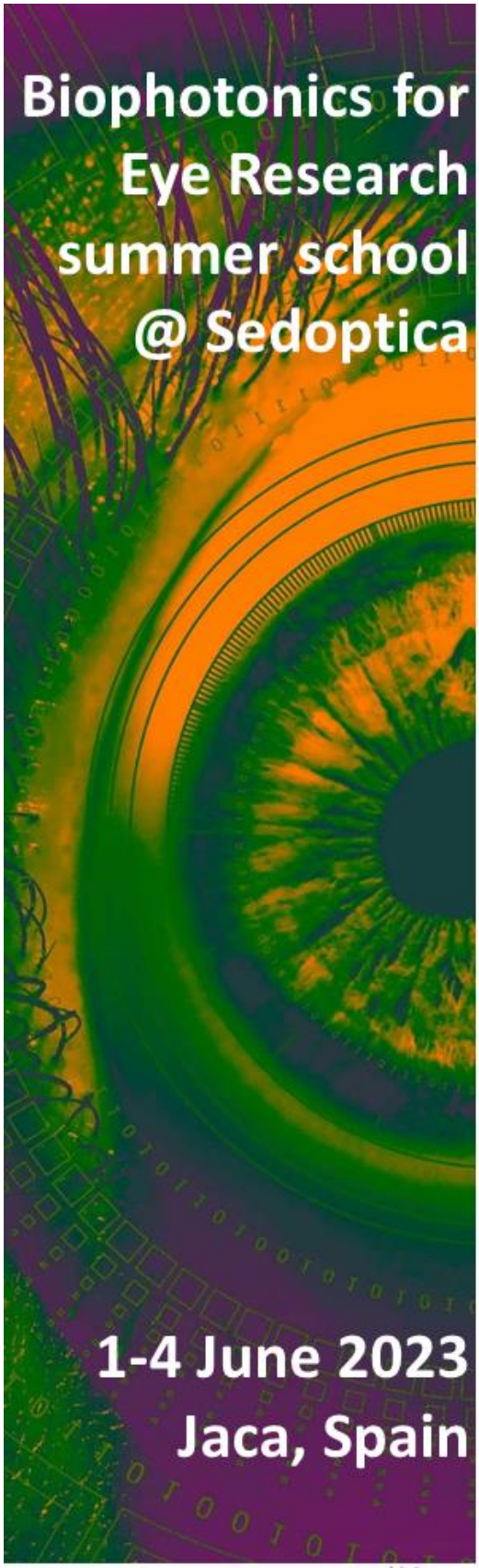

Biophotonics for Eye Research
BER2023
JACA 1-4 JUNE

The Biophotonics for Eye Research summer school @Sedoptica is a scientific meeting dealing with aspects of the Physics and Engineering of the human eye.

This meeting aims to follow on from the summer schools organized previously by the Visual Sciences committee @SEDOPTICA. In this meeting, we shall focus on new results and techniques in imaging technology and optics of vision.

The format of the meeting is a series of classes, invited lectures with ample time for discussion and interaction, and scientific contributions presentations. The interaction of basic science and cutting edge technology to develop future solutions for better vision will be at the center of the workshop.

Young researchers and doctoral students will present their research in dedicated sessions.

The meeting will be hosted in University of Zaragoza residence in Jaca, the Aragonese Pyrenees (1-4 June 2023).

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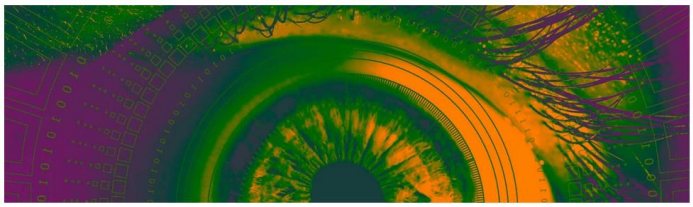

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María Viñas	Institute of Optics-CSIC (Spain)
Francisco Ávila	University of Zaragoza (Spain)
Mikel Aldaba	Technical University of Catalonia-UPC (Spain)
Justo Arines	University of Santiago de Compostela-USC (Spain)
José Juan Castro	University of Granada (Spain)
Carmen Martínez	University of Valladolid (Spain)
María S. Millán	Technical University of Catalonia-UPC (Spain)
E. Josua Fernández	University of Murcia (Spain)
Juanma Bueno	University of Murcia (Spain)
Pablo Artal	University of Murcia & VOPTICA (Spain)
Susana Marcos	University of Rochester (USA)
Carlos Dorronsoro	Institute of Optics-CSIC & 2EyesVision (Spain)
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Carmen Canovas	Johnson & Johnson Surgical Vision (The Netherlands)
Andrea Curatolo	Int. Centre for Translational Eye Research-ICTER (Poland)
Sabine Kling	ETH Zurich & University of Bern (Switzerland)
Linda Lundström	KTH Royal Institute of Technology (Sweden)

LOCAL COMMITTEE

Francisco Ávila	University of Zaragoza (Spain)
Laura Remón	University of Zaragoza (Spain)
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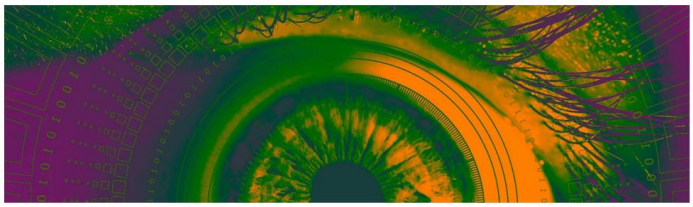
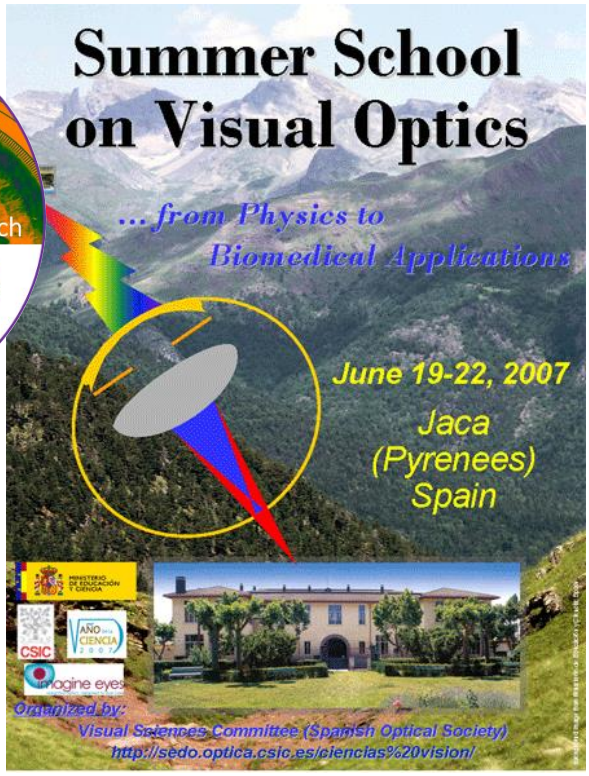
BER2023

Biophotonics for Eye Research summer school @Sedoptica





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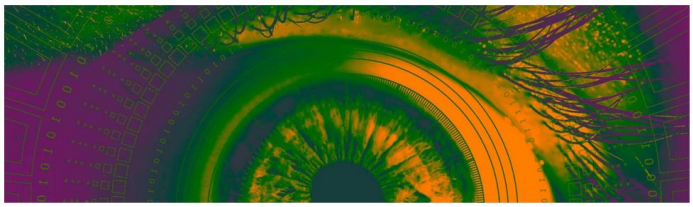
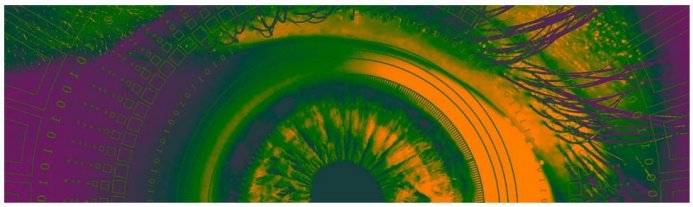


BER2023 will gather students, researchers, and renowned scholars in an international forum on Biophotonics for eye research, with a series of classes, invited lectures with ample time for discussion and interaction, and scientific contributions presentations. The interaction of basic science and cutting-edge technology to develop future solutions for better vision will be at the center of the workshop.

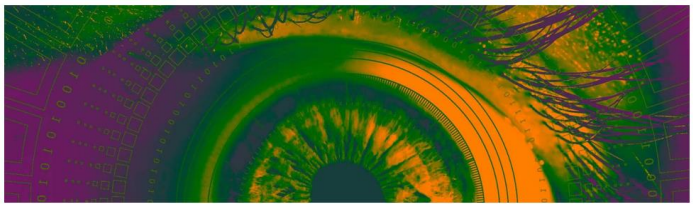
TECHNICAL PROGRAM

	1 June-Thursday	*2 June-Friday*	*3 June-Saturday*	*4 June-Sunday*
Morning		***SESSION I*** Optics and vision	***SESSION IV*** New horizons in refractive, cataract and eye surgery	***YOUNG RESEARCHERS SESSION***
		SESSION II Structure and Biomechanics of the eye	***SESSION V*** Diagnostics tools & Visual Function	***AWARDS CEREMONY & CLOSING REMARKS***
Afternoon	***MINI COURSE*** Early career skills for a career in Optics & Photonics	***SESSION III*** Novel technologies for unsolved problems in Visual Optics	***SOCIAL EVENT*** Pyrenee mountains	
Evening	***KEYNOTE TALK*** Biophotonics for eye research ***WELCOME RECEPTION BER2023***	***SOCIAL EVENT*** Dinner with the experts		

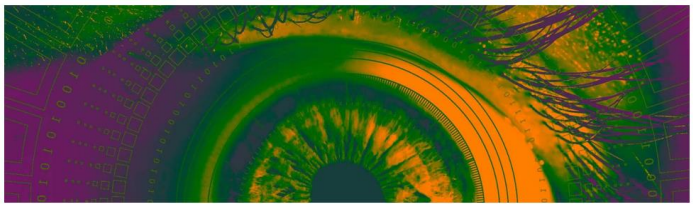
1 JUNE		**THURSDAY**		
	3:00-6:00 pm	**MINI COURSE.** ***Early career skills for a career in Optics & Photonics***		
	3:00-4:15	**Workshop**. Career development. Soft skills and Networking **Hands-on**. Grants & fellowships preparation		
	4:15-4:45	**Break**		
	4:45-5:15	**Session**. Career development opportunities: OPTICA & SPIE		
	5:15-6:00	**Round table**. Academia vs Research vs. Industry. Everything Everywhere All at Once.	Pablo Artal Carlos Dorronsoro Valentín Guadaño Yaiza García Moderator: Mikel Aldaba	| UMU & VOPTICA | CSIC & 2EyesVision | Lasing | Bausch & Lomb
	7:00-8:00 pm	**KEYNOTE TALK**		
		Prof. Pablo Artal University of Murcia (Spain)	*Biophotonics for eye research*	
	8:00-10:00 pm	**WELCOME RECEPTION**		



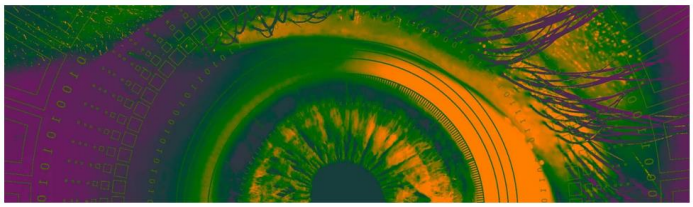
2 JUNE		**FRIDAY**	
	9:00-11:00 am	**SESSION I. Optics and vision**	
	9:00-9:20	**Prof. Susana Marcos** Univ. Rochester (USA)	*Aberrations, modified optics and neural adaptation*
	9:20-9:40	**Prof. Linda Lundstron** KTH Royal Institute of Technology (Sweden)	*Focus on the periphery: Optical and neural factors*
	9:40-10:00	**Prof. E. Josua Fernández** Univ. Murcia (Spain)	*Chromatic aberration in the human eye and its impact in vision and imaging*
	10:00-10:20	**Prof. Brian Vohnsen** Univ. College Dublin (Ireland)	*What is the Stiles-Crawford effect?*
	10:20-10:40	**Prof. Justo Arines** Univ. Santiago de Compostela (Spain)	*Hartmann-Shack: from the base to the application*
	10:40-11:00	**Discussion**	*Moderator: Mikel Aldaba*
	11:00-11:30	**Break**	
	11:30-1:30	**SESSION II. Structure and Biomechanics of the eye**	
	11:30-11:50	**Sabine Kling** Swiss Federal Inst. Tec.-ETH (Switzerland)	*Ocular Biomechanics*
	11:50-12:10	**Judith Birkenfeld** Institute of Optics-CSIC (Spain)	*Optical Coherence Tomography for the investigation of ocular biomechanics: An overview of different excitation methods and their applications*
	12:10-12:30	**Prof. Juan Manuel Bueno** University of Murcia (Spain)	*In Vivo Multiphoton Imaging of Ocular Structures*
	12:30-12:50	**Prof. Carmen Martínez** University of Valladolid (Spain)	*Corneal regeneration: Biological and optical studies*
	12:50-1:15	**Discussion**	*Moderator: Francisco Ávila*
	1:30-2:30	**Lunch**	
	2:30-4:30 pm	**SESSION III. Novel technologies for unsolved problems in Visual Optics**	
	2:30-2:50	**Pablo Pérez-Merino** University of Ghent (Belgium)	*New intraocular lens technologies: Ray Tracing optimization & Bio-interfaced pressure sensors*
	2:50-3:10	**Zhijian Zhao** University of Tübingen (Germany)	*Developing multiphoton imaging of the living retina to understand the visual cycle*
	3:10-3:30	**Andrea Curatolo** International Centre for Translational Eye Research (Poland)	*Structural and functional imaging of the retina with Spatio-Temporal Optical Coherence Tomography*
	3:30-3:50	**María Viñas-Peña** Institute of Optics-CSIC (Spain)	*Investigating the ocular optics, biomechanics and structure using light-based technologies*
	3:50-4:10	**James Germann** Institute of Optics-CSIC (Spain)	*Multi-Photon Microscopy: How the microscale affects the macro-world*
		Discussion	*Moderator: Alejandra Consejo*
	8:00-10:00 pm	**SOCIAL EVENT. Dinner with the experts**	



