

Foresight Project Report

A discussion of the potential impact of
technology on the UK optical sector to 2030



Full Report

Commissioned by The Optical Confederation
& The College of Optometrists

Principally funded by The Central Optical Fund

Report by 2020health
March 2016

2020health
MAKING HEALTH PERSONAL

Published by the Optical Confederation and the College of Optometrists.
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Authors' disclaimer

Throughout the Foresight Project Report we have necessarily cited technologies, manufacturers, providers and institutions to convey either general or specific activity within optics and speculate on future developments. These references are not intended as promotion or endorsement, or to suggest the greater value of such over unnamed competition.

This research was supported by the Optical Confederation and the College of Optometrists. The authors had final editorial control of the report, and views expressed within do not necessarily reflect those of the report commissioners. All facts have been crosschecked for accuracy in so far as possible.

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Chairman's Foreword



Alan Tinger FCA, CCMi
Chairman, Foresight Project
March 2016

It has been said that the only way to predict the future is to have power to shape it. Likewise it is often said that knowledge is power. Putting the two together, does it mean that we can predict the future if we have the knowledge? That may well be so in theory but it is a pipedream in reality, in a fast moving world where the science fiction of one generation is the daily life of the next.

The purpose of the Foresight Project is to ensure that the optical sector is better equipped to understand as much as it can where technology, ocular medical developments and demographics are leading to in the years ahead. With that knowledge it should inform debate as to how the sector can help shape and adapt to the challenges and opportunities.

When I proposed the project to colleagues on the Optical Confederation Leaders Group back in 2012 they agreed that if funding could be obtained for a sizeable share of the budget, the members of the Optical Confederation and the College of Optometrists would together fund the balance.

I cannot praise highly enough the support of the Directors of the Central Optical Fund (www.centrafund.org.uk) who agreed to the Fund providing 60% of the budget, which allowed the project to go forward. It was a significant grant for the Fund and the time and trouble their Trustees took to understand the benefit of the project for the sector is typical of the terrific work they do to finance worthwhile projects for the sector that simply would not get off the ground without their support. I encourage all readers of the Foresight Project report to consider donating to the Fund.

The members of the Optical Confederation (OC):

Association of British Dispensing Opticians (ABDO)

Association of Contact Lens Manufacturers (ACLM)

Association of Optometrists (AOP)

Federation of Manufacturing Opticians (FMO)

Federation of (Ophthalmic & Dispensing) Opticians (FODO)

OC members along with the College of Optometrists (COptom) have worked together as never before in the best interests of the whole sector. Underlying the thinking is the desire to ensure that we are not going to be training students for roles that will no longer exist in the same way in the future or continuing with business models that have worked well in the past but cannot continue forever in a global economy driven by technological innovation and demographic change.

As well as the funding, key to the project was how we would undertake the research. Having listened by chance to Julia Manning speaking about eye health during a television debate I quickly found out that she had trained and practised as an optometrist in her early career prior to setting up the 2020Health think tank. When colleagues and I agreed to commission 2020Health to undertake the research we had no idea what an inspired choice it would be. I can only describe their work as outstanding both in terms of inputs and, more importantly, outputs and outcomes. 2020Health's principal researcher on the project, Jon Paxman, together with Julia Manning (CEO) and Alex Blacknell (Research Manager) have been a pleasure to work with.

Neither could the research have been undertaken without the agreement of so many people from within and outside the sector to contribute, be interviewed and to speak frankly on their subject. I thank you all for your contributions to making the Foresight Project possible.

To support the research the project had to be managed and directed to ensure that it was completed on time, within budget and correctly focused. As well as the time I spent with 2020Health, this was achieved through a Steering Group and also an Oversight Group that both met quarterly, comprising:

Alan Tinger (Chairman)*
Henrietta Alderman (CEO, AOP)*
Simon Rodwell (CEO, ACLM)*
Sir Anthony Garrett (CEO, ABDO)
David Hewlett (CEO, FODO)
Ian Humphreys (CEO, COptom)
Chris Hunt (Chairman, OC)
Bryony Pawinska (CEO, FMO)

*Members of the Steering Group.

I thank all colleagues for their participation in all our many debates on the project and for their wisdom, understanding and guidance. I also thank Don Grocott (former Chairman of the OC) and Kevin Gutsell (former CEO of FMO) who were both involved in the early stages of the project. Indeed it was Don who came up with the title, Foresight Project.

The Foresight Project report is only the start. It can only move from being a document of interest to be of serious benefit if it is widely read and debated by all parts of the sector including educators, regulators and beyond with a view to the future. What it will lead to is for readers and debaters to work on but I go back to where I started this Foreword – knowledge is power. Here are both.

About the Foresight Project Report



Julia Manning
Chief Executive, 2020health
March 2016

2020health is delighted to have been commissioned to undertake this research into the trends, influence and considerations of technology on practice, behaviours, education and regulation within the optical sector.

No profession will be untouched by new technologies; many have seen the workplace transformed already through the automation of process and procedures. The health professions need to consider the impact that technology is having on public access to information, diagnostics, understanding and behaviour. It presents an unprecedented opportunity to upskill and signpost the public, for people to actively participate in their health and wellbeing and enable professionals to deal with health needs that truly require their specialist skills. New technologies mean that with the guidance of eye health professionals, prevention, promotion and treatment can be embedded in the local community. But this needs to be prepared for, planned and managed in order to harness the potential and create long-term affordable and sustainable services.

We sincerely hope the Foresight Project Report will form the foundation of planning for the sector for the next 10–15 years so it can adapt and thrive. As a former optometrist, producing this research has given me immense personal satisfaction and pride in the public health role of the optical sector.

During the course of this work we benefited from interviews, discussions and envisioning sessions with many of those in the sector, in practice, in related research, in supporting roles and education. We are hugely grateful to them for their time.

We are indebted to the Optical Confederation and the College of Optometrists who enabled this research to be undertaken, and to all our sponsors. As well as driving our on-going work of 'Making Health Personal', sponsorship enables us to involve frontline professionals and the public in policy ideas and development, and to communicate with and involve officials and policymakers in the work that we do. Involvement in the work of 2020health is never conditional on being a sponsor.

Profiles

Project Chairman

Alan Tinger

Alan Tinger is a Chartered Accountant and a Companion of the Chartered Management Institute. He is Chairman of the Local Optical Committee Support Unit (LOCSU), a Director of, and Consultant to, the Federation of (Ophthalmic & Dispensing) Opticians (FODO), and a member of the Optical Confederation Leaders' Group. Alan was formerly a Financial Consultant to the General Optical Council, Managing Director and Part-Owner of Galaxy Optical Services (to whom Tesco PLC outsource the main supply and support functions of Tesco Opticians), and Finance Director of Miller & Santhouse PLC. He is also a Trustee, Treasurer and Chair of the Audit Committee and of the Investment Committee of the Royal National Institute of Blind People (RNIB Group), a Trustee of Action for Blind People and Chairman of a Registered Housing Association.

Report authors

Julia Manning

Julia Manning is a social entrepreneur, writer and campaigner. She is the founder and Chief Executive of 2020health, an independent, social enterprise Think Tank whose aim is to "Make Health Personal". This means giving people the information, understanding and confidence to take a meaningful role in their health and wellbeing, and creating the conditions for a healthy society. Campaigns that have emanated from 2020health's research include for a Head of Wellbeing for schools; the right to have a Personal Health Budget and control over our Personal Health Records; for a cross-departmental government task force to tackle obesity, and the 'Health Tech and You Awards', a digital health promotion partnership with Axa PPP and the Design Museum. Julia originally studied visual science at City University, created a digitally enabled home-visiting optometry practice in 2004 and formed 2020health in 2006. She is a Research Associate at UCL in Medical Anthropology, and a Fellow of the RSA.

Jon Paxman

Jon is a senior researcher with 2020health. He has contributed to several Health IT reports, including 'Making Connections', supporting a digital learning exchange between the US Veterans Health Administration and UK NHS in 2013. As lead researcher he has explored ways of improving access and outcomes within specific areas of primary care, with publications including 'Personal Health Budgets: A Revolution in Personalisation'; 'Protecting the Nation: Every Child Matters' (examining childhood immunisation); and 'Whole in One: Achieving equality of status, access and resources for people with depression'.

Alex Blacknell

Alex is a qualified solicitor with experience in private practice. For the last seven years she has worked as an adjudicator for a statutory complaints handling body, analysing documentary evidence and drafting written adjudication decisions on issues including fitness to practice, disability and racial discrimination. She has also had articles published in a number of professional periodicals. Alex began work with 2020health in 2014, conducting workshops in schools as part of the research for the Fit for Schools report. She now oversees the report writing process.

Matt James

Matt has a wide ranging portfolio of expertise spanning public policy, academia and third sector. He has convened numerous public symposia that have brought together key stakeholders to discuss the ethical, social and legal implications of new technologies. Matt has written widely on these issues and participated in several EU funded projects exploring public responses to new technologies. Matt has a degree in political history and sociology, and a Master's degree in bioethics and medical law. He was recently elected a Fellow of the Royal Society of Arts and Commerce (FRSA).

Foresight Project Report

Executive summary

Exponential growth of digital technology and fast-evolving demographics are altering the expectations and habits of consumers, businesses and NHS service providers. The pace of change is almost overwhelming, with automation of professional testing and measurement, DIY-health opportunities for the public, vast online resources and services, and the emancipation of research information. And yet, many of the practices and models of the optical professions have remained largely unchanged for decades. In the words of John F. Kennedy, “Change is the law of life. And those who look only to the past or present are certain to miss the future.”

Future landscape

To inform the 15-year view for optics it is important to recognise what an ageing population means for society and services. In the UK, the proportion of persons aged 65 and over increased from 15% in 1985 to 17% in 2010 (ONS, 2012); by 2030 it is projected that those aged 65+ will account for 22% of the total population. In terms of individuals, 2010–30 projections suggest a 50% rise in people aged 65+ and 100% more aged 85+ (ONS 2010, 2015). The average cost of providing hospital and community health services for a person aged 85+ is around three times greater than for a person aged 65 to 74 years (Cracknell, 2010).

Population changes will have a profound impact on the demand for optical services and products. An ageing population brings with it multiple forms of eye disease and related health concerns, while rising obesity levels will lead to more diabetes-related eye problems. Increasing myopia levels in children also need to be addressed.

NHS expenditure on eye health services has nearly doubled within the last ten years (to £2.3bn) and hospital attendances for ophthalmology represent the second highest number of outpatient attendance for any specialty. Much of the costs of eye care are found in the treatment of disease.

Progress has been made with slowing progression of glaucoma, ‘wet’ age-related macular degeneration (AMD) and diabetic retinopathy. However within the timeframe under review it is unlikely that biomedical technologies will advance to the point where the prevalence of eye disease is reduced,¹ particularly in the absence of a transformational treatment for the leading cause of sight-loss in the UK, dry AMD. Even with new abilities to treat disease, greater demand and costs can result. On balance, the 15-year view is one of spiraling NHS spend and significantly more demand on Hospital Eye Services (HES).

“...the 15-year view is one of spiraling NHS spend and significantly more demand on Hospital Eye Services.”

The future of NHS commissioning is difficult to predict, with new delivery models currently being trialed by NHS ‘vanguard’ sites; but due to already stretched HES, and in the drive to deliver more care in the community, the NHS is likely to be commissioning more community eye care services from optometrists in the 2020s. Much of this requires the optometrist to work at the very top of their skillset and undergo regular re-accreditation

¹ Potential breakthroughs during our timeframe include a vaccine for type 1 diabetes, although only around 10% of people with diabetes have this type (90% have type 2). The early vaccines will most likely delay onset and perhaps enable patients to continue making small amounts of their own insulin after onset (DiabetesUK, 2013).

