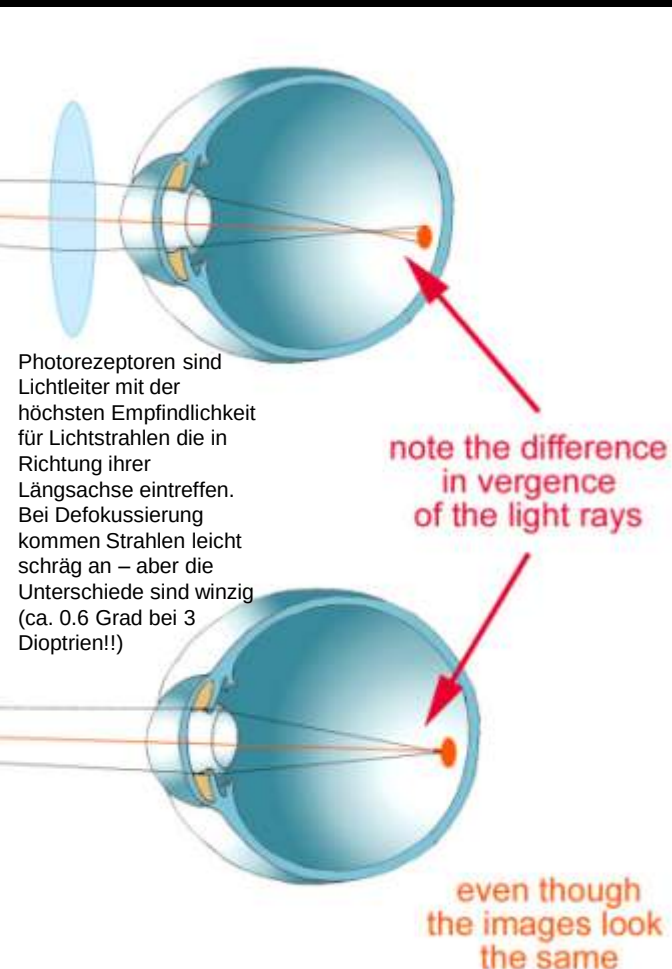
zeigt einen Funktionsdefizit der myopen Retina:
positive Defokussierung wird nicht mehr erkannt

Auge kürzer

MYOPES



Auge länger



Zentrale Fragen:

Wie könnte die Netzhaut im emmetropen Auge den Unterschied zwischen echter und berechneter Defokussierung erkennen?

Was hat sich in der myopen Netzhaut geändert, wenn dies nicht mehr funktioniert?

(Könnte auch die biochemische Signalkaskade von Retina zu Aderhaut zu Sklera verändert sein? – Experiment folgt →)

auffallend ist, dass Emmetropisierung anscheinend im niederen Ortsfrequenzbereich funktioniert (1 and 8 Streifen/Grad, ähnlich wie Akkommodation)

Retinal Responses to Simulated Optical Blur Using a Novel Dead Leaves ERG Stimulus

Athanasios Panorgias,¹ Stephanie Aigbe,¹ Emily Jeong,¹ Carles Otero,² Peter J. Bex,^{1,3} and Fuensanta A. Vera-Díaz¹

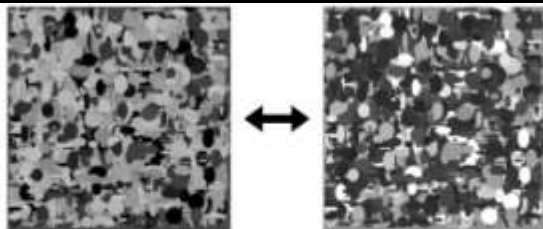
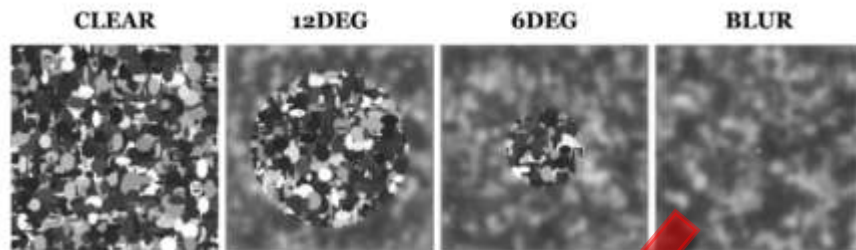


FIGURE 1. Example of contrast reversal for the DLS. Each DLS is shown for 250 ms before the other DLS is shown on the screen. The double change luminance in a decrement/increment fashion symmetrically from the average grayscale value of 127, resulting in a change in contrast polarity.



CONCLUSIONS. Blur type, magnitude, and location all affect the retinal responses. Our data indicate that the retinal area between 6 and 12 degrees eccentricity has the largest effect on the retinal responses to blur. In addition, certain optical blur types appear to have a more detrimental effect on the ERGs than others. These results cannot be solely explained by changes to image contrast and spatial frequency content, suggesting that retinal neurons might be sensitive to spatial cues in order to differentiate between different blur types.

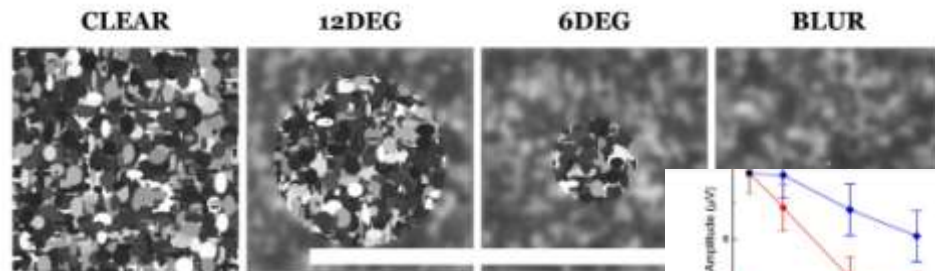


FIGURE 2. Illustrations of the four different blur spatial configurations of the DLS. The CLEAR image is in focus at all eccentricities. The 12DEG and 6DEG images illustrate a stimulus in which the center (respectively) is in focus while the rest of the image is blurred. The BLUR image illustrates a stimulus of the three illustrated blurred images is DEF with 0.5 μ m magnitude. A white 0.6 degree M stimulus to facilitate fixation.

Dead Leaves ERGs to Simulated Optical Blur

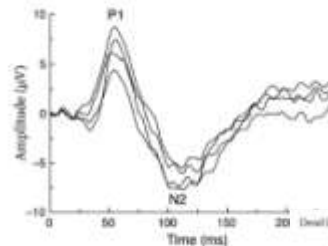


FIGURE 3. Four representative ERG traces recorded DLS from four different subjects. The P1 indicates the peak of the waveform, and N2 the second negative peak.

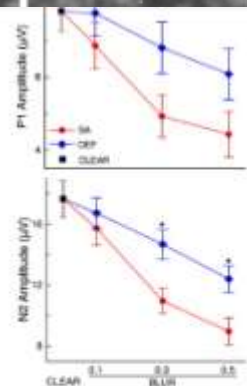


FIGURE 4. P1 (top) and N2 (bottom) amplitudes for CLEAR and BLUR images (0.1, 0.2, and 0.5). The black squares correspond to the ERG amplitude of the CLEAR image; the blue diamonds depict the amplitude of the BLUR conditions; and the red squares the amplitude of the SA condition. The mean bars correspond to ± 1 SE. The asterisks indicate the statistically significant differences between the SA and BLUR conditions.

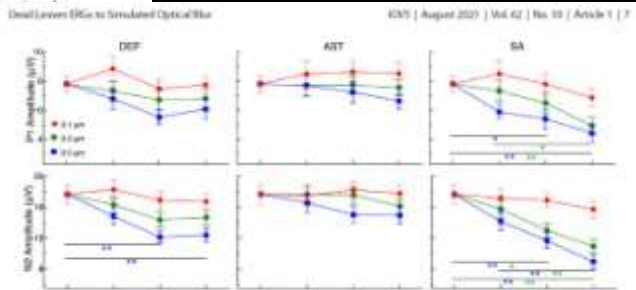


FIGURE 5. Average ERG P1 (top row) and N2 (bottom row) amplitudes for DEF (left column), AST (middle column), and SA (right column) conditions. The black squares correspond to the CLEAR image; the blue diamonds depict the amplitude of the BLUR conditions; and the red squares the amplitude of the SA condition. The mean bars correspond to ± 1 SE. The asterisks indicate the statistically significant differences between the SA and BLUR conditions.

Hypothese:

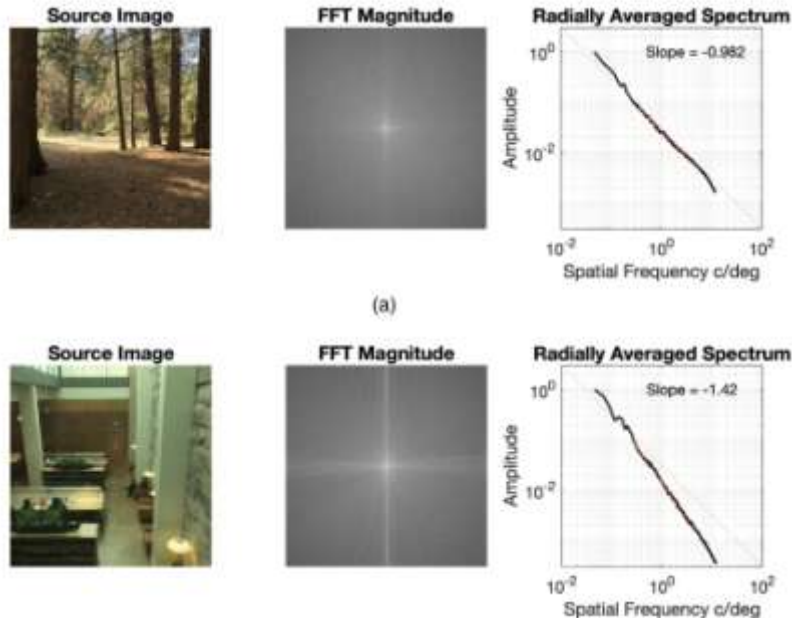
unsere visuelle Umwelt enthält nicht mehr genug feine Details

Das kann zwar stimmen, aber der Unterschied ist klein und wir haben gefunden, dass niedere Ortsfrequenzen zur Emmetropisierung ausreichen

Visual Neuroscience

The Spatial Frequency Content of Urban and Indoor Environments as a Potential Risk Factor for Myopia Development

Daniel Ian Flitcroft,^{1,2} Elise N. Harb,³ and Christine Frances Wildsoet³



Spatial Frequency and Myopia Development

IOVS | September 2020 | Vol. 61 | No. 11 | Article 42 | 5

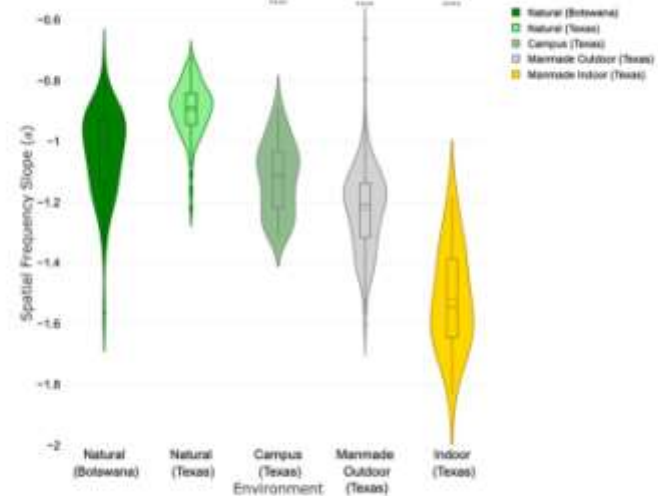


Figure 3. Violin plots of the calculated amplitude spectrum slopes (α) for the different types of images from the Botswana and Texas image sets. Significance markers (*) indicate comparison with the Texas natural image set.

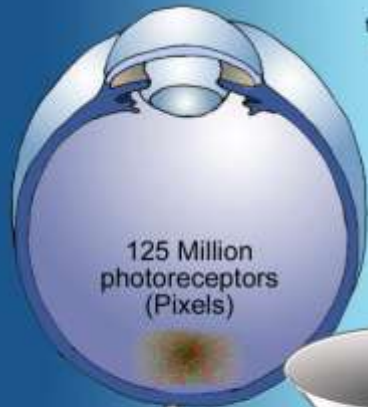
Mögliche Rolle der ON- und OFF-Mechanismen in der Retina bei der Emmetropisierung

Warum ON and OFF?

it makes no sense
to separately process each of
the highly correlated "pixels"
in the retinal image



Kamera speichert jedes
Pixel separat, die
Netzhaut nicht



125 Million
photoreceptors
(Pixels)

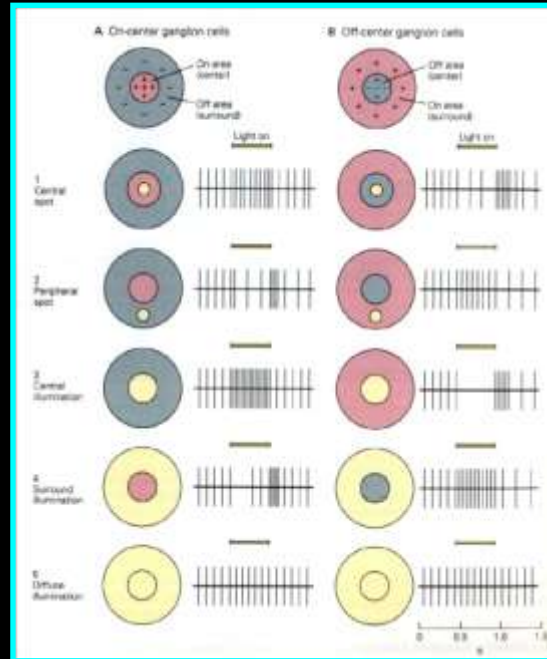


1 Million
nerve fibres
(cables)

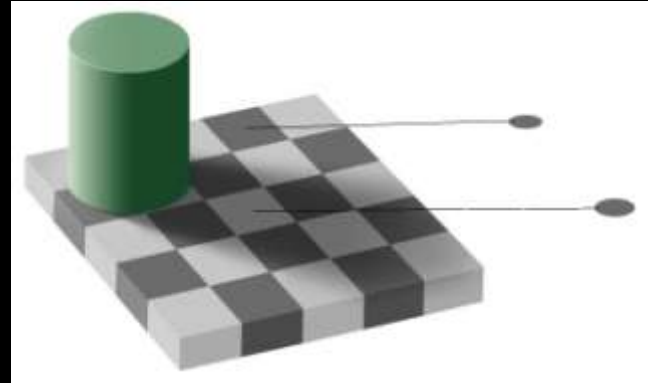


about 100 mg retina
keep 50%
of the cortex busy

Wichtiger Trick
zur Informationsreduktion:
ON und OFF Mechanismen
in der Netzhaut



Deshalb können absolute Helligkeiten kaum
abgeschätzt werden (Adelson-Illusion 1995)



1989



Visum Res. Vol. 31, No. 5, pp. 833-844, 1991
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0042-6969/91 \$3.00 + 0.00
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REFRACTIVE-ERROR CHANGES IN KITTEN EYES PRODUCED BY CHRONIC ON-CHANNEL BLOCKADE

EARL L. SMITH III, DONALD A. FOX and GARY C. DUNCAN
College of Optometry, University of Houston, Houston, TX 77204-6052, U.S.A.



Abstract—The dependence of the emmetropization process on retinal ON-channel activity was examined in developing kittens by making regular intravitreal injections of D,L-2-amino-4-phosphonobutyric acid (APB). In comparison to sham-injected control eyes, the APB-treated eyes had shorter axial lengths and were more hyperopic. Since chronic atropinization did not alter the development of the APB-induced hyperopia, these anomalous refractive errors are not the result of altered accommodative function. The axial hyperopia observed in the APB-treated eyes indicates that the mechanisms responsible for normal axial elongation are dependent to some extent on ON-channel activity and that, even in the presence of a clear retinal image, OFF-channel activity, by itself, is not sufficient to regulate the normal emmetropization process.

