Institution: Aston University

Unit of Assessment: 3 Allied Professions to Health, Dentistry, Nursing and Pharmacy

Title of case study: Eyoto™ Ltd: an Aston University ophthalmic spin-out.

Period when the underpinning research was undertaken: 2008 to 2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor James Wolffsohn	Lecturer → Professor (2007)	2000 to date
Dr Tom Drew	PhD student Research Fellow → Lecturer	2008-2012 2012-2015
Dr Alec Kingsnorth	PhD student Research Fellow	2011-2014 2014-2015
Dr Mark Dunne	Lecturer → Senior Lecturer	1990-date

Period when the claimed impact occurred: December 2013 to December 2020

Is this case study continued from a case study submitted in 2014? ~~Y~~/N

1. Summary of the impact

Inability to access precise, objective, low-cost diagnostics, poses an acute problem for high quality eye-care, globally. Eyoto™ was spun-out from Aston University in 2015 to commercialise the Wolffsohn group's translational research. Eyoto™ now produces novel instrumentation for use in the ophthalmic industry, and by eye-care practitioners in stores and remotely, via telemedicine.

The following **Impacts on Commerce and the Economy** are claimed:

1. Highly-skilled job creation in the UK
2. Financial growth and international expansion of Eyoto™ Ltd
3. New products - eMAP™ instrumentation for lens manufacturers and dispensing opticians
4. New products - iPad apps, teleoptometry and the eBOX™

2. Underpinning research

Wolffsohn's research interests centre on dry eye/tear film, presbyopia (in lay terms, loss of eye focus with increasing age), the development / evaluation of optical instrumentation and creation of apps to provide objective, detailed assessments of eyesight. This expertise forms the basis of Wolffsohn's commercial exploitation.

Digital imaging system and bespoke image analysis to map lens power: Wolffsohn first described his novel approach to dynamic, highly sensitive (1000 times more accurate) optical power measurement of the human lens in 2001, using a substantially modified autorefractor. This imaged and analysed an illuminated ring pattern (**S3.1**). In brief, the autorefractor's video output was hacked so that the illuminated pattern imaged through the lens could be processed using a bespoke algorithm developed by Wolffsohn. The power of the lens is directly proportional to the image distortion, allowing the power to be mapped. A subsequent study modified the process to image an illuminated line grid (**S3.2**), which would ultimately form the basis of Eyoto's eMap system. Subsequently, Wolffsohn's PhD student, Drew, combined high-speed live digital video with high-resolution optical coherence tomography (OCT) in the first description of such instrumentation. (OCT is a non-invasive technique that images the eye in cross-section, using low coherence light as the penetrating wave.) Clinical application was demonstrated by measuring the indentation of the ocular epithelium as a function of contact lens edge profile and shape (**S3.3**). By combining features of each of these developments (**S3.1-3.3**), created a system that could combine power mapping with detailed profiling of an ophthalmic lens.

Sight testing with novel apps: Eye examinations typically occur in person. Patients read letters that become progressively smaller from a wall chart and optometrists then score the patient's visual ability according to the last line read accurately and the fraction of letters identified correctly on the following line. Further informative tests of functional vision such as reading speed and contrast sensitivity are rarely used in the clinical setting due to cost issues (time and materials) and the complexity/subjectivity of data interpretation. Wolffsohn, Kingsnorth and Drew addressed this issue by creating visual presentation and objective analysis software (apps) to measure reading speed (**S3.4**), contrast sensitivity (**S3.5**) and glare (**S3.6**). Designed for use on iPads or tablets, these apps additionally gather information on working distance, tilt, head orientation and blinking using the tablets in-built sensors to better assess human adaptation to refractive corrections. Clinical testing of their apps has confirmed greater sensitivity and reproducibility when compared with traditional assessments, alongside significant reductions in the times taken for testing. Analysis is near instant, being an in-built feature of each app (**S3.4-3.6**) and specialist training is no longer required to run such tests.