(or 'revalidation'). Some services will call on the upskilled optometrist, while other services might see wider collaboration as optometrists and dispensing opticians (DOs) become active participants in multidisciplinary teams. Upskilling and new shared care opportunities may enable optometrists to become better recognised as ocular health experts in the community. At the same time, salaried NHS opportunities will increase for the optometrist both in the acute setting and community-based services, working alongside ophthalmologists and delivering cost-effective wrap-around care.

Evolving professional roles and the impact of population ageing will combine with technological disruption, itself subject to emerging behavioural trends alongside social and commercial expediency.

Business

Technological advances in communication provide huge opportunities for business to reach out to and educate patients and customers. Patients will be encouraged to become more active in their care – 'participations' – through educational resources, content marketing, real time online booking and patient portals. The increased level of information available to patients about their own health (e.g. Electronic Health Records) and about eye health generally (from the Internet and commercial marketing) will see the 'uberisation'² of eye health and new expectations of service provision. The routine use in eye exams of certain diagnostic tests and equipment currently seen as specialist (e.g. optical coherence tomography, OCT) will be expected and demanded by increasingly empowered and knowledgeable patients.

A collaborative professional-patient relationship will also be encouraged by technologies such as app-based disease monitoring, smartphone solutions for low vision, and 'smart' clinical contact-lenses (e.g. glaucoma pressure (IOP) monitoring and glucose

monitoring). Some of these technologies shift the responsibility of care further into the domain of the patient, though with the essential support of the professional, who interprets data, educates, signposts and reassures.

The retail side of optics, the provider's most essential source of income, will continue to feel the effects of the ever growing online marketplace, with direct to consumer contact lenses, frames and glazing, virtual try-on (with real-time social media connectivity), bespoke 3D printing, eye-health screening and both online and app-based refraction. 'Generation rent' and cash-strapped first-time buyers, in particular, will be attracted by cheap and immediate solutions provided in the digital marketplace. This in turn will provoke new marketing and business strategies from high street providers, with a stronger focus on eye health, loyalty schemes and their own, augmented online services. Opportunities will exist for practices to develop new trade in the recreation, fashion, workplace and gaming markets, particularly with the development of smart and augmented reality glasses.

Developments in treatment and correction will provide both new and niche opportunities for community practitioners, extending from smart accommodating contact lenses for presbyopes to early intervention technologies on a range of conditions, perhaps including daily-wear contact lenses to stem myopia progression and gaming technology for amblyopia correction. The negative effect of technology on eye health (e.g. excessive screen-time, reduced time spent outside) may lead to further demands placed upon the eye care professional. Improved diagnostic technology will likely enable rapid objective tests to detect early stage eye disease, including glaucoma and AMD. The optometrist of the future may also undertake 'pre-diabetes' testing, and even provide NHS support with OCT in the early detection of neurological conditions.

² The use of technology to circumvent bureaucracy and legislation, leading to 'disruption' in the interests of productivity and efficiency.

Against a backdrop of further acquisitions and mergers, the independent practice will need to consider niche offerings to survive against the purchasing power of the multiples. They will attempt to capture a powerful share of the 'grey pound', the (50+) generations with the greatest disposable income and leisure time. Some struggling independents will join the independent joint venture model. The specialised multiples, like many independents, will increase their emphasis on eye health to help distinguish their offering from online providers and supermarkets, whose growth in areas of both eyewear and eye care is expected to be aggressive. For domiciliary practices, demographic changes together with advances in portable equipment will provide opportunities to expand services, and also collaborate with others to develop alternative delivery models.

"The very methods of manufacturing are set to be revolutionised by 3D printing, in turn bringing about the normalisation of made-to-measure frames, the consumer as co-creator, and the increase of direct-to-consumer marketing."

Technological advances will also alter business conditions for manufacturers, who will see a yet more competitive industry, with venture capitalists and crowd funding initiatives launching start-up and university-researched technologies. We are seeing the birth of an era in low-cost testing and diagnostic technologies (many smartphone based) aimed at non-traditional providers, even patients themselves, as well as novel assistive technologies for a growing low-vision market. And in eyewear itself, the very methods of manufacturing are set to be revolutionised by 3D printing (additive manufacturing), in turn bringing about the normalisation of made-to-measure frames, the consumer as co-creator, and the increase of direct-to-consumer marketing.

Education & Regulation

Just as businesses need to evolve their offering, so educators need to respond to disruption, in all its forms. Universities, currently supporting further clinical opportunities through post-graduate qualifications for optometrists, will need to re-evaluate their undergraduate optometry programmes. Together with clinicians and regulators they will reconsider the necessary scope of traditional background subjects (e.g. ophthalmic lens theory, history of optics, mathematics), as well as spectacle dispensing competencies; at the same time they will consider expanding patient contact time (real or virtual), introducing students to multi-disciplinary team working, and teaching on therapeutic prescribing. Growth opportunities in contact lenses will see more market pressure on universities to raise contact lens education levels of students. And before the 2020s, educators will need to recognise a new generation of phoropterless refracting technologies, both in and beyond the high street.

Dispensing opticians (DOs), much more exposed to the occupational threats of automation, should see a curriculum with wider emphasis on cutting-edge technologies, paediatrics, low vision and contact lenses. Teaching will need to embrace digital dispensing, and may even in time extend into areas of orthoptics. Educators will need to instill, in younger DOs especially, stronger communication and soft skills and a deep-rooted desire for Continuing Professional Development (CPD) well beyond Continuing Education and Training (CET) minimum requirements.

"Educators will need to instill in young DOs stronger communication skills and a deep-rooted desire for CPD well beyond CET minimum requirements."

As the population ages, clinical services increase, and extended chair time reduces practice profits, DOs may push ever harder for refracting rights. These conditions may synchronise with new refracting technologies, notably improved autorefraction, automated subjective refraction and even patient-led refraction, to favour an option of fully delegated refraction.

The full delegation of refracting responsibility would require changes to regulation. Regulators and policy makers have an ever harder task to keep track of technological developments: discerning what is, and what is not, in the public interest; what represents risk, and what represents consumer right. The regulators need to be concerned about online businesses that prioritise trade opportunity above health considerations. They need to warn the public of the risk of choosing self-refraction over a full eye health exam. They can 'kite-mark' online companies operating according to UK regulation, but they cannot regulate sales and services delivered from abroad. Limitations and loopholes are not reasons to deregulate, however. Policy makers will not easily relinquish what is considered best practice in public protection and disease prevention.

The great challenge for the setters of regulation and standards is to keep abreast of technology so that (potentially) outdated operating frameworks and criteria do not restrict safe affordable care, public access, and the business viability of providers that the NHS depends upon.

All change by 2030?

Patient-led eye-testing and screening, followed by practitioner interpretation and validation, will become a reality during the 2020s: the question is, from where or in what will this be delivered? Smartphone-based, patient-operated refraction with voice-prompt is set to be available in the UK from 2016. Patient-operated, handheld OCT and acuity testing is in development in the UK and could be market ready by 2020. User-friendly, smartphone-based fundus imaging and testing modules have already created solutions one fiftieth

the price of some standard office-based equipment. The quality and reliability of new technology takes time to assess, of course, but the evolution of cheaper micro-technology holds significance not just for mobile eye services and personal use, but also for new delivery models entirely. It points to a future where automated, telehealth-enabled sight testing could be available via health kiosks in large general practices, pharmacy stores and elsewhere, for 'low-risk' adults at least. The place of sight tests does not have to remain within traditional optical practice. And we may by this time be printing our own frames, even simple lenses, with home technology. If so, online suppliers may begin to doubt even *their* future.

Conclusion

There are no guarantees of who will be delivering what, and where, by 2030. But unless professionals and businesses adapt with the times, they risk becoming unviable. Arguably the optical sector, with its deep dependency on retail, will be the health sector to feel it first. Call it the second-machine age or our modern Gutenberg moment: many medical monopolies that have enjoyed supremacy for (quite literally) hundreds of years have now to work out how to evolve their offering, or be dismantled from the outside in.

"The optical practice will need to give the public stronger reasons to enter its premises in the future."

The optical practice, in whatever form, will need to give the public stronger reasons to enter its premises in the future. The impending fundamental and irreversible changes within the optical sector are many, but so are the opportunities to embrace them and move forward. Those who become agile, value relationships, learn how to harness the public's interest and share expertise, will be the ones who flourish.

Foresight Project:

Background

i) About the Foresight Project

The Foresight Project ran for the twelve months of 2015. It was jointly funded by the Central Optical Fund, the Optical Confederation (comprising the five main representative bodies in the UK optical sector) and the College of Optometrists. The project objective was to look at the potential future impact of technology on the optical sector by considering evolving and novel, even conceptual, technologies, and scoping out implications for stakeholders.

By highlighting potential disruption and directions of travel across business, education and regulation, this report aims to create awareness and encourage readiness for future developments.

ii) Research and methodology

The Foresight Project drew from five principal information streams. The first was published literature and opinion, for the most part involving world-wide online searches within the optical press, medical journals and media reports. The second stream was interviews: 91 in total, mostly one-to-one with experts and stakeholders, with an average duration of around 50 minutes. Interviews spanned business, IT, manufacturing, start-ups, commissioning, policy advice, representative bodies within the optical sector, ophthalmic dispensing, optometry, ophthalmology, scientific research, university education and CPD, and regulation. Predominantly UK focused, our interviews also engaged experts from the USA, Canada, Switzerland and Germany within the fields of research, education, start-ups and industry.

A third stream of information came from our attendance at optical events and presentations, and a fourth from discussions with exhibitors (predominantly manufacturers and distributors) at two optical fairs: 100% Optical (London) and Optrafair (Birmingham). A fifth stream was discussion and envisioning sessions between 2020health and the College of Optometrists (2), the GOC (1), and a range of experts from within and beyond the optical profession at a Foresight Workshop held at the AOP offices (1).

To bring oversight and scrutiny to our methodology we met regularly with a Steering Group, with senior representation from the Local Optical Committee Support Unit (LOCSU), Association of Contact Lens Manufacturers (ACLM) and Association of Optometrists (AOP). Four further meetings were held with a wider Oversight Group, comprising senior figures from LOCSU, the Optical Confederation and College of Optometrists (See Appendix B). These groups also provided suggestions for interviews and participants, in addition to those sought directly by the report authors. 2020health also organised feedback on early report drafts from an external reading panel comprising experts in ophthalmology, nursing, general practice, biomedical science and medical anthropology.

Foresight Project Report Part 1:

The landscape to 2030

1. INTRODUCTION

We are living in profoundly disruptive times. Digital technological innovations birthed, developed and miniaturised in the 20th century have metamorphosed into 21st century familiar essentials that have so rapidly permeated our every-day lives we have barely been given time for reflection. We find ourselves in what has already been coined 'The second industrial age' (Brynjolfsson, 2014), with the smartphone the 'Gutenberg (press) of healthcare' (Topol, 2015), such are the immense anticipated repercussions of digitisation. As Niels Bohr remarked, "Prediction is very difficult, especially if it's about the future"; but without taking time to reflect on the effects of digital technologies on society, professions and cultures, a lack of understanding will hamper any attempt to plan, prepare, protect or exploit either individually, locally, nationally or internationally, the 'connected' age in which we now find ourselves.

Others elsewhere have started to think about the wider effects of 'digital', and the new discipline of digital anthropology has begun to emerge. It makes little sense to examine areas of impact in narrow isolation because the very nature of digital connectedness causes a convergence of fields of study with wide repercussions. In the arena of health, where costs, demand and expectations are all rising unsustainably, and where digital technology facilitates radical opportunities for information, education, prevention and participation ('participations'), it is vital that we do all we can to consider the impact on a sector as a whole.