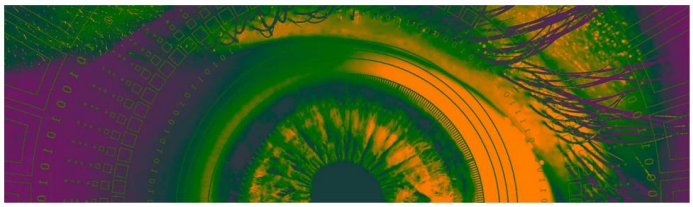
3 JUNE		**SATURDAY**	
	8:00-9:00 am	**BREAKFAST REDES TEMÁTICAS** **Hybrid event by invitation**	
	9-11 am	**SESSION IV. New horizons in refractive, cataract and eye surgery**	
	9:00-9:20	**Prof. Maria S. Millán** Technical University of Catalonia-UPC (Spain)	*Presbyopia-correcting intraocular lens with diffractive profile. Chromatic considerations*
	9:20-9:40	**Carlos Dorronsoro** Institute of Optics-CSIC & 2EyesVision (Spain)	Simulation and validation of multifocal lenses with SimVis technology
	9:40-10:00	**Prof. JM Meijomé** University of Minho (Portugal)	*Multifocal Contact Lenses for Myopia Control*
	10:00-10:30	**Discussion**	*Moderator: Laura Remón*
	10:30-11:00	**Break**	
	11:00-1:30 pm	**SESSION V. Diagnostics tools & Visual Function**	
	11:00-11:20	**Prof. Alejandra Consejo** University of Zaragoza (Spain)	*Diagnostic Tools for Keratoconus*
	11:20-11:40	**Prof. Mikel Aldaba** Technical University of Catalonia-UPC (Spain)	*New technologies in visual refraction*
	11:40-12:00	**Prof. Meritxell Vilaseca** Technical University of Catalonia-UPC (Spain)	*Clinical applications of a visible and near-infrared multispectral camera for reflectance evaluation of eye fundus structures*
	12:00-12:20	**Prof. Miriam Casares** University of Granada (Spain)	*Alcohol, driving, and visual performance*
	12:20-1:00	**Discussion**	*Moderator: Oscar del Barco*
	1:00-2:00	**Lunch**	
	5:30-7:30 pm	**SOCIAL EVENT. Trekking on the Pyrenee mountains**	
	8:00-10:00 pm	**CONFERENCE DINNER**	



	SUNDAY		
9-12 am	**YOUNG RESEARCHERS SESSION: PAPERS & POSTERS**		
9-10:30 am	**Paper session**		
	T1	**Aina Turull-Mallofré**	*Prediction of the spherical subjective refraction using accommodation data in machine learning models*
	T2	**Rosa Vila-Andrés**	*In-line characterization of toric contact lens permanent marks using a lensless microscope*
	T3	**Eduardo Esteban-Ibañez**	*Clinical validation of daily soft multifocal contact lens simulations using SimVis Gekko based on in-vitro measurements*
	T4	**André Amorim**	*Age and gender contribution to refraction and keratometry based axial length estimates derived using a support vector regression algorithm*
	T5	**Alba M. Paniagua-Díaz**	*Straylight and Optical Memory Effect characterization of ex-vivo cataractous crystalline lenses*
	T6	**Alejandro Martínez Jiménez**	*Dual Ultrahigh Speed Swept-Source & Time Domain Optical Coherence Tomography system using a time-stretch laser and a KTN deflector*
		Discussion	*Moderator: María Viñas-Peña*
10:30-12 am	**Poster session + coffee break**		
4 JUNE	**P1**	**Ebrahim Safarian Baloujeh**	*Effect of small angle misalignments on ocular wavefront Zernike coefficients*
	P2	**Francesco Martino**	*Do interocular differences affect binocular visual performance after inducing forward scattering?*
	P3	**Joan Goset**	*Eye movements inPost-COVID-19 condition patients*
	P4	**PaulaGarcía**	*Colorimetric screen characterization based on a non-primary constancy colour model*
	P5	**Diana Gargallo**	*Using a clinical OCT to characterize the edge shape of Contact Lenses (CL)*
	P6	**Pilar Casado**	*Exploring the relationship between axial length and disability glare vision*
	P7	**Lourdes Camblor**	*Caracterización del color percibido en visión con luz infrarroja pulsada*
	P8	**Danielle Viviana Ochoa**	*Effects of optical irradiation with laser and LED light sources on cell cultures of leukemia*
	P9	**João M.M Linhares**	*A Color Vision Test – comparing results between computer screens*
	P10	**José A.R. Monteiro**	*A Color Vision Test Assessed by Neural Networks*
	P11	**Laura Clavé**	*Colour vision change after multifocal diffractive IOL implantation*
	P12	**Victor Rodriguez-Lopez**	*Direct Subjective Refraction: a new approach for refractive error measurements and the impact of accommodation*
	P13	**Sara F.Lima**	*Impact of refractive error compensation methods on a webcam eyetracking system*
	P14	**Alba Herrero-Gracia**	*Comparison of the Farnsworth Munsell 100 Hue and MUC tests in the over 50s*
	P15	**Anabel Martínez-Espert**	*Assessment of the optical performance of presbyopic intraocular lenses by measuring of the Through the Focus Point Spread Function*
	P16	Withdrawn	



P17	**IñakiBlanco-Martínez**	*Contribution of the anterior corneal topography to off-axis wavefront aberration: a pilot study*
P18	**Inas Baoud Ould Haddi**	*Effect of aberrometry in intraocular lenses on visual quality*
P19	**Raquel Salvador-Roger**	*Calibration of a tunable Lens for optometric applications*
P20	**Sara Ferrer-Altabás**	*Low-cost manually tunable lens for astigmatic compensation in optical instruments*
P21	**Fátima Cuéllar**	*Optical imaging quality and expected range of vision of two presbyopia-correcting intraocular lens designs*
P22	**Marina Bou**	*Development of a portable and low-cost multispectral fundus camera*
P23	**María Mechó-García**	*Repeatability in wavefront measurement at different pupil sizes in Young subjects*
P24	**Santiago Sager**	*A compact binocular adaptive optics visual simulator for clinical use in highly aberrated patients*
P25	**Sara Silva-Leite**	*Visual Function of Myopic Young Adult swith a Novel Ophthalmic Lens for the Control of Myopia Progression*
P26	**Jessica Gomes**	*Dynamic accommodation from wavefront aberrometry in symptomatic and asymptomatic subjects*
P27	**XinyuWang**	*Adaptive Optics vision simulator for 2-photon visión*
P28	**ErikM.Barrios**	*Restoration of retinal images using dictionary learning-based methodology*
P29	**María Pilar Urizar**	*Towards a low-cost optical biometer: development of a low-cost optical delay line for axial scans and a whole-eye beam scanner for fixation checks*
P30	**Elena Moreno**	*Wavefront shaping and optical memory effect of ex-vivo cataractous crystalline lenses*
P31	**Pilar Granados-Delgado**	*Eye dominance and visual quality*
P32	**Amal Zaytouny**	*Clinical validations of the SimVis binocular visual simulator*
	Moderators: María Viñas-Peña, Francisco Ávila, Mikel Aldaba	
12 -12:15 pm	**CLOSING REMARKS. AWARDS CEREMONY**	



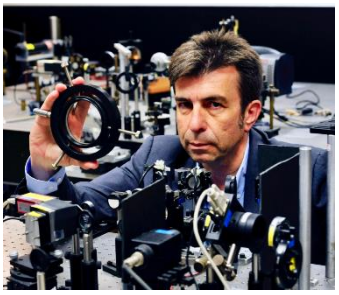
KEYNOTE TALK

Biophotonics for eye research

Pablo Artal Soriano

LOUM. University of Murcia (Spain)

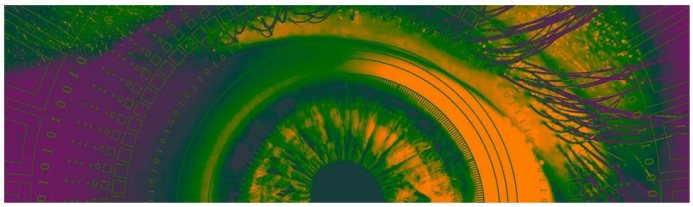
This presentation will cover in a tutorial-style several of the recent topics of research in visual optics carried out in my laboratory. This will include, wearable adaptive optics for the eye, the importance of the eye's peripheral vision and vision under pulsed infrared light.



Pablo Artal *was born in Zaragoza (Spain) where I studied Physics at the University of Zaragoza. He was a pre-doctoral fellow at the Madrid-CSIC "Instituto de Optica" under the supervision of Javier Santamaria, a post-doctoral research fellow, first at Cambridge University (UK) and later at the Institut d'Optique in Orsay, France. After returning to Spain, he obtained a permanent researcher position at the Instituto de Optica. In 1994, he became the first full Professor of Optics at the University of Murcia, Spain founding the "Laboratorio de Optica". He spent sabbatical years in Rochester (USA) and Sydney (Australia). He is currently a distinguished visiting professor at the Central South University in Changsha, China.*

Pablo Artal's *research interests are centered on the optics of eye and the retina and the development of optical and electronic imaging techniques to be applied in Vision, Ophthalmology and Biomedicine. He pioneered highly innovative and significant advances in the methods for studying the optics of the eye and contributed substantially to our understanding of the factors that limit human visual resolution. In addition, several of my results and ideas in the area of ophthalmic instrumentation over the last years have been introduced in instruments and devices currently in use in clinical Ophthalmology. He has published more than 350 reviewed papers that received more than 24600 citations (h-index of 80) in Google Scholar, presented more than 200 invited talks in international meetings and around 150 seminars in research institutions around the world.*

He was elected fellow member of the Optical Society of America (OSA) in 1999, fellow of the Association for research in Vision and Ophthalmology (ARVO) in 2009 and 2013 (gold class), fellow of the European Optical Society (EOS) in 2014 and fellow of the SPIE in 2016. In 2013, he received the "Edwin H. Land Medal" for scientific contributions to the advancement of diagnostic and correction alternatives in visual optics. This award was established by the Optical Society of America (OSA) and the Society for Imaging Science and Technology (IS&T) to honor Edwin H. Land. This medal recognizes pioneering work empowered by scientific research to create inventions, technologies, and products. In 2014, he was awarded with an Advanced Research grant of the European Research Council. In 2015, he received the "King Jaime I" award in New Technologies. In 2018, he was awarded the Spanish National Research award "Juan de la Cierva" and in 2019 the "Edgar D. Tillyer" award of the Optical Society of America for "the pioneering use of optics and photonics technologies to unravel the human visual system and to improve eye diagnostics and correction". In 2021, he was awarded the medal of the Spanish Royal Physics Society. I am a co-inventor of 30 international patents in the fields of Optics and Ophthalmology and the co-founder of four spin-off companies developing my concepts and ideas.



SESSION I Optics and vision

Aberrations, modified optics and neural adaptation

Susana Marcos

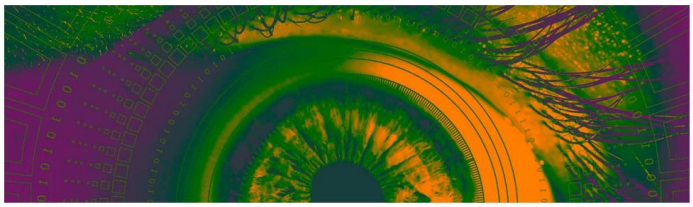
Center for Visual Science. University of Rochester (US)

Aberrations degrade the quality of the images projected on the retina. The optical quality of the eye is driven by the geometry and structure of the ocular components of the eye. Changes in cornea or lens occur with age, accommodation, corneal disease or conditions such as cataract, presbyopia and myopia results in changes in the optical quality of the eye. Quantifying the contributions of the structure of cornea and lens on the optical aberrations of the eye is important to improve the treatment strategies in the eye. These treatments may entail modifying the corneal shape, replacing the crystalline lens by an intraocular lens, or fitting a contact lens.

Adaptive Optics (AO) is an excellent way to manipulate the optics of the eye and simulate vision with these corrections prior to a more invasive procedure. State-of-the-art head-mounted see-through devices that allow testing different lens designs AO can also provide full correction of the aberrations of the eye, leaving the eye diffraction-limited, opening possibilities to investigate the spatial limits to spatial resolution.

Perceived visual quality is not only determined by optical blur produced by the aberrations, but also to perceptual aspects, including neural adaptation. Adaptive Optics is also an ideal tool to measure after-effects associated to sharpening on blurring the image (with the deformable mirror).

Susana Marcos *es David R Williams Director of The Center for Visual Science, Nicholas George Professor of Optics at the Institute of Optics and Professor of Ophthalmology at the Flaum Eye Institute. She is Professor of Research Founder of the VioBioLab and past director at the Instituto de Optica-CSIC. She has pioneered multiple technologies for diagnostics and treatment in the eye, protected in 24 patents, many licensed to industry. She is co-founder of spin outs Plenoptika and Quicksee. She has served in numerous professional organizations, including as President of the Spanish Research Agency Advisory committee, Optica Chair of Publications Council and Board of Directors. She has won many awards including Optica Adolph Lomb Medal, Optica Edwin Land Medal, ICO Prize, Jaime I Award in New Technologies, Ramon y Cajal Medal by the Royal Academy of Science, National Award in Engineering.*



Focus on the periphery: Optical and neural factors

Linda Lundström

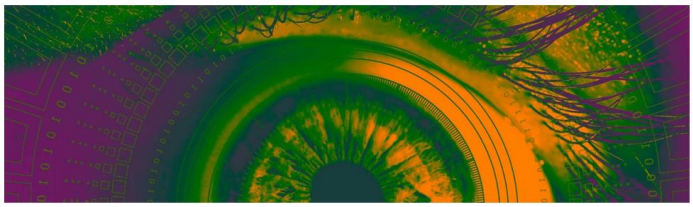
Department of Applied Physics, Royal Institute of Technology (KTH) (Sweden)

We investigate how peripheral optical errors affect vision with the aim to design better peripheral corrections to (1) reduce the ocular growth in myopia and (2) improve the remaining vision for individuals with large central visual field loss. Compared to central vision, peripheral visual function depends on a complex interaction of optical and neural limitations. The optical aberrations, both chromatic and monochromatic, are considerably larger in the periphery and the neural sampling density is lower. Hence, visual functions such as high contrast resolution, which are limited by the optical image quality for central vision, can be sampling limited off-axis. We therefore investigate the influence of chromatic and monochromatic aberrations on different peripheral visual functions.

Peripheral vision is evaluated with our adaptive optics visual simulator under well-controlled optical conditions for both monochromatic and polychromatic aberrations. Different visual functions are evaluated with sinusoidal Gabor gratings of different orientations presented on a calibrated monitor in 10-bit grayscale, utilizing alternative forced choice in Bayesian psychophysical procedures. Generally, high contrast peripheral resolution acuity is relatively insensitive to optical errors whereas low contrast sensitivity and detection acuity depend more on the peripheral image quality. Additionally, peripheral vision shows asymmetries both regarding the orientation of the stimuli and the sign of defocus.

ACKNOWLEDGEMENTS: Peter Unsbo, Abinaya Priya Venkataraman, Dmitry Romashchenko, Petros Papadogiannis, Simon Winter, Charlie Börjeson and Anna-Caisa Söderberg. Research funding from the European Commission and the Swedish Research council.