On-center neurons Cat 2-Amino-4-phosphonobutyric acid APB Axial length

838

EARL L. SMITH III et al.

INTEROCULAR AXIAL-LENGTH DIFFERENCES

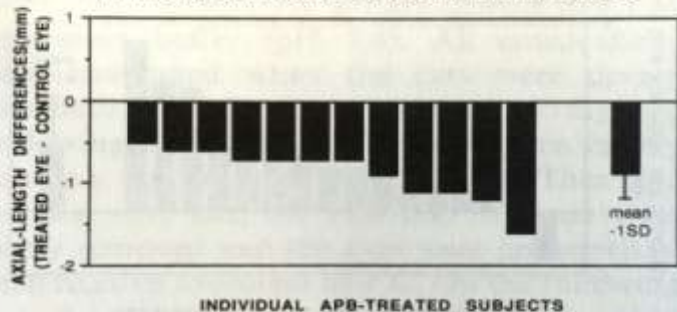


Fig. 3. Interocular axial-length ratios for the control and APB-treated eyes (APB-treated eye/control eye). Data for individual subjects are ranked according to the differences in axial length.

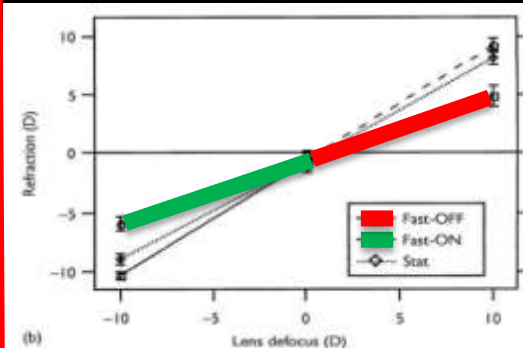
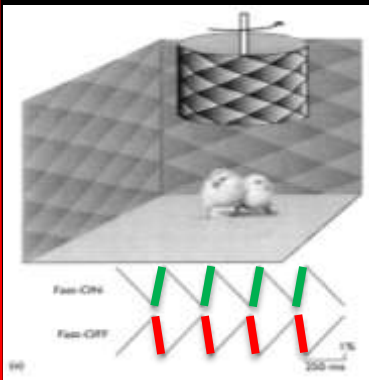
2002 / 2003

DEVELOPMENTAL NEUROSCIENCE

Refractive compensation to optical defocus depends on the temporal profile of luminance modulation of the environment

D. P. Crewther^{1,2,CP} and S. G. Crewther¹

School of Psychological Sciences, La Trobe University, Melbourne¹; Brain Sciences Institute, Swinburne University of Technology, Melbourne, Vic. 3201, Australia²



NEUROREPORT

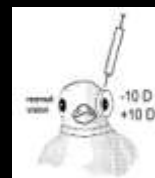
Inhibition of retinal ON/OFF systems differentially affects refractive compensation to defocus

S. G. Crewther^{1,CP} and D. P. Crewther^{1,2}

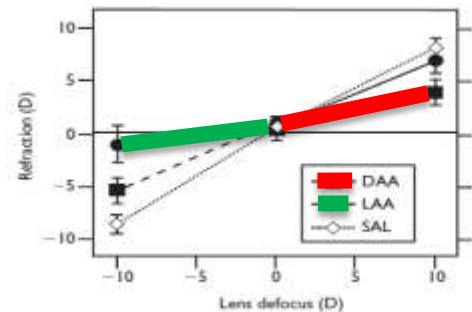
and Sciences, La Trobe University, Melbourne¹; Brain Sciences Institute, Swinburne University of Technology, Melbourne, Australia²



LAA (L- α -aminoacidipic acid):
hemmt ERG -ON Antwort, und
verringert Myopie, induziert
durch Negativlinsen



DAA (D- α -aminoacidipic acid):
hemmt die ERG -OFF Antwort,
und verringert Hyperopie,
induziert durch Positivlinsen
(relativ mehr Myopie)

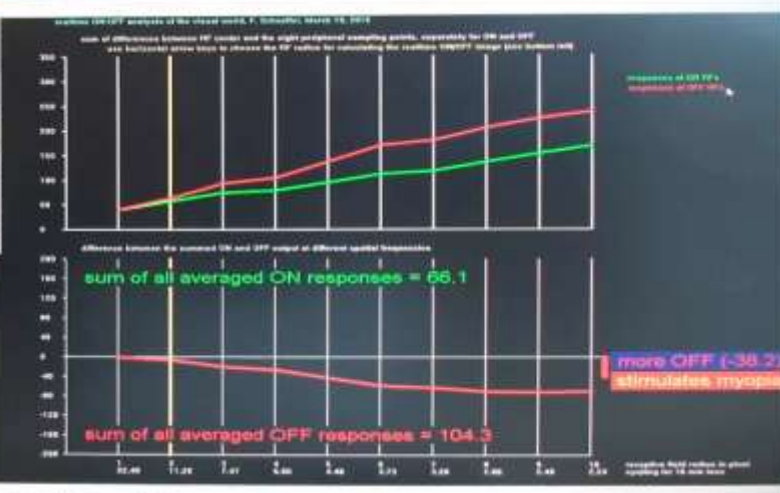


Wieviel ON- und OFF-Stimulation erfahren wir in unserer visuellen Umgebung? Messung mit eigener Software.

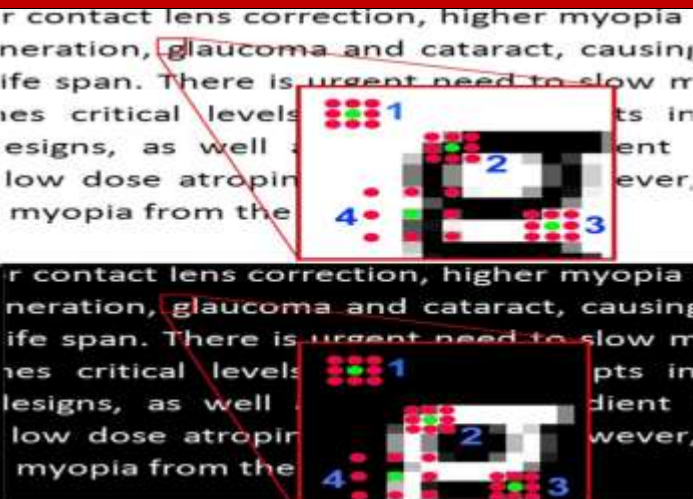
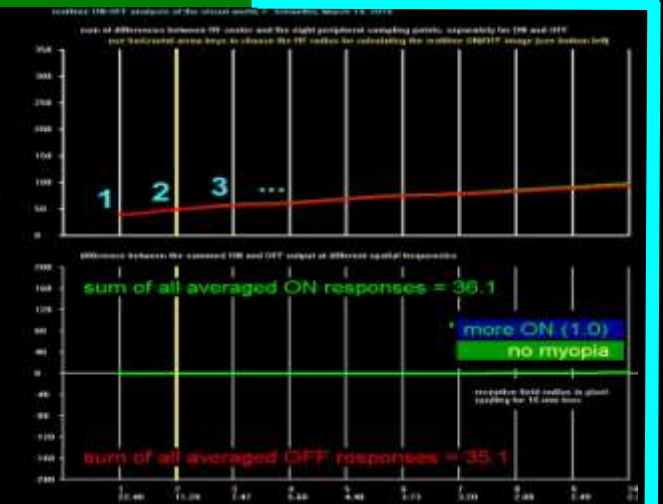
2018

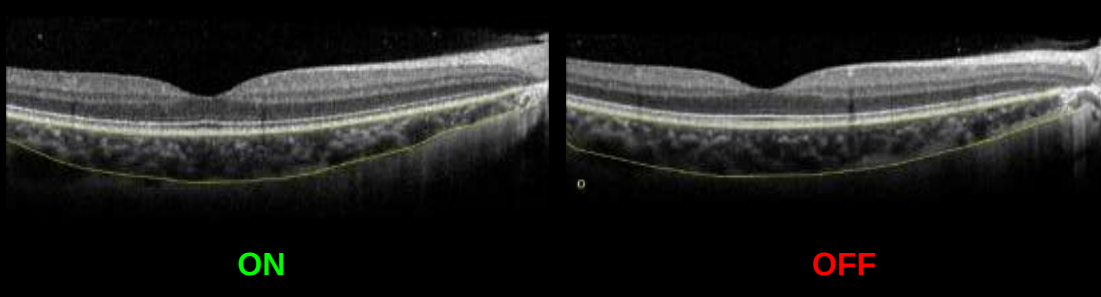


Bilder: ausgeglichene ON /OFF Reizung



Text: unausgeglichene ON / OFF Reizung



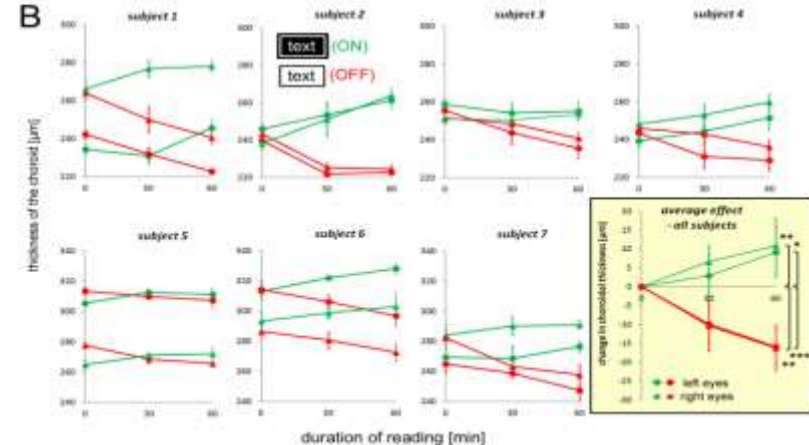
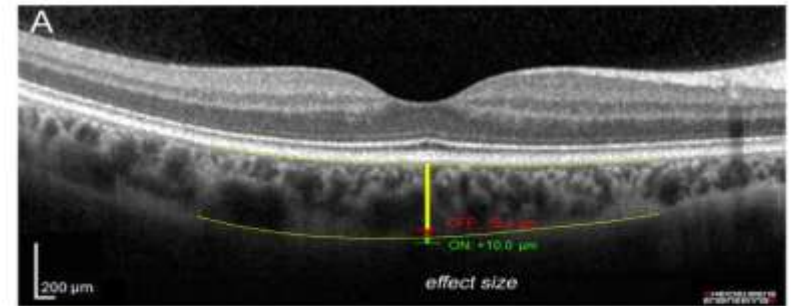


- Sieben junge Probanden lasen Text auf einem grossen TV-Schirm (65") in 3 m Entfernung, eine Stunde lang – einmal mit normalem Kontrast und einmal mit invertiertem Kontrast (Helligkeiten abgeglichen)
- OCT und Aderhautdickenmessung nach 30 min und 1 Stunde

Ergebnis:

reading dark text on bright background makes the choroid thinner

reading bright text on dark background makes the choroid thicker



OPEN

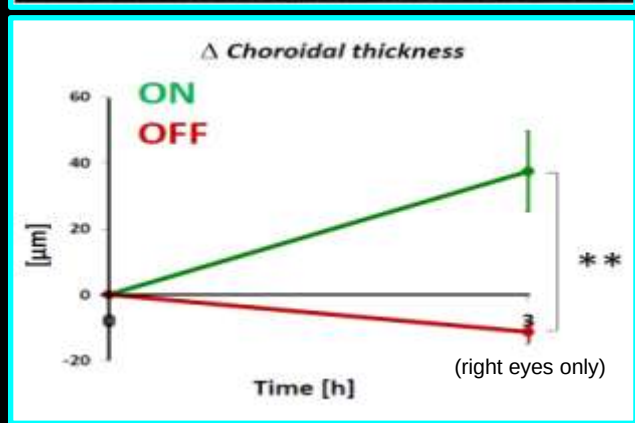
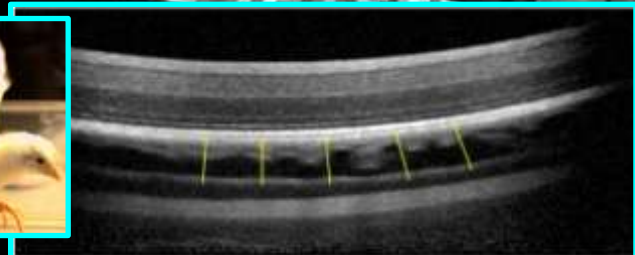
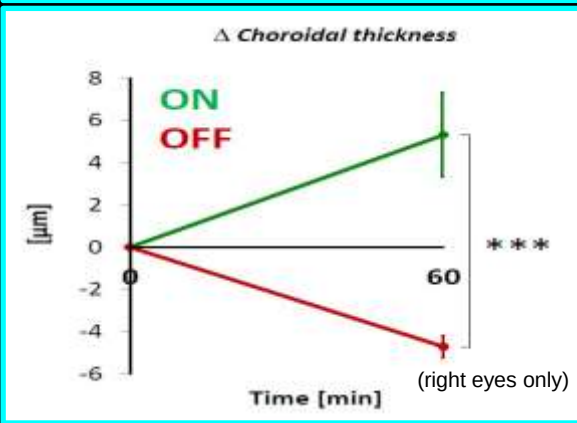
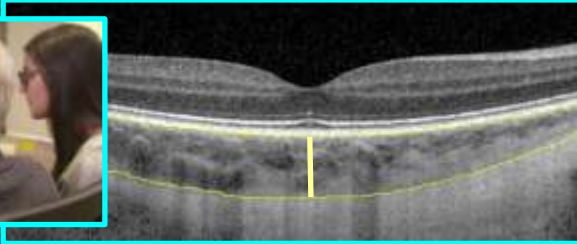
Reading and Myopia: Contrast Polarity Matters

Andrea C. Kleinman, Min Wang & Frank Schaeffel

Received: 3 February 2018
Accepted: 2 July 2018
Published online: 19 July 2018

In myopia the eye grows too long, generating poorly focused retinal images when people try to look at a distance. Myopia is tightly linked to the educational status and is on the rise worldwide. It is still not clear which kind of visual experience stimulates eye growth in children and students when they study. We propose a new and perhaps unexpected reason. Work in animal models has shown that selective activation of ON or OFF pathways has also selective effects on eye growth. This is likely to be true also in humans. Using custom-developed software to process video-frames of the visual environment in real-time we quantified relative ON and OFF stimulus strengths. We found that ON and OFF inputs were equally overstimulated. Using stimuli that selectively activate the ON or OFF pathways, we found that the healthy eye grows when exposed to red and white text from below, whereas the myopic eye grows when exposed to red and white text from above. Therefore, reading with red text on a black background may be beneficial for myopia control.

auch mit künstlicher ON/OFF Reizung kann man die Aderhautdicke bei Menschen und Hühnern ändern



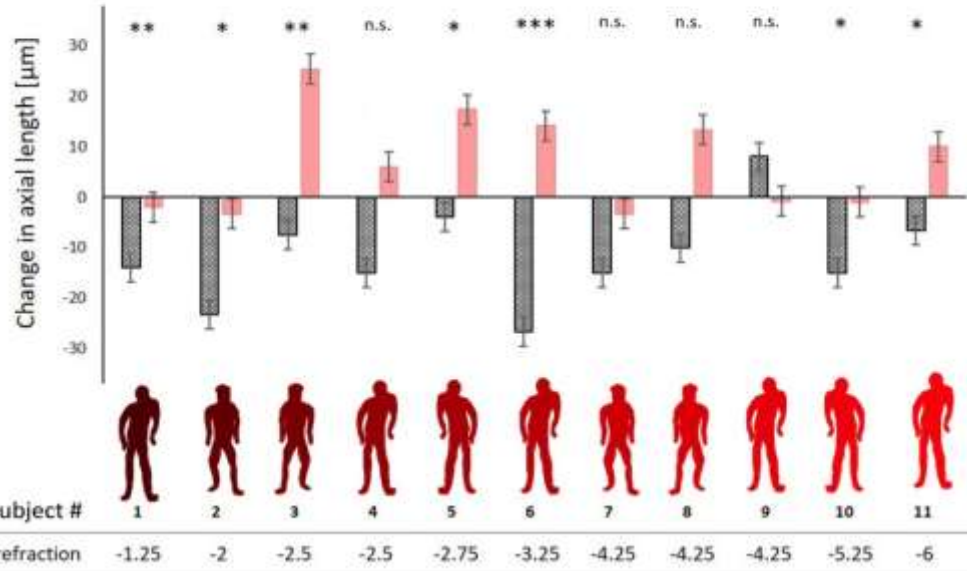
Wang M, Aleman AC, Schaefel F (2019)
Invest Ophthalmol Vis Sci 60(7):2599-2611

Test der biochemischen Signalkaskade: Kann Lesen mit invertiertem Kontrast auch bei myopen Probanden das Auge kürzer machen ?