The world of optics is no exception to the digital innovation movement. Recent years have brought automated refractors, deep level analytics of the OCT, iPhone ophthalmoscopes, clear-lens extraction, free-form lenses, online purchasing of corrective eyewear, online refraction and market dominance of the 'multiples'. In line with healthcare generally, technology is raising quality, capability and speed in optics, though making the delivery of eye care more expensive. With an ageing society, age-related eye problems are set to rise, indicating increased costs

to the NHS and putting extra pressure on already strained hospital-based services.

Ophthalmic technology will drive behaviour change amongst professionals, the public, manufacturers and businesses, and could contribute positively to the much needed transformation of the UK's (unsustainable) model of labour intensive eye care service delivery. This study is designed to elicit as much information as possible within the given time-frame to inform planning and decision making across the wide spectrum of players in the field of optics. What is certain is that greater agility will be required, and it will be systems, providers and personnel who can adapt to the drivers of change, the emerging models of health and the needs of the public, who will survive.

As background to this work we give some context for the digital age and the NHS response, and consider more generally what technology could mean for behavioural change.

1.1 The digital age

The digital age in which we live is making more data available to more people, at greater speed and in deeper detail, than ever before. Ninety per cent of existing digital data was created in the past two years: the digital 'big bang' has occurred without most people realising, although many have already sensed the 'information overload' feeling! Data, including patient generated data, is only going to increase, so it is incredibly important that we consider how we manage and exploit it to our advantage.

The increase in data was predicted. Moore's Law is a computing term which originated around 1970, named after George Moore, the cofounder of Intel. The essence of the law, which still holds, is that processor speeds, or overall computer processing power (computer data processing unit, CPU), doubles every two years. This computer power has driven global connectedness, as demonstrated by the world wide web, text messaging, email and social media.

1. Introduction

According to IBM, 2.5 billion gigabytes of data was generated *every day* in 2012 (BBC, 2014).

Since the 1980s we have become used to digital in our everyday lives: the personal computer, word-processing software, laptops, mobile phones and tablets. Our expectations of what we can achieve in a day's work bear little resemblance to two or three decades ago. Although verbal communication had been transformed by the telephone, written communication still depended on accurate typing and the postal service. Now documents are completed in a day, with as many copies, in complicated designed formats, printed as required. There is barely a sector now untouched by digital technology, whether art, film, architecture, music, leisure, printing, medicine, engineering, law, etc. Digitisation has not only transformed the way we live and the way we work but is enabling a new 'DIY' culture with creative coding and software, allowing people all over the world to design or adapt services and make new connections in a very short space of time. Sophisticated search engines combined with the straightforward uploading of data mean that almost anyone with access to the internet can do things for themselves previously the domain of customer services, experts and professionals. This digital disruption means that we can now do our own banking, travel planning, auctioneering, publishing and market comparisons. Manufacturing is fast becoming a domestic possibility with 3D printing, and already web-based companies are turning personal designs into tangible products.

What we can now pack into the working day once took us a week or more. We have been enabled to become much more productive, but do we feel more pressured? And in our domestic lives we are now doing several tasks at the weekend that previously formed the heart of several people's careers. Within families the younger generation have broadly ensured that the older generation are not disadvantaged, providing personal support on in-home and communication technologies. However there has been a resulting disconnection for those who are on

their own or who are not on the internet. The digital age for some represents isolation, not emancipation.

Wearable digital technology was first witnessed in the digital insulin pump created by Medtronic (Minimed 502) in 1983, followed by digital hearing aids, in about 1987 (ignoring digital watches and Walkmans!). In 2000 the Bluetooth headset appeared, followed three years later by the digital pacemaker (Vitatron-C, vitatron.com), which allowed clinicians to download patient information in 18 seconds. Recording fitness data became possible digitally in 2006, and in 2009 the first 'Fitbit' was launched. The first smartwatch (the Pebble) appeared in 2012 and Google glass in 2013. The past few years has seen digital devices and app development grow exponentially; and as customised electronic health records have emerged, capturing one's own health data is now comprehensively in the control of the consumer. This has led to the term the 'Quantified Self' or 'self-quantification' – the ability to collect, measure and analyse personal data – and June 2015 saw the first 'Quantified Self' Expo (quantifiedself.com) in the US, exploring what this means for society. Part of this research is to consider whether self-quantification will produce a fundamental shift in the professional–public relationship. And could we soon see the merging of the quantified self and the Internet of Things (IoT), where personal health data transfers automatically to the IoT objects in your life?

In many sectors, digital tools are taking paid-for work out of the economy through automation. In the paper *The Future of Employment: How susceptible are jobs to computerisation?* (Frey & Osborne, 2013), researchers estimate that 'over the next decade or two' 47% of jobs will be automated. The paper lists the probability of a job being computerised in order of 'least' (0.0028) to 'most' (0.99). Out of 702 listed job descriptions, ophthalmic lab technicians are listed at 656 with a 0.97 probability of disappearing, and dispensing opticians at 391 with a 0.71 risk. Optometrists are comparatively safe at 188 with a 0.14 risk, and surgeons are at 15 with a virtual no-risk probability of 0.0042.

1. Introduction

As already stated, we cannot predict the future as development is so fast. But for reasons of health and work and behaviour, we need to examine trends and compose tomorrow's questions. In the field of optics, smartphone-based solutions, 3-D printing and cloud-based computer analysis have the potential to change work patterns – diminishing costs, widening choice and reducing the effects of human error.

The detrimental effects of technology on health were noted with the arrival of 24/7 TV and remote control, the rapid rise of home gaming consoles and then smartphone culture. The implications for eyesight, posture, weight and general health from excessive screen time are not fully known. By the age of 18, the average European has spent four full years of 24-hour days looking at a screen (Sigman, 2010). Will we see short-sightedness become widespread in the West as it has already in the Far East?

We need also to think about health literacy and how to ensure digitisation does not exclude the less-tech 'savvy' or those on low incomes and cause an increase in health inequalities. We need also to think about the integrity of the health system, and equity of access to services. Already we have seen variation in access to digital health support for people with mental illnesses, this being made available in some areas on the NHS and only with private payment in others.

Digital also challenges the notion of best practice, as the pace of change means that by the time digital innovation is deployed at scale, it is already out of date. This is a huge test for the NHS, which is notoriously slow at seeking out best practice, and which will struggle to keep pace with digital health technologies.

1.2 The digital age and the NHS

Whilst large medical technologies such as MRIs, Da Vinci Robots and cardiac mapping systems have been readily adopted by the relevant NHS professionals, the more personal digital technology opportunities, such as electronic healthcare records,

Bring Your Own Device (BYOD), Big Data, apps and wearables, as well as telehealth systems, have seen much slower progress. Wearables may be dismissed as 'health bling' by some, but the NHS England Medical Director, Sir Bruce Keogh, for one is championing their potential and predicting a revolution in self-care. In an article in the Guardian, January 2015, he said technology "enables you to predict things, to act early and to prevent unnecessary admissions, thereby not only taking a load off the NHS but, more importantly, actually keeping somebody safe and feeling good" (theguardian.com, 2015). The net result will be that more people will have more information about themselves, and with an understanding of the data, will be empowered to make better choices.

Likewise, telehealth systems that allow remote monitoring of patients' vital signs, video consultations and advice services have received mixed reviews, but in combination with pathway redesign it has been transformational in many circumstances.³ Airedale NHS Foundation Trust now provides telehealth services to over 20 prisons, and its work on supporting care home residents and staff has recently been awarded 'Vanguard' status with extra investment from NHS England (Airedale Trust, 2015). While telehealth has seen little development to date in the field of UK eye care, remote retinal screening is an application of telehealth well established in the Veteran's Health Administration in the USA.

'Big Data' is regarded as the untapped well of patient information that sophisticated medical analytics will scrutinise in order to 'augment the human intellect'. Software that can analyse essentially unstructured or disconnected information allows the investigation of a much greater amount of data and variables, looking for patterns that will be predictive of outcomes. One example from Amara Health Analytics is a solution that seeks to prevent sepsis. For each patient it 'continuously ingests data streams from hospital systems that monitor heart-rate, temperature, respiratory function and other physiological factors and combines that with

³ See 2020health's Healthcare without walls, 2011 and Making Connections, 2013.

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doctors' notes, lab and pharmacy data, operative reports and discharge summaries to predict the onset of sepsis' (computing.co.uk, 2014). This real-time feedback is the gold-standard of care and is an approach that McLaren (the motor racing company) have been working on in the UK, applying it to areas such as paediatric intensive care and the management of diabetes.

Beyond the automated processing of multiple and complex data sets, the hope is that big data will enable more real-world personalised medicine. Current clinical trials select candidates with no other condition than the one for which a new medication is being trialled, but the majority of people who take any medication have other health conditions (co-morbidities). What is not known is how people will respond in the real-world situation, and how effective their medication will be, e.g. for COPD, when they are also suffering from diabetes and glaucoma. The hope is that big data will help us find out and design more effective treatment regimes.

Tim Kelsey, who until December 2015 was NHS England's national director for patients and information, has emphasised the importance of data that the NHS holds: "This is a huge dataset which is unparalleled in the world and is about to grow exponentially larger, and just needs some big data analytics to derive some insight from it" (computing.co.uk, 2015). The initial NHS attempt to source data from health records was unfortunately a PR disaster. Leaflets about the 'care.data' programme, sent out to every home in the country, often got hidden in junk mail, were unclear to readers who did find them and gave no option to opt-out of the programme. Concerns were raised about lack of choice, inaccurate patient records and uncontrolled access to our 'pseudonymised' personal data, from which we could be individually re-identified. American author Eric Topol called it 'careless.data'.

False-starts aside, there are still unknowns to big data. Much of it is inaccurate and inconsistent, and it cannot be 'cleaned up' in the traditional way. We also have no research yet on whether big data

leads to positive outcomes more often than not (nytimes.com, 2014). But it remains a big new hope, and in 2014 US ophthalmologists launched their own 'Intelligent research in sight' (IRIS) registry, able to combine patient data from about 30 different electronic health record systems that can then be followed longitudinally and analysed for outcomes.

NHS England and Public Health England (PHE) have both responded to digital health technology with the appointments of a National Clinical Director for Innovation and a Deputy Director of Digital, in October and November 2014 respectively. Public Health England have said that they want to change from a 'broadcast model' to an 'engagement model' with the public; they are developing an endorsement model, 'it works', to allow or encourage others to adopt or prescribe digital health tech that would be promoted by NHS Choices (or similar). The 'Big White Wall' portal for those needing emotional health support is being used as a test-case.

NHS England has announced its intention of 'kite-marking' apps in the NHS app library (NHS England, 2014) and is looking to the 15 Academic Health Science Networks (AHSNs), intended to generate economic growth through innovation, to drive the uptake of proven innovations in the NHS.

At the World Economic Forum in Davos, Switzerland, January 2016, the NHS CEO Simon Stevens announced the first wave of 'Test Beds', including five health and care 'Innovation' Test Beds and two 'Internet of Things' Test Beds, which have been developed with the support of the AHSNs. The projects were chosen partly for their ability to evaluate and collect evidence of the improvements made for patients, as well as on their engagement of local leadership and capacity for trial innovation at scale. Projects include connected mobile health tools for people with Type 1 or Type 2 diabetes to improve self-management, and a 'Perfect patient pathway' long-term conditions support system consisting of an integrated intelligence centre to assist with appropriate and timely help (NHS England, 2016).