3. References to the research

S3.1 **Wolffsohn, J.S.,** Gilmartin, B., Mallen, E A. H. & Tsujimura, S. (2001). Continuous recording of accommodation and pupil size using the Shin-Nippon SRW-5000 autorefractor. *Ophthal. Physiol. Opt.* **21**, 108-113. https://doi.org/10.1046/j.1475-1313.2001.00586.x.

S3.2 **Wolffsohn, J.S.,** O'Donnell, C.O., Charman, W.N., & Gilmartin, B. (2004). Simultaneous continuous recording of accommodation and pupil size using the modified Shin-Nippon SRW-5000 autorefractor. *Ophthal. and Physiolog. Opt.* **24**, 142-147. https://doi.org/10.1111/j.1475-1313.2004.00186.x.

S3.3 **Wolffsohn, J.S.**, **Drew,T.**, Dhallu,S., Sheppard, A., Hofmann, G.J. & Prince, M. (2013). Impact of soft contact lens edge design and midperipheral lens shape on the epithelium and its indentation with lens mobility. *Invest. Ophthalmol. Vis. Sci.* **54**, 6190-6196. https://doi.org/10.1167/iovs.13-12425.

S3.4 **Kingsnorth, A.** & **Wolffsohn, J.S.** (2015). Mobile app reading speed test. *Brit. J. Ophthalmol.* **99**, 536-539. https://doi.org/10.1136/bjophthalmol-2014-305818.

S3.5 **Kingsnorth, A.**, **Drew, T.**, Grewal, B. & **Wolffsohn, J.S.** (2016) Mobile app Aston contrast sensitivity test. *Clin. Exp. Optom.* **99**, 350–355. https://doi.org/10.1111/cxo.12362.

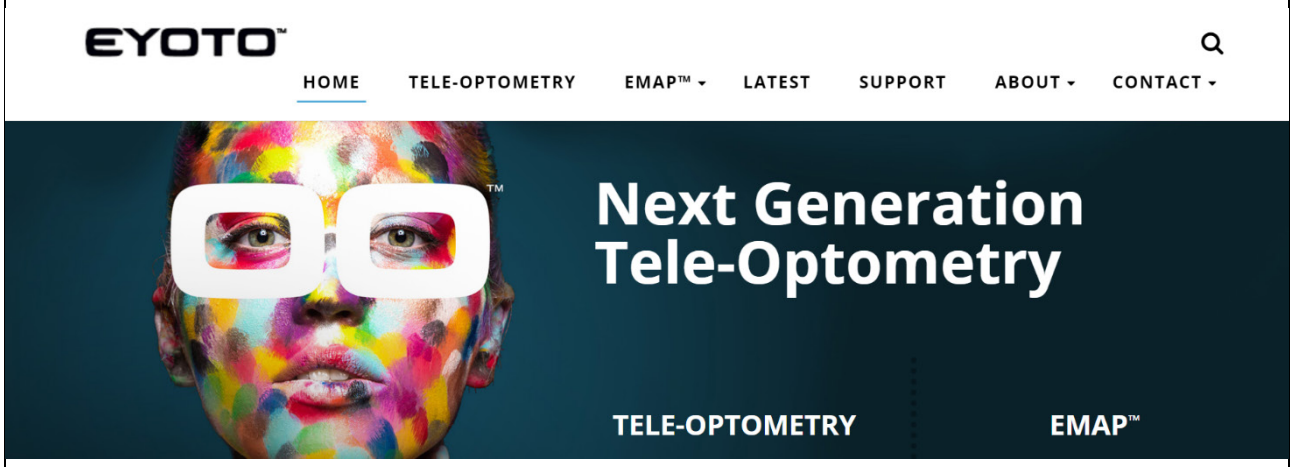
S3.6 Buckhurst, P.J., Naroo, S.A., Davies, L.N., Shah, S., Buckhurst, H., **Kingsnorth, A.**, **Drew, T.** & **Wolffsohn J.S.** (2015). Tablet app Aston halometer for the assessment of dysphotopsia. *J. Cataract Refract. Surg.* **41**, 2424-2429. https://doi.org/10.1016/j.jcrs.2015.05.041.