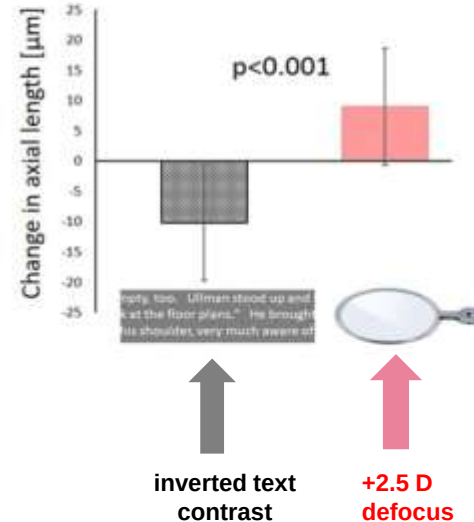
Myopic subjects

■ inverted text contrast
■ +2.5D defocus

empty, too. Ullman stood up and
at the floor plans." He brought
his shoulders, very much aware of



average data



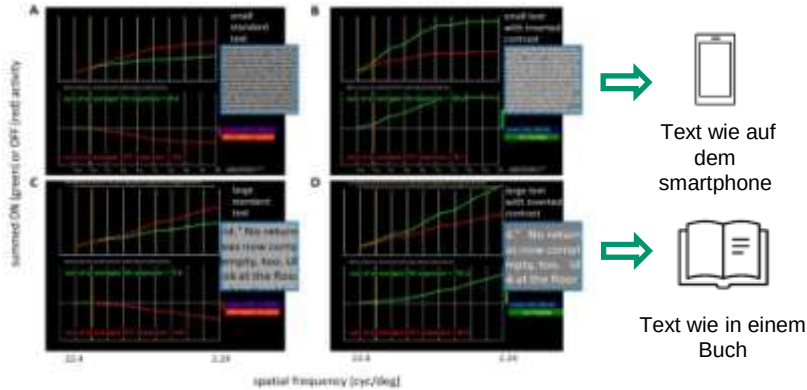
Ja! – auch myope Probanden können vorübergehend kürzere Augen entwickeln (ca 10 μm kürzer, und 20 μm kürzer als mit Positivlinsen), wenn sie Text mit invertiertem Kontrast lesen

Ergebnis 1: die kurzsichtige Netzhaut kann noch eine Verdickung der Aderhaut auslösen – die biochemische Signalkaskade ist intakt !

Ist Textgrösse wichtig?

gleiche Texthelligkeit in allen Experimenten

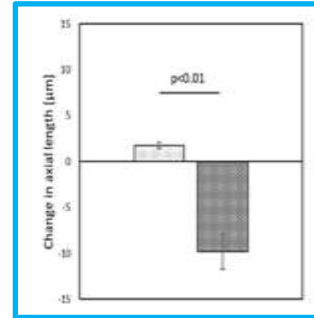
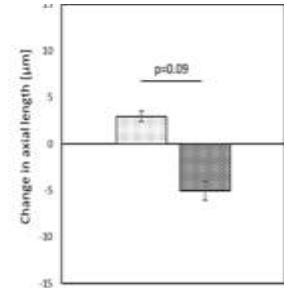
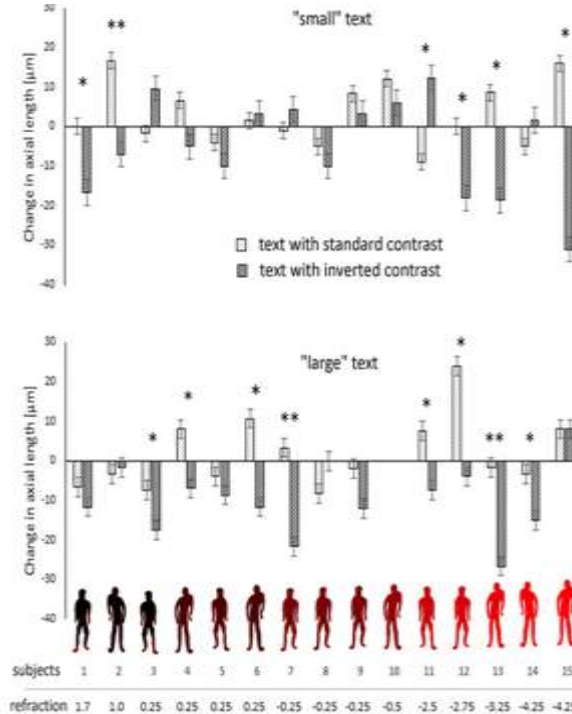
Analyse der ON versus OFF Reizstärke beim Lesen des Textes



Textgrösse ist wichtig!

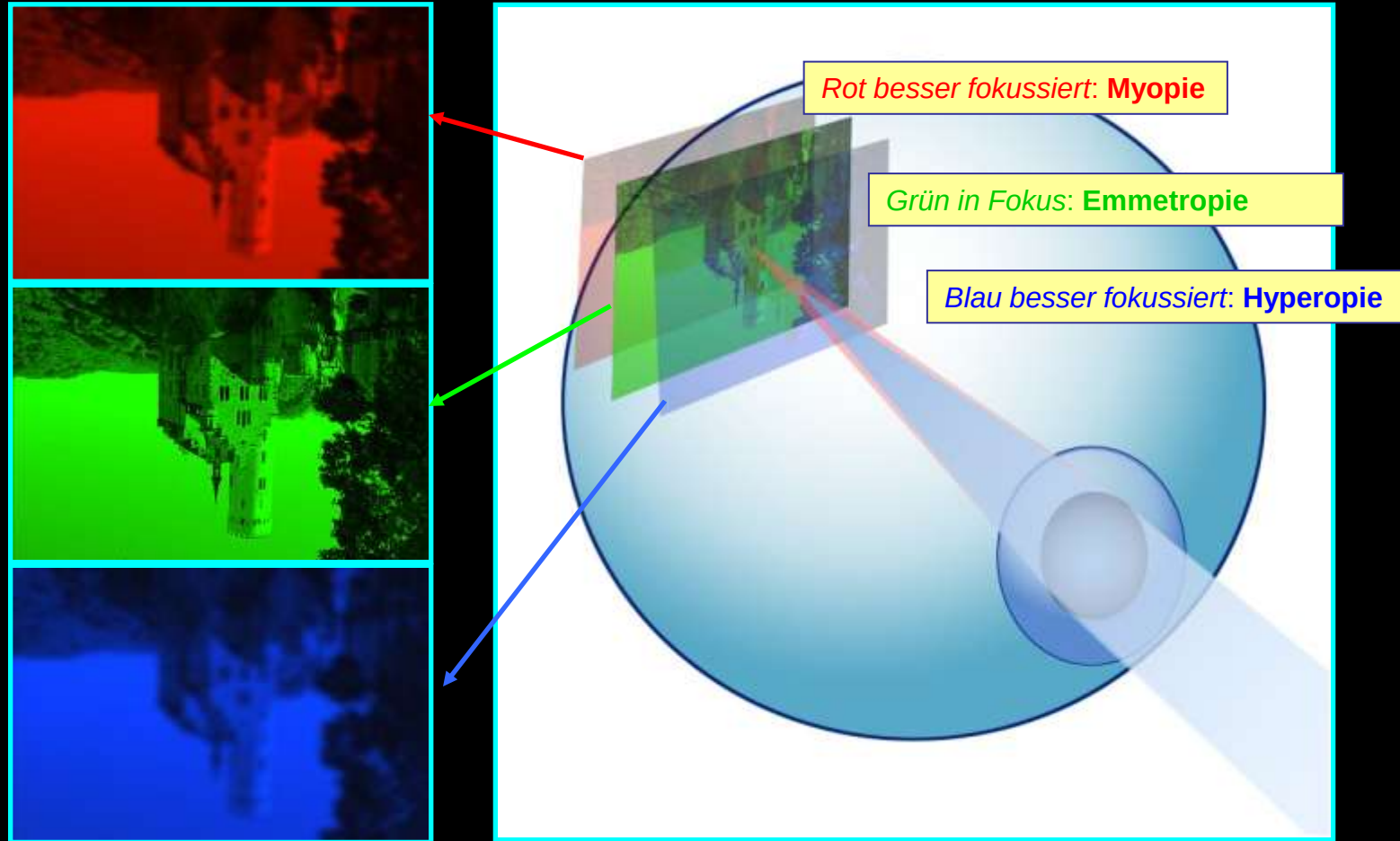
Text mit invertiertem Kontrast war wirkungsvoller, wenn die Buchstabenhöhe 0.57 Grad war, verglichen mit 0.28 Grad

Buchstaben auf dem Smartphone sind zu klein, um die relevanten ON/OFF Rezeptiven Felder in der Retina zu stimulieren



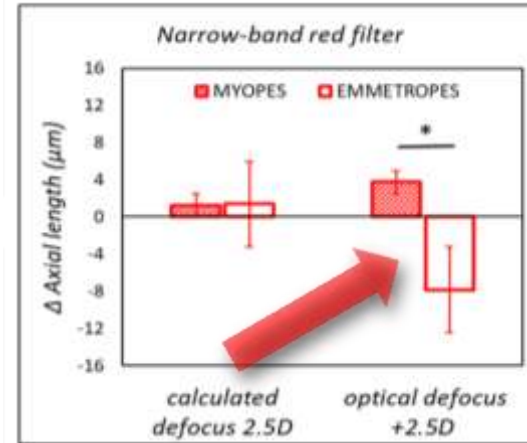
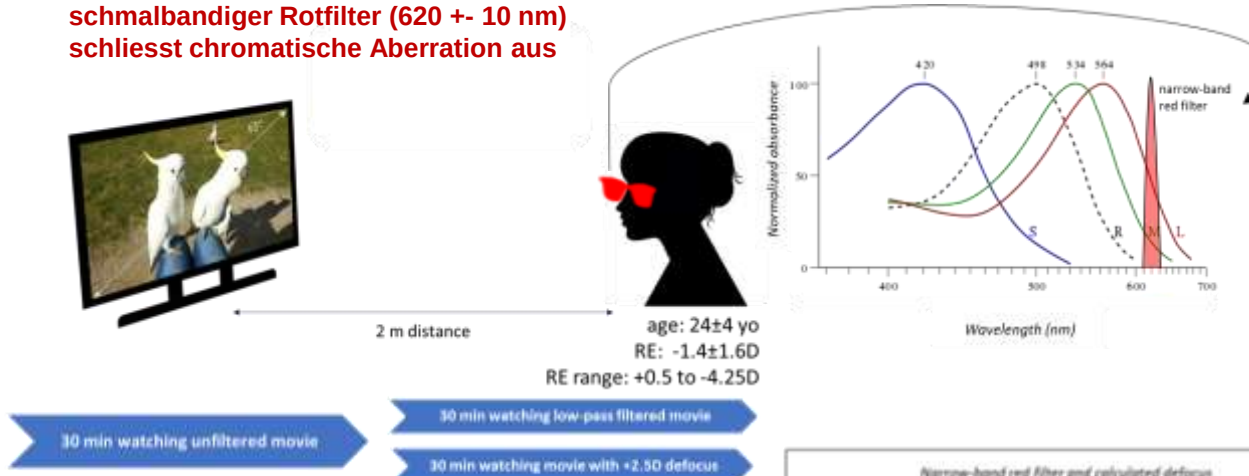
Ergebnis 2: grösserer Text (wie in einem Buch) ist wirksamer als kleinerer Text (wie auf dem smartphone)

zurück zur Vorzeichenerkennung durch die Netzhaut:
longitudinale chromatische Aberration wäre ein perfekter Stimulus



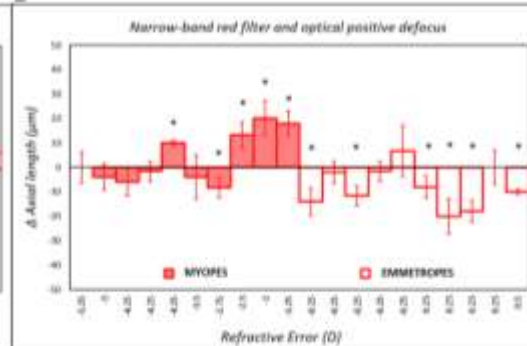
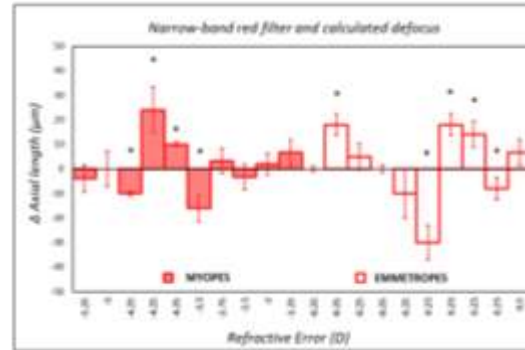
Ist chromatische Aberration nötig, damit die Netzhaut das Vorzeichen der Defokussierung erkennt?

**schmalbandiger Rotfilter (620 $\pm$ 10 nm)
schliesst chromatische Aberration aus**



Ergebnisse 1 & 2

- chromatische Aberration ist nicht nötig, damit die emmetrope Netzhaut das Auge kürzer macht, wenn eine Positivlinse getragen wird (roter Pfeil)
- Die myope Netzhaut kann es wieder nicht



Die Rolle von Farbe bei der Emmetropisierung

Clinical and Epidemiologic Research

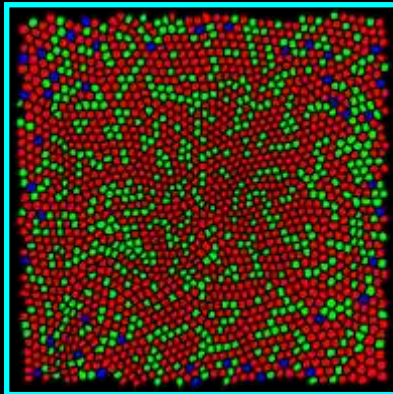
Association Between Color Vision Deficiency and Myopia in Chinese Children Over a Five-Year Period

Capital Medical University, Beijing, China A total of 2849 grade 1 students (aged 7.1 ± 0.4 years) from 11 primary schools were enrolled and followed up for five years.

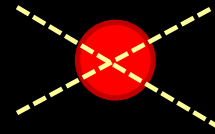
Citation: Gan J, Li SM, Atchison DA, et al. Association between color vision deficiency and myopia in Chinese children over a five-year period. *Invest Ophthalmol Vis Sci.* 2022;63(2):2. <https://doi.org/10.1167/iov.63.2.2>

The prevalence of color vision deficiency was 1.68%, with 2.81% in boys and 0.16% in girls. Color-deficient cases consisted of 91.6% deutan and 8.3% protan. Over the five years, the cumulative incidence of myopia was 35.4% (17/48) in the color-vision deficiency group, which was lower than the 56.7% (1017/1794) in the color normal group ($P = 0.004$). Over the five-year study period, the change in spherical equivalent refraction in the color vision-deficiency group (-1.81 D) was also significantly lower than that in the color normal group (-2.41 D) ($P = 0.002$).