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Further considerations

The Royal College of Physicians (RCP) recently announced that doctors should only recognise medical apps that have been CE marked, with medical devices being determined as those that 'diagnose, support diagnosis or clinical decisions, make calculations to determine diagnosis or treatment, or are used for any medical purpose'. However many innovators have deliberately not sought to have their product recognised as a medical device to avoid regulatory hurdles. This also raises questions of patient generated data (PGD), since if the data has come from a non-CE marked app or device, then RCP guidance implies the data should be ignored. Some developers believe this stands in the way of patient power and progress – that the public should be enfranchised, data democratised and information asymmetry rebalanced.

In the Royal College of General Practitioners' report 'An inquiry into patient centred care in the 21st century' (RCGP, 2014), technology was barely mentioned. It stated that "Technological developments should be embraced and harnessed by general practice to create synergy, or else we risk further fragmentation and inefficient use of money and time," but in the recommendations, the only reference to technology was the need for GPs to be supported in enabling public access to their GP online record.

Overall, there remains much professional resistance to people having more control over their health data and choices. As Dr Mohammed Al-Ubaydli, founder of 'Patients Know Best', wrote in his book 'Personal Health Records: A guide for clinicians', professionals need to understand that these technologies will free them up to do more of what they are trained to do, including that which is clinically interesting and more complex, and less of the routine and mundane. The argument will have to be accepted over the next decade. In fact, training of all clinical specialties needs to be reviewed immediately in the light of advances in technology and what this means for managing healthcare.

1.3 What does technology mean for behaviour?

In 2006 no one had a broadband connection on their mobile phone. Within just a decade, 2.5 billion people have achieved 24/7 connectivity to the internet and each other, something that few of us would have imagined. It is estimated that by 2020, 80% of adults will have this capability.

Digital technology has increased convenience and removed constraints from almost every area of our lives. It gives us the opportunity to better relate to the world around us, to be more informed in decisions we make throughout the day. We can know more, more quickly (download speeds have increased by a factor of 12,000) and be aware of our choices as never before. And as people have adopted technologies, they share experiences of real life that stimulate innovation, and share information that was previously the preserve of the academic or specialist. The quality and quantity of data has increased exponentially.

There are health hazards associated with technology, as previously mentioned, including increased sedentary behaviour as a result of remote controls, automated cooking (microwaves), robotic vacuum cleaners, internet shopping, etc. As so many tasks can now be directed and automated from a computer screen, activity driven by the requirement to physically meet people and visit specific locations has been reduced. Screen time – whether on the TV, computer, tablet or mobile – is partly to blame for the increased incidence of myopia in the Far East. In the West, excessive screen-time is an acknowledged 'obesogenic' behaviour (Cloutier, 2015) and studies have shown that children who exceed the recommended screen time are more likely to experience 'ill-being' (Rosen, 2014) and have poorer diets (Lowry, 2015). Those who are already overweight report a diminished health-related quality of life (HRQoL) (Goldfield GS, 2015).

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As digital technology can mean instantaneous communication, unmet expectations of contact and availability can lead to frustration. Added to this, the phenomenon known as 'fear of missing out' (FOMO) leads young people in particular to be very reluctant to turn off their mobile screens. (The authors note that many adults also constantly have their phone with them, on the desk or on the table at meetings.) The evidence on how FOMO is negatively impacting behaviour is beginning to be collated (Przybylski, 2013). We already know that when school children have screens in their bedrooms there is often a problem with sleep deprivation, which manifests itself in fatigue in school and in lower performance levels (Rich, quoted by Feinberg, 2011); such deprivation can go on to have long-term health consequences (Colten, 2006).

The advancing capacity and widening availability of digital technologies has huge potential for behaviour change amongst service providers, businesses and the public, and this is how we have approached our review of technologies in the optical sector. Behavioural themes considered are:

1. **Communication and education** – instant contact has been enabled through mobile and real-time visual, spoken and written electronic messaging. Online digital publication of research materials, information and peer generated experiences have given us the opportunity to easily cross-check academic evidence, professional expertise and personal experiences. The concept of the 'expert patient' is now realisable. The opportunity for businesses to personalise patient messages is simpler, supported by relevant and engaging content marketing.
2. **Prevention and early intervention** – easier, faster and superior quality digital analysis and evaluation are providing health and wellbeing early-warning systems at a detailed level. Understanding some of the in-depth findings is a learning process for the professional if they desire the opportunity. Assessment can be more thorough and again the information retrieved has increased relevance to the individual.
3. **Treatment and correction** – there are more options than ever before available to the individual. For the patient, a recognition of motivation and objectives is crucial to determining the best solution; for the professional, knowing their patient's preferences, opportunities and capabilities is key for optimal (and business-essential) outcomes.
4. **Independence and self-care** – due to increasing availability of health tracking, online purchasing and DIY testing, the consumer has become emancipated and the professional has to adapt to a role of support and signposting. Technology enables those with visual disabilities to have much greater and faster access to information that is truly transformational. Health literacy is fundamental to making the most of the opportunities. Self-care raises the question of why manufacturers should not be allowed to contact the public directly.
5. **Interdependence and partnership working** – as detailed health information can be viewed and shared by an individual, and 'remote' monitoring and testing facilitated, there can be much deeper understanding of conditions and choices, with greater access to care that was previously difficult to obtain. Authority can now be shared by the public and professionals.
6. **Recreation and lifestyle** – as innovators respond to unmet needs or spawn new trends, avenues can open up that span essentials to luxuries, as determined by roles, work or choices. Digital innovation presents new prospects for diversification to the business strategist, professional and manufacturer.
7. **Ophthalmology advances** – upstream developments can improve outcomes or change options for the public, depending on their situation.

1. Introduction

Personalisation and digital enablers

The pace of innovation is so rapid it is hard to keep up with developments, or know how to sort the wheat from the chaff. Much of what we will pay attention to will be driven by our perceptions of value, and that which offers commercial viability for the optics sector. Either way, personalisation is paramount; options need to be relevant to us as individuals, both practically and emotionally, otherwise we will lack the motivation to take advantage of opportunities.

This is especially true if what people want, and value, is more personal contact. However, such are the spiralling costs of delivery, the 'virtual companion' will need to become a more accepted part of future healthcare. Interestingly, in a review of the use of 'simple' telehealth, a system of supportive text information exchange nicknamed 'Florence', the conclusion was:

"This service evaluation demonstrates that patients found this simple telehealth strategy for managing hypertension easy to use, convenient and acceptable. Patients liked feeling increased levels of support and Florence had a role as a companion, in promoting patients to educate themselves further and providing reassurance about normotension in cases of white coat hypertension. As previously found, the skills and knowledge gained by patients from using Florence have led some patients to commence longer-term health behaviours such as self-directed ongoing monitoring and purchase of their own home machines." (Cotrell, 2012)

Digital technology has suffered from the expectation that it is (always) time saving. The reality is often that it is more connected and streamlined, but deliberation and time are required to make the most

of its application. Businesses are concerned with loyalty, remuneration, health, design, education, workforce and job satisfaction. So they need to consider how digitisation is going to meet those needs more comprehensively and positively affect behaviour, both of staff and of customers, the latter who may feel they are undertaking tasks previously done for them.

Capability, motivation and opportunity are the core considerations. Randomised controlled trials (RCTs) are undertaken to provide evidence of efficacy, quality and safety. But due to the lengthy processes involved in preparation, trial and evaluation, as well as expense, RCTs will struggle to keep up with rapidly evolving technologies.⁴ So business will have to think more about monitoring implementation of what they do in the digital age, retaining the ability and flexibility to stick with what works and move on from what does not.

As individuals, we will have to become more 'intentional': we need to drive, not be driven by, technology, to achieve desired outcomes. Being a 'participateint' requires work; digital may be instantaneous in its data gathering but it takes time to understand and then put that information to use. Added to this, behaviours do not exist in a vacuum – there are other competing or supporting behaviours that need to be considered. Environment and culture are key considerations of whether or how any particular digital technology is going to impact our behaviour.

Despite the current explosion in wearables, medical investors are expressing more interest in medical technologies. Enabling the next generation of batteries for both miniaturisation and longevity is of keen interest. There is much activity among start-ups in vision-related technology for those with sight loss, but the focus is on assistance not on prevention. It is a crowded market and investors are interested in the early growth / incubator stage of development.

⁴ Further, whilst RCTs have notable strengths, they are also recognised as limited in that they generalise to the population and can lack external validity (Rothwell, 2005; Harriette *et al.*, 2007).

1.4 Conclusion

Customer-centric innovation is even more important than before and optics has the freedom (unlike many NHS services) to deliver this. As digital technologies are changing so fast, business strategy and implementation have to be aligned, developed and deployed together, not in sequence. Leaders in health understand the need for more people to have more information about themselves, to understand the data and be educated to make better choices. The health professional will have a greater role to play in public education and understanding, although there are also many online health groups that offer public peer support opportunities. Increasingly we will see the individual with a condition become the 'expert patient', adapting their behaviour to make healthier lifestyle choices and understanding the importance of prevention and monitoring, all through having much more meaningful information.

Optics is an interesting field in which to review the effect of digital technology. For most of us, vision is the guiding sense and it has fascinated innovators who seek to enhance and tap into this precious ability and compensate for its loss more effectively. It is an incredibly emotive and sensitive function, both because of the importance of visual information and because the eye is truly 'the light of the body' – through its structure, it gives us so much information about the functioning of the rest of the body. We are being presented with more visual information than ever before, and most people will need help with understanding and interpretation. This is an expanding role for all health professionals.

Optics is also a very public, accessible sector, already being one of the most available health-related disciplines, but also with under exploited potential in leisure and retail. Technology opens up many new opportunities for eyewear, from manufacturing to fashion, to the fusion of communication technology with frames and lenses.

We have been cautious with our predictions in this paper; after all the future is created by us as individuals and we cannot predict those individual choices. One thing we can predict with confidence, however, is that the world will not stay the same.

2. UK DEMOGRAPHICS TO 2030

When it comes to the issue of ageing, trends are clear: people are living longer. And with an ageing society comes an increase of age-related health conditions, including a range of eye diseases and vision problems, and an exponential rise in healthcare costs. But the increase of ocular health issues are not confined to the elderly; our nation's rising levels of obesity bring greater risk of diabetes and thus diabetic retinopathy, and a 'myopia boom' among children and young people (a world-wide phenomenon) is also impacting the optical profession and the NHS.

2.1 Demographic expectations

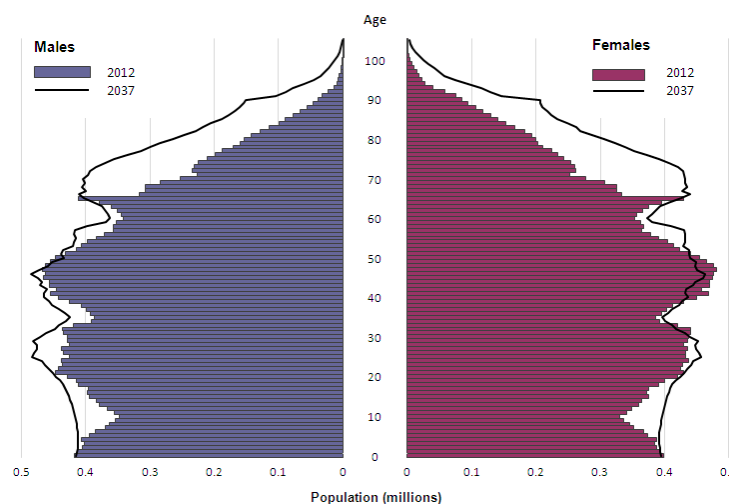
Published demographic projections typically draw from data produced by the Office for National Statistics (ONS) and are generally in close agreement. Among the UK's population of some 64 million, there are currently 14.7 million aged 60 and above; by 2030 projections suggest this cohort will have reached 20 million (ONS 2013). Projected growth from 2010 to 2030 indicates a 50% rise in people aged 65 and over, 100% more people aged

85 and over, and as much as a sevenfold increase of centenarians. The UK population as a whole is likely to have risen by around 10% (to 71 million), taking also into account expected net inward migration (Rutherford, 2012; ONS, 2015). A 25-year prediction based on the 2011 census for the UK population is shown in Fig. 1.