The quality of the research described above is evidenced by **S3.1-S3.6**, published in international, peer-reviewed journals and the following competitively-awarded RCUK and industrial research grants: **EPSRC / Birmingham Optical Group EP/G501181/1 £85,789,** Development of low cost advanced technology equipment to enhance the provision of community eye care and develop UK ophthalmic manufacturing (2008-2011); **Innovate UK Ref131754 £149,998**, Integrated optical and geometric imaging to allow real-time ophthalmic medical device validation and clinical assessment (2014-2015); **Johnson & Johnson Vision Care Inc. (USA) $296,250** Enhancing contact lens edge design through high resolution OCT and high speed photography (2009-2011); **Bausch & Lomb Inc. (USA) £88,303**, Toric intraocular lens imaging (2009-2011); **Rayner Intraocular Lenses Ltd. £54,150**, Assessment of visual function and optics of intraocular lenses (2015-16); **Allegan Sales LLC (USA) $91,750**, Validation of visual function assessment while using a tablet or smartphone (2017-19); **Alcon Eyecare UK Ltd. £57,082**, Multifocal visual performance study – seamless transition with precision profile MF lenses (2018-19).

4. Details of the impact

Ophthalmic industry instrumentation is typically expensive, manufactured in low volume and is mostly used subjectively by highly-qualified opticians, optometrists and ophthalmologists. In 2008, Wolffsohn conceived the benefits of creating ophthalmic instrumentation that would enhance analytical objectivity and allow high quality eye-care to be provided where skilled professionals are unavailable. Since no suitable commercial outlet was available, Wolffsohn, ex-PhD student Drew and Dunne incorporated Aston Eyetech Ltd. in December 2013 (**S5.1**). Launched in 2014, Aston Eyetech spun out of Aston University into the Aston Science Park and began formal trading in 2015, with a direct pipeline agreement to the Wolffsohn groups' intellectual property (**S5.2**).

In 2019, market research determined that more disruptive branding was needed and accordingly, Aston Eyetech was renamed Eyoto™ Ltd. (**S5.3**). A formal branding/marketing campaign soon followed:



From the launch and continuing expansion of Eyoto™ and the research detailed above (**S3.1-3.6**) we claim the following impacts on commerce and the economy:

Commercial Impact 1 - Highly-skilled job creation in the UK: Launching with just 2 employees in 2014, as of Nov-2020, Eyoto now employs more than 30 highly-skilled staff in fields including ophthalmic engineering, image processing, software engineering and manufacturing (**S5.4**).

Commercial Impact 2 - Financial growth and international expansion of Eyoto™ Ltd: Initial seed funding from 2014 onwards enabled Eyoto™ to develop a suite of refraction hardware, associated software and iPad apps with artificial intelligence-driven diagnostic algorithms. This was followed by Series A investment of [text removed for publication] in 2017 (**S5.5**) and incorporation of a US subsidiary, Eyoto Inc., in 2018 (**S5.4**). As of Nov-2020, Eyoto™'s venture capital funding now totals [text removed for publication] and sales have exceeded [text removed for publication], with a current order book in excess of [text removed for publication] (**S5.4**).

Commercial Impact 3 - New products - eMAP™ instrumentation for lens manufacturers and opticians: Wolffsohn, Drew and Dunne had planned to start trading by developing and marketing the apps for visual function tests (**S3.4-3.6**) but in 2014-15, the market was more interested in instrumentation for quality control of spectacle lens production. **S3.1-3.3** describe the concepts behind such instrumentation and so Eyoto™ initially developed that research into their first suite of commercial products (**S5.6**). [text removed for publication].