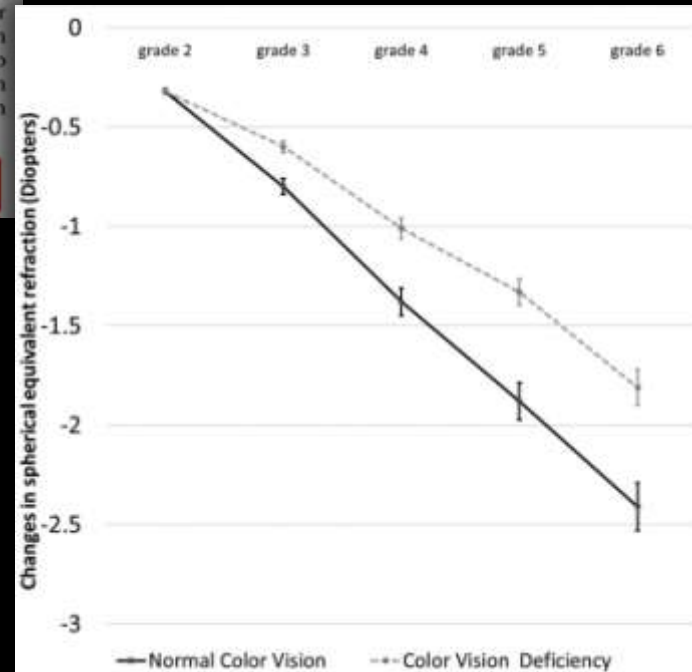
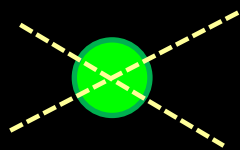
color-deficient individuals are less susceptible to myopia onset and development.



protanop



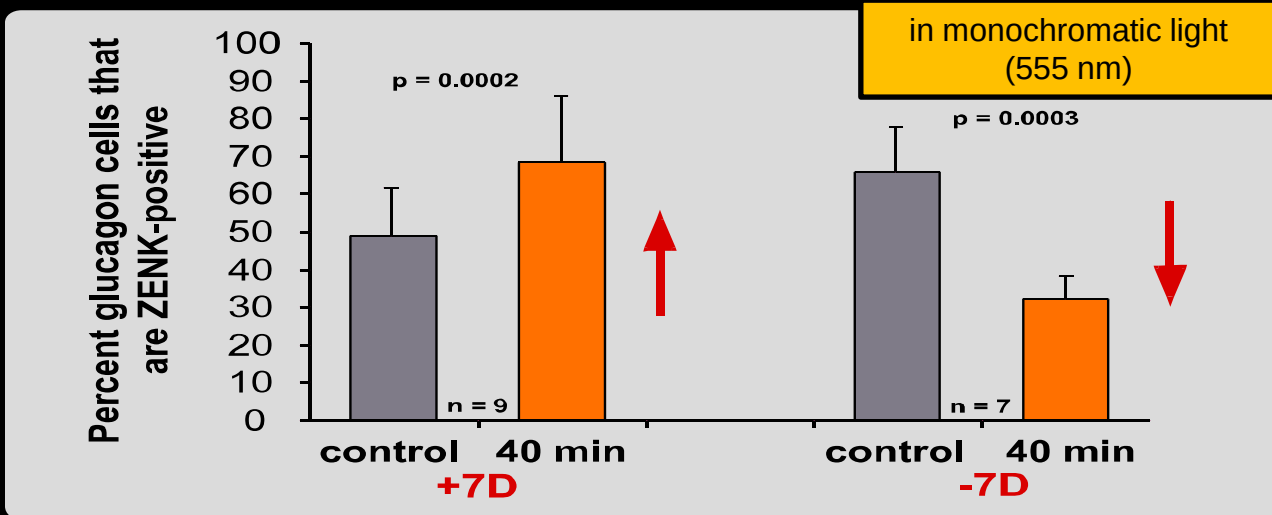
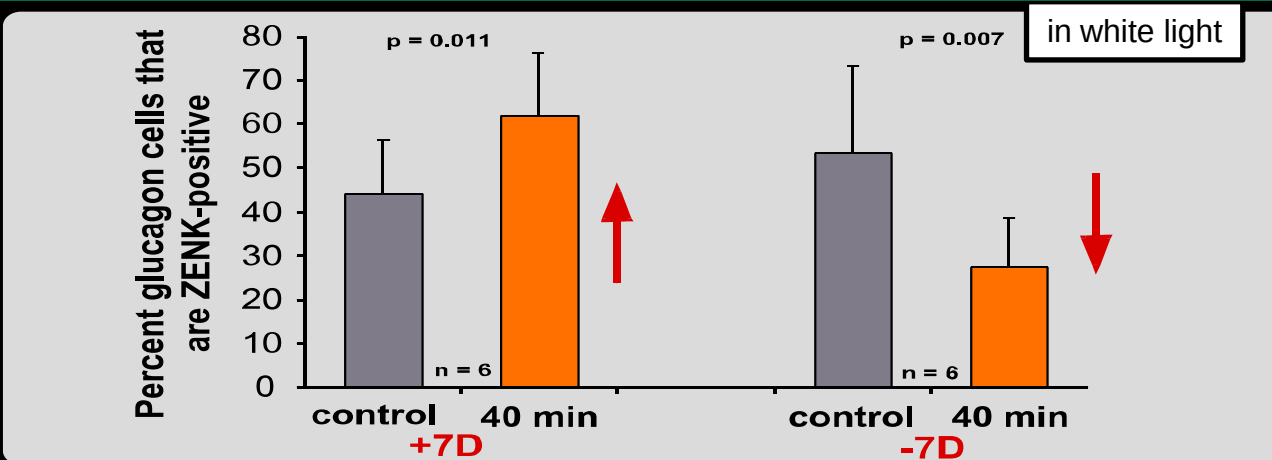
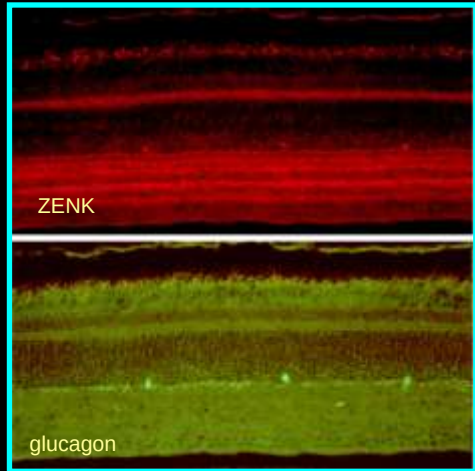
deutanop

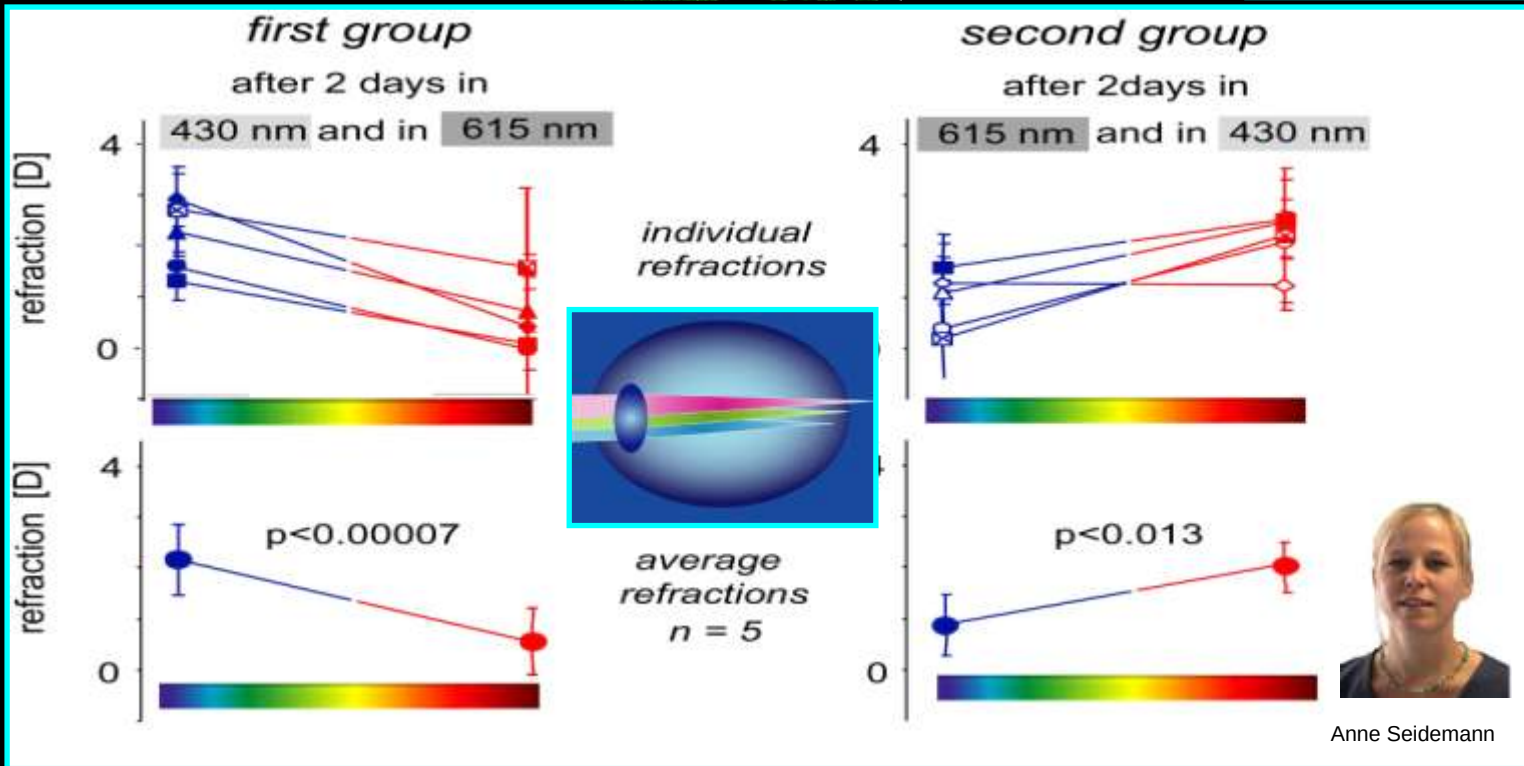


Myopie und Hyperopie können bei Hühnern mit Brillenlinsen auch in **monochromatischem Licht** erzeugt werden, und ZENK (ein Marker, der in Abhängigkeit vom Vorzeichen einer Defokussierung expriemiert wird) reagiert normal



retinal glucagon amacrine cells "know" in a few minutes the sign of defocus: expression of the ZENK protein (2002,1999)



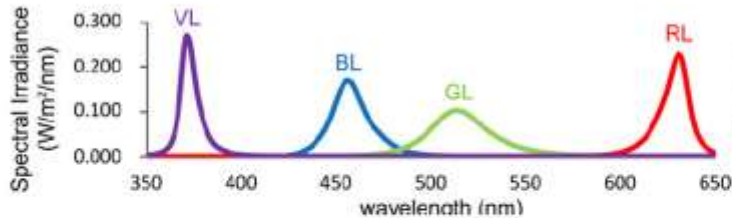


Violet light suppresses lens-induced myopia via neuropsin (OPN5) in mice

Xiaoyan Jiang^{a,b,1}, Mabelle T. Pardue^{c,d,1}, Kiwako Mori^{a,b}, Shin-ichi Ikeda^{a,b}, Hidemasa Torii^{a,b}, Shane D'Souza^a, Richard A. Lang^{a,f}, Toshihide Kurihara^{a,b,2}, and Kazuo Tsubota^{a,g,2}

PNAS 2021 Vol. 118 No. 22 e2018840118

<https://doi.org/10.1073/pnas.2018840118>

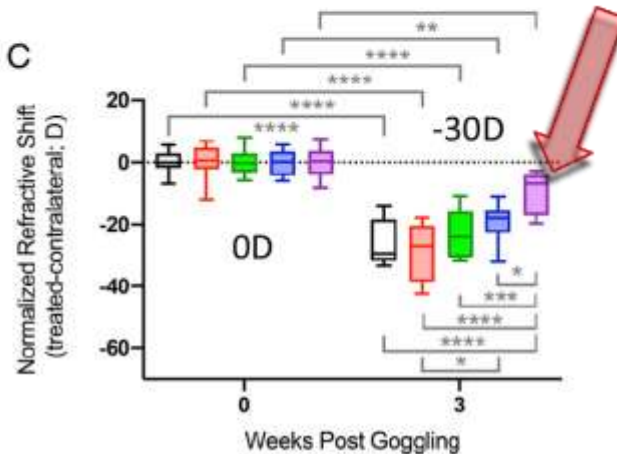


was added to white background light every evening 5-8 p.m.



OD -30D

C

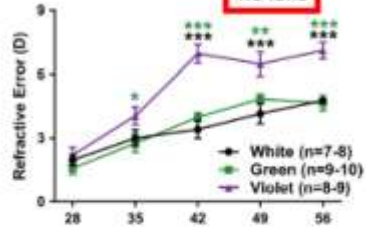
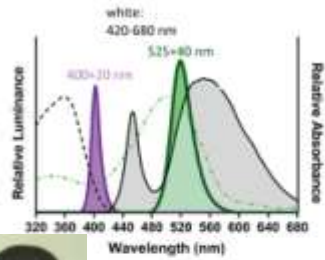


auch blaues Licht (400 nm) hemmt Myopie, induziert durch Negativlinsen, bei Mäusen

Visual Neuroscience

Short-Wavelength (Violet) Light Protects Mice From Myopia Through Cone Signaling

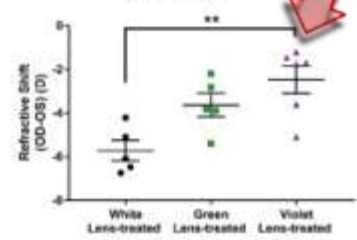
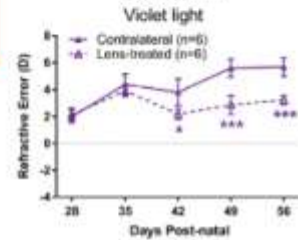
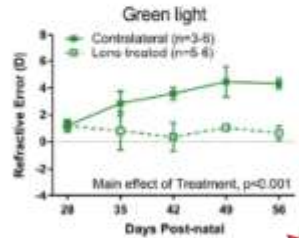
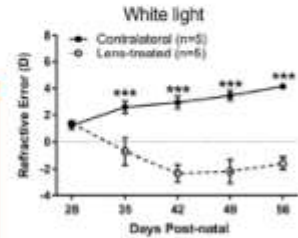
Ryan Strickland,^{1,2} Erica G. Lankford,^{1,2} and Michelle T. Pories^{1,2}
IOVS | February 2020 | Vol. 61 | No. 2 | Article 13 | 4



no lens



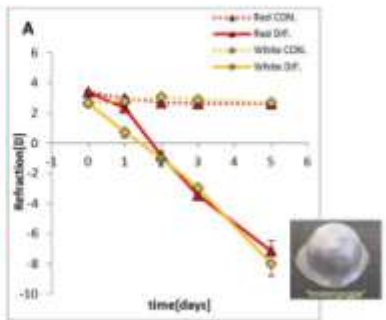
no lens
vs
-10D



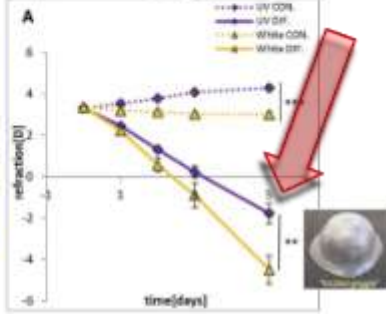
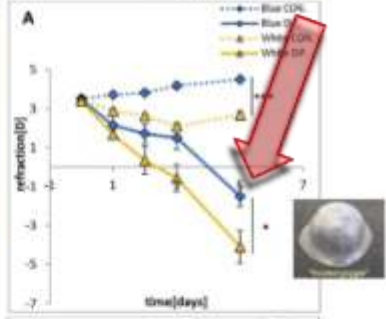
Anatomy and Pathology/Oncology

Effects of Light of Different Spectral Composition on Refractive Development and Retinal Dopamine in Chicks

Min Wang,^{1,2} Frank Schaeffel,¹ Bing Jiang,¹ and Marita Fehlkemper¹



Hühner: sowohl blaues als auch UV Licht (365 nm) hemmt Depriavtionsmyopie



Research Paper

Violet Light Exposure Can Be a Preventive Strategy Against Myopia Progression

Hidenasa Torii ^{1,2}, Toshitake Karibara ^{1,2}, Yuko Seko ¹, Kazuno Negishi ¹, Kazuhiko Ohnuma ¹, Takaaki Inaba ^{1,2}, Motoko Kawashima ¹, Xiaoyan Jiang ^{1,2}, Shinichiro Kondo ¹, Maki Miyasuchi ^{1,2}, Yukihiko Miwa ^{1,2}, Yutaku Katada ^{1,2}, Kiwako Mori ^{1,2}, Keiichi Kam ¹, Kinya Tsubota ^{1,2}, Hiroshi Goto ¹, Mayumi Ohtsuka ¹, Megumi Hatori ^{1,2,3}, Kazuo Tsubota ^{1,2,4}

Abstract

Myopia is a leading cause of visual impairment worldwide. Although the pathogenesis of myopia is not fully understood, excessive near work and insufficient outdoor light exposure are considered major risk factors. Recent studies have suggested that blue light, particularly violet light (VL), may play a role in myopia progression. This study investigated the effects of VL exposure on myopia progression in a murine model. Mice were divided into two groups: VL-exposed and control. The VL-exposed group received a daily dose of VL (400 nm, 0.1 mW/cm²) for 4 weeks. The control group received no VL exposure. The axial length of the eyes was measured at baseline and after 4 weeks. The results showed that VL exposure significantly reduced the increase in axial length compared to the control group. These findings suggest that VL exposure may be a preventive strategy against myopia progression.