Linda Lundström *is a professor in Applied Physics at KTH specialized on the peripheral human eye. I have a MSc in Engineering Physics and I did my PhD in Visual Optics at KTH on building and programming a Hartmann-Shack wavefront sensor for peripheral measurements with the aim to improve the remaining vision for people with large central visual field loss. After that, I held a postdoc position with Pablo Artal at LOUM in Spain, working on instrumentation to decipher the progression of myopia. In 2009, I returned to KTH and am now leading the research in the Visual Optics group, which consists of two senior scientists and 2-3 doctoral students/postdocs. Our research concerns the formation of the retinal image and the optical limits to vision. We develop techniques in wavefront sensing, adaptive optics, and psychophysics specially to investigate the peripheral visual field and the effects of optical manipulation. Applications span from basic research to central visual field loss due to AMD and myopia development. Apart from research, I teach basic optics courses, mainly for students on the optometry education offered at Karolinska Institutet. I am also head of the division for Biomedical and X-Ray Physics at KTH.*



Chromatic aberration in the human eye and its impact in vision and imaging

Enrique Josua Fernandez

Laboratorio de Óptica, Centro de Investigación en Óptica y Nanofísica (CiOyN), Universidad de Murcia (Spain)

In this course several aspects of the chromatic aberration will be presented. It will start with the origins and the geometrical optics characterization of the chromatic aberration, to later show some of the most successful chromatic eye models currently used in the field[1]. Experimental methods for the determination of the chromatic aberration in the eye will be shown, discussing some of the practical issues associated to the existing techniques[2]. Both subjective and objective methods will be described and compared to gain a deep understanding of the limitations of each modality.

The impact of chromatic aberration in vision will be presented[3]. In this regard, its role in accommodation will be discussed. The apparent paradox of the correction of chromatic aberration for visual enhancement in normal vision, exhibiting a modest benefit when any, will be reviewed and discussed[4].

Finally, the role of chromatic aberration for retinal imaging will be presented. The only ophthalmic technique that uses inherently polychromatic light is optical coherence tomography (OCT). An introduction to this imaging modality will be given, together with some experimental methods for the correction of chromatic aberration in this context[5,6,7]. To conclude, limits to the performance and benefits of the chromatic aberration correction in OCT will be presented.

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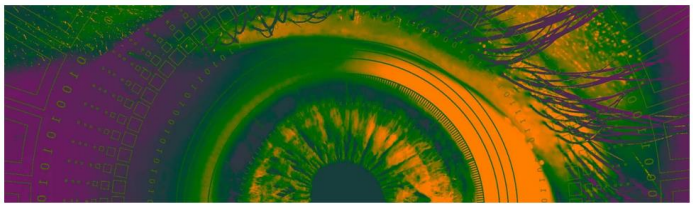

What is the Stiles-Crawford effect?

Brian Vohnsen

School of Physics, University College Dublin (Ireland)

The Stiles-Crawford effect (SCE) has remained an enigma in visual optics since its discovery 90 years ago by Walter Stiles and Brian Crawford.[1] Together, they quickly recognized that it has its origin in the retina that dampen the impact of oblique light. Yet, its true cause has eluded a satisfactory understanding for decades. Undoubtedly this is due to the time-consuming and challenging psychophysical techniques employed when analysing it point-by-point with Maxwellian light as well as a concurrent interest in waveguide optics.[2] At times, it has also been confused with an optical directionality in backscattered light, better known as the optical SCE. Both give rise to Gaussian-like distributions in the pupil plane, that can be confounded with the SCE. Only in the past decade has leakage of light been identified as the principal cause of the SCE,[3,4] deviating from the widespread assumption of imperfect waveguide coupling to the retinal photoreceptors.

Here, I will review the current understanding of the SCE (see Fig. 1) and report on how it impacts vision when integrated across the natural pupil providing a photopic apodization that is nearly an order-of-magnitude higher than with Maxwellian light while largely absent in scotopic conditions.[5] I will discuss how the same optics may have an impact on emmetropization and, therefore, on why being outdoors is vital to prevent the onset of myopia.[6] This suggests a delicate balance between the refractive optics of the anterior eye with the elementary light-capturing cones and rods of the retina to obtain good vision throughout life.

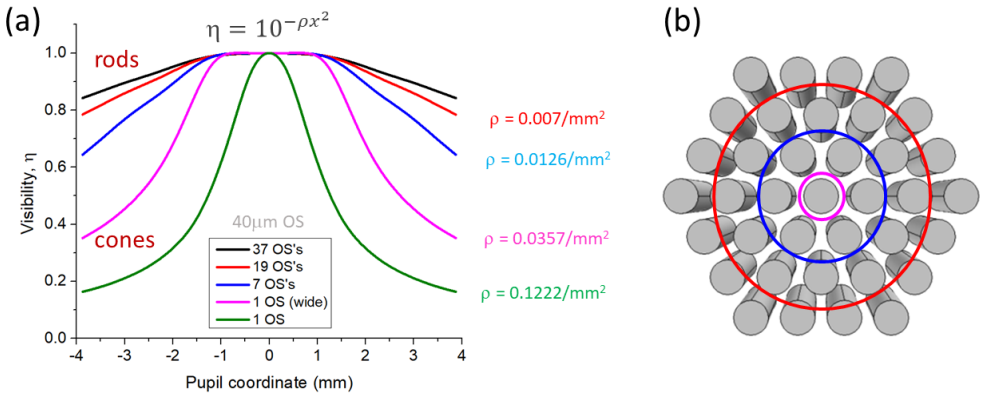

Figure 1: Model of light leakage between adjacent cells and corresponding effective SCE visibility plot.

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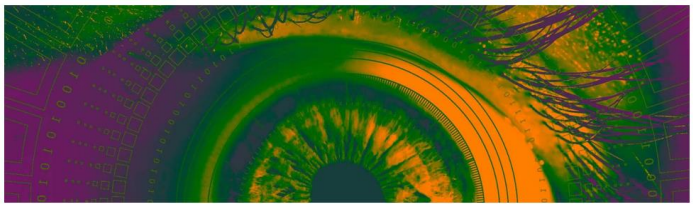

Hartmann-Shack: from the base to the application

Justo Arines

Department Applied Physics, Photonics4Life research Group, Faculty Optics & Optometry, University of Santiago de Compostela (Spain)

The Hartmann-Shack is probably the most used wavefront sensor in visual optics. It is present in most of the Optics laboratories in the world. However, now it is just a tool for most of the scientists. Despite its simplicity in terms of hardware (just a microlens array and a detector) the estimation of the wavefront with a Hartmann-Shack involves different optical concepts, engineering and computational aspects. This talk is planned to describe in detail the concepts and questions related with the bases and uses of the Hartmann-Shack[1]. We will start with some history, from the Hartmann sensor to the Hartmann-Shack. We will deal with the exact equations and the approximations that relates centroid displacements with wavefront gradients[1]. We will learn that the Hartmann-Shack can be used with point and extended sources[1], that can be used to center deformable mirrors or Spatial Light modulators[2]. That there is an optimum number of Zernike polynomials to be estimated, and the different sources of error involved on the estimation error[3]. We will understand the rules of Zernike scaling and transformation[4], the influence of the microlens distribution[5], the way in which ocular movements can be used to develop a synthetic Aperture Hartmann-Shack sensor[6], how to increase its dynamic range and sensitivity.

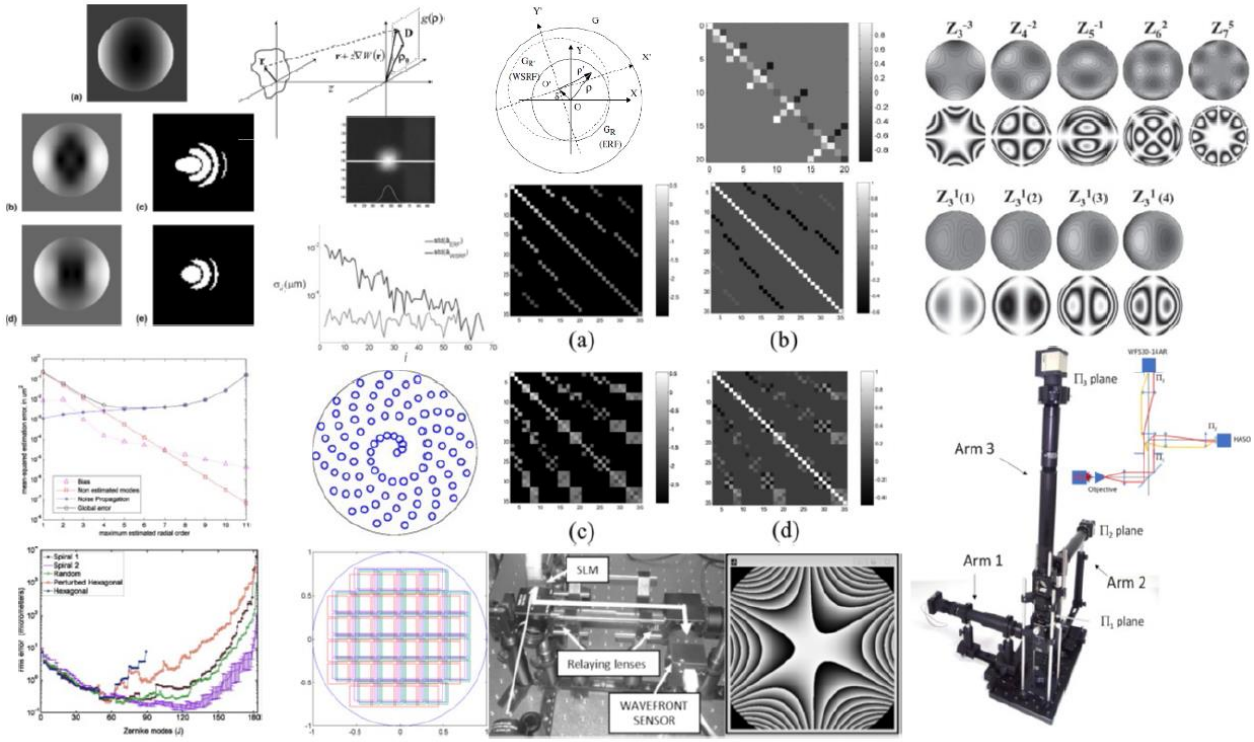

Figure 1: Collage of different studies related with Hartmann-Shack sensor

ACKNOWLEDGEMENTS: Ministerio de Ciencia e Innovación PID2020-115909RB-I00, and to S. Bará, J. Ares, E. Pailos, P. Prado, E. Acosta, and R. Navarro.

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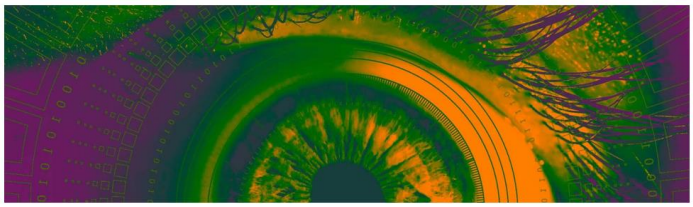

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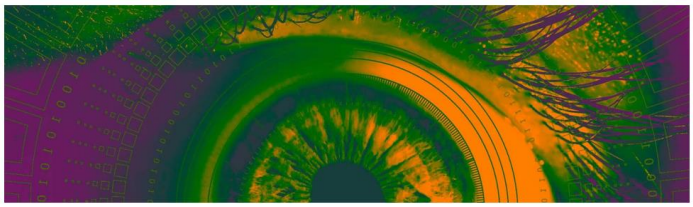
Justo Arines *is Associate Professor at the Faculty of Optics and Optometry of the University of Santiago de Compostela. Previously, he was hired by the University of Vigo and the University of Zaragoza. His teaching experience focuses on degrees in Physics and Optics and Optometry, as well as master's degrees associated with these topics. His main line of research is Visual Optics with special emphasis on the measurement and correction of aberrations to improve the retinal image, also participating in other fields such as microprocessing of surfaces with lasers, the circadian effects of light, or the inactivation of microorganisms with UVC radiation.*



SESSION II Structure and Biomechanics of the eye

Ocular Biomechanics

Sabine Kling[1,2]

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[2] ARTORG Center for Biomedical Engineering Research, Medical Faculty, University of Berne (Switzerland)

As a determinant of its geometrical shape, mechanical tissue properties are an important factor to consider when evaluating the refractive power and optical performance of the eye.

The cornea forms the anterior transparent shell of the eye and represents its most important refractive component. Already minor deviations from its ideal aspheric shape deteriorate the visual acuity. Moreover, there are several degenerative diseases that induce localized progressive tissue weakening (e.g. iatrogenic ectasia, keratoconus), which severely reduces the eye's optical quality. These conditions may be addressed with photochemical corneal cross-linking (CXL), which locally increases corneal stiffness and induces refractive changes[1] at the same time. Consequently, modifying mechanical properties has been proposed as a more flexible alternative to glasses promising the correction of asymmetric refractive errors. The second most important refractive component of the eye is the crystalline lens. It is the only ocular component that permits steady accommodation and provides the eye with a wide range of focus. With increasing age, the crystalline lens loses this capability as it turns stiffer making it less responsive to the accommodative mechanical stimulus exerted by the ciliary muscle. The gradual loss of visual accommodation starts at age 40 years and is known as presbyopia. Up to date, neither the precise mechanism of accommodation, nor the origin of presbyopia is fully understood. This knowledge however is critical when developing novel treatment solutions for presbyopia, be it functional artificial lenses for implantation that mimic the natural behavior of a young crystalline lens[2], or laser surgery creating microincisions into the lens re-establishing its deformability[3–5]. In this talk, the involved biomechanics in corneal ectasia, refractive surgery, CXL treatment and accommodation will be discussed and the diagnostic potential of in vivo elastography[6] will be explored.

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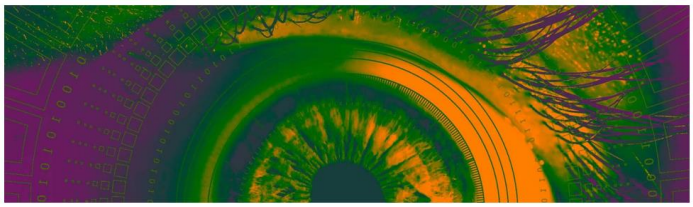
Sabine Kling *is currently a junior group leader at the Biomedical Engineering Institute at ETH Zurich and at the ARTORG Center for Biomedical Engineering Research at the University of Bern. She obtained her PhD on the topic of corneal biomechanics at the University of Valladolid and has spent her postdoctoral time at the Universities of Geneva and Zurich. Her current research is focused on the anterior eye and the relation between structural and functional tissue properties. She is an author of over 56 peer-review publications, five book chapters and has contributed to over 64 International and National conferences.*



Optical Coherence Tomography for the investigation of ocular biomechanics: An overview of different excitation methods and their applications

Judith S. Birkenfeld[1], Ahmed Abass[2], Sergey Alexandrov[3], David Bronte-Ciriza[4], Andrea Curatolo[5], Ashkan Eliasy[2], James A. German[1], Andrés de la Hoz[1], Karol Karnowski[5], Bernardo Lopes Teixeira[2], Eduardo Martinez-Enriquez[1], Ryan McAuley[3], Andrew Nolan[3], Alejandra Varea[1], Lupe Villegas[1], Ahmed Elsheikh[2], Martin Leahy[3], Jesus Merayo-Lloves[6], Maciej Wojtkowski[5], Fernando Zviertcovich[1], Susana Marcos[7]

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[3] Tissue Optics and Microcirculation Imaging Facility, School of Physics, NUIG (Ireland)
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[5] International Centre for Translational Eye Research (Poland)
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[7] Center for Visual Science, The Institute of Optics, Flaum Eye Institute, University of Rochester (US)

Ocular biomechanics play an important role in maintaining the eye´s form and function. Abnormal biomechanical properties may be an indicator of ocular pathology or structural deterioration of the eye. Localized biomechanical weakening of corneal tissue, for example, is thought to precede keratoconus (KC), a progressive non-inflammatory corneal disorder that results in thinning and protrusion of the cornea into a conical shape[1]. Corneal alterations are usually detected when the vision is already irreversibly affected, but the changes in the biomechanical properties take place before these morphological features occur[2]. For the more common eye condition myopia, which results from a mismatch between the focal length of the ocular components and the axial length of the eye, studies have shown an alteration of the scleral biomechanical properties in the equatorial and posterior scleral regions[3]. The ability to quantify biomechanical changes in the ocular tissue could enable earlier detection of disease progression, more individualized treatment options, and avoid irreversible vision loss, corneal transplants, or retinal detachment. Non-contact approaches that quantify biomechanical properties in vivo include Optical Coherence Elastography (OCE)[4-6], Brillouin microscopy[8], and air-puff deformation Scheimpflug imaging[9, 10]. Recently, Optical Coherence Tomography (OCT) devices have been coupled to air-puff excitation sources to capture the deformation event at the corneal apex or on the horizontal meridian[10-11].