"This demographic transition occurring across the industrialised world is an unprecedented event in the history of humanity." Forum of the Future, 2010

Shifts in UK age demographics have been explained by two key factors. First, people are simply living longer thanks in part to positive changes in living standards, health care and quality of life. Secondly, we are now reaping the consequences of the 'baby boom' years following the Second World War.

Figure 1. Estimated and projected age structure of the UK population, 2012 and 2037. ONS 2012-based projections (source: ons.gov.uk)



2. UK demographics to 2030

2.2 Life expectancy and life style

While extended life expectancy is one of the great triumphs of our modern age, people are now living for longer with multiple long term conditions which necessitate the provision of more long term care. The NHS is faced with increased demand for services at the same time as managing the associated financial implications.

A healthy life expectancy is defined as expected years of remaining life in 'good' or 'very good' general health (House of Lords 2013: 21). In 2008, UK men at age 65 had a 'healthy' life expectancy of 9.9 years, and women of 11.5 years. The challenge is to extend the period of good general health through beneficial lifestyle choices and habits. One recent study of 70–79 year olds found that the most physically active women with the highest fruit and vegetable consumption were eight times more likely to be alive five years later (five years from baseline

measurement) than the women with the lowest rates (Nicklett *et al.*, 2012).

2.3 Demographic impact on eye health

There is a strong association between age and deterioration in eye health, and an ageing population and increase in people with multiple long term conditions suggests a higher incidence of eye disease and sight loss in the future (NHS England, 2014a). Predicted increases are shown below in Table 1.

Most people with serious vision loss and eye health problems will have other significant health or social care needs, such as emotional support, psychological services and vision rehabilitation. Life-long monitoring, support and treatment are also common for those who have developed eye diseases such as glaucoma, diabetic retinopathy and macular degeneration.

Table 1. Projection of partial sight and blindness (<6/12) by disease type, UK (people), 2010 to 2030 (Source: Access Economics 2009: 45–47)

Total cases	Age Related Macular Degeneration	Cataract	Diabetic Retinopathy	Glaucoma	Refractive Error	Other
2010 n = 1,856,000	16.8% 312,789	13.7% 254,417	3.4% 63,140	5.3% 98,424	53.3% 989,814	7.4% 137,422
2020 n = 2,260,000	17.9% 404,920	14.0% 316,697	3.2% 72,388	5.2% 117,630	52.2% 1,180,828	7.4% 167,397
2030 n = 2,873,000	19.6% 563,576	14.5% 416,931	2.8% 80,511	5.2% 149,520	50.4% 1,449,197	7.4% 212,779
20-year % increase of cases	80%	64%	28%	52%	46%	55%

2. UK demographics to 2030

Taking all surgical specialties into account, the most common surgical intervention performed by the NHS in England is cataract extraction (NHS England 2014a). Between 2003/04 and 2012/13 total spend on eye health services in England increased by 90%, from £1.2bn to £2.3bn⁵ (primary and secondary care). Hospital attendances for ophthalmology account for the second highest number of outpatient attendance for any specialty – 6.8 million attendances in 2011/12, equating to 8.9% of all outpatient attendances in hospitals in that year (NHS England 2014a).

As a result of our rapidly ageing population, and against a backdrop of a forecast NHS financial gap of £30bn a year by 2020/21 in England alone (NHS England, 2014b), a greater incidence of eye disease and sight loss will increase demands on hospitals and community health resources, and associated health and social care budgets. Crucial to meeting patient need will be ensuring that care and treatment is provided in the right place, at the right time and in the right manner.

2.4 The rise of myopia

Beyond major eye disease, and yet still of direct relevance to NHS spend (through General Ophthalmic Services), is the rising incidence of myopia. There appears to be an escalating prevalence of myopia globally, which brings with it the rising danger of myopia-related pathologies.

The myopia epidemic is not fully understood, but research indicates that reduced time spent outdoors in daylight, and increased close-work indoors, is putting children and young people at risk of permanently damaging their vision (Rose *et al.*, 2008; Dolgin, 2015).

The incidence of myopia is highest across East Asia, afflicting more than 80% of 18-year-olds in some urban regions (e.g. within China, Singapore and South Korea). A study in 2009 set out to test whether boosting outdoor time would help to protect the eyesight of Chinese children. The three-year trial

involved adding a 40-minute outdoor class to the end of the school day for a group of six- and seven-year-olds at six randomly selected schools. Children at six other schools had no change in schedule and served as controls. Of the 900-plus children who attended the outside class, 30% developed myopia by age nine or ten compared with 40% of those at the control schools (Dolgin, 2015). The study suggests that sunlight – not simply the use of distance vision – may be an important contributor to healthy ocular development.

The increased time young people spend indoors can be attributed not only to a stronger emphasis on education than previously, but also screen time. The UK eye surgeon David Allamby reports that since 1997 he has witnessed a 35% rise in the number of patients diagnosed with advancing myopia, which he attributes to increased use of smartphones and other hand held technology (Davies, 2015).

“Recent studies have indicated that an average smartphone user holds their device 30cm from their face while some use it as close as 18cm. Newspapers and books, on the other hand, are typically kept at least 40cm from the eyes.”

Knight, 2013

The combination of increased close work and reduced time spent outdoors is expected to fuel a rise of myopia among Millennials. Significant culture change is needed; otherwise Allamby’s prediction for the UK may well be accurate: a 50% myopia increase in children and young people by 2025, with up to half of 30-year-olds myopic by 2033 (Svetlik, 2013).

⁵ A significant amount was spent on the Action on Cataracts initiative at the turn of the century, and some growth will have been driven by an ageing population.

2.5 Eye health and the economy

Total NHS expenditure on eye health in the UK was estimated at £2.64 billion in 2013 (RNIB 2013: 12; 47). This figure includes expenditure on hospital care such as inpatient and outpatient admissions, provision of eye tests, medication and prescription costs.

Drawing from a range of data published by the NHS in England, Scotland and Wales (RNIB 2013: 14) total NHS expenditure on problems of vision in the UK breaks down as:

- £2,255 million in England
- £119 million in Wales
- £216 million in Scotland
- £52 million in Northern Ireland (estimated)

Consideration also needs to be given to the costs of sight loss that impact upon a country's economy, which recent research has sought to model (Access Economics, 2009). The wider costs include local authority spend on providing residential and community support and care, along with substantial indirect costs, including economic inactivity.

Table 2 summarises estimates of NHS sight tests, 'problems of vision' and indirect costs resulting from sight loss, for the UK in 2013 (RNIB 2013: 12, 46-47; Access Economics 2009). Combining these categories we arrive at a total cost to the UK economy of £7.4 billion. Were we to factor in full 'burden of disease costs', accounting for years of life lost due to (1) morbidity and (2) premature death,⁶ the figure would rise to around £22 billion (Access Economics, 2009).

Table 2. Estimations of NHS sight tests, 'problems of vision' and indirect costs due to sight loss, UK 2013 (Sources: RNIB 2013: 12, 46-47; Access Economics 2009).

Expenditure	Detail	Cost
Primary care	Provision of eye care services, including NHS sight tests	£496 million
Inpatient	Provision of ophthalmology services	£536 million
Outpatient	Provision of ophthalmology services	£677 million
Social care	Provision of residential and community care to blind and partially sighted people	£370 million
Indirect costs	Unpaid care, reduced employment and other indirect costs to UK economy as a result of sight loss	£5.3 billion

The escalation of NHS spend on eye care services is inevitable during the period under review. Some of the financial burden could in theory be lightened by widespread culture change towards healthier lifestyles. We are hopeful (and will continue to campaign with others) for progress in this regard, but the planning of services needs to respond to current trends. It would also be unrealistic to assume

that biomedical technologies will advance over the next 10–15 years to such an extent that the prevalence of eye disease is reduced (see Section 10). And we must not forget that technological advancement does not always equate to reduced NHS spend. For example were a breakthrough dry-AMD treatment to become available, the NHS would need to expand its AMD services considerably.

⁶ That is, the monetary conversion of DALYs (disability adjusted life years)

2. UK demographics to 2030

As we look towards 2030, two important financial considerations need to be borne in mind.

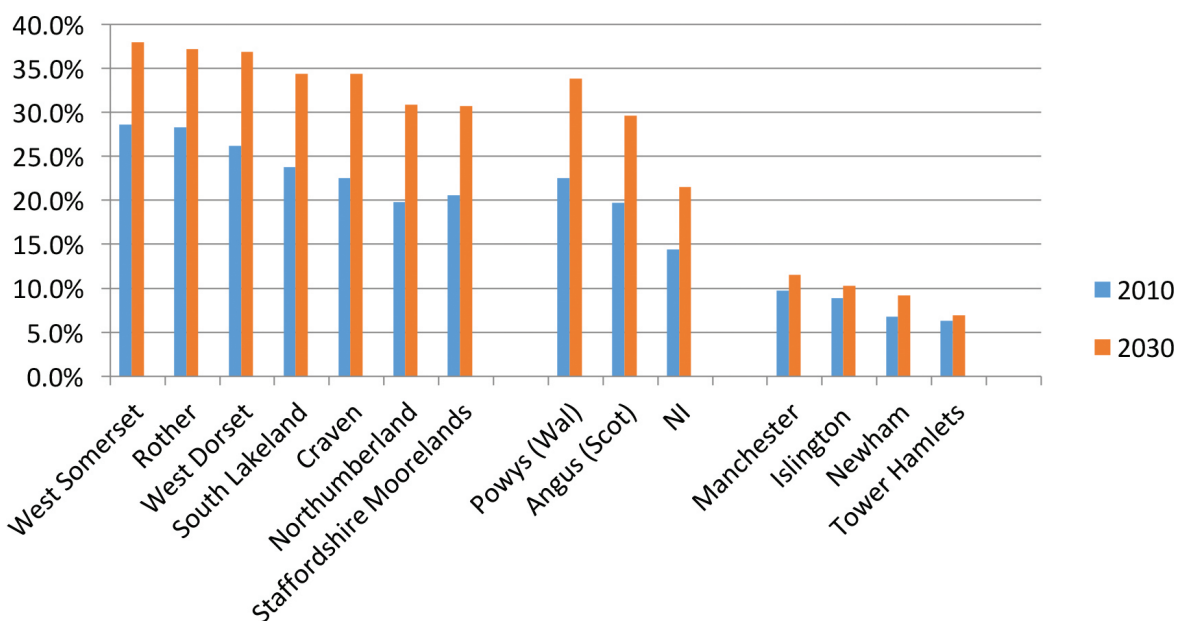
1. The average cost of providing hospital and community health services for a person aged 85+ is around three times greater than for a person aged 65 to 74 years (Cracknell, 2010).
2. State benefits and the NHS accounted for just under half of government expenditure in 2009/10. With much of this spending directed at elderly people, their growing number will present challenges for providers of these particular services as well as for the public finances as a whole (Cracknell, 2010).

The strain on services will be felt in some parts of the country much more than others due to the non-uniform spread of the 65+ population. While local authorities with large city-based populations see high concentrations of working-age people, rural areas accommodate a far greater proportion of retirees.