Introduction

Myopia is a refractive error of the eye that causes distant objects to appear blurry. It is caused by the eye's shape, which is too long, causing light to focus in front of the retina. Myopia is a leading cause of visual impairment worldwide. Although the pathogenesis of myopia is not fully understood, excessive near work and insufficient outdoor light exposure are considered major risk factors. Recent studies have suggested that blue light, particularly violet light (VL), may play a role in myopia progression. This study investigated the effects of VL exposure on myopia progression in a murine model.

Methods

Mice were divided into two groups: VL-exposed and control. The VL-exposed group received a daily dose of VL (400 nm, 0.1 mW/cm²) for 4 weeks. The control group received no VL exposure. The axial length of the eyes was measured at baseline and after 4 weeks. The results showed that VL exposure significantly reduced the increase in axial length compared to the control group.

Results

The results showed that VL exposure significantly reduced the increase in axial length compared to the control group. These findings suggest that VL exposure may be a preventive strategy against myopia progression.

Conclusion

VL exposure may be a preventive strategy against myopia progression. Further studies are needed to confirm these findings in humans.

Keywords

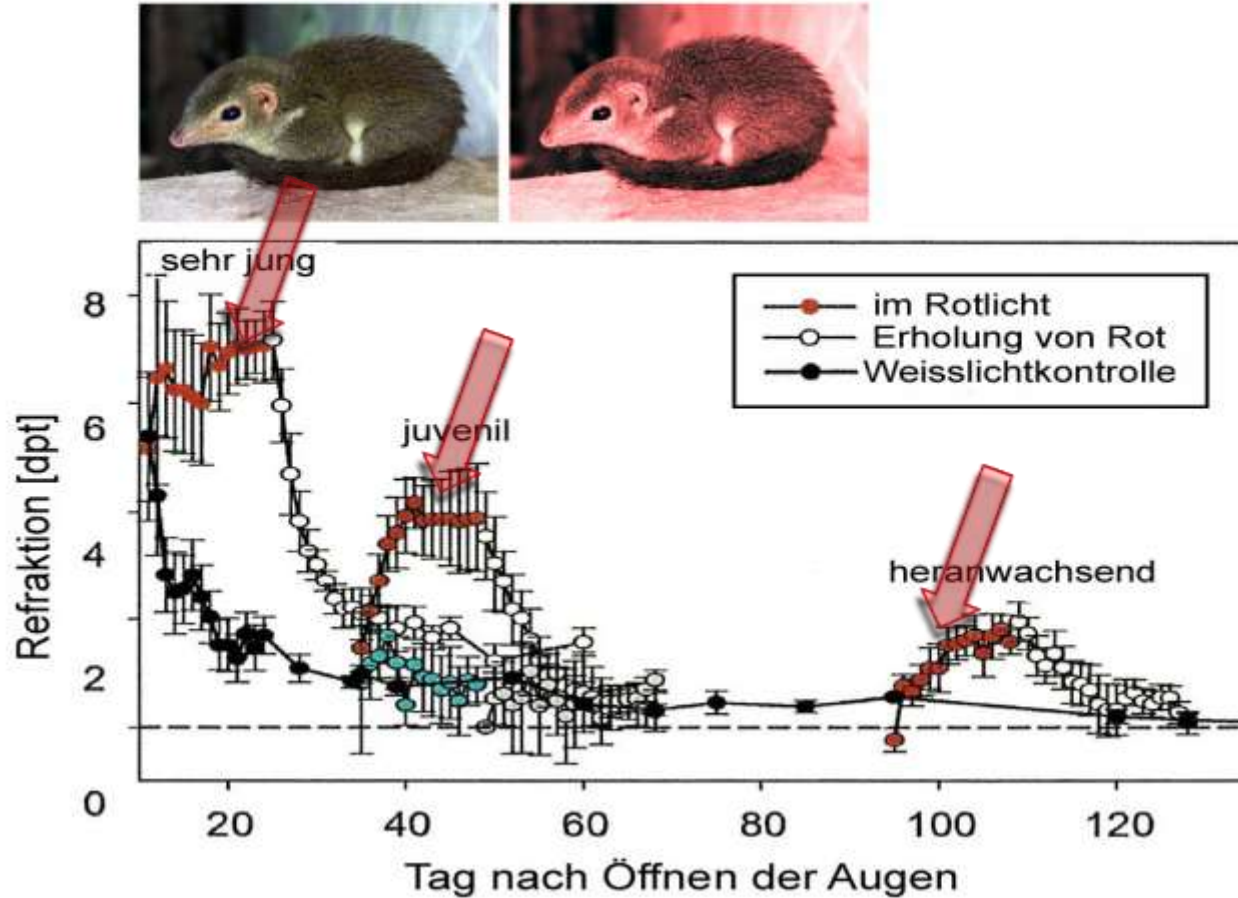
Myopia, Violet Light, Axial Length, Murine Model

Figure 1

Figure 2

Figure 3

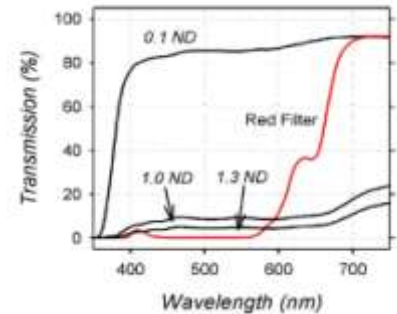
noch überraschender: Tupeias werden in **rotem Licht weitsichtiger** (Gawne et al, starker Effekt!)



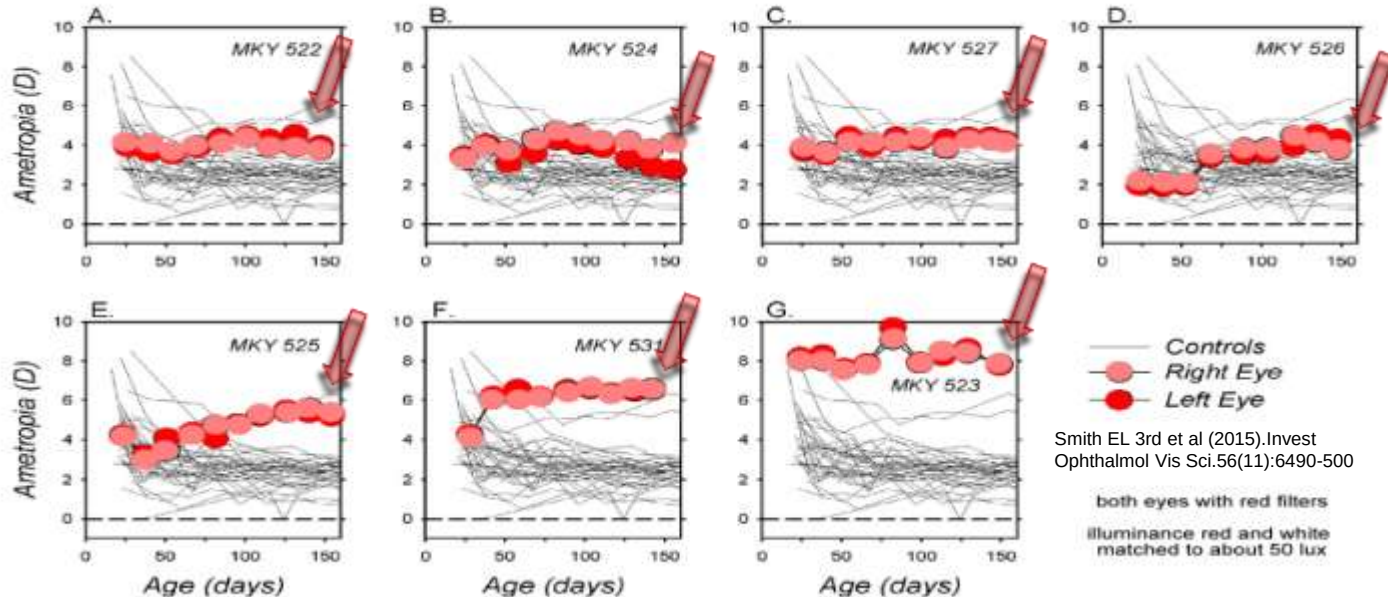
Visual Psychophysics and Physiological Optics

Effects of Long-Wavelength Lighting on Refractive Development in Infant Rhesus Monkeys

Earl L. Smith III,^{1,2} Li-Fang Hung,^{1,2} Baskar Arumugam,^{1,2} Brien A. Holden^{*,2} Maureen Neitz,³ and Jay Neitz³



Red Lens-Induced Hyperopia



Smith EL 3rd et al (2015). Invest Ophthalmol Vis Sci. 56(11):6490-500

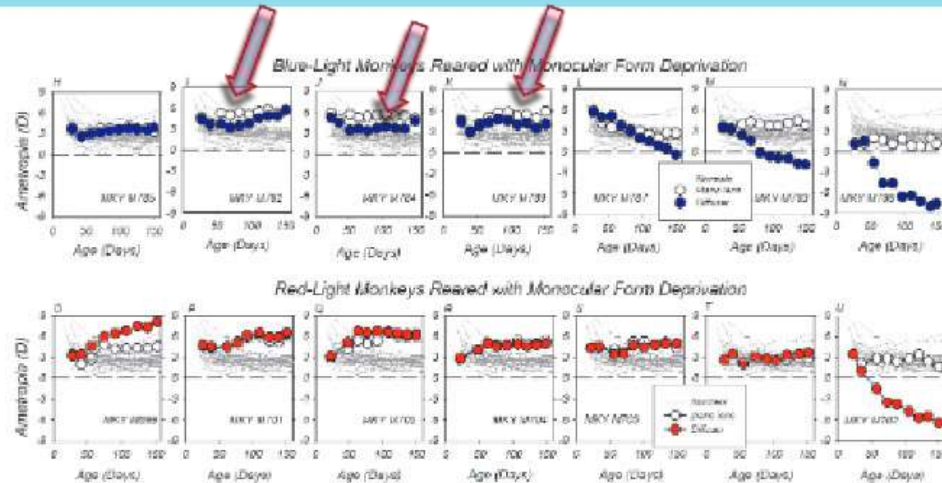
aber blaues Licht erzeugt hauptsächlich mehr variable Refraktionen und hatte keinen Effekt auf die Deprivationsmyopie bei Affen

Effects of narrowband, short-wavelength ambient lighting on form-deprivation myopia in infant rhesus monkeys

Li-Fang Hung, Krista M. Beach, Zhihui She, Lisa A. Ostrin, Earl L. Smith III

ARVO 2021

(schlechte Auflösung,
da Poster nur online
verfügbar)



SUMMARY

3. Compared with typical white ambient lighting, narrowband, short-wavelength lighting neither enhanced nor inhibited either the incidence or degree of form deprivation myopia in infant monkeys, which is in contrast to our previous observations that narrowband, long-wavelength lighting inhibited FDM.

bei jungen Probanden (20-32 Jahre) erzeugte schmalbandiges **rotes** und **grünes** Licht in einer Stunde längere Augen (durch dünnere Aderhaut), und **blaues** Licht kürzere Augen (durch dickere Aderhaut)

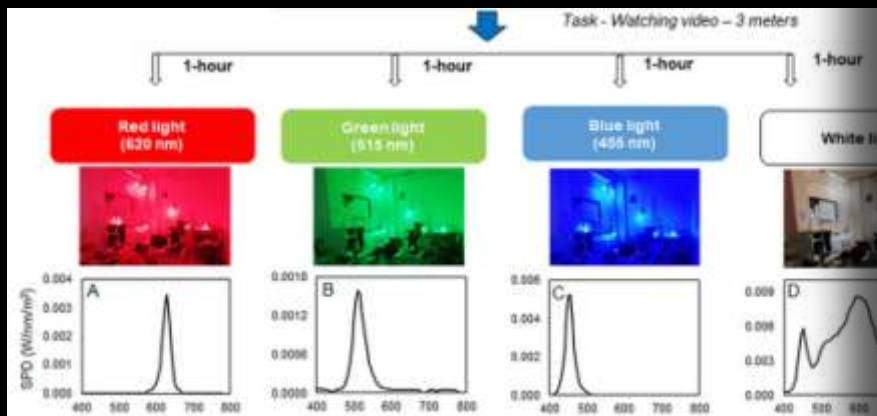
Visual Neuroscience

Short-Term Exposure to Blue Light Shows an Inhibitory Effect on Axial Elongation in Human Eyes Independent of Defocus

Swapnil Thakur, Rohit Dhakal, and Pavan K. Verkicharla

Myopia Research Lab – Prof. Brien Holden Eye Research Centre, I V Prasad Eye Institute, Brien Holden Institute of Optometry and Vision Sciences, I V Prasad Eye Institute, Hyderabad: <https://doi.org/10.1167/iov.62.15.2>

Citation: Thakur S, Dhakal R, Verkicharla PK. Short-term exposure to blue light shows an inhibitory effect on axial elongation in human eyes independent of defocus. *Invest Ophthalmol Vis Sci*. 2021;62:15:22. <https://doi.org/10.1167/iov.62.15.2>



Achsenlängen des Auges

Aderhautdicken

Combined Effect of Chromatic and Optical Defocus on Ocular Biometry

IOVS | December 2021 | Vol. 62 | No. 15 | Article 22 | 5

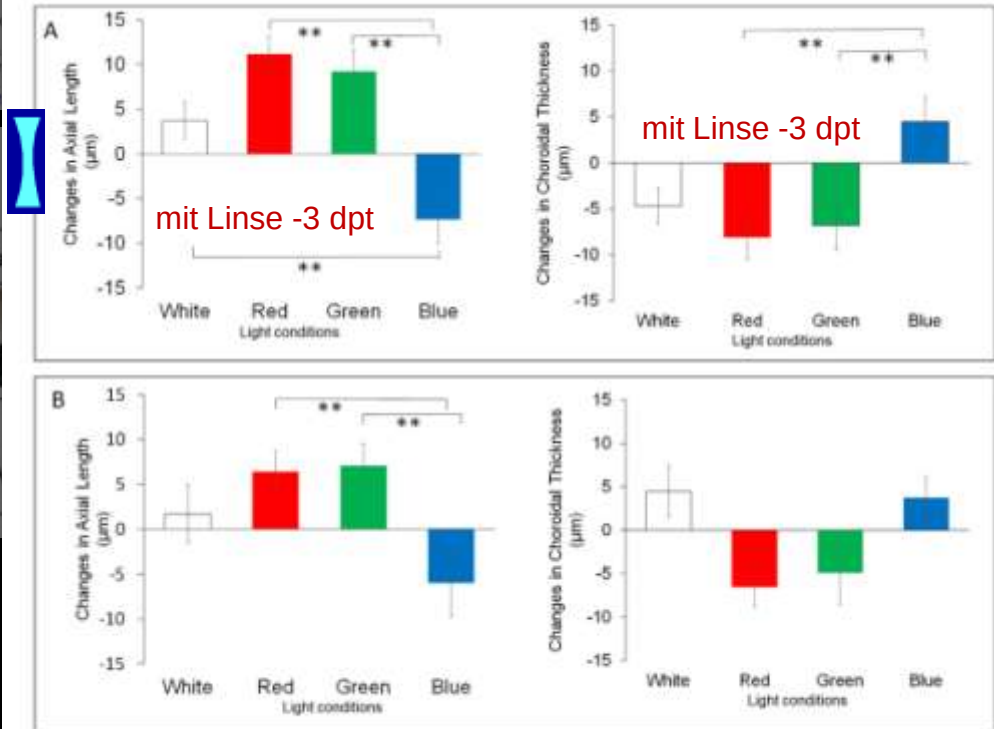


FIGURE 3. Changes in axial length and choroidal thickness in the defocused eye (top panel) and non-defocused eye (bottom panel) after 1 hour of light exposure. Error bar indicates standard error of mean (SEM). ** Indicates P value < 0.05 .