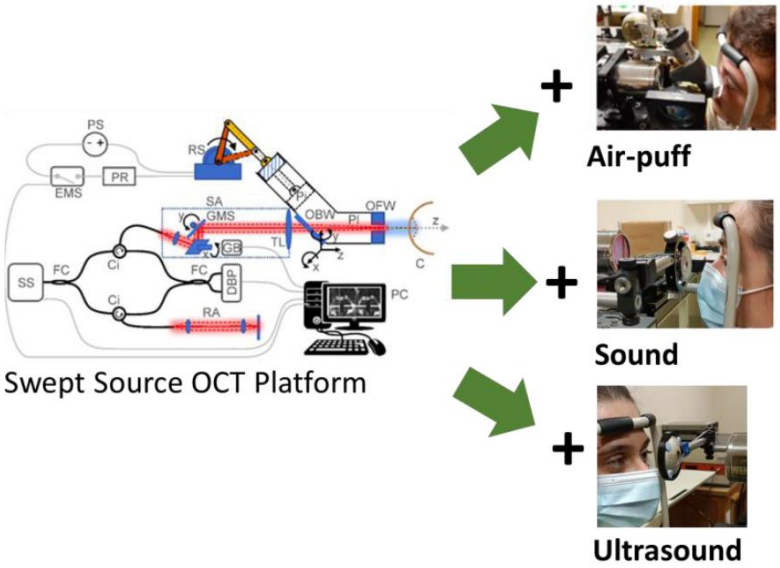
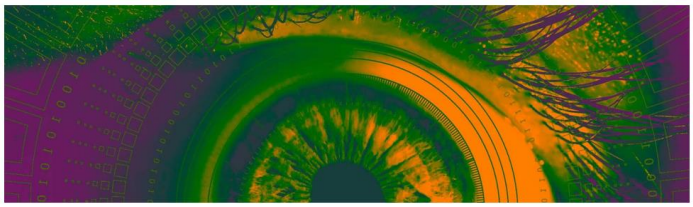


Figure 1: Overview of the developed OCT-based methods for the investigation of corneal and scleral biomechanics at the Visual Optics and Biophotonics laboratory, including a swept-source OCT coupled to cross-meridian air-puff deformation OCT, sound excitation, and ultrasound excitation.



In this talk, we present our recently developed OCT-based methods for the investigation of corneal and scleral biomechanics (fig. 1), including cross-meridian air-puff deformation OCT[12, 13, 14], ultrasonic wave-based OCE[15, 16], and co-axial acoustic-based optical coherence vibrometry (CoA-OCV)[17], and their applications. We will present current results from a patient study that include KC patients and healthy subjects, and from several animal model studies for the investigation of corneal and scleral biomechanics. We will introduce several deformation parameters and biomarkers for the cornea and the sclera and their use to retrieve actual biomechanical parameters, by means of Finite Element modelling (estimation of the Young´s Modulus) and a modified Rayleigh-Lamb wave model[18] (estimation of the Shear Modulus).

ACKNOWLEDGEMENTS: ERC (2018-ADG-SILKEYE-833106); H2020 European Project Imcustomeye and Multiply (H2020-ICT-2017 Ref. 779960, H-2020-MSCACOFUND-2015 Ref. 713694); Spanish Government (FIS2017-84753-R, IJC2018-037508-I and CSIC JAE Intro Fellowship); L'Oréal-UNESCO "For Women in Science" Spain; Fundacja na rzecz Nauki Polskiej (MAB/2019/12); Polish Government (NAWA ULAM/2020/1/00176).

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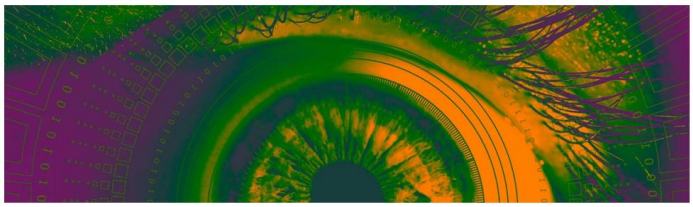
Judith S. Birkenfeld *is a Juan de la Cierva researcher at the Institute of Optics of the Spanish National Research Council (IO-CSIC). She obtained an M.Sc. in physics, an M.Sc. in medical physics, and a certificate in business administration from the University of Heidelberg, Germany. She then moved to Spain to pursue her Ph.D. at the Visual Optics & Biophotonics Lab (IO-CSIC) with Prof. S. Marcos and received her Ph.D. in physics from Complutense University. Birkenfeld received several postdoctoral fellowships at the Massachusetts Institute of Technology (MIT), Harvard Medical School, and the Wellman Center for Photomedicine, USA before returning to Spain. Her research is motivated by solving currently unmet medical needs and focuses on applications in eye and skin research, using state-of-the-art techniques from optics, photonics, and artificial intelligence. From 2020-2023, she was the local coordinator of the EU Horizon 2020 project Imcustomeye, a multinational consortium developing novel technologies based on photonics and modeling approaches to detect changes in ocular biomechanics, a promising biomarker for the early detection of various eye conditions.*

Birkenfeld won the prestigious Spanish L'Oréal-UNESCO "For Women in Science" award in 2021 and was included in the EVI TOP LIST of Women in European Vision Research. She is chair-elect of Optica's Microscopy and OCT Technical Group and co-founder and faculty of MITlinQ, an MIT-based program to accelerate innovation technology.



In Vivo Multiphoton Imaging of Ocular Structures

Juan M. Bueno

Laboratorio de Óptica, Instituto Universitario de Investigación en Óptica y Nanofísica, Universidad de Murcia (Spain)

For more than 20 years, multiphoton (MP) microscopy (both Two Photon Excitation Fluorescence [TPEF] and Second Harmonic Generation [SHG]) has become a powerful tool for ex vivo assessment of ocular tissues.[1,2] It provides high resolution images, without the need of external markers and absence of photodamage. In particular, the visualization of individual collagen fibers within the cornea and the sclera are of relevant clinical interest to potentially differentiate healthy from diseased conditions.[3] However, the implementation into in vivo human eyes has been challenging with only a few attempts performed in animal models.[4] Limitations have been imposed by the maximum permissible exposure (MPE), the presence of aberrations and scattering (especially at deeper locations within the tissues) and uncontrolled involuntary movements.

Here we report MP images of the living human eye obtained with a clinically-oriented MP microscope.[5] This is a compact prototype with a mode-locked infrared laser (l = 800 nm) being used as illumination source. The beam is scanned across the ocular structures of interest and the MP signals are acquired in the backward direction, travelling through appropriate spectral filters and reaching a photon-counter unit. The whole system was controlled by a custom software that allows freely modifying each acquisition parameter.

Results show that useful MP images can be acquired in ~0.5 s using an average laser power of 20 mW (at the corneal plane). These experimental settings are about one order of magnitude below the MPE limits. The instrument was successfully employed to obtain non-contact and non-invasive MP images at several locations from different ocular structures. As an example, Figure 1a shows a SHG image from the sclera of one of the volunteers involved in the experiment. For the sense of completeness Figure 1b depicts an ex vivo SHG image from the sclera of a human donor. It can be observed that both images present a similar collagen distribution and individual collagen fibers are visualized. This instrument might become an important tool in Ophthalmology for early diagnosis and tracking of ocular pathologies.

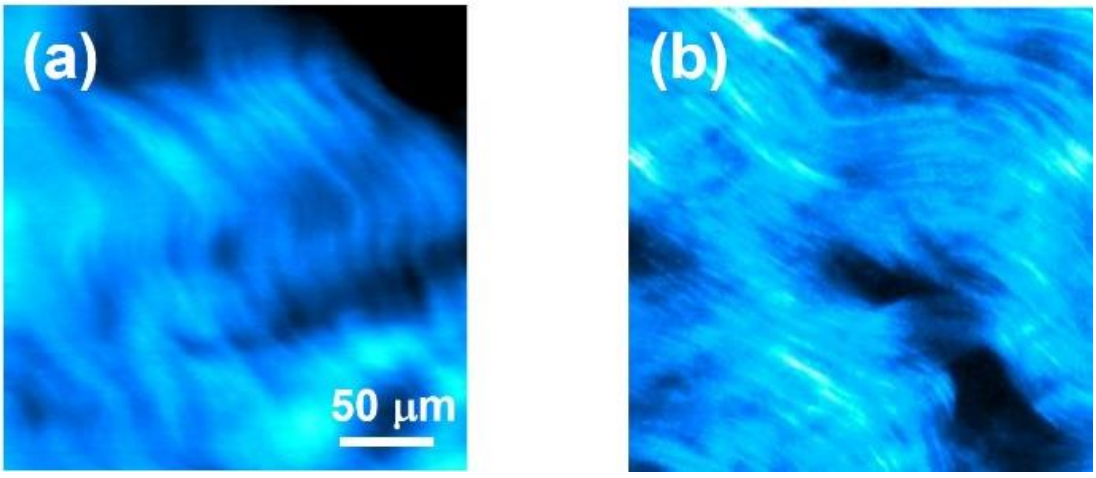


Figure 1: Comparison of SHG images of the human sclera recorded in in vivo (a) and ex vivo (b) conditions.

ACKNOWLEDGEMENTS: This work was supported by the Agencia Estatal de Investigación, Spain (grant PID2020-113919RB-I00/AEI/10.13039/501100011033).

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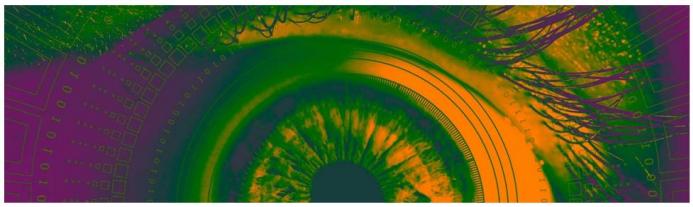
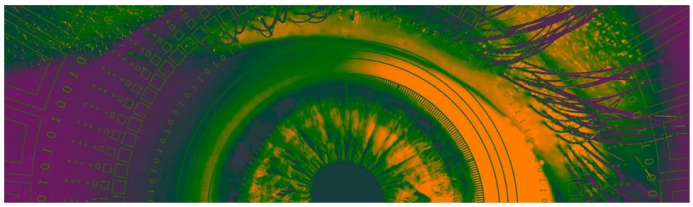


JUAN M. BUENO (PhD in Physics 1999, Doctorate Extraordinary Award) has been a faculty member since 1994 at the University of Murcia in Spain, where he currently holds a position as Full Professor of Optics. He has been Director of the Department of Physics and President of the Vision Science Division of the Spanish Optical Society. In 2017 he was elected Senior Member of the Optical Society of America (formerly OSA, now OPTICA). Dr. Bueno performs his research at the Center for Research in Optics and Nanophysics, leading the biomedical imaging section. Prof. Bueno's research focuses on biophotonics, with special emphasis on multiphoton microscopy of collagen-based structures and polarization properties of tissues. A number of his publications are considered as landmark works. Since 2017 he is Senior Member of OSA (now OPTICA). He is also inventor/co-inventor in a number of patents in the field of Visual Optics and co-founder of Voptica SL a spin-off company.



Corneal regeneration: Biological and optical studies

M. Carmen Martínez García and Patricia Gallego Muñoz

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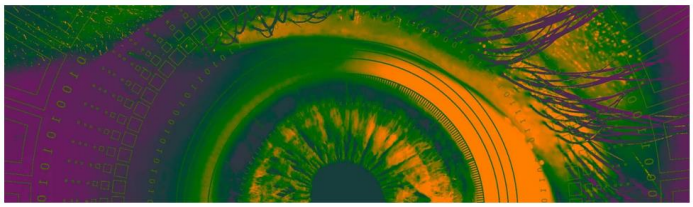
La córnea histológicamente está formada por un epitelio superficial poliestratificado, conjunto de células poligonales que descansa sobre una membrana basal. Una gruesa capa de tejido conectivo formada esencialmente por células muy diferenciadas, los queratocitos, y numerosas fibras de colágeno denominada estroma. La diferenciación (especialización) de estas células hace que sus citoplasmas tengan escasos orgánulos y numerosas prolongaciones. Por otra parte, estas células se encargan de sintetizar colágeno y proteoglicanos (PGs) de la matriz extracelular. El colágeno está dispuesto en láminas paralelas y ortogonalmente dispuestas en el centro de la córnea. El colágeno más abundante es el colágeno tipo I que forma complejos heterodiméricos con el colágeno tipo V. Entre las fibras de colágeno se encuentran los PGs que juegan un papel esencial en el espaciamiento de las fibras de colágeno y en la distribución de estas. Finalmente, la córnea tiene una gruesa membrana basal, la membrana de Descemet, y un epitelio simple plano en contacto con el humor acuoso cuyas funciones son la nutrición y el mantenimiento del equilibrio hídrico de la córnea, fundamental para su transparencia. Cuando se produce un daño en la córnea se rompe el equilibrio entre sus componentes, los cuales, como hemos dicho, se encuentran muy ordenados y especializados para conseguir la transparencia.