Ophthalmic lenses may be spherical (correction of shortsightedness), toric (correction of astigmatism), complex (varifocal lenses) or customized (e.g. for eye disease). Verification and quality control, particularly of complex designs, was challenging when using previous methodologies and counterfeiting was difficult to detect. Using the Wolffsohn group's research and Eyoto's patent, (**S3.1-3.3 & S5.6**), Eyoto developed eMAP™ for QA products: eMAP^{C1} for detection of lens defects early in the manufacturing process and eMAP^{C2} for final lens inspection

(**S5.7**). Realising that there would similarly be benefit in demonstrating lens quality to patients both of different grades of new lenses and even their own spectacles, Eyoto also developed the eMAP™ for retail (**S5.7**) for use in opticians' premises. Each of these instruments, as originally envisaged by Wolffsohn and colleagues, generates a power map, which shows how light is magnified and/or distorted by various regions of the lens. Such power maps can readily be used to explain to customers why their current spectacles might not assist them as needed and also to help them choose the most suitable new lenses/frames that will best correct their eyesight (**S5.8**).

Commercial Impact 4 - New products – refined iPad apps, teleoptometry and the eBOX™: The Eyoto founders' original vision is now coming to the fore. As declared in publications **S3.4-3.6**, Eyoto licensed the iPad apps from Aston early in the company's development. These apps automate complex visual tests. For example, in the reading speed test, the iPAD (or tablet) camera charts eye movement whilst its microphone precisely times the audible reading. iPads and tablets are highly portable devices that can function without access to mains power. Eyoto's latest products – equipment for remote and mobile eye examinations respectively (teleoptometry and the eBOX™; **S5.9**) can be used both in the UK and abroad. Eyoto envisage that ultimately, their teleoptometry could give access to eyecare for the estimated 1/3rd of the world's population who currently have no such opportunity (**S5.9**). Meanwhile, Wolffsohn and colleagues have recently invented a digital slit lamp that can be controlled remotely by a specialist (**S5.10**), which in combination with the apps, form the basis of Eyoto's latest product - the mobile eBOX™ (**S5.9**).

In conclusion, the CEO of Eyoto summarises Wolffsohn's ongoing contribution by stating: "*We are proud of our history with Aston University on whose research the company is built, and place an extremely high value on our relationship with Professor James Wolffsohn*" (**S5.5**).

5. Sources to corroborate the impact

S5.1 Aston Eyetech certificate of incorporation

S5.2 Aston University-Aston Eyetech pipeline agreement

S5.3 Aston Eyetech-Eyoto certificate of name change

S5.4 Confidential letter from the CEO of Eyoto™ Ltd.

S5.5 [Text removed for publication]

S5.6 Patent application WO 2018/073576 A2. **Drew,T.,** Krawcznski, M. Joshi, O. Davies, J. Sudera, S. & Dean, J. Lens examination equipment and method. https://patentimages.storage.googleapis.com/0a/b9/a1/373139824682d4/WO2018073576A2.pdf.

S5.7 Eyoto eMAP brochures: https://www.eyoto.com/_userfiles/pages/files/emap_for_qa_brochure_janury_2020.pdf and https://www.eyoto.com/_userfiles/pages/files/emap_for_retail_brochure_jan2020_version_1.pdf.

S5.8 Eyoto article on power maps: https://www.eyoto.com/latest/34/the_significance_of_power_maps_the_opticians_perspective.

S5.9 Eyoto articles on teleoptometry https://www.eyoto.com/tele-optometry.aspx and prior notification of the eBOX™ launch https://www.eyoto.com/products/ebox.aspx.

S5.10 Patent application WO2019/001928 A1. **Wolffsohn, J.S.,** Tulloch, A., Obzanski, K. & **Drew, T.** Ophthalmological apparatus.

https://patentimages.storage.googleapis.com/29/1a/94/e882c68775eb59/WO2019001928A1.pdf.