As Fig. 2 suggests, the strategy for health and social care services in Tower Hamlets or central Manchester may look markedly different to that of Craven, West Dorset and Powys.

Returning to the projected eye disorder figures (to 2030) of Table 1, we should bear in mind that these represent national averages. For example, if AMD is set to rise by 80% nationally, the rise will be of an even greater order in South Lakeland and Northumberland, with wide implications for NHS (wet-AMD treatment) and social care services. Accommodating an above 64% rise in demand for cataract operations will also be a challenge in many parts of the UK, if access to services is not to be compromised. Commissioners will therefore need to carefully review and evaluate the role primary care services can play in tackling the sizeable challenges facing the NHS, especially the acute setting, as we explore in the next section.

Figure 2. Predicted rises in 65+ population: Selected UK regions only.
Data source: neighbourhood.statistics.gov.uk



3. LOOKING TO THE FUTURE: THE IMPACT OF NHS COMMISSIONING ON OPTOMETRIC SERVICES

As discussed in Section 2, NHS expenditure on eye health services has roughly doubled within the last ten years (NHS England 2014a). Hospital attendances for ophthalmology account for the second highest number of outpatient attendance for any specialty, and eye health now accounts for 4.5m GP consultations each year (out of a realistic estimated total of 190m for 2012–13)(BMJ, 2014).

NHS England's *Call to Action* (2014) included salutary recognition of the likely rises in age-related eye disease over the next decades. The popular mantra of politicians for some years has been that of moving care closer to home, although cost savings have not always appeared obvious to commissioners. There is also a call to support patients as active participants in their own care, enabling informed choices and shared decision making. Evidence shows that 50% of sight loss⁷ can be avoided through improved eye care and early detection of problems (RNIB, 2012): public education and quick, easy access to eye care services are both critical.

Various models of community eye care pathways have evolved. In Scotland, Wales, and – to a much smaller extent – Northern Ireland (NI) there are for the most part centrally-commissioned community eye care pathways. In Scotland and Wales it is standard to find community practices delivering enhanced eye care services and Minor Eye Conditions (MECs). Just over 90% of practices in Wales are signed up to national enhanced services, which have recently been extended to include dry AMD monitoring and post-operative cataract examinations (Optometry Wales, 2015). Northern Ireland's Local Enhanced Service optometry programme is currently confined to Glaucoma refinement level 1, which has reduced around 65% of referrals (2020health interviews), though a PEARS (Primary Eye-care Acute Referral Scheme) pilot is underway. In England the situation is more localised, with CCGs having the choice to commission local community eye services,

MECs and other pathways from individual practices or Local Optical Committees (LOCs, comprising a number of local practices), and/or from consultant-led community ophthalmology services (COS).

Community commissioning gives practice-based optometrists opportunity for a more service-based role (opportunities for domiciliary practices are fewer in this regard). However not all CCGs in England are offering high street optometry a greater role to play in NHS care, for a variety of reasons. These include the belief that community eye care would be better served by an alternative NHS model (e.g. consultant-led community ophthalmology services); a lack of confidence that commissioning further services from the high street would actually reduce NHS costs; or indeed the low priority of eye care in terms of service redesign, given the potential of greater cost savings elsewhere (2020health interviews, 2015).

LOCSU estimate community eye care pathways to have about 25% penetration in England currently (locs.co.uk) and would prefer to see the centralised commissioning of such, so to end the current 'postcode lottery' for patients and introduce standardised remuneration across England (LOCSU, 2014).

Outside CCG commissioning, there are examples of hospitals that commission (sub-contract) services from optometrists who are well known to the ophthalmology department, for example in the case of the shared care scheme for stable wet macula patients (CAMS) in Kent. In this instance, the agreement is made exclusively between the practice and hospital.

The implications of eye care pathways for future optometric practice, and thus business models, are significant. During our project period we heard from some interviewees of practices whose business

⁷ The term 'sight loss' tends to be used even when vision is correctable or treatable (e.g. refractive error, cataracts).

3. Looking to the future: the impact of NHS commissioning on optometric services

viability was now largely dependent on the additional NHS eye care services they offered. These may be few and far between currently, but we should recognise that a practice offering a suite of additional eye care services may secure an important income stream, albeit a vulnerable one.

3.1 Will community eye care pathways expand or contract?

The question of future eye care commissioning rests on evidence of best practice and cost savings. According to NHS England 'Five Year Forward View', cost savings across the NHS are dependent on closing the follow gaps:

- 1) The health and wellbeing gap: if the nation fails to get serious about prevention then recent progress in healthy life expectancies will stall, health inequalities will widen, and our ability to fund beneficial new treatments will be crowded-out by the need to spend billions of pounds on wholly avoidable illness.
- 2) The care and quality gap: unless we reshape care delivery, harness technology, and drive down variations in quality and safety of care, then patients' changing needs will go unmet, people will be harmed who should have been cured, and unacceptable variations in outcomes will persist.
- 3) The funding and efficiency gap: if we fail to match reasonable funding levels with wide-ranging and sometimes controversial system efficiencies, the result will be some combination of worse services, fewer staff, deficits, and restrictions on new treatments.

On paper, community eye care services appear to tick every box, particularly with an emphasis on access and prevention, the harnessing of technology, and system efficiency. The College of Optometrists is currently undertaking an evaluation of what economic benefits community eye care services may bring to the NHS (a report is due 2016), while LOCSU is aiming to collect evidence on the cost-benefits of such services through a National Data Repository, which should include data on disease prevalence and demographics.⁸

Data is much needed because to date there have been no wide-ranging, comprehensive analyses of costs and outcomes of community eye care services. Individual CCGs do however report efficiencies, and limited studies have shown some positive outcomes.

For instance, a study of repeat glaucoma measurements, undertaken by City University in collaboration with Bexley Care Trust, found onward referral rates to hospital of just 24%, suggesting (if extrapolated) 'cost savings for the NHS of up to £10 million per year.' In response to this study, NHS London rolled out the scheme across South London (City University London, 2015). Through our research, such low onward referral rates were not the norm, with CCGs and interviewees reporting rates of around 35% – 40%. We would also approach the extrapolation with caution since reimbursement for services varies across CCGs: we found a range of £15 – £35 for repeat glaucoma measurements. This still represents a significant saving on the hospital follow-up tariff (£60 / £87), but it is important to recognise that whilst CCGs are looking to reduce referrals and thus costs, compared to savings that could be achieved from (for example) reducing the incidence of stroke, the saving is very small.⁹

⁸ See LOCSU press release: 'New LOCSU database will make 'watertight' case for Community Services.' Available: www.locsu.co.uk/communications/news/?article=161

⁹ The average cost per patient to the economy in the five years following a stroke is between £15,000 and £30,000, and there are 110,000 strokes per year. http://www.nao.org.uk/wp-content/uploads/2005/11/0506452_economic_analysis.pdf

3. Looking to the future: the impact of NHS commissioning on optometric services

The potential for eye care community pathways to reduce NHS spend has been made all the more possible thanks to Payment by Results (PbR) tariffs, which are now common within the acute setting. During our project period we interviewed five CCGs and contacted a further 20 to obtain commissioning information on local NHS spend (via Freedom of Information requests). One CCG in the east of England summed up its approach as follows:

The prices paid to Community Optoms depend on the complexity of the eye examination taking place – i.e. what part of the eye is being examined (glaucoma screening, anterior or posterior eye exams)...tariffs range from 29% to 42% of the PbR tariff.

This we found typical across the majority of CCGs (eleven out of thirteen) that responded to our FOI with specific cost breakdown information. In Scotland all supplementary eye exams are remunerated at £21.50, representing on average lower remuneration than in England and Wales, although the optometrist there receives higher NHS payment for the 'enhanced' primary eye exam.¹⁰

A number of CCGs were remunerating PEARS or MECs at £60, representing 54% of the PbR first outpatient visit tariff. This reflects Wales' Band 1 tariff (£60), which covers acute eye conditions. We did however find PEARS or MECs commissioning not always working to the benefit of CCG finances. Where community optometrists have taken MECs out of the hands of GPs, there is additional cost to the CCG – indeed to the NHS as a whole, since GP commissioning is block-contracted, not activity-based PbR. Cost savings can therefore only be made where minor eye problem activity at the local hospital is reduced.

“The main challenge is around governance and equipping community optometrists with the confidence and the shared IT to facilitate joined up care.”
2020health interviews, 2015

Some interviewees suggested that not all hospitals want to relinquish the 15-minute 'easy' work that cross-subsidises the more complex cases (since the tariff is not tailored enough to account for the difference) and they thus attempt to retain all patients. The comment echoes opinion expressed by the Clinical Council for Eye Health Commissioning in its recent response to Improving eye health and reducing sight loss – a call to action (CCEHC, 2014). Discussing the shift of care into the community, the authors recommend:

Any changes to the current [models of care] do need to be reviewed to avoid unintended consequences. Hospital tariffs are artificial constructs and loss of some more lucrative routine patients for hospitals might mean that other tariffs need adjusting if the hospital eye service department is to remain financially viable.

We also heard counter arguments made on this very point. One NHS Medical Director we spoke with argued that if the more routine and lower-tariff work could be pushed into the community, hospital eye consultants (a limited resource) could be freed up to do more of the complex and 'interesting' work which attracts the higher tariff. This would be potentially beneficial to patients, staff job satisfaction (working higher up their skillset) and NHS finances.

¹⁰ Scotland GOS: primary NHS eye exam is remunerated at £37 for adults under 60; £40 for those over 60, and £45 for over 60s where a digital fundus image is taken. www.aop.org.uk

3. Looking to the future: the impact of NHS commissioning on optometric services

Further delivery models

Commissioners may also consider the option of establishing the aforementioned consultant-led community ophthalmic service (COS). This NHS-run service effectively straddles primary and secondary care with the objective of reducing pressure on the acute setting while enabling ease and speed of access. Since NHS staff salaries remain unchanged and overheads are perhaps only marginally reduced, the scope for savings is much narrower, as compared to commissioning from community optometry.¹¹ As noted above, consultant-led COS may be commissioned to the exclusion of other community eye care pathways, although some CCGs (e.g. NHS Leeds, NHS Shropshire and NHS Wakefield) are operating a three-tier service to manage patients through a funnel of care, with COS sitting as a bridge between community optometry and the acute sector.

Looking to the future, multi-speciality community providers (MCPs; see case study 2) and 'vertically' integrated Primary and Acute Care Systems (PACS) may emerge, as suggested in the NHS Five-year Forward View (NHS England, 2014b). Such models of combined services could, inter alia, drive community day-case eye surgery, and offer a role for a community optometrist in an NHS-salaried position. The consultant-led COS could fit neatly into both of these systems, while Local Optical Committee (LOC) companies and individual practices would probably find the MCP model offering the widest opportunities.

MCPs and PACs notwithstanding, the future expansion of community eye care pathways is largely dependent on building trust between primary and secondary care providers, and also commissioners. Tariffs need to be fair and balanced, and skillsets recognised. Strong partnership working already exists in some areas of England (e.g. Herefordshire, Shropshire, Telford & Wrekin), but ophthalmologists not infrequently harbour doubts about relevant expertise within the primary setting.

Eye surgery in the community setting

Case study 1: Telford & Wrekin COS

Since 2011 patients in Telford and Wrekin have had the rare opportunity to access cataract surgery and other ophthalmology services in a community setting. The service at Wrekin Community Clinic was launched to improve outcomes for local patients through reduced waiting times, and earlier diagnosis and treatment of common eye conditions. The Clinic is home to the country's first SurgiCube operation unit, which helps to ensure a sterile environment for eye operations by keeping an ultra-clean airflow around the operating area and operating instruments.