Los modelos estudiados, han sido modelos de procedimientos quirúrgicos o daños que se pueden observar en la clínica y que nos han servido para el estudio de cómo las córneas dañadas pierden la transparencia y la recuperan en el proceso de cicatrización. Para ello hemos unido estudios ópticos, en diferentes etapas del proceso de regeneración, estudios y hemos relacionado, algunos de ellos, con los procesos moleculares que tienen lugar. Los primeros estudios se realizaron en córneas de gallina con operaciones de cirugía refractiva PRK. En estas, el daño se produce en el epitelio y en diferentes profundidades del estroma dependiendo de las dioptrías a corregir. Debe por tanto, regenerarse el epitelio, la unión del epitelio con el estroma y el estroma que además debe ordenarse de nuevo. Desde el punto de vista celular se produce una proliferación de las células del epitelio y de las células del estroma que a su vez aumentan de tamaño e incrementan sus orgánulos para realizar la síntesis de colágeno y PGs, esta matriz en un principio está muy desordenada. Desde el punto de vista clínico esto conlleva un haze (backscattering) y desde el punto de vista óptico a una disminución de la transmitancia que se va recuperando a medida que la cicatrización se lleva a cabo [1] Estudios realizados durante la cicatrización para ver la correlación entre la disminución de la transmisión y el "scattering", demostraron experimentalmente, que había un incremento del "scattering" y que este estaba concentrado en ángulos pequeños.[2] Estudios posteriores se centraron en el epitelio, puesto que es el encargado de formar una superficie refractiva lisa. Durante la cicatrización tanto el epitelio como la membrana basal deben regenerarse y desarrollar sus uniones. Este proceso es largo y complicado por ello evaluamos su relación con la transmisión de la luz de forma cuantitativa. Los resultados demostraron una correlación entre la rugosidad del epitelio y la transmitancia, pero no entre el espesor de este y la transmitancia.[3]

Otros procedimientos quirúrgicos que se utilizan principalmente para el tratamiento del queratocono son los de "Cross-Linking" (CXL). Este procedimiento se realiza exponiendo a radiación UV, después de la desepitelización de la córnea e impregnación con riboflavina, con la intención de producir un entrecruzamiento del colágeno que endurezca la córnea en estas patologías. Con este procedimiento fueron intervenidos gallinas y conejos. La cicatrización en ambos casos mostró una reepitelización rápida y una muerte de los queratocitos debida, por una parte, a la desepitelización y por otra a la radiación UV; así como a una reorganización del colágeno. Se realizó un análisis cuantitativo y comparativo entre las córneas de las dos especies para estudiar la reorganización del colágeno con un microscopio de generación de segundo armónico (SHG) y se observó que el efecto de la técnica era diferente. La reorganización del colágeno dependía de la organización inicial del colágeno, así, las córneas de gallina en las que el colágeno esta inicialmente muy ordenado el efecto del CXL es mínimo mientras que en los conejos cuyas córneas tienen el colágeno inicialmente menos ordenado la



reorganización tras la intervención es mayor.[4] Dentro de estas técnicas quirúrgicas de CXL probamos a realizarlas con luz menos dañina que la radiación UV, para ello se utilizó luz verde y como fotosensibilizador el rosa bengala. La muerte de queratocitos fue menor y más superficial y la cicatrización más rápida, consiguiendo semejante efecto biomecánico.[5,6] Por otro lado, los estudios de la organización del colágeno, llevados a cabo con un SHG y utilizando el coeficiente de orden (CO) como métrica para comparar los dos tratamientos demostraron que el CO era mayor en las córneas tratadas con luz verde y rosa bengala.[7]

Daños graves se pueden producir de manera accidental en algunos puestos de trabajo como las quemaduras corneales por ácido o álcalis. El estudio de estas quemaduras supone un gran reto de reconstrucción para la córnea teniendo en cuenta los numerosos procesos que tienen lugar durante un largo plazo de cicatrización. El primer gran reto es la reepitelización, que, si bien se produce de manera rápida, estas células no se unen a la membrana basal dando lugar a úlceras recurrentes, por ello, estudiamos la síntesis de esta membrana y sus alteraciones.[8] Además, la reorganización del colágeno y las implicaciones sobre la transparencia son muy llamativas, produciéndose opacidades desde el punto de vista clínico y una disminución de la transmitancia. La diferenciación de queratocitos a fibroblastos y/o miofibroblastos, grandes células con numerosos orgánulos dedicados a la síntesis y secreción de colágeno tipo I y tipo III y PGs que dan lugar a una matriz, muy abundante y desordenada, y que se remodela a lo largo del tiempo. Esta remodelación y reorganización del colágeno fue seguida y estudiada por imágenes de SHG y cuantificadas por una herramienta matemática que suministra información sobre la orientación preferencial de las fibras (ST) e hicieron posible el estudio de los cambios estructurales a lo largo del tiempo.[9] Por otro lado, se realizó un estudio de los cambios microscópicos y moleculares que llevan a la recuperación casi total en un periodo de 6 meses.[10]

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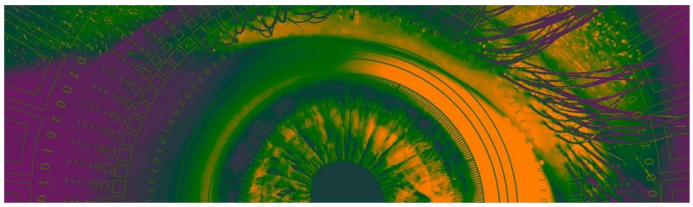
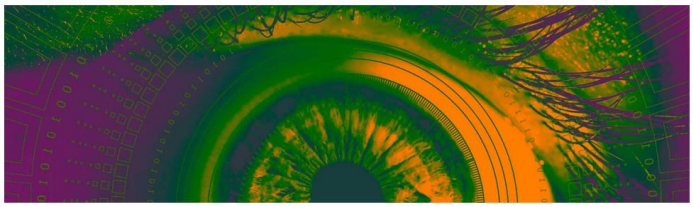
M. Carmen Martínez *joined the Optometry School in January 1998, when she became Lecturer in Cell Biology and Histology. Nowadays, I am a teacher in biomedical engineering and Head of the Techniques Optical of Diagnostic Group multidisciplinary research group. My research is aimed at investigating the corneal wound healing process. At the beginning, I started assessing the corneal wound healing process after different refractive surgeries such as LASIK and PRK. After that, we carried out different studies of additive surgery after intracorneal segments implantation and cross-linking*



*surgeries, all of them in "in vivo" animal models. This research is underpinned by **a multidisciplinary** team of researcher ophthalmologists, biologists, physicists, and opticians, that permitted us to unravel the different aspects of the healing process. The overall aim of my research is to identify the cellular and molecular mechanisms, as well as their regulation during the healing process. With this purpose, we developed an "in vitro" model of stromal human corneal cells wound to assess the healing response after its treatment with different growth factors.*

*The cornea is a structure where collagen is organized as a network that possesses incredible optical and mechanical properties. One of the most important challenges, after an injury, is to recover transparency. We developed an "in vivo" model of alkali burn on which we studied the transmittance of the light related with the molecular expression of the ECM and by electron microscopy to reveal the collagen packing arrangements. With the same purpose, to study the recovery of transparency we are involved in collaborative projects with the University of Murcia (Dr. JM. Bueno) aimed at developing a second harmonic microscope. These **new technologies** provide information about the packing of collagen molecules and their arrangement. Three publications and several congress communications in ophthalmologist and optical physics societies demonstrate these collaborations.*

I have been supervisor of three PhD thesis with the highest distinction and Extraordinary Doctoral Award 2015-2021



SESSION III Novel technologies for unsolved problems in Visual Optics. Minisimposium OPTICA TG Applications of Visual Science

New Intraocular lens Technologies: Ray Tracing Optimization & Bio-interfaced Pressure Sensors

Pablo Pérez-Merino

Centre for Microsystems Technology (CMST), Ghent University and imec. (Belgium)

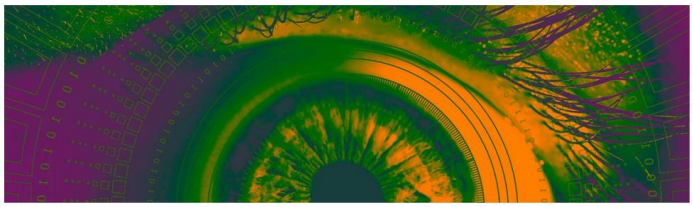
Cataract and presbyopia affect billions of people worldwide, these ocular conditions are usually related with the natural ageing and an established solution is to replace the crystalline lens by an intraocular lens (IOL). The implantation of an IOL is the most frequently performed surgical procedure in the world, with an estimation of 20 million-cataract operations/year globally, but the recent increase in optical lens designs has not been paralleled by a further sophistication of the IOL power calculation formulas.[1] Besides, the IOL is a pure optical solution, passive in nature; so by adding more functionality with miniature electro-active components, the IOL could also act as a smart medical device inside the eye able to sense and interpret the intraocular pressure (IOP) in real-time.

1. Ray Tracing Optimization: new method for IOL power calculation

Current methods of IOL power calculation generally fail in patients with irregular corneas, such as keratoconus or after corneal refractive surgery, because they rely on assumptions about the corneal shape or estimated lens position that may lead to postoperative refractive surprises.[2,3] One reason for this shortcoming is that IOL power calculations generally aim at minimizing the residual refractive error. This study introduces IOL selection based on virtual ray tracing.[4] Custom-developed algorithms for ray tracing optimization (RTO) were used to combine the natural corneal higher-order aberrations (HOAs) with multiple sphero-cylindrical corrections in 210 higher order statistical eye models for developing keratoconus (SyntEyes KTC[5]) and 75 cataract surgery eyes with previous LASIK surgery. The magnitude of defocus and astigmatism producing the maximum Visual Strehl was considered as the optimal sphero-cylindrical target for IOL power calculation. Corneal astigmatism and the RMS HOAs ranged from − 0.64 ± 0.35D and 0.10 ± 0.04 µm (regular corneas with astigmatism) to − 3.15 ± 1.38D and 0.82 ± 0.47 µm (SyntEyes KTC at 120 months). Defocus and astigmatism target was close to neutral for eyes with low amount of HOAs, where 91.66% of eyes agreed within ± 0.50D in IOL power calculation (RTO vs. SRK/T). However, corneas with higher amounts of HOAs (>0.35 µm for a 4-mm pupil) presented greater visual improvement with an optimized target. In these eyes, only 18.05% of eyes agreed within ± 0.50D (RTO vs. SRK/T and Barrett True K). The power difference exceeded 3D in 42.2% while the cylinder required adjustments larger than 3D in 18.4% of the cases. Certain amounts of lower and HOAs may interact favourably to improve visual performance, shifting therefore the refractive target for IOL power calculation.

2. Smart IOL platform for real time IOP monitoring

The recent developments in micro-machining and implantable opto-electronic devices have enabled the integration of flexible sensors and circuits on ophthalmic platforms. Different publications demonstrated the in vivo assessment of IOP inside the eye by embedding an optical pressure sensor (Fabry–Pérot cavity-based configuration) in an IOL.[6,7] However, for IOP monitoring the implanted sensor is interrogated with an external optical system, limiting: the location of the sensor behind the iris (non-optical area) and detector automation for continuous data transfer. This work present a generalized simulation model using COMSOL Multiphysics to predict the capacitive-based pressure sensor output based on pyramid-microstructured dielectric elastomer, with various geometric and material parameters in a pressure range of 0-5 kPa, and the processing steps for the fabrication of the pyramid-microstructured parallel-plate capacitor based on silicon mould preparation and PDMS moulding (Sylgard-184) and ITO/PET electrode lamination. A 15 x15 pyramid microstructure array was



designed, where the base length of the pyramid microstructures and the spacing between them is 50 µm. Initial capacitance was 0.47 pF and the sensitivity 0.025 kPa^{-1}.

ACKNOWLEDGEMENTS: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 101028137.

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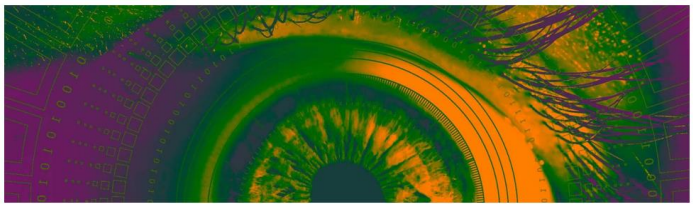
Pablo Perez-Merino *completed his Ph.D. in the Visual Optics and Biophotonics group of the Institute of Optics of the Spanish National Research Council (CSIC, Spain). Currently, he is a Marie Sklodowska-Curie Fellow at the Centre for Microsystems Technology (CMST) at Ghent University and imec, where he is developing new smart optical systems and imaging technologies for ophthalmic applications. He is co-founder of a spin-off company, 2EyesVision SL.*



Developing multiphoton imaging of the living retina to understand the visual cycle

Zhijian Zhao and Christina Schwarz

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The mammalian retina is a light sensitive tissue lining the inner surface in the posterior portion of the eye. As part of the central nervous system, the retina is the most accessible tissue to study neuronal physiology. However, imaging techniques to noninvasively measure retinal function are still rare. Two-photon (2P) ophthalmoscopy has potential in quantifying retinal function via endogenous fluorophores that are involved in important physiological processes. For example, all-trans-retinol is a particularly efficient fluorophore[1,2] and a transient molecule during the regeneration of visual pigment. Via 2P absorption, it is possible to excite this fluorophore through the optical transmission window of the anterior optics of the eye with an ultrashort pulse laser at near-infrared wavelengths[3,4]. Fluorescence is then emitted in the visible wavelength range and can be captured outside the eye.

The major premise for successful application of 2P ophthalmoscopy in the living eye is light safety[5,6]. We developed a custom 2P adaptive optics scanning light ophthalmoscope (2P-AOSLO) to minimize the light levels required. The system is optimized for low dispersion due to its all-reflective design. Adaptive optics ensures spatial confinement of the excitation point spread function. Further, the 2P-AOSLO is equipped with a state-of-the-art retinal tracking system to reduce the eye-movement related image motion7. A pulse picker will be used to rapidly modulate the pulsed imaging light. Through these advanced optical techniques, we set the stage to image the retina at single cell resolution (~1 µm) and record the photoreceptor physiology during visual stimulation. In the future, the 2P-AOSLO can be used for morphological, physiological, and psychophysical studies.

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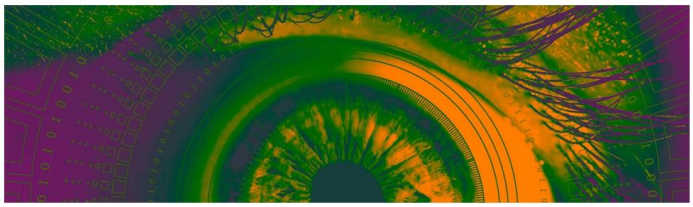
Zhijian Zhao *did his Ph.D. in Institute of Complex Systems (Cellular Biophysics) at Research Center Jülich, (Jülich, Germany. Later, he joined Euler lab as a postdoc at the Center for Integrative Neuroscience (CIN) and Institute for Ophthalmic Research (FIA) in Tübingen, where he focused on anatomy and physiology of the retina. Currently, he is the postdoc at Christina Schwarz's lab at Institute for Ophthalmic Research, Centre for Ophthalmology. He is establishing the two-photon adaptive optics scanning light ophthalmoscope for imaging of the living retina.*



Structural and functional imaging of the retina with Spatio-Temporal Optical Coherence Tomography

Andrea Curatolo[1,2]

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[2] Institute of Physical Chemistry Polish Academy of Sciences, Warsaw, Poland

Imaging retinal structure and function opens the gates to a comprehensive diagnosis of the eye and vision. Several retinal diseases are currently diagnosed by their structural hallmarks and their associated alteration to a healthy retinal morphology with techniques such as optical coherence tomography (OCT)[1]. Yet, the pathological process often affects retinal function without a structural manifestation, especially in the early stages of disease. Visual acuity and psychophysical tests are the standard of care in subjective testing of retinal function and overall vision. However, having a technique that can objectively quantify both the retinal structure and its functional response to light would be very advantageous, especially to inform therapy selection and monitoring[2]. We developed a variant of full-field OCT, termed spatio-temporal optical coherence tomography (STOC-T) to capture ultrafast, 3-D, phase-sensitive OCT volumes of the retina, and deployed it in two systems for use on humans and mice[3], adding a temporally and spatially configurable visible light stimulus. With these systems, we acquired 4-D structural and functional (optoretonography) data for both human and mouse retinas and study the influence of the light stimulus on the retinal photoreceptor response. We measured the photoreceptors frequency response of three healthy human volunteers in the range from 5 Hz to 45 Hz. We compared photoreceptor frequency response results acquired from either separate measurements or a chirped frequency flicker, allowing for a faster characterization. We also demonstrate the ability to spatially map the response to a patterned stimulus with light stripes flickering at different frequencies, highlighting the prospect of characterizing the spatially-resolved, temporal-frequency response of the retina[4]. Lastly, we show the system translation required for mouse retina functional imaging and initial optoretinography results in albino mice.