Affen werden im Rotlicht weitsichtiger und benötigen "breitbandiges" Licht zur Emmetropisierung (wohl auch der Mensch ?)
Hühner, Mäuse, und Meerschweinchen werden dagegen im Rotlicht kurzsichtiger und im Blaulicht weitsichtiger (und Hühner emmetropisieren auch im monochromatischen Licht)

Wirkung von **schmalbandigem** Licht auf die Emmetropisierung



**Emmetropisierung
bricht zusammen
– eher mehr Myopie !**

NEU
IOVS 2022, Thakur et al
blau macht kürzeres
Auge beim Mensch



Emmetropisierung bricht zusammen !



Hühner und Meerschweinchen reagieren wie von der longitudinalen chromatischen Aberration erwartet



interessanter sind Experimente mit **breitbandigem** Licht , z.B. verschiedene Lampen

Myopiehemmung bei Kindern mit Rotlicht in China ?



Preprints are preliminary reports that have not undergone peer review.
They should not be used to guide clinical practice.
Information is provided by the author(s) and is not endorsed by Research Square.

Low-intensity, Long-wavelength Red Light Slows the Progression of Myopia in Children: an Eastern China-based Cohort

Lai Zhou

Ningbo Eye Hospital

Chao Xing

the Second Affiliated Hospital of Wenzhou Medical University

Wei Qiang

Ningbo Eye Hospital

Chaoqun Huo

Ningbo Eye Hospital

Liyang Tong (✉ liyang_tong20@126.com)

Ningbo Eye Hospital

Research Article

Keywords: myopia, red light, wavelength, axial length, choroid biotization

Posted Date: June 25th, 2021

myopia progression over 9 month:

without laser therapy: from -3.09 D to -2.87 D (n = 105)

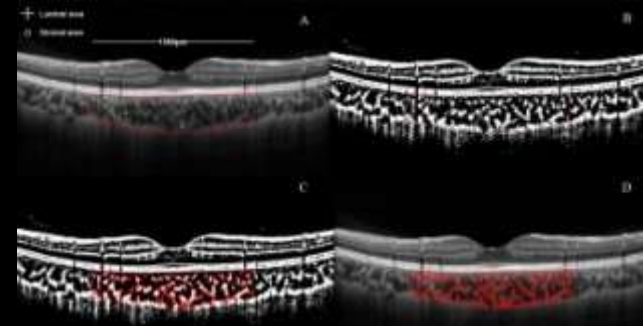
with laser therapy: from -3.04 D to -3.57 D (n = 56)



All the children wore spectacles and underwent repeated 650-nm, low-intensity, single-wavelength red light treatment twice a day for three minutes each time.

Issues:

- 0.4 mW at 635-650 nm – is almost **nothing**
- experiments in monkeys at 630 nm, 274 lux, **about x 40,000 brighter**
- no clear information about light delivery
- company not accessible (from europe?)



der wohlbekannte Faktor helles Licht

Weniger Myopie bei mehr Aufenthalt im Freien 2007



Lisa A. Jones



Don Mutti

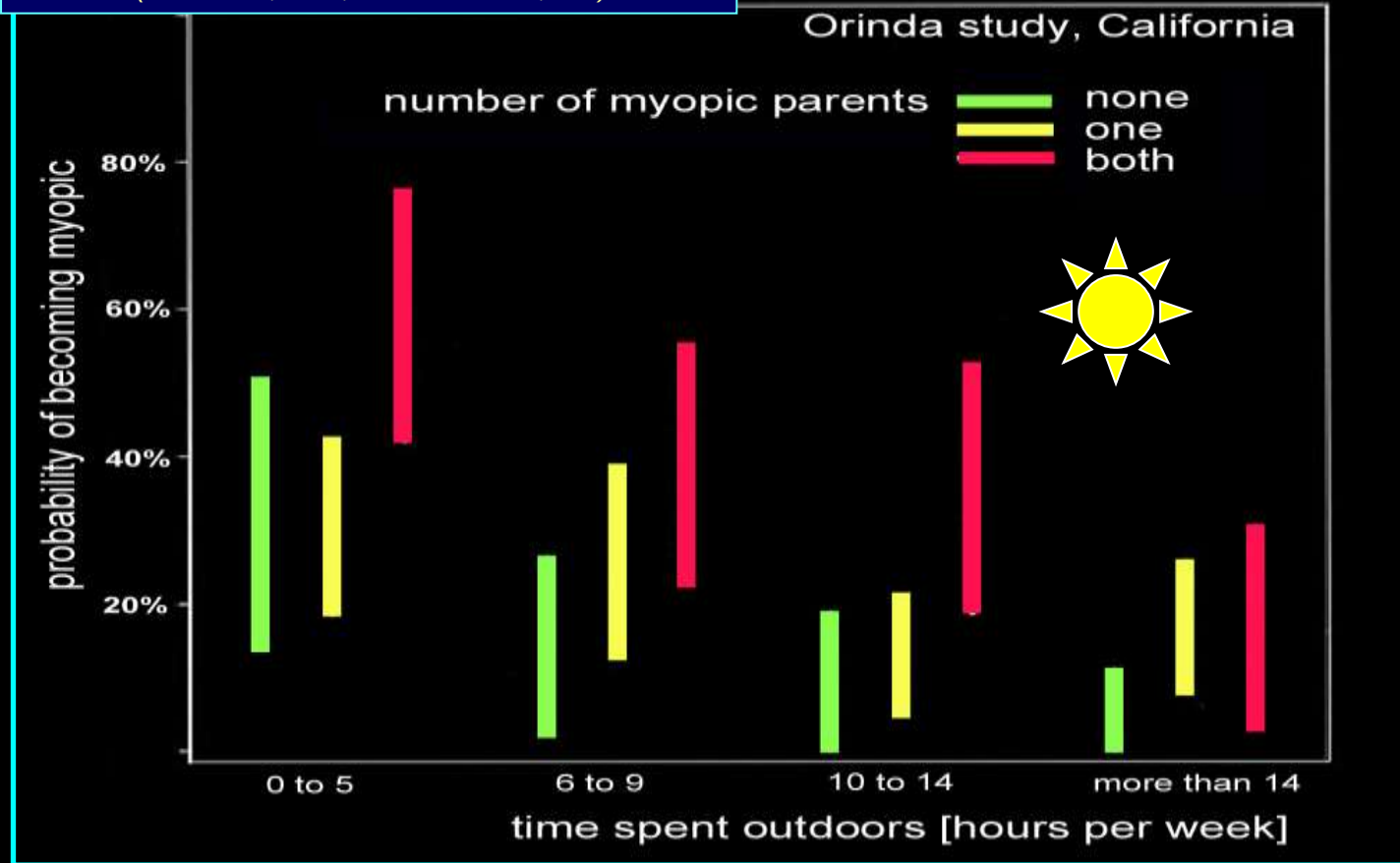


Karla Zadnik

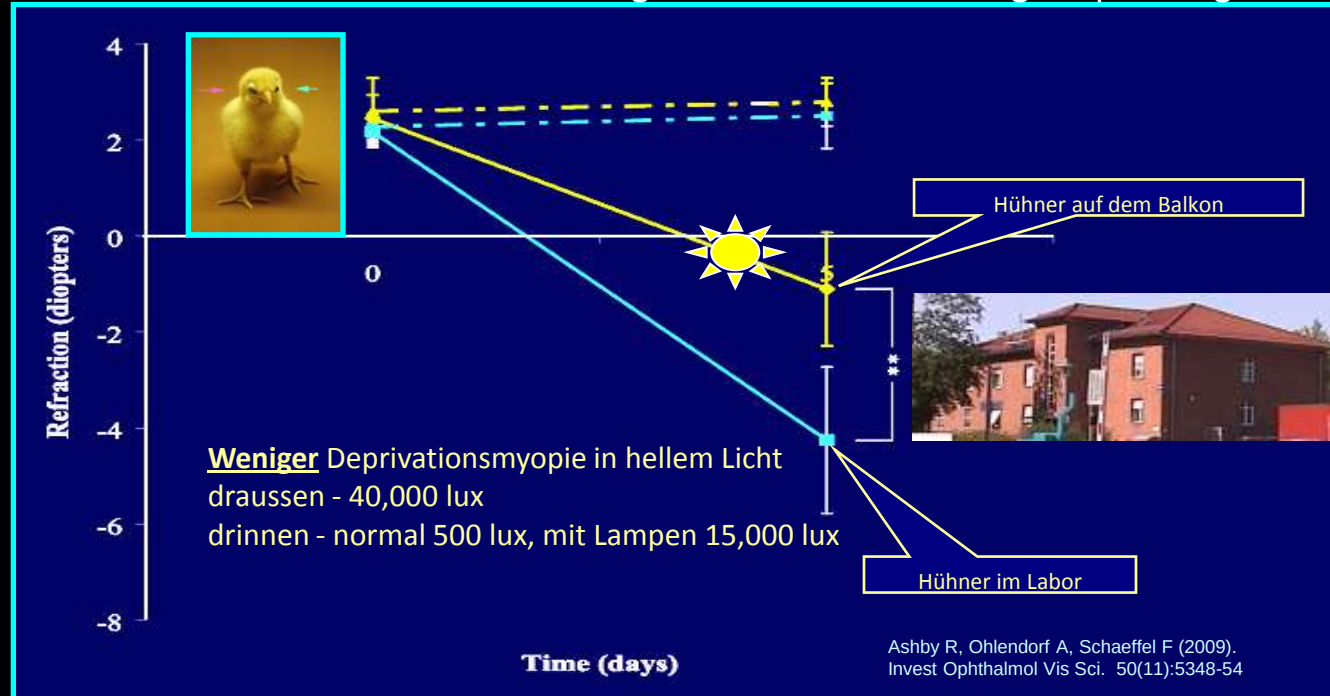
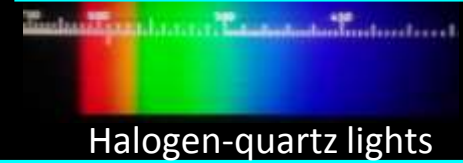
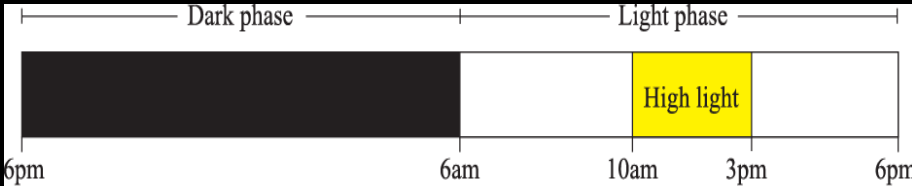


Kathy Rose and Ian Morgan

wiederentdeckt nach Hermann Cohn 1892
(Jones et al, 2007; Rose et al 2008, +++)



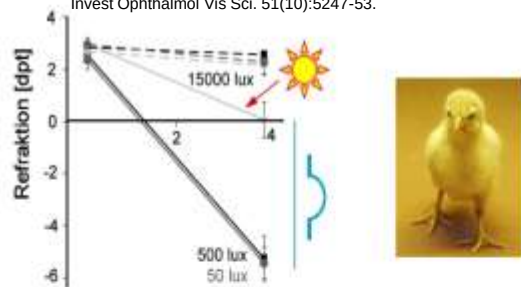
Hemmung der Deprivationsmyopie durch helles Licht bei Hühnern 2008



Wirkung von heller Beleuchtung auf die Myopieentwicklung bei Tiermodellen

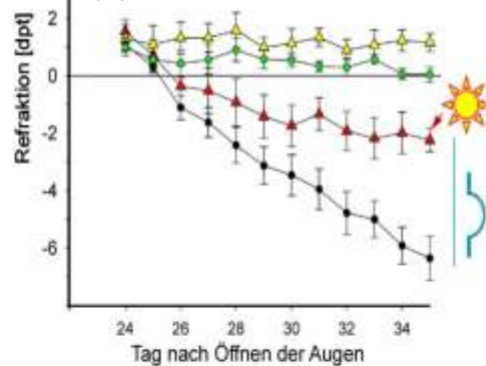
A

Ashby RS, Schaeffel F (2010).
Invest Ophthalmol Vis Sci. 51(10):5247-53.



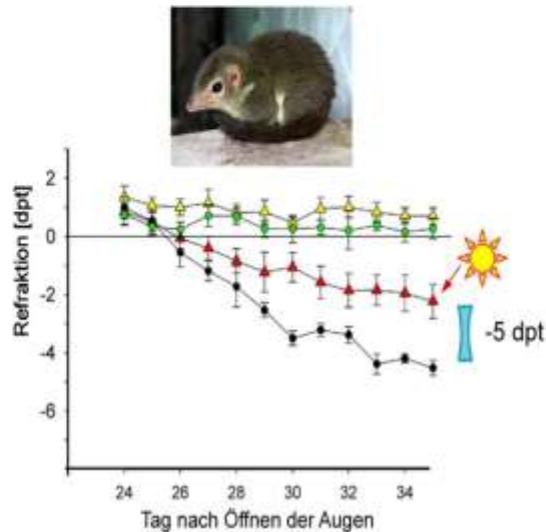
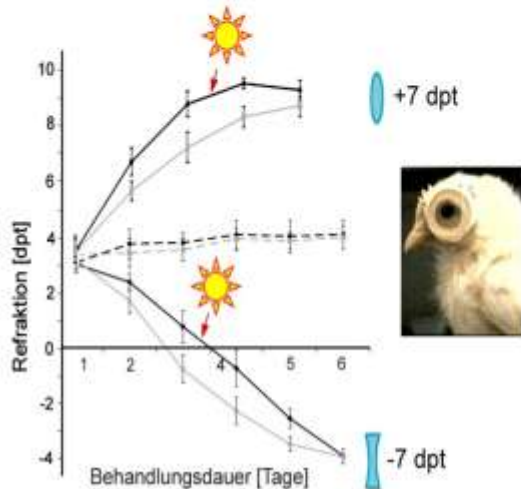
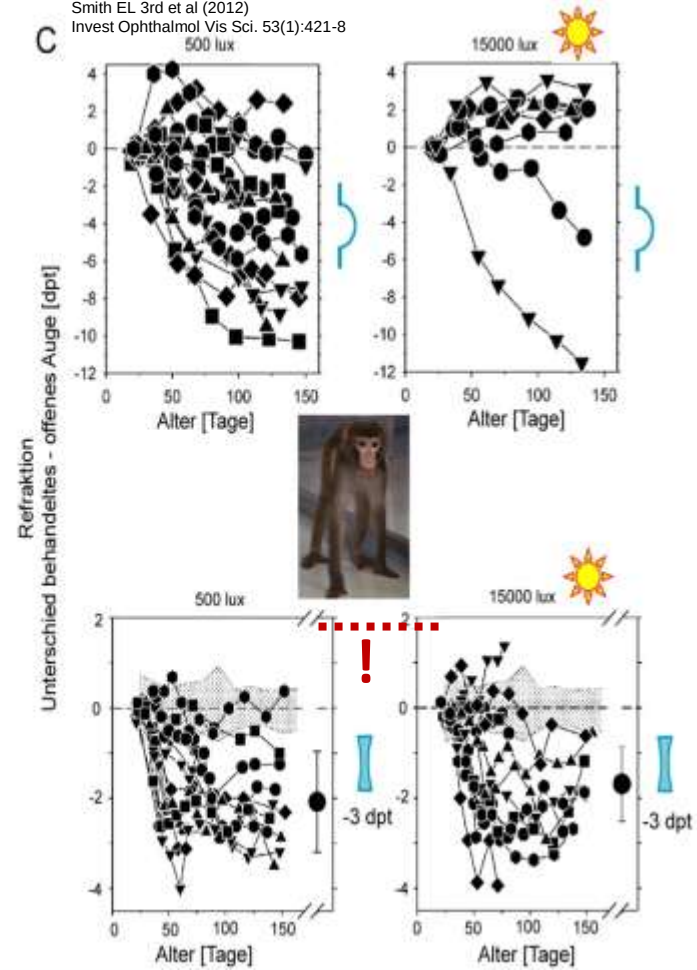
B

Norton TT, Siegart JT Jr. (2013)
Exp Eye Res. 114:48-57



C

Smith EL 3rd et al (2012)
Invest Ophthalmol Vis Sci. 53(1):421-8



Pei-Chang Wu, Taiwan

Wu PC et al (2018) Ophthalmology 125(8):1239-1250
 "Relatively lower outdoor light intensity activity with longer time outdoors, such as in hallways or under trees, also can be considered."