Case study 2: Whitstable Medical Practice

The Whitstable Medical Practice is a 'multi-specialty community provider' (MCP), and one of NHS England's identified 'vanguard sites'. Services include day-case cataract surgery (performed by a team of East Kent consultant ophthalmologists), which was set up after a private company carrying out NHS cataract operations pulled out due to lack of profit. The initiative has saved back-log at the East Kent Hospitals Trust, which has no capacity to increase cataract services.

Given the current direction of travel across the devolved nations, it is reasonable to think that the community optometrist of the future could have notably wider participation in the delivery of NHS eye care services ten years from now. LOC companies, through which much of this work will be sought and delivered, may well evolve into LOC federations in specific areas of England, as we are seeing with the Greater Manchester Primary Eyecare Company, with four LOCs currently signed up to run eight services across the four areas. How federated LOCs will sit within the landscape of competitive tender and Any Qualified Provider (AQP) is unclear, but lasting change will rely on informed planning and design.

¹¹ In Leeds, for example, consultant-led COS remuneration is £84 to £112, comparable to the hospital outpatient tariff. 2020health FOI response 24 April 2015.

3.2 Will the General Ophthalmic Services (GOS) contract transfer to CCGs?

The possibility of devolved General Ophthalmic Services contracts in England is very real considering the intention of NHS England to transfer more power to CCGs over primary care commissioning (NHS England, 2015). Anecdotally we sensed no appetite among CCGs for GOS control, since CCGs have already considerable and complex commissioning responsibilities. However, CCGs in control of GOS presents the notion of local redesign based on population needs, and even a de-standardised sight test fee, resulting in variation across England much as we see in the remuneration of community eye care pathways currently. Some interviewees feared this might even lead to a reduction in the GOS sight test fee in some areas.

To justify a reduction in sight test fee, the new arrangements would have to be seen as beneficial to patients, not just to the NHS purse. In fact, one likely outcome of this would be a reduction in providers able to offer NHS sight test services (particularly independents); the CCG could thereby inadvertently reduce public access overall. In general, CCGs will be more likely to look for savings through an offering of community eye care pathways and by exploiting new models of delivery.

3.3 Scotland: the question of free sight testing for all

In 2006 NHS Scotland introduced a completely new GOS contract which saw the biggest change in NHS eye care for 60 years. The traditional NHS 'sight test' of refraction and eye health examination was replaced by a free-to-all comprehensive eye examination appropriate to a patient's need, symptoms and general health, at the practitioner's discretion. The expectations were that cost savings would be made in the longer term, principally through the early detection and treatment of eye disease, thereby limiting the negative impact on the wider economy, including productivity.

The initial cost of introducing the new eye examinations may have been as much as £30 million, although the firm 4-consulting has estimated Scotland's free eye care to be benefiting the country by £440 million per annum,¹² particularly since the free test has, they claim, attracted a significant proportion of people who would otherwise not have had their eyes examined (4-consulting, 2012). Data used by 4-consulting have been questioned, however. Dickey *et al.*, (Aberdeen University, 2012), examining the utilisation of Scotland's free eye care examinations, dismissed as inaccurate the claim of a 64% increase in tests following the introduction of free eye examinations. Collected data instead implied a relative increase in 2005–06 of around 18%, with an overall three-year increase at 13%. The study also suggests that uptake has not been raised across socio-economic groups in equal measure, with a proportionally lower increase among those with low-income and low-educational attainment. Nevertheless, the policy was claimed to have had a positive effect on health care utilisation more generally.

Data from the Information Services Division (ISD) of NHS Scotland suggests the proportion of the Scottish population having an eye examination has continued to rise, increasing from 33.4 percent in 2009 to around 38% in 2014 (ISD Scotland, 2015).

In terms of the optometric work undertaken, Henderson *et al.*, (2012) found no significant difference in the detection rates of eye conditions between the English and Scottish GOS, despite the fee in England (£20.70 at the time) being significantly less than in Scotland, where fees range from £37 to £58.50 (the latter where a supplementary exam charge of £21.50 is included for an extended appointment for under 60s).

¹² This extrapolated figure factors in the number of additional years with corrected vision or prevention of further loss of vision, adjusted for changes in quality of life.

3. Looking to the future: the impact of NHS commissioning on optometric services

Observation

We believe that a widening of free access to lower-income groups by the raising of the NHS Tax Credit Exemption Certificate threshold (£15,276 in 2014/15; NHS HC12) should be a consideration for policy makers, especially to ensure that low-paid individuals without access to discounted sight tests are not discouraged by cost.

Scotland's experience (and limited data) may not be enough to convince policy makers elsewhere of the benefits of the universal free sight test. Both policy makers and commissioners may believe that the key to better eye care, prevention and early intervention – and ultimately reduced NHS and social care spend – is simply the improved education of the public. After all, even a well-salaried individual has access to a free or heavily discounted sight test (via a chain provider) in most regions of the country, at some stage of the year.

At the same time, it is important to recognise improvements in sight testing uptake over the last 10 years outside of Scotland. For example, statistics for 2013/14 show 12.8 million NHS sight tests undertaken in England (GOC, 2014), representing a 30% increase on 2003/4, when the figure stood at 9.8 million (GOS, 2005). Some of this could be attributable to the 'Action on Cataracts' drive in the early 2000s, and also to the ageing population with a greater proportion in need of reading (presbyopic) correction. Wales saw a 15% rise in NHS testing over the same period, possibly helped by optometrists' increased public profile due to PEARS and other schemes.

3.4 Summary

Whilst we can predict, with a reasonable degree of certainty, demographic changes and even disease trends to 2030, it is a much harder task to predict the commissioning landscape. This is particularly true of England, with the shift towards localised decision making and budgeting. In the event of compelling data on costs and outcomes, we may well see a more uniform push for community eye care services across England in years ahead, though studies will need to take account of delivery models and geographic considerations, with evidence effectively communicated and disseminated to convince commissioners. Relationships between community optometrists and ophthalmologists also need strengthening for efficient partnership working. Professional membership of Local Optical Committees and Local Eye Health Networks, feeding into both the CCG and the Health and Wellbeing Board, will be critical.

Forecasting on the GOS contract (outside of Scotland) is another challenge. As confirmed by interviewees, GOS does not reimburse practices the true cost of delivering sight tests, and fails to acknowledge the extra chair time elderly patients often require. Moreover, the remit of the GOS contract remains narrow in light of optometric skillsets. Scotland's GOS contract is more advanced in this respect, and it is noteworthy that an increasing number of optometrists in Scotland are gaining independent prescriber qualifications.¹³ Scotland has also made at least some headway with increased access of vulnerable groups to sight tests (Ikenwilo, 2013). This remains an important issue in England, where Public Health doctors have raised concerns about the GOS disincentivising practices being located in socio-economically deprived areas and thus presenting barriers to sight tests, even though many people are entitled to an NHS optical voucher.

¹³ According to GOC, there were 114 IP-registered optometrists in Scotland circa mid-2015, proportionally much higher than in England (171). Indications are that a significant number of optometrists in Scotland are undergoing IP training.

3. Looking to the future: the impact of NHS commissioning on optometric services

On balance we think it likely that the GOS contract will be re-evaluated and redesigned for the 21st century within our forecast timeframe: this may happen through a central decision process or through local leadership. The likelihood of adopting the Scottish free-to-all model is slim, in part because cost-savings evidence will be difficult to prove unequivocally.

Finding savings in the NHS is a focus of the new government and NHS England. With acute hospitals still absorbing the majority of the NHS budget, it may be considered an economic imperative to conduct a national review of all ophthalmic pathways to see where savings can be made. However it is not anticipated that ophthalmology will be a priority as the overall spend is small compared with other specialties.

In the following pages we will discuss technology's potential impact on specific commissioning considerations. In general terms, it is safe to predict that the optometrist of 2025 will have opportunity for wider involvement in NHS eye care services than currently. A greater proportion of optometrists (than now) may find themselves in the employ of the NHS, working as part of a multi-disciplinary team in the acute sector, MCP or PAC. However, those working in busy commercial centres may not see significant involvement in wider NHS care, especially where there exist consultant-led Community Ophthalmology Services.

Foresight Project Report Part 2:

Technology and disruption

In the following pages we discuss technology and technology-driven procedures that are set to influence, even transform, community eye care services. These are arranged around the behaviours they could affect, from both a professional and public perspective:

(S.4)	Communication and education
(S.5)	Prevention and early intervention
(S.6)	Correction and treatment
(S.7)	Independence and self-care
(S.8)	Interdependence and partnership working
(S.9)	Fashion and lifestyle
(S.10)	Ophthalmology

S.4 – S.9 present a description of (sometimes disparate) technologies followed by consideration of business implications and disruption, with reflection on public behaviour and potential business solutions. Quick-view charts of the technology, with time-line expectations and impact, are provided at the end of each category section. These are colour-coded for ease of navigation across the subdivisions of (i) vision, (ii) vision and health, and (iii) health. Technology exclusive to private business or consumer is separated from that relevant to both businesses and the NHS.

S.10 is in effect an additional section that briefly explores potential developments in ophthalmology that require consideration for their possible impact on community optometry.

Whereas PART 2 discusses theme-based disruptions within the public and business sphere, PART 3 draws these together to understand impact on specific business areas within the optical sector.

4. COMMUNICATION AND EDUCATION

Introduction

Digital health technologies facilitate radical opportunities for empowering citizens with information, education and participation. Professionals have wrestled for decades with the difficulties presented by patient non-compliance with a recommended treatment or activity; for example in the field of optics, regular use of eye drops or attending clinics for glaucoma monitoring. Cultural reasons for this are complex, but without doubt one of the key factors has been a lack of understanding (and memory!) on the part of the individual as to the function, procedure and purpose of the instructions given. Health literacy is not the only consideration; a lack of attention to an individual's culture is also to blame (The Lancet.com, 2015). Only relatively recently has easily accessible, reliable information begun to emerge outside of the 'professional' environment to enhance understanding and signpost people to where support can be found.

Across healthcare, information technology (IT) is playing a vital and rapidly expanding role in supporting personal choice and control. Despite this, there remains a crucial role for the professional in advising on reliable sources and giving intelligent interpretation where needed. Much of what is online and available in the form of apps is currently unregulated. Whilst this has enabled rapid innovation, it does mean that IT is not without its risks. In common with all areas of healthcare, there are fears that unregulated websites and apps may (perhaps inadvertently) deter behaviours that clinicians and policy makers are attempting to encourage. In response to this, NHS England is developing a 'kite mark' system for approved apps, and already has a 'safe and trusted' app library at apps.nhs.uk. Likewise, Public Health England has appointed a head of digital health (as from November 2014), whose brief includes an evolving endorsement 'It works' model to assess new digital health technologies. That said, it will be hard for any formal evaluation system to keep up with the exponential growth of

4. Communication and education

digital health technology, and online communities are already a good source of public peer assessment and ratings. Websites such as PatientsLikeMe and HealthTalk enable people to connect with others, often globally, with the same condition and share experiences of what has helped or hindered their condition. PatientsLikeMe now enables the public to get involved in clinical trials, and it recently signed a deal with Walgreens in the USA (owner of Boots Chemists in the UK) to allow patients to compare medication side-effects (Mobihealthnews, 2014).

The public already has easy online access to quality eye care education and signposting via NHS Choices, as well as through charities such as eyecaretrust.org.uk and the College of Optometrist's site lookafteryoureyes.org. Multiple providers such as Specsavers, Vision Express and Boots have also created website pages devoted to patient education. In considering the technology that is present and emerging in optics, this section highlights developments in communication and information, both going beyond pure education to actual individual participation and control of certain aspects of sight testing. This is being experienced across all specialities in health and medicine, in what has been described as 'Medicine turned upside down' (Topol, 2015). The democratisation of health has arrived.