ACKNOWLEDGEMENTS: Foundation for Polish Science (MAB/2019/12); The International Centre for Translational Eye Research (MAB/2019/12) project is carried out within the International Research Agendas Programme of the Foundation for Polish Science, cofinanced by the European Union under the European Regional Development Fund.

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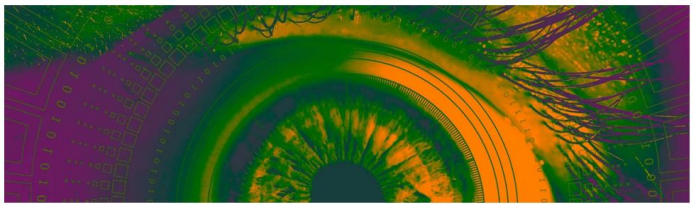
Andrea Curatolo *is an expert in biophotonics and biomedical imaging, especially in optical coherence tomography (OCT) and derived techniques to enhance diagnostic accuracy and guide surgery, aimed at improved health outcomes, mainly in ophthalmology and oncology. Dr Curatolo holds a PhD in biophotonics from The University of Western Australia. Since 2020, Andrea works at the International Centre for Translational Eye Research (ICTER), affiliated with the Institute of Physical Chemistry of the Polish Academy of Sciences (IPC-PAS), in Warsaw, Poland, where he leads the Image-Guided Devices for Ophthalmic Care group, or IDoc in short. He is an author of more than 35 publications in Q1 peer-reviewed international journals, including three book chapters. He is also involved in the clinical translation and commercialization of biophotonics technologies; he is an inventor on several patent applications, and he is engaged in collaborations with MedTech startups.*



Investigating the ocular optics, biomechanics and structure using light-based technologies

Maria Viñas-Peña[1,2]

[1] Institute of Optics. Spanish National Research Council (CSIC) (Spain)
[2] Wellman Center for Photomedicine & Harvard Medical School, Massachusetts General Hospital (US)

Vision relies on a complex system, which comprises an optical camera and a neural processor, adjusting to match visual coding and environment. Light-based technologies have allowed further understanding of its limits and pave the way to the development of novel treatments. Adaptive Optics (AO) has allowed significant insights on visual science[1], from the optical properties of the eye (measure/control of the monochromatic, and very recently, chromatic aberrations[2] of the human eye, and their interactions), as well as the processes of neural adaptation behind them, and incredible achievements in the area of visual simulation. The understanding of the interactions of these aberrations and their effect upon correction is essential to explore the limits of human spatial vision, and to design and optimize new alternatives of optical corrections.

In particular the study of Myopia and possible treatments have been boosted via the development of high resolution non-invasive imaging techniques. One of the strategies under investigation is collagen cross-linking of the sclera, a procedure inspired by the fact that during ocular growth, scleral development critically determine eye size and thus the refractive status of the eye, and that strong phenomenological correlations have been found between Myopia and the morphology and tissue-structure of the eye. Therefore an intervention of the abnormal development of the sclera may provide ways to halt the excessive axial elongation. But sclera is a very challenging tissue, where mechanical and structural properties are spatially heterogeneous, varying locally and from the anterior to posterior regions. Therefore a combination of light-based technologies is needed to understand the mechanical/structural/chemical tissue changes. Optical coherence elastography (OCE) has emerged as a promising technique with high spatial resolution and high sensitivity to non-invasively quantify biomechanical properties of soft tissues[3], and has allowed very recently in vivo non-invasive quantitative measurement of the shear modulus of the human cornea and sclera, as well as in SCXL eyes[4]. But underlying structural and chemical changes in myopic eyes remain unclear. Very recently we have used Second Harmonic Generation (SHG) microscopy and Fluorescence lifetime imaging microscopy (FLIM) to investigate the structural (orientation and packaging of the collagen fiber) and chemical (number of crosslinks between the fibers) changes. Another promising strategy is the use of multifocal contact lenses (MCLs) to slow down the progression of myopia by providing the patients with adequate visual cues that could normalize the eye growth[5]. MCLs rely on the principle of simultaneous vision, where image quality of an image at far is slightly reduced in order to gain vision at near. AO based visual simulators are particularly attractive to test vision in subjects with new optical designs prior to delivering or even manufacturing a lens. Very recently, we have demonstrated that MCLs effectively expand the depth of focus using a novel simulator, SimVis based on the concept of temporal multiplexing of an optotunable lens driven at a speed above the temporal integration of the visual system, which captured the through-focus optical and visual performance of the MCL.

Moreover, in the last years AO-based visual simulators have revolutionized the management of Presbyopia, the loss of the autofocus accommodation of the human eye with age, and its treatment. AO-simulations of new corrections enable investigation of interactions between a subject's optics and a given correction, characterization of differences across corrections, and eventually selection of the correction that optimizes perceived visual quality and performance in subjects. We have shown that diverse novel refractive multifocal designs (concentric and asymmetric) as well as commercial refractive and diffractive IOLs can be simulated using different active optical elements (SLM, SimVis) integrated in an AO system, and demonstrated equivalency between the patient's vision through the simulated lenses and physical lathe-manufactured phase-plates or physical IOLs in a cuvette. Moreover, AO-based visual simulators make even possible the pre-operative simulation of post-operative multifocal vision[6,7].

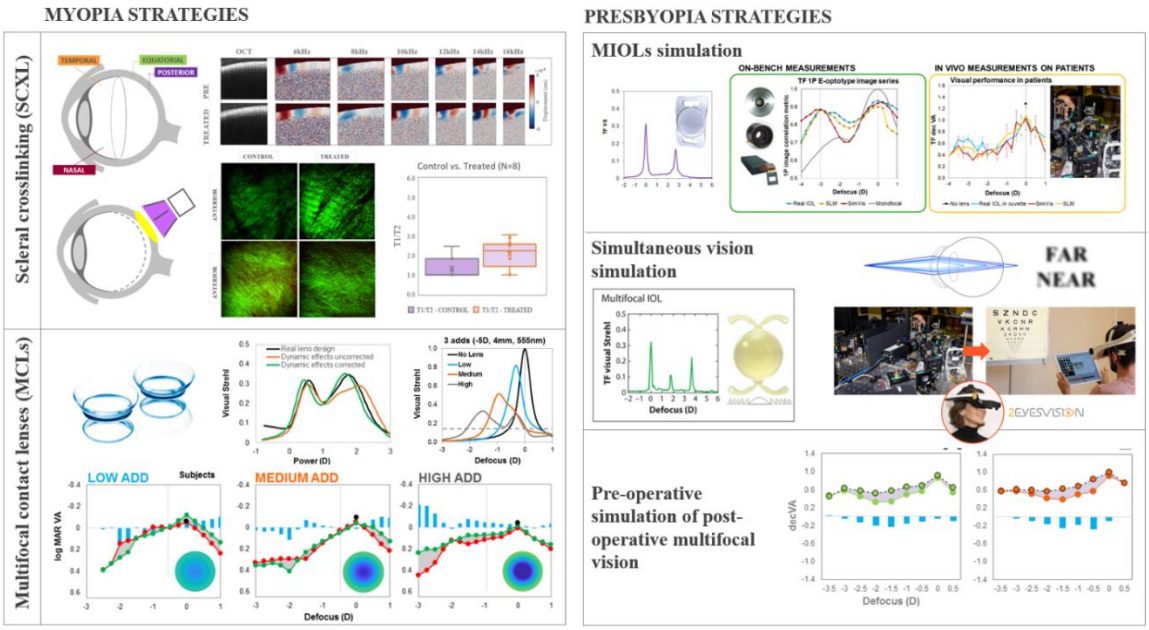


Fig 1. Applications of Light-based technologies for eye research. (1) Examples of vibrography images obtained using OCE, SHG images and T1/T2 ratios obtained from FLIM for normal and treated scleras. (2) Visual quality with real/simulated MCLs. (3) On bench and in vivo trough focus optical/visual quality with real/simulated (SLM, SIMVIS, and real IOL in a cuvette) refractive bifocal MIOL.(3) Illustrations of AO-based and clinical visual simulators. (5) Pre-operative through focus visual simulation of post-operative multifocal vision using a clinical and an AO-based visual simulators.

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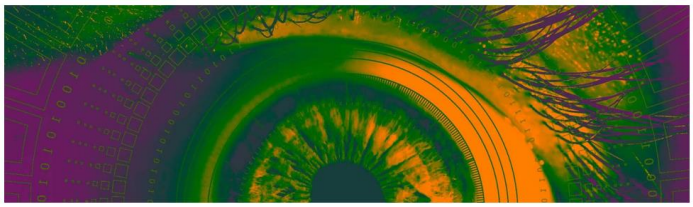

Multi-Photon Microscopy: How the microscale affects the macro-world

James A. Germann

VIOBIO, IO-CSIC (Spain)

Collagen fiber orientation and variability affects the mechanical properties of ocular tissue. For example, the anterior portion of the stroma (the thick, collagen rich layer of the cornea) has interwoven collagen fibers, while in the posterior potion of the stroma the fibers form sheets that are stacked on top of each other. This difference in interweaving between the two portions leads to differences in mechanical strength, as measured by AFM[1]. With a second harmonic generation (SHG) microscope, we can image the collagen fibers layer by layer through the entire depth of the cornea and visualize this interweaving. When the interweaving is disrupted, the cornea will suffer, as seen in keratoconus, where SHG imaging of advanced-stage keratoconic corneas can show a distinct lack of interweaving in the anterior stroma[2]. This leads to sagging of the cornea due to loss of mechanical strength. In contrast, when the corneas are treated with photo-crosslinking, a pharmaceutical treatment of keratoconus, the collagen fibers of the treated tissue appear straighter and keep their organization when removed from the ocular globe. By measuring how the organization is preserved versus depth, we have measured how effective these treatments are through the entire tissue[3].

In addition to the cornea, the sclera is also mainly composed of collagen and provides form to the ocular globe. As such, changes to the sclera affect the ocular globe as a whole, such as the thinning of the sclera and the axial elongation of the globe seen during myopia. Myopia is one of the fastest growing health crises, with the projected incidence rate projected to be 50% globally by the year 2050[4]. The refractive error associated with myopia can be corrected with a pair of spectacles, however a high refractive error will increase the risk of glaucoma[5] and retinal detachment[6]. The exact biochemical cascade that leads to myopic eye growth is still unknown, although one of the end points of scleral reformation is an increase in the expression of MMP-2[7]. To better understand the black box of myopia, we are investigating which molecules begin the myopic cascade, such as dopamine and retinoic acid[8], and the final product of the cascade, which is the reordering of the scleral microstructure[9]. We are also investigating how anti-myopia treatments, such as latanoprost and atropine, affect the microstructure of the sclera.

Thick ocular tissues can easily be measured and characterized with multi-photon confocal microscopy. Like a standard confocal microscope, the multi-photon microscope has increased axial resolution but does not require a pinhole as the probability of two photons hitting the same molecule within a femtosecond (10^{-15} s) outside of the focal volume of a high numerical aperture objective is small, even with a pulsed, coherent laser source. In our multi-photon microscopy lab, we focus on two different imaging modalities, two-photon fluorescence microscopy (2PFM) and SHG microscopy. 2PFM is identical to the one-photon case, with the molecule absorbing excitation photons and releasing fluorescence photons with slightly less energy than the absorbed photons (Stokes shift), with the difference being that two-photons are required to excite the molecule. In contrast, the SHG process is a lossless transition, so the emitted photon has all of the energy of the absorbed photons. SHG microscope does require that the measured molecules be non-centrosymmetric, as is the case in collagen. In this talk, we will be discussing our work and current trends in imaging the cornea and sclera with microscopy and an emphasis will be placed on collagen fiber organization in tissue and fluorescence in the retina. We will examine how these tools add to vision research.

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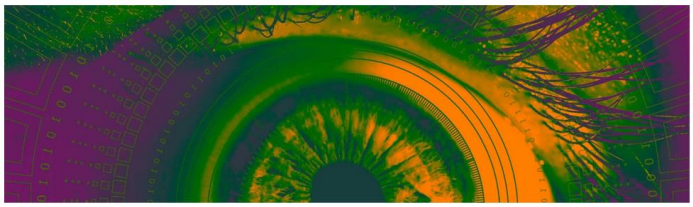

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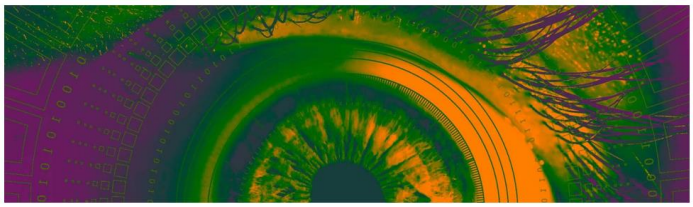
James A. Germann *is a senior postdoctoral researcher in the Visual Optics and Biophotonics group at the Institute of Optics in CSIC. He uses novel technologies to research the relationship between the microstructure of the cornea and the sclera and macroscopic properties, such as mechanical strength. He has developed different imaging devices to characterize the ocular structures at the cellular level (confocal, multiphoton, and second harmonic generation microscopy) and to study the macroscopic shape of the eye in vivo and experimental lens designs ex vivo based on Optical Coherence Tomography. For his Ph. D. project, he developed a novel four-focus microscope design for measuring and tracking single fluorescent particles in solution and measuring the 3D flow velocity of fluorescent particles.*

The societal impact of Dr. Germann's work is the study of ocular diseases, in particular myopia and keratoconus, to better understand their origin and provide an early diagnosis. Keratoconus is a blinding, ocular disease with a relatively low prevalence (15-23 cases per 100,000 people) that develops mainly in adolescents. It is caused by a change in the structural properties of the cornea and nowadays is diagnosed with the change in shape of the cornea. Myopia, also known as near-sightedness, is expected to reach epidemic proportions by 2050, with 50% of the world population myopic and some Asian countries reaching a prevalence rate of 95%. Myopia is primarily driven by the elongation of the eye that in extreme cases can compromise the structural properties of the sclera.