Strategie 2001 bis 2009

- optimierte Tischposition
- mehr Sehen in die Ferne
- Anwendung "3010 Regel"
- Augenübungen

➡ aber Myopie nahm weiter zu



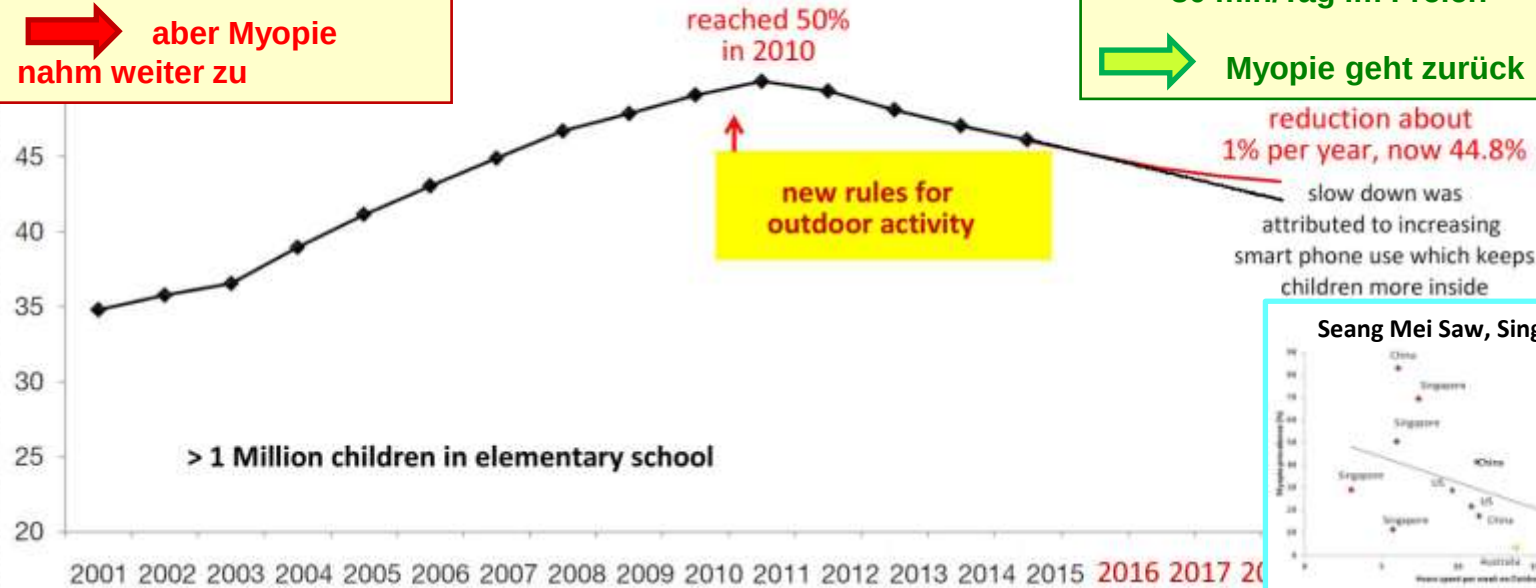
viele neue Daten bestätigen die hemmende Wirkung von hellem Licht auf die Myopieentwicklung

Strategie ab 2010

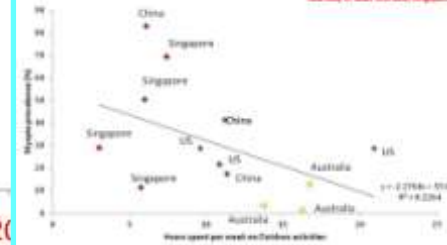
- optimierte Tischposition
- mehr Sehen in die Ferne
- Anwendung "3010 Regel"
- Augenübungen
- + 80 min/Tag im Freien

➡ Myopie geht zurück

percentage of children with distance visual acuity of < 20/25



Seang Mei Saw, Singapore



(Ramat Gan, Israel)

Yuval Cohen ^{1,2}, Rafael Irtharrem ³, Arwa Massarwa ⁴, Naphan Khama-Bakri ⁴, Hadar Ben-El ^{1,2}, Ofra Chavidi ^{1,2}

The Ilan University, Ramat Gan, Israel

Enhances Fire Circuits: Human Alert

¹ Des. Inherens Eye Consultants, Buenos Aires, Argentina⁴Department of Optometry and Vision Science, Hadassah Academic College[†]Department of Ophthalmology, Hadassah Hebrew University Medical Center

Shyria is known to be associated with genetic and environmental risk factors. The world-wide rapid synchronous rise of the prevalence of shyria, indicates a common environmental factor. This outdoor protects children from the development of shyria, (3,7) decreasing the amount of time that children spend outdoors has the ability to reduce the onset of shyria. (3,4)

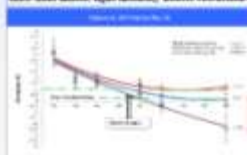
What is the proposed mechanism of the protective effect of exercise activity?

Accommodation: reflex mechanism.⁷

Page 100: control image bias?

Light intensity: nonfluorescent control^a

How does incident light intensity affect reflection in humans?



Ambient light intensity of 500 lux (indoor light levels) induces myopia in 30% of the chicks.

To measure the effect of nursery school light intensity, indoors and outdoors, on refraction and pupil size.

38 1184 Children: 4-17 yr

Attended the same recovery school (55-58) for at least 6 months.

Light intensity was measured using LiCorneux device (LiCorneux LX-101A, LiCorneux Electronics Co., Inc) inside the nursery shelter at the four corners and the centre. Outdoors in the playground in the sun / shade.

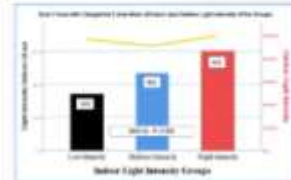
Phosphor phosphorescent
(Phosphor GmbH, Harnberg, Germany)
Non-cytotoxic reflective color
Pant D1600

Excluded:
Spherical equivalent (SE): +3.38 D
Incomplete data
Strabismic

Statistica: SPSS version 22, significance $P < 0.01$ 

```

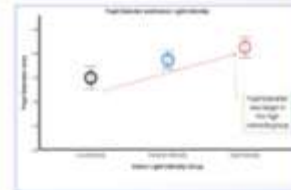
graph TD
    A[1004] --> B[Included 3072]
    A --> C[Excluded 313]
    B --> D[Hypertensive 1038 (96.9%)]
    B --> E[Hypertensive 33]
  
```



Light intensity of the groups differed indoors, yet similar outdoors. For the purposes of data analysis, children were divided into three indoor illumination groups (Low $N=304$, Medium $N=389$ and High $N=360$). Children's ages were similar between the groups (4.9 to 5.2 years).



Tachygasterus induces light intensity (center and periphery) were found to be correlated with spherical refraction ($p=0.28$, -0.005) and with the cylinder.



Pupil size and spherical refraction were correlated (yell. 1, yell. 2).

- In nursery school, the higher the indoor light intensity, the greater the refraction.
- Monitoring nursery school light intensity should be part of the child safety procedures.
- Light dependent pupil diameter is less likely to be involved in refractive development.

References 1. Jorgensen T, Jensen L. Mergers and acquisitions among cultural entities: a firm size effect on growth. *Journal of Management* 2000; 26: 1037-1054.
2. Ray G, Sankaranarayanan V. Factors driving success for providers of merger or acquisition facilitation. *Sloan Management Review* 2000; 42: 117-129.
3. Hitt RM, Hambrick DC. Executive cognition, corporate culture, and organizational performance: a review and research agenda. *Journal of Management* 2003; 29: 301-320.
4. Hitt RM, Hambrick DC. The effects of top management's cognitive maps and mental models on strategic decision making. *Strategic Management Journal* 1997; 18: 285-314.
5. Jones K. *Strategic Management: Concepts and Cases*. Boston: Addison Wesley Longman, 2001; 351-359.

The research was partially funded by Livan, a nonprofit organization.

und schliesslich: **neue Entwicklungen bei der Hemmung der Myopie durch spezielle Brillengläser**

Überblick über die neue optische Korrekturen zur Hemmung der Myopie

(A) RRG Brillengläser (radial refractive gradients)

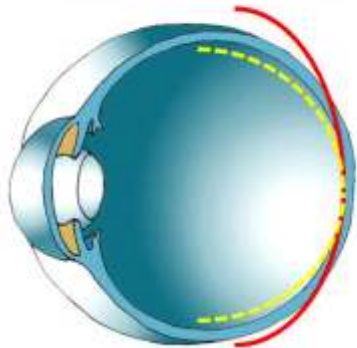


Zeiss MyoVision™

2012

Essilor Myopilux™
spectacles

2015



Σ RRG waren nicht so
erfolgreich wie erhofft
(aber > 1 Million verkauft)

(B) multifokale Kontaktlinsen

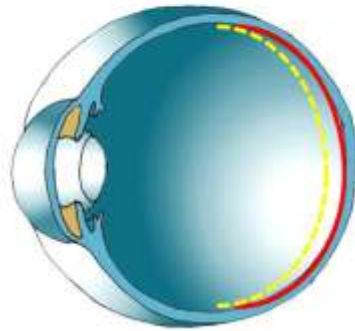


i.e.
MySight
CooperVision

2017

DISC-SH
lenses,
Hong Kong

2014



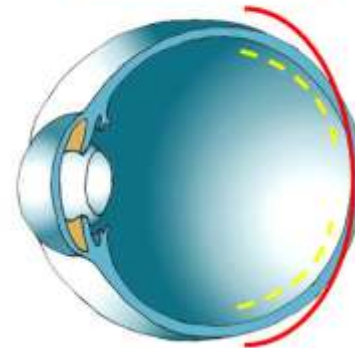
Σ multifokale Kontaktlinsen
erfolgreich
(12 months: -0.31 D/-0.12 mm)

(C) Brillenlinsen mit "Multifokalität"



Hoya MiyoSmart
lens, Hong Kong

2017



Σ Zwei- Jahresstudie
erfolgreich
(24 months: -0.44 D/-0.24 mm)

Start in Deutschland April 2021



DIMS erzeugt im Augenblick die
größte Begeisterung
Hoya plant Studien in Frankreich,
Italien und Deutschland

Essilor hat das DIMS-Verfahren auch
übernommen

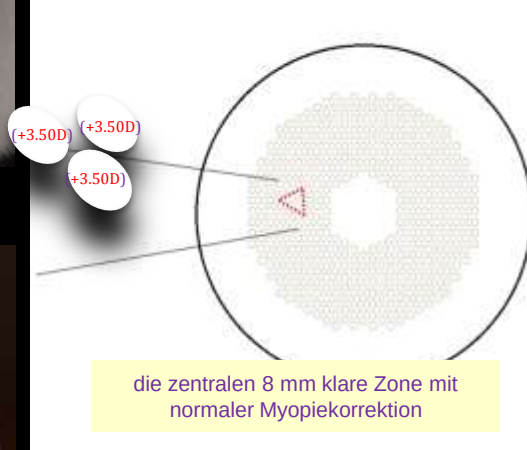
neuer Zugang: Brillenlinsen mit vielen kleinen Pluslins-Segmenten

Chi-ho To, Hong Kong

(er sah aus dem Bus, als die Idee aufkam)



"defocus incorporated multiple segment lens" (DIMS)



Lam et al, Brit J Ophthalmol 2021
PMID: 33731364 DOI: 10.1136/bjophthalmol-2020-317664

n = 65 Kinder mit MyoSmart Brillen
n = 55 Kinder mit konventionellen Brillen
Augenlängenwachstum über 3 Jahre
 0.31 ± 0.26 mm vs. 0.57 ± 0.26 mm

2017

Ziel war, ebenfalls eine zweite myope Bildebene einzubauen, aber ohne die Bildverzerrung, wie von MyoVision



Bildqualität in der "zweiten Schärfeebene" oder: Können DIMS-Linsen von Presbyopen auch zum Lesen verwendet werden?

Kamera auf 30 cm fokussiert

"presbyope" Kamera auf Unendlich fokussiert, aber Text ist auf 30 cm

"presbyope" Kamera auf Unendlich fokussiert aber Text ist auf 30 cm mit DIMS Linse

Implementing the protocol in clinical practice, but standard of care is lacking. We have developed a protocol for myopia control incorporating all scientific evidence.

Protocol: Target for myopia control are axial length and refractive error. Children are examined every 6 months. Before intervention, risk factors as outdoor exposure and myopia family history are assessed, children are fully examined, and axial length is plotted on the growth curve (Tideman et al. Acta Ophthalmol 2018) to identify expected growth and risk of high myopia. First, lifestyle recommendations including 2 hours daily outdoor exposure are provided. Children who present with axial length of the 75th percentile or more on the growth chart receive an initial treatment of atropine eye drops 0.5% and they receive multifocal photochromatic glasses to compensate for side effects. Children below the 75th percentile are started on low dose atropine, ortho-K, or multifocal lenses in accordance with the wishes and feasibility of the patient and parents. When no decline of progression (with shift to lower percentile on the growth chart) is observed under the initial treatment, treatment is altered to a higher dose of atropine, or a combination of optical and pharmaceutical interventions.

Treatment success: Applying this protocol to 300 children in the clinic, we achieved 70% reduction of myopia progression; 72% managed to

Study number = 3123
page defect = 1.10
city defect = 0.95

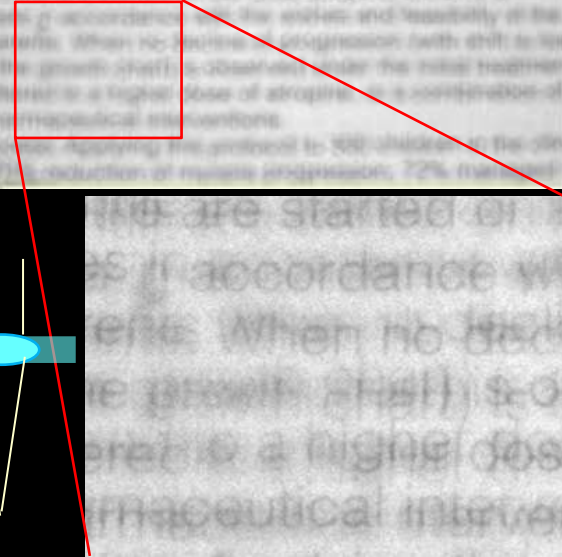
Protocol: Target for myopia control are axial length and refractive error. Children are examined every 6 months. Before intervention, risk factors as outdoor exposure and myopia family history are assessed, children are fully examined, and axial length is plotted on the growth curve (Tideman et al. Acta Ophthalmol 2018) to identify expected growth and risk of high myopia. First, lifestyle recommendations including 2 hours daily outdoor exposure are provided. Children who present with axial length of the 75th percentile or more on the growth chart receive an initial treatment of atropine eye drops 0.5% and they receive multifocal photochromatic glasses to compensate for side effects. Children below the 75th percentile are started on low dose atropine, ortho-K, or multifocal lenses in accordance with the wishes and feasibility of the patient and parents. When no decline of progression (with shift to lower percentile on the growth chart) is observed under the initial treatment, treatment is altered to a higher dose of atropine, or a combination of optical and pharmaceutical interventions.