As information becomes real-time enabled by the popularity of social media, the latter is now considered essential to business. It has been most successfully exploited to date by Specsavers, who beyond TV advertising have run YouTube and MSN takeover days. YouTube is the most used social platform, Facebook the most used social networking site but Twitter, LinkedIn and Instagram are increasingly important to business. Tesco's national twitter account has 7,389 followers, yet the independent Taank Optometrists in Cambridge have secured a following of over 1,000, to whom they send updates on frames, lenses and local news. Visual information is of increasing importance

(we now know that it only takes the brain 13 milliseconds to process an image): the growth of platforms such as Instagram, Pinterest, Tumblr and Vine demonstrate the contemporary relevance of visual image communication, especially to younger generations. Practices will become more reliant on digital marketing consultancy and/or staff with expertise in digital communication and social media.

"Visual marketing plays an important role with the Millennial generation. 58% of Millennials look to Pinterest for inspiration in at least one fashion category, while 49% look to Instagram." Netbase, 2013

In this section:

- Smartphone and apps: communication and compliance
- Practice IT: online booking to patient portals

4.1 Smartphone / Tablet

Compliance technology has specific business relevance for provider and manufacturer. Important to optometric business is technology that reinforces customer loyalty; and important to manufacturer is technology that optimises the customer experience of its product. Compliance may also be understood in terms of self-care: thus important to the public is technology that encourages health regimes and improved wellbeing, which we discuss within the category of 'self-care' in Section 7.

A) Communication

Technology has transformed the way in which optometric practice is able to communicate with its patient base, notably in terms of email and text appointment reminders, a capability already embedded within Practice Management Systems

4. Communication and education

(PMS). E-reminders are useful for patient loyalty, reminding patients to book an annual or biannual sight test, and may help reduce missed appointments ('Did Not Attend' or DNAs), though there is limited evidence of this within the context of primary care (BioMed Central, 2015). The e-reminder also cuts paper trails and postage, reducing stationary costs and staff administration time.

Around 93% of UK residents own a mobile phone (MOA, 2014) and 64% of mobile users in the UK have a smartphone (comscore.com). One recent study of smartphone use found that around half of users look at their mobile within the first 15 minutes of waking, and over 80% within the first hour (Deloitte, 2014). Text reminders, in particular, are the fastest, most economical and efficient method of patient contact and it is only the minority of practices that have yet to adopt 21st century communication. Nonetheless, it was noted anecdotally during the project period that not all practices with PMS are making use of text reminders.

B) App-based education: contact lenses

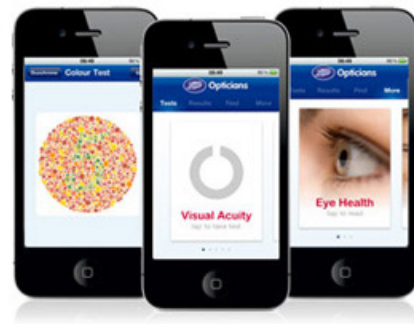
Compliance apps for eye care products may have particular value to contact lens manufacturers. Among the contact lens management apps is Johnson & Johnson's ACUVUE LensPal, designed to encourage successful transition to contact lens wear. Featuring video tutorials and reminders, the app is intended to reduce the one in five drop-out rate of new contact lens patients within the first month of wear.

The concept of app support is perfectly in line for new contact lens (CL) wearers, the vast majority of whom are younger adults – the smartphone generation. The average age of a contact lens wearer in the UK is 36 (Contact Lens Spectrum, 2013): many will first try lenses in their teens and twenties. While there are a number of generic CL management apps (e.g. 'forEyes', contact lens tracker), we would expect to see other major CL manufacturers developing compliance apps over the next five years.

C) App/web-based vision testing: provider opportunities

Public-use vision testing apps, which can serve as an indicator of visual acuity, astigmatism and colour weakness, may appear to have limited scope for disruption as stand-alone products. Their use by an individual would be infrequent, and the competition from a wide variety of apps, each vying for space on the user's smartphone, is considerable. Apple Store downloads in March 2015 revealed the most popular App categories to be: games (21.4%), business (10.1%), education (9.9%), lifestyle (8.3%) and entertainment (6.8%). Health and fitness apps saw less than 3% of all downloads (statista.com). No vision testing app was appearing in the top 200 health and fitness apps in the Google Play Store at the time of writing.

Figure 3. Boots' eye check app



The app offers basic tests of visual acuity, astigmatism, duochrome and colour vision. Additional features include recommendations according to results; further questions to assess the health of eyes; eye health advice; and a Boots Opticians finder.

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A vision-testing app that signposts the user to a specific sight test provider could however hold business potential. After all, if an individual looking for an eye testing app is viewing available products, why not ensure they have opportunity to choose one that signposts them to your business?

The Boots Eye Check app (Fig. 3, p.41) is such a product. Featuring basic vision tests and eye health advice, it has been downloaded tens of thousands of times according to the Apple and Google Play stores. There is a convenient store locator within the app and the user can (web enabled) fill out an eye-test contact form online. It is not known how many patients have made an eye appointment with Boots as a direct result of this technology.

It is possible that other multiples will create eye-check / store-finder apps within the next few years. The development of such may cost tens of thousands of pounds, but is thereafter cheap to update and can adapt to the requirements of online booking. There are limited opportunities for independent practices in this regard, but it is not inconceivable that a manufacturer such as Johnson & Johnson (see above) could offer individual practices the chance to be contacted through their app. Software providers of PMS or marketing solutions could also integrate a similar facility within the independent's website. Interestingly, no multiple chain is currently offering a basic vision test via its website as an online gateway to a full eye check.

D) Professional: smartphone/tablet apps

From conversion charts to testing tools to contact lens support, there are a number of apps aimed squarely at the professional. There are also professional education apps, as well as online education and support, for example by DOCET (Directorate of Optometric Continuing Education and Training), which offers interactive and non-interactive online CET. More recently the College of Optometrists released its 'Guidance for professional practice' app¹⁴ to give optometrists

quick access to refresher education and professional standards information, even offline.

Well-known among professional education tools is the Eye Handbook (EHB) app (Fig. 4), which has an eye pathology atlas and symptom explorer as well as drug information and interactions. The app also allows further professional education via EHB forums, enabling the user to connect with eye care professionals worldwide, post pictures and ask questions.

Our interviews and research indicated limited ophthalmic interest in apps specifically intended for patient education. Perhaps part of the reason for this is the inclusion of patient education sections within other software applications. The EHB, for example, contains a patient education module. And whilst the iPad test chart is the hub of Vision Toolbox by Thompson Software Solutions (pioneers of computerised test charts), patient information is included, supported by images and a video to help explain various eye conditions.

Figure 4. Eye Handbook (EHB) app



¹⁴ Available only for College members, accessed via guidance microsite.

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Useful apps cited by interviewees also included Bausch + Lomb's Toric eyeApp, designed to provide a starting point for toric lens selection and modification; and Johnson & Johnson's Vision Care Eye Grading, used to evaluate common ocular presentations.

Professional apps have value within the practice setting, while at the same time supporting optometry beyond, for example in domiciliary care or school settings. And whilst perhaps not game-changing within the practice setting, such digital tools may give a slight commercial or clinical edge over 'disconnected' competitors. This is a growth area, and one particularly valuable to the practitioner who seeks further professional development within contact lens dispensing and services-focused optometry. (See also Part 4, Education and training.)

4.2 Practice IT: online booking to patient portals

Real-time online booking and even the optometric patient portal are already a reality, but rarely do we find these services.

Only a small proportion of independent practices are offering online appointment booking, and fewer still real-time booking, let alone patient record access. Among the multiple practices (at the time of writing), Boots and Vision Express provide the most streamlined online booking facility; Specsavers stores have an online sight-test request form; Tesco requires the potential patient to fill out registration first on its website and then sign in, before making an online booking; Asda requests the patient to telephone its local branch.

Given that none of the multiples allow real-time booking, with patient sight of available appointment times, the suggestion to simply phone a local branch may in fact be the quickest and easiest option currently available. Appointment booking among the multiples and most independents therefore appears years behind mainstream cinema, hotel and travel booking.

A window into the future of online patient access is provided by Optix Software's PMS platform. Comprehensive and versatile as an in-house practice management tool, its MySight online portal offers real-time appointment booking for patients along with the ability for them to view prescription and contact lens details, see fundus photographs and update personal contact information. In April 2015, Optix launched the MySight app for both Android and IOS devices.

With increasing prevalence of online NHS and private appointment booking, optometric practices without this capability are in danger of appearing out of touch. The online booking service Zesty.co.uk offers online booking with nine different types of health practitioner (dentist, osteopath, physio, etc) but optometry is noticeable by its absence. This is a missed opportunity.

4.3 What this means for business

4.3.1 Considerations

Technology that facilitates communication and education has specific business relevance to the provider and manufacturer. Important to optometric business is anything that reinforces patient loyalty; and important to the manufacturer are opportunities that optimise the patient experience of its product. Important to both are opportunities that sustain sales.

Real-time online booking should be the norm by 2020, and as people get used to having access to their GP record and become more aware of the medical record apps, we anticipate the optics market will respond with a variety of patient portals. This is not only an opportunity, but vital if the optics sector is to be seen as an integrated health partner, and eye health an essential component of one's health record. People will come to regard anything less as amateurish. As we explore in other sections, the chance for optometry to diversify, afforded by new technologies, will be helped by recognition of the optometrist's role as central to public wellbeing.

4. Communication and education

In a world where customer loyalty is often trumped by perceived value for money (a cheaper option that appears to be of equal worth), optics needs to exploit the opportunities that technology offers to engender allegiance. There are a host of relatively new organisations pursuing innovation (e.g. Academic Health Science Networks), offering facilitated technology development (e.g. Institute of Biomedical Engineering at UCL, the Digital Health Institute for London) and publishing eyesight related apps (centerforvisionandlearning.com). Practice awareness of newly available technologies will impress patients, and the diversity of innovation means that cultural considerations can be catered for in a more effective way.

Trends elsewhere in health show that citizens are becoming more demanding, with higher expectations of both services and treatments. They will access much more information online and from peers, reducing their dependence on professionals. However vision remains the most valued of the senses, and due to our ageing population, concern for preservation of eyesight will increase.

Key areas of research in communications presently include improving longevity of portable technology through an improved battery life, expanding options of wearables, and exploring the next step on from wearables, such as Project Underskin (NewDealDesign, 2014). This direction of travel points to the increasing mobile connectivity of the citizen.

4.3.2 The public

Whilst improved web-based and mobile communications can improve public compliance and loyalty, they also create a growing culture of self-care and self-education. Many sectors of healthcare are overwhelmed with demand, but optician practices, pharmacies and dentists are dependent on high footfall to sustain their income. Increasingly online information and networks will reduce the individual's need, or perception of need, of seeing professionals face to face.

Over time it is likely that older people (in particular) will compare their interaction with optical practice with that of general practice or pharmacy. In fact, those in optics should want them to, in order to strengthen relationships and emphasise the importance of eye health. If we think about how citizens will be interacting with other sectors in health, we can draw parallels. The modern patient will demand vision test appointment-booking online. With access to their EHR, they will expect to see records of eye health and refraction, whether via PMS patient portals or PMS-linked GP records. They will also have greater e-connectivity with other patients through online forums set up by and for those with specific health conditions. People living more remotely in rural areas will expect to see