SESSION IV New horizons in refractive, cataract and eye surgery

Presbyopia-correcting intraocular lens with diffractive profile. Chromatic considerations

María S. Millán

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In cataract surgery, an intraocular lens (IOL) replaces the natural crystalline lens. IOL power calculations of monofocal implants commonly target distinct distance vision. However, visual requirements at closer distances cannot be satisfied by monofocals and, similarly to the case of presbyopia, patients become spectacle dependent to perform their ordinary activity. Increasing patient demand for spectacle independence has been an extraordinary incentive for the development of presbyopia-correcting IOLs. The first diffractive multifocal IOLs (DMIOLs) were bifocal lenses that provided good far and near visual acuities but insufficient intermediate vision. Many current DMIOLs incorporate a third focal point to help improve intermediate vision while maintaining performance for distance and near vision. Other lenses are based on an extendeddepth-of-focus (EDOF) design to produce a long and narrow focal segment in the image domain. DMIOLs have a hybrid diffractive-refractive design that consists of a high-power refractive lens (base lens) and an additional (add) low power diffractive profile engraved on either the front or the back surface of the IOL following a sawtooth pattern of echelettes. Diffractive IOL profiles are designed to split light into a number of operative diffraction orders,[1] with optimum performance at the wavelength that corresponds to the maximum photopic efficiency of the eye (550nm). In most diffractive bifocals, the far focus corresponds to the 0th diffraction order (base power) whereas the near focus corresponds to the 1st diffraction order (near add power). However, other market-available DMIOL designs use different diffraction orders to achieve distinct properties.[2,3] In DMIOLs, the optical power and the energy efficiency depend strongly on the wavelength. This fact has a clear impact on various aspects of IOL testing such as the optical quality, chromatic aberration, halo formation and, beyond that, on the clinical postoperative visual evaluation and on the spatio-chromatic vision of implanted eyes. Theoretical analysis, numerical simulation and invitro optical bench testing have proved to be useful methods, complementary to clinical trials, to interpret these phenomena and even predict the expected postoperative visual acuity and potential risk of dysphotopsia.

Recent findings are also presented and discussed. We show the limitations of using near infrared based equipment, such as aberrometers with wavelength in the range 780 to 850 nm, for the clinical assessment of subjects implanted with DMIOLs. We also present some asymmetric alterations in the spatio-chromatic vision produced by DMIOLs, with significant changes in resolution depending on the object distance and the spectral band of illumination.

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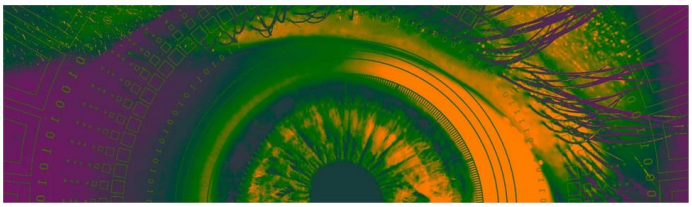
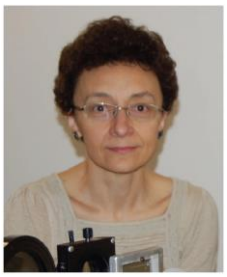
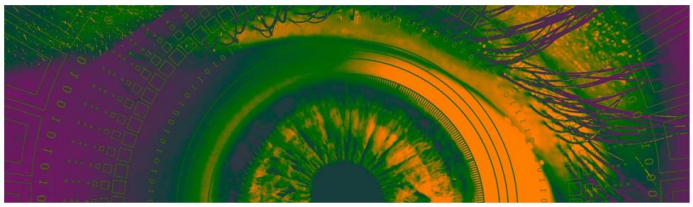




María S. Millán *is full Professor at the Universitat Politècnica de Catalunya-BarcelonaTech (UPC), Spain. Her research interests include information optics, image processing and their applications to medicine (ophthalmology), industry, and security. She leads research projects on intraocular lenses. Guest editor on the Photonics (MDPI) 2022 special issue: "Ocular imaging for eye care". She serves the optics community through several national and international societies, with particular dedication to the development of Optics in Latin-American countries. She has been representative of the Spanish ICO Territorial Committee. SPIE Fellow, EOS Fellow, OPTICA Senior and Fellow member. María S. Millán has been President of the Spanish Society of Optics. Fellow Scholar of the Colombian Academy of Mathematics, Physical and Natural Sciences.*



Simulation and validation of multifocal lenses with SimVis technology

Carlos Dorronsoro[1,2], Xoana Barcala[1], Irene Sisó-Fuertes[1], Eduardo Esteban[1], Amal Zaytouny[2], María Vinas[2], Alberto de Castro[2], Enrique Gambra[1], Susana Marcos[3] and Lucie Sawides[2]

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SimVis Gekko (2EyesVision, Spain) is a novel visual simulator that allows to experience multifocal vision prior to cataract/refractive surgery or contact lens fitting. It is based on SimVis technology, which employs optoajustable lenses working under temporal multiplexing[1] to mimic the optical performance of any multifocal design (trifocal, bifocal, edof, enhanced monofocal), at all distances[2].

Different sources of information can be used for an accurate replication of the lens performance, including the actual lens design provided by the manufacturer (physical design, phase map in the pupil plane, power map…) and metrology measurements reported in the literature or obtained by external laboratories. Using this input data, the Through-Focus Visual Strehl (TFVS) corresponding to each multifocal lens is computed, and the temporal coefficients (i.e., the time that the optoadjustable lens needs to stay in each focus to mimic the lens design) are obtained[2,3,4,5]. The set of temporal coefficients corresponding to the SimVis simulation is first validated computationally by estimating its TFVS and then experimentally using a high-speed focimeter based on a high-speed camera[6].

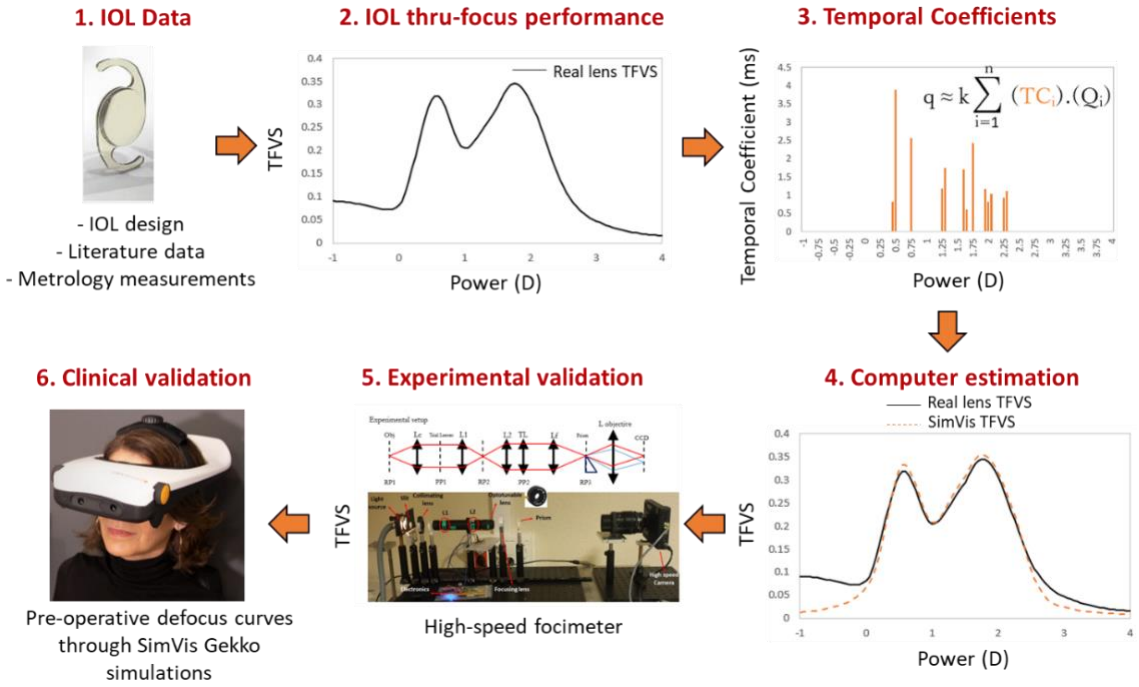
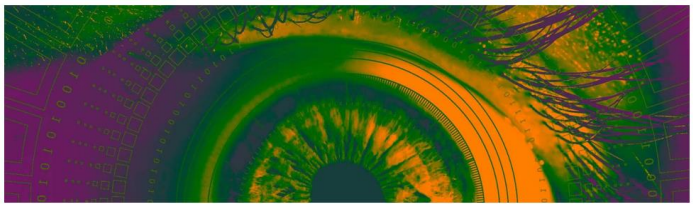


Figure 1. Validation protocol flow diagram

Finally, the simulation of the multifocal lens is validated clinically in a group of patients. For the validation of multifocal contact lenses, monocular defocus curves are obtained in the same group of subjects with both the SimVis simulation and the real multifocal contact lenses[8,9]. For the validation of multifocal intraocular lenses, bilateral defocus curves with the SimVis simulation are obtained in a group of observers, and compared with the bilateral post-operative defocus curves found in patients implanted with the corresponding real lens, as reported in scientific publications[7].

In this study we present a compendium of the different procedures used to simulate a wide variety of different multifocal lenses and the clinical validations of those SimVis simulations.



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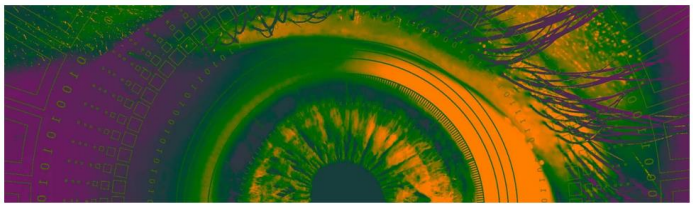


Multifocal Contact Lenses for Myopia Control

José Manuel González-Méijome

Department and Center of Physics – Optometry and Vision Science, School of Science (Portugal)

Myopia management for the young patient has changed significantly over the last two decades. Instead of compensating the refractive error, the standard of practice today moves quickly towards the prescription of active treatments that can simultaneously reduce the rate of axial elongation. This is the concept of myopia control or reduce of myopia progression. This can be achieved with specially designed spectacles (multiple lenslets, peripheral gradient), corneal reshaping (orthokeratology), soft contact lenses (bifocal or multifocal contact lenses, peripheral gradient) and/or pharmacological drugs (0.01 to 0.1% atropine) [1-4].

Soft contact lenses are the most common contact lenses prescribed and have demonstrated to have a significant impact improving the vision-related quality of life of children of and for the last 5 years, several designs have been demonstrated efficacy in myopia control including multifocal and bifocal designs for presbyopia correction and other lenses designed specifically for the young myopic eye.

The present lecture presents a summary of the main optical designs used in contact lens platforms (figure 1) for myopia management, their background science in animal models[5,6], their optical and visual performance[7-9], efficacy[10] and safety[11] outcomes (figure 2). Particular attention will be paid to new insights into the effect of treatment optics in the efficacy outcomes[12] as well as the potential effect on other potentially relevant functions such as accommodation[13], (figure 3) the electrophysiological response of the retina[14] and the structural response (figure 4) of the choroid[15].

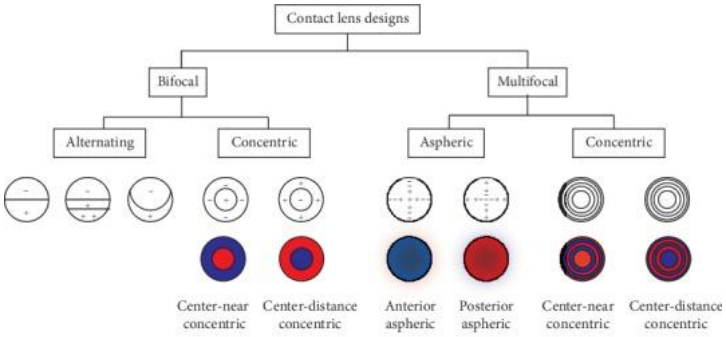


Figure 1: Optical designs used for presbyopia correction and myopia control in contact lens platforms (Remón et al., 2020).

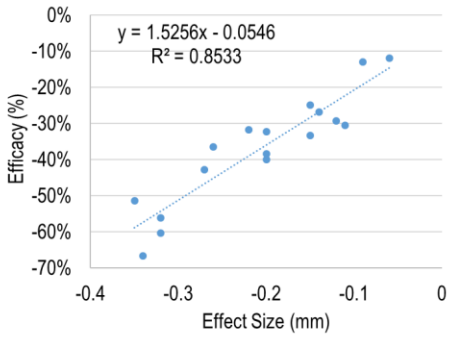


Figure 2: Correlation between the effect size and the efficacy for different myopia control methods (from the author).

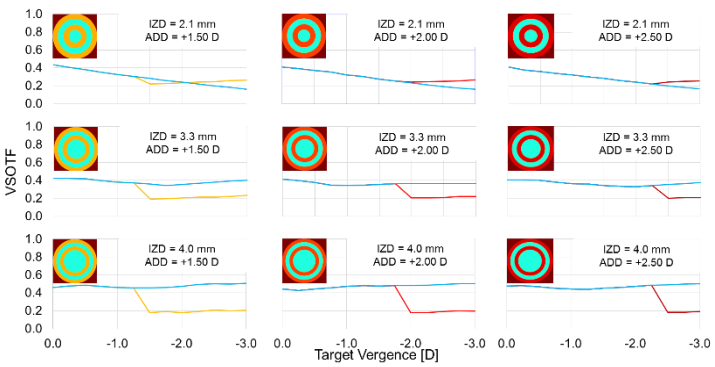
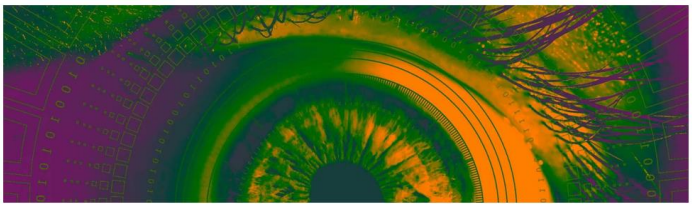


Figure 3: Changes in image quality measured with metric (VSOTF) for different target vergences, with normal accommodation (blue lines) or suppressing accommodation by the amount of plus power provided by the optics of the lens (+1.50 to +2.50D). Besides plus power, designs change their inner zone diameter (Faria-Ribeiro et al, 2018)[13].