Treatment success: Applying this protocol to 300 children in the clinic, we achieved 70% reduction of myopia progression; 72% managed to

Study number = 10174
page defect = 1.10
city defect = 0.95

Protocol: Target for myopia control are axial length and refractive error. Children are examined every 6 months. Before intervention, risk factors as outdoor exposure and myopia family history are assessed, children are fully examined, and axial length is plotted on the growth curve (Tideman et al. Acta Ophthalmol 2018) to identify expected growth and risk of high myopia. First, lifestyle recommendations including 2 hours daily outdoor exposure are provided. Children who present with axial length of the 75th percentile or more on the growth chart receive an initial treatment of atropine eye drops 0.5% and they receive multifocal photochromatic glasses to compensate for side effects. Children below the 75th percentile are started on low dose atropine, ortho-K, or multifocal lenses in accordance with the wishes and feasibility of the patient and parents. When no decline of progression (with shift to lower percentile on the growth chart) is observed under the initial treatment, treatment is altered to a higher dose of atropine, or a combination of optical and pharmaceutical interventions.

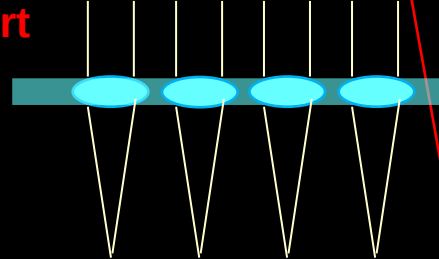
Treatment success: Applying this protocol to 300 children in the clinic, we achieved 70% reduction of myopia progression; 72% managed to



Brennweite ähnlich menschl. Auge

16 mm focal length
f/# 5.6

Aber es ist bemerkenswert
dass die Retina ein
"zerhacktes Bild" als zweite
Schärfeebene akzeptiert
- Die Retina braucht kein
"kontinuierliches Bild"





OPEN ACCESS

Myopia control effect of defocus incorporated multiple segments (DIMS) spectacle lens in Chinese children: results of a 3-year follow-up study

Carly SY Lam^{1,2}, Wing Chun Tang,¹ Paul H Lee,³ Han Yu Zhang,¹ Hua Qi,⁴ Keigo Hasegawa,⁴ Chi Ho To^{1,2}

Conclusions Myopia control effect was sustained in the third year in children who had used the DIMS spectacles in the previous 2 years and was also shown in the children switching from SV to DIMS lenses.

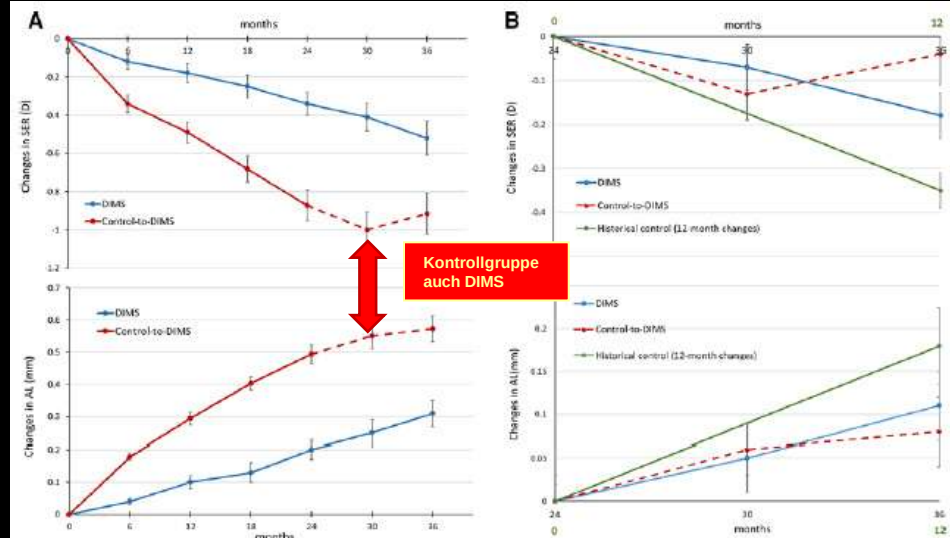


Figure 2 (A) Changes in spherical equivalent refraction (SER) and axial length (AL) from baseline to 36 months. The red dotted line represents the period (24–36 months) during which the previous single vision control group wore defocus incorporated multiple segments (DIMS) lenses. (B) The third-year changes in SER and AL in the DIMS and Control-to-DIMS groups. The green line shows the 12-month changes in SER and AL in the historical control group.

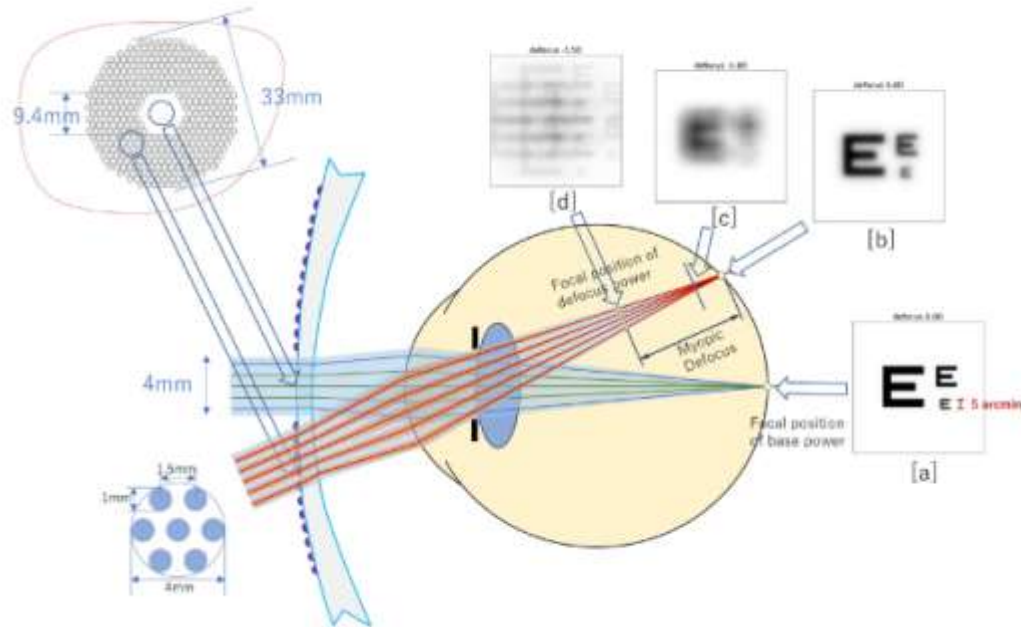
Article

Effect of Defocus Incorporated Multiple Segments Spectacle Lens Wear on Visual Function in Myopic Chinese Children

Carly Siu Yin Lam¹, Wing Chun Tang¹, Hua Qi², Hema Radhakrishnan³, Keigo Hasegawa², Chi Ho To¹, and W. Neil Charman³

Effects of DIMS Lens Wear on Visual Function

TVST | August 2020 | Vol. 9 | No. 9 | Article 11 | 3



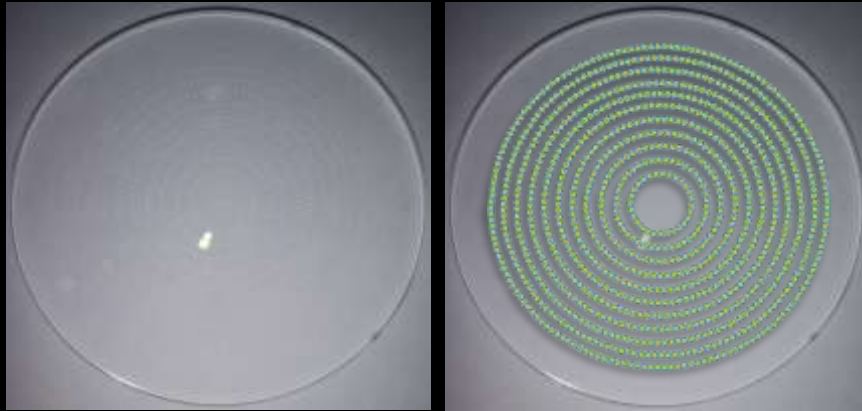
Conclusions

There were no significant differences between the visual function of the DIMS and SV groups over 2 years. Although some changes in visual function, such as distance VA and accommodation, were observed in myopic children after 2 years of DIMS lens wear, similar changes occurred in those who wore regular SV spectacles. Children in both lens groups showed better distance HCVA, but decreased AA and accommodative lag after 2 years. In conclusion, DIMS lens wear had no adverse effect on the measured visual function. Further studies are needed to determine any effects occurring over longer periods of time.

Essilor Dec 2019: "A game-changing innovation to control myopia progression"



Stellest™ lens
H.A.L.T.™ technology



"Breakthrough in spectacle lens design for myopia control"
近视控制镜片的设计突破

- a one year study in Chinese children shows **60% myopia inhibition**
- is currently marketed in China (for selected customers)

Novel DOT Lenses from SightGlass Vision Show Great Promise to Fight Myopia



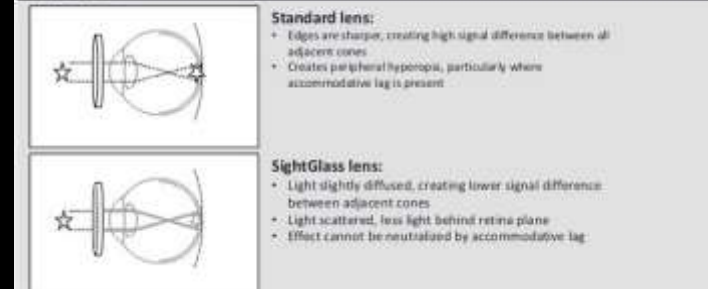
April 21, 2020

By Joe Rappon, OD, MS,
Jay Neitz, PhD
Maureen Neitz, PhD

... und noch eine neue Strategie



SightGlass lenses provide peripheral blur and reduce peripheral hyperopia



- (US/Canada multicenter 12 month study: "between **59 and 72% myopia inhibition**"

Novel DOT Lenses from SightGlass Vision Show Great Promise to Fight Myopia

Facebook Twitter LinkedIn Email Print

April 21, 2020

By Joe Rappin, OD, MS, FAOD

Jay Neitz, PhD

Maureen Neitz, PhD

Spectacles have been the primary modality for myopia correction since their invention in the 13th century, and they remain the more commonly used today than contact lenses, especially in children. Spectacles that are proven effective for reducing myopia progression in a well-designed clinical trial would be a preferred modality for myopia management as they would require little change from patients, their parents, and prescribing OPs. This is also true because, as a class, spectacles have a better safety profile than either contact lenses or pharmaceuticals.

Safety results from the 12-month planned interim analysis showed that for each group, all measures of visual acuity remained clinically stable through Month 12, and no serious adverse events were reported. In terms of efficacy, both test arms demonstrated superiority for cycloplegic SER change from baseline, with a reduction in myopia progression of 59 percent and 74 percent at 12-months ($P < 0.0001$ for both test arms). For the same period, both test arms also demonstrated superiority in terms of axial length change from baseline, with a reduction in axial

Ophthalmic lenses for treating myopia

Abstract

Eyeglasses are disclosed that include eyeglass frames and a pair of ophthalmic lenses mounted in the frames. The lenses include a dot pattern distributed across each lens, the dot pattern including an array of dots spaced apart by a distance of 1 mm or less, each dot having a maximum dimension of 0.3 mm or less, the dot pattern including a clear aperture free of dots having a maximum dimension of more than 1 mm, the clear aperture being aligned with a viewing axis of a wearer of the pair of eyeglasses.

Classifications

G02C7/022 Ophthalmic lenses having special refractive features achieved by special materials or material structures

[View 10 more classifications](#)

To demonstrate the safety and efficacy of SightGlass Vision's DOT lenses, we designed a robust multicenter, subject- and observer-masked, randomized, controlled pivotal clinical study, CYPRESS (NCT03623074). This study enrolled, randomized, and dispensed lenses to 256 eligible children across 14 clinical trial sites in the U.S. and Canada. At the time of enrollment, subjects were six to 10 years old having myopia between -0.75D and -4.50D (SER) and were randomized into one of two test lens designs or a control lens in a 1:1:1 ratio. Children are being followed for 36 months, with interim analyses planned at 12 and 24 months. Myopia progression is being assessed through cycloplegic (open-field) autorefractometry, and axial length is being measured using Haag-Streit Lenstar biometers. DNA was also collected to characterize cone photopigment genes as part of a program to identify myopia risk predictors.

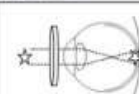
The subjects are racially diverse and had an average integer age of 6.1 years ($SD \pm 1.2$ years) at screening, making this one of the youngest cohorts ever studied in a myopia management trial. The average cycloplegic SER was -1.94D ($SD \pm 1.0D$), and the average axial length was 24.02 mm ($SD \pm$



Child Wearing SightGlass Vision DOT Lenses

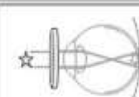


SightGlass lenses provide peripheral blur and reduce peripheral hyperopia



Standard lens:

- Edges are sharper, creating high signal difference between adjacent cones
- Creates peripheral hyperopia, particularly where accommodative lag is present



SightGlass lens:

- Light slightly diffused, creating lower signal difference between adjacent cones
- Light scattered, less light behind retina plane
- Effect cannot be neutralized by accommodative lag

WO2018026697A1

WIPO (PCT)

Download PDF Find Prior Art Similar

Other languages: French

Inventor: Jay Neitz, James KUICHENBECKER, Maureen Neitz

Worldwide applications

2017 - JP WO KR SG MY TW CA EP AU SG CN 2018 - US
2019 - PH 2020 - US

Application PCT/US2017/044635 events

(alles funktioniert im niederen Ortsfrequenzbereich (< 10 Zykl/Grad) und ohne Akkommodation, beide Mechanismen sind parallel aktiv)



funktioniert nicht im myopen Auge

- Tiefpass ohne PLUS-DEFOKUS
- langsame Antwort, lange Exposition nötig
- Atropin, Pirenzepin, Dopamin, NO, helles Licht hemmen

unterschiedliche genetische Netzwerke mit wenig Überlappung

- ON Stimulierung hemmt mit kurzen Lichtpulsen, > 5 Hz

- Tiefpass mit PLUS-DEFOKUS
- schnelle Antwort, kurze Exposition ausreichend
- Nicht Atropin, Pirenzepin, Dopamin, NO, helles Licht
- Flicker mit OFF Stimulierung hemmt

- dauerndes Wachstum, wenig Energieverbrauch, Aderhaut dünn

● bi-directionale Signale ZENK/Egr1, RA, BMP2, ...
↓
Sauerstoff

- Hemmung hat hohen Energieverbrauch, Aderhaut dick, ↑ Sauerstoff

sklerale Fibroblasten

Schlussfolgerungen

Es bleiben noch Fragen zu den biologischen Mechanismen der Myopie.

Wir können nicht erklären, warum sich Myopie nicht selbst hemmt, und warum Myopie durch verschiedene Interventionen zwar verlangsamt, aber nicht ganz gestoppt werden kann.

Etwas hat sich in der myopen Retina verändert ... es wird spannend, herauszufinden, was es ist.