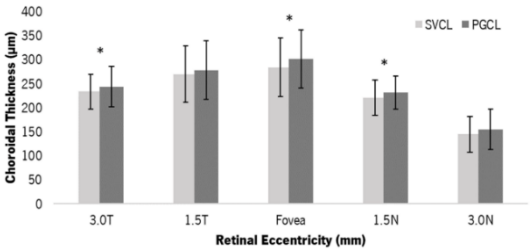


Figure 4. Average (and SD bars) of the ChT values with the SVCL and PGCL for the five eccentric choroidal zones. The ChT with the PGCL (dark grey) was thicker than the SVCL (light grey) after 30 minutes of wear. *Statistically significant differences between conditions (T-test, p-value ≤ 0.050). (Amorim-de-Sousa et al, 2023)[15]

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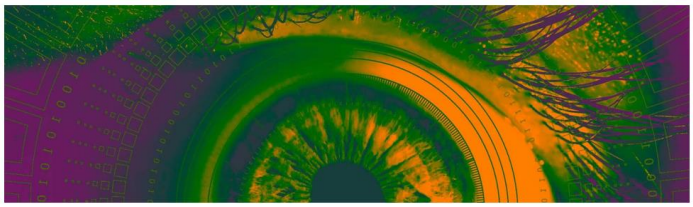
Along with his teaching tasks in Optometry and Vision Sciences, he coordinates the line of Research in Clinical and Experimental Optometry, including the study of the retinal response to myopia control treatments, among other topics with clinical and scientific impact. He has published more than 200 articles in indexed journals (WoS h=35). He is the author or co-author of 3 books and 30 book chapters and has presented conferences in more than 30 countries. Also, it is currently: President/Dean of the Faculty of Sciences, Chief Editor of the scientific magazine "Journal of Optometry", President of the Educational Committee of the European Academy of Optometry and Optics, member of the European Qualifications Board and of the committee of evaluators of various research funding agencies in 4 countries, and Ambassador for Portugal of the Society of Ocular Surface and Contact Lenses.



SESSION V Diagnostics tools & Visual Function

Diagnostic Tools for Keratoconus

Alejandra Consejo[1,2]

[1] Department of Applied Physics, School of Engineering and Architecture, Universidad de Zaragoza (Spain)
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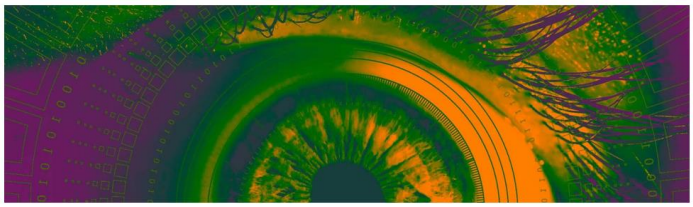
Keratoconus is a progressive disease that affects the cornea's curvature, causing distorted vision and possible blindness if left untreated. Early diagnosis and treatment are crucial to preserving vision. Thanks to recent advances in diagnostic tools, it is now possible to detect the disease more accurately and at an earlier stage.

Scheimpflug imaging, which captures corneal topography, is considered the gold standard for diagnosing keratoconus. This technique provides detailed information about the corneal shape, thickness, and curvature, enabling more accurate diagnosis. While traditional parameters are still clinically used, new analytical methods based on machine learning are now employed to improve early detection rates. Furthermore, corneal densitometry analysis, estimated from Scheimpflug imaging, is a promising research area for early keratoconus detection.

Thanks to these diagnostic tools, earlier detection of keratoconus has led to improved patient outcomes. In this talk, we will review and discuss the latest research in early keratoconus diagnosis.

Alejandra Consejo *is a researcher specializing in Biomedical Engineering, particularly in the human eye and vision science. She is an assistant professor at the Applied Physics Department at the University of Zaragoza (Spain). She has worked in research institutions in Poland, Belgium and the UK. Her research interests range from early diagnosis of different eye diseases using the support of advanced image processing, statistics, and machine learning to the characterization of the physiology of our eyes and investigating the biocompatibility in contact lens wear. She was awarded as the best PhD graduate in Europe (EYRA, 2017), as Young Research Talent (Tercer Milenio Awards, 2021), and as leader of the best research innovation (Unita Innovation Prize 2022).*



New technologies in visual refraction

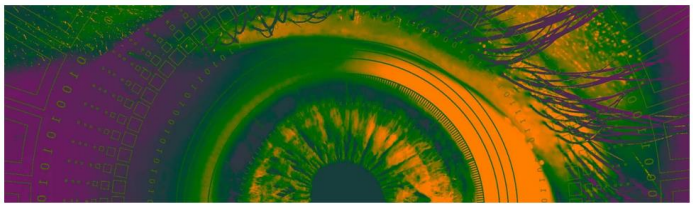
Mikel Aldaba Arévalo

Centro de Desarrollo de Sensores, Instrumentación y Sistemas, Universitat Politècnica de Catalunya (Spain)

The ocular refractive status refers to the locus within the eye conjugate with optical infinity during minimal accommodation, and depending on it, eyes can be classified as emmetropic or ametropic (myopic, hyperopic or astigmatic refractive error). Refraction is the term applied to the technique to determine the refractive status, in order to arrive at the dioptric lens combination that results in maximum visual acuity with minimal accommodation. Uncorrected refractive error is the main cause of visual impairment worldwide, mainly in developing regions because of the lack of eye care professionals, and it is expected to increase further due to the "myopia boom". Automated technology capable of performing accurate refractions could help reduce this problem; moreover, it would also be beneficial in developed countries where cost-effective methods based on new technologies are demanded. To date, none has completely succeeded, mainly for two reasons: (i) the lack of control of accommodation during refraction and (ii) the fact that objective methods do not consider the patient's psychophysical response.

This talk will start introducing the role that refraction plays on research and industry and addressing the question of "Why refractive error is important?". After that, the presentation will follow with a review of basic concepts of ocular refraction such as its definition and measurement, including the state-of-the-art of subjective, objective and automated refraction methods and ophthalmic devices. Finally, some of the new lines of research that have recently shown up will be presented.

Mikel Aldaba *received a BSc in Optics and Optometry in 2003 from the University of Valladolid, Spain, and a BSc in Optometry and Vision Science in 2005 from the University of Minho in Braga, Portugal. Subsequently, he enrolled in the PhD programme in Optical Engineering from the Polytechnic University of Catalonia (UPC), obtaining his degree in 2012 with a thesis on the eye's accommodative response measurement by means of a double-pass system. He has authored 22 peer-reviewed articles, has presented communications in 54 conferences, has published two book chapters and holds three patents. His research is primarily focused in visual optics, where, in the last 15 years, he has been working on different topics such as accommodation, refraction, aberrations, optical quality, intraocular lenses, dry eye, instrumentation and colour vision. Currently he is Tenure Track Lecturer at UPC as Serra Hunter fellow and member of the Spanish Optical Society's Vision comitte board.*



Clinical applications of a visible and near-infrared multispectral camera for reflectance evaluation of eye fundus structures

Meritxell Vilaseca

Centre for Sensors, Instruments and Systems Development (CD6), Universitat Politècnica de Catalunya (UPC) (Spain)

Optical imaging systems for noninvasive fundus diagnosis are crucial to assist ophthalmologists in their daily practice. In particular, high-resolution color fundus cameras are widely used in the clinical setting. However, since they provide RGB images, some retinal structures and substances with different spectral signatures associated with specific ocular diseases may remain undetected due to metamerism or limited spectral range.

In the last years, there have been some attempts to include MultiSpectral Imaging (MSI) technology in fundus cameras, thus combining spectroscopy with imaging technology to provide both spectral and spatial information of retinal landmarks. MSI fundus cameras are expected to improve the capability of identifying the absorption properties of the retina in-vivo, which may be relevant to advance the diagnosis and treatment of many diseases. For instance, they can spotlight degenerated tissue, vascular hemorrhages, drusen, etc., and also build oxygenation maps of the retinal vasculature. Furthermore, if the spectral sensitivity of MSI cameras is not limited to the visible range, they are able to provide information from layers that are commonly hidden in color images. In particular, the use of wavelengths beyond 900 nm, in which radiation can penetrate deeper into the biological tissue, allows the choroid to be observed.

Nevertheless, most of the recently developed fundus cameras that include MSI technology consist of traditional fundus cameras with the original illumination or detection systems replaced, which have low spatial resolution and require spatial scanning, or exhibit slow spectral sampling owing to the use of tunable filters or light-emitting diodes (LEDs). Consequently, the relatively long acquisition time leads to artifacts in the images due to eye movements; to avoid this, they only include few spectral bands. Snapshot MSI posed a solution to this problem, but at the expense of spatial resolution and computational cost. Moreover, most of these systems operate only in the visible range.

In this talk, we will review the results obtained with a newly developed benchtop MSI fundus camera that performs fast imaging of the eye fundus in the VIS and NIR regions (400 to 1300 nm) with high spectral (15 bands) and spatial resolutions, overcoming all the limitations described above[1]. The device is based on CCD and InGaAs sensors, and narrow-band LEDs. Fundus images (Fig. 1) and reflectance curves of structures of healthy and pathological eyes will be shown[2], especially those reflecting in the relatively unexplored range beyond 900 nm, which can potentially be useful for improving the medical diagnosis of certain diseases affecting deeper fundus layers.

Additionally, we are currently working on the development of a portable MSI fundus camera based on a smartphone and the first results obtained will also be discussed.

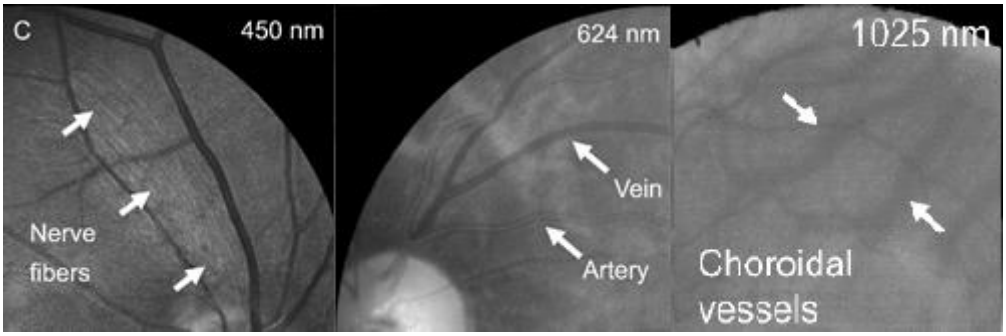
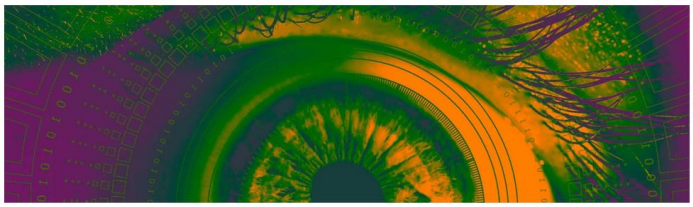


Figure 1: Spectral images of some fundus structures taken at different wavelengths.



ACKNOWLEDGEMENTS: This publication is part of the project PID2020-112527RBI00, funded by MCIN/AEI/10.13039/501100011033.

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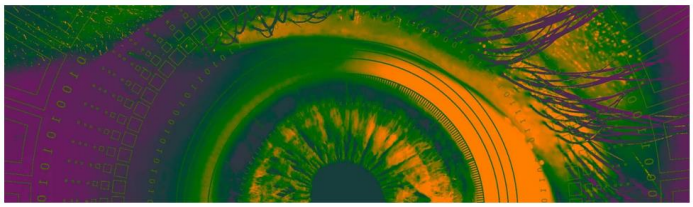
At present, she is the scientific director of the CD6 (since 2019), a member of the TC8-07 Technical Committee of the 8th Division of the CIE (International Commission on Illumination) "Multispectral Imaging", of the European Optical Society (EOS), the Optical Society of America (Optica) and the Spanish Society of Optics (SEDOPTICA).



Alcohol, driving, and visual performance

Miriam Casares López[1], José J. Castro Torres[1], Francesco Martino[1], Sonia Ortiz-Peregrina[1], Pilar Granados-Delgado[1] and Rosario G. Anera[1].

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Introduction: Vision is perhaps the most important perceptual function influencing driving and, thus, visual impairment may alter driving performance[1]. It is known that some psychoactive substances, such as alcohol, have a negative effect on vision. Specifically, driving under the influence of alcohol, a behavior frequently adopted by drivers, is one of the leading causes of road accidents[2,3]. Speed management is an important indicator of how participants adapt their driving speed to compensate for a complex situation[4]. Therefore, the aim of this study was to assess the influence of vision and other factors on speed management under the influence of alcohol.

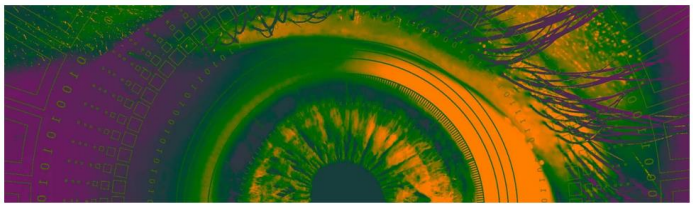
Methods: a total of 31 volunteers (16 females) were enrolled in the study. All participants completed three experimental sessions: a session with no alcohol consumption (baseline), a session after the intake of 300 ml of red wine (Alcohol 1), and a session after 450 ml red wine (Alcohol 2). The Breath alcohol concentration (BrAC) was measured in each session. In the three experimental sessions, vision was assessed by means of the contrast sensitivity and the retinal Straylight (log(S)). Driving performance was evaluated using a fixed-base driving simulator. The speed adaptation was calculated in each scenario as the difference between the driving speed and the speed limit.

Results: Monocular and binocular contrast sensitivity was reduced following alcohol consumption (χ^2=26.50; p<0.001 and χ^2=21.87; p<0.001, respectively). The straylight increased under the influence of alcohol (χ^2=30.06; p<0.001). Such differences were significant when comparing Alcohol 1 and Alcohol 2 conditions. Regarding driving performance, in average, participants drove above the speed limit in the three experimental conditions. Participants drove faster in Alcohol 1 condition compared to baseline. However, in Alcohol 2 condition, participants slower than in baseline conditions (Table 1). The speed management varied in the different scenarios. Factors other than the experimental condition, such as road complexity, driving experience, and the subjective perception of the influence of alcohol on driving performance, influenced speed management. Also, contrast sensitivity showed a significant influence on speed management (t=2.322; p=0.021).

	Baseline	Alcohol 1	Alcohol 2	p-value
BrAC (mg/l)	--	0.18 ± 0.08	0.29 ± 0.11	--
Monocular CS (log)	125.26 ± 18.20	108.80 ± 19.09	102.16 ± 18.87	B-A1: 0.003* B-A2: <0.001** A1-A2: 0.162
Binocular CS (log)	153.42 ± 11.87	140.46 ± 20.83	137.51 ± 21.63	B-A1: 0.013* B-A2: <0.001** A1-A2: 0.547
log(S)	0.87 ± 0.10	0.93 ± 0.14	0.98 ± 0.14	B-A1: 0.005* B-A2: <0.001** A1-A2: 0.229
Speed Adaptation (km/h)	8.80 ± 14.54	9.59 ± 14.44	7.17 ± 14.08	B-A1: 1.000 B-A2: 0.082 A1-A2: 0.007*

Table 1: Mean values ± SD of the BrAC, the speed adaptation in the general route, and the visual variables in the three experimental conditions: baseline (B), Alcohol 1 (A1), and Alcohol 2 (A2). The p-value resulting from the pairwise comparisons are also included.

Conclusions: Visual performance deteriorated following alcohol consumption, particularly for high alcohol



dosages. Speed management was also influenced by alcohol use, in such a way that participants speeded more for low alcohol concentrations, and slowed more for higher alcohol concentrations. Different factors determined the speed selected by drivers, including contrast sensitivity. This indicated that participants with better contrast felt more confident when driving under the influence of alcohol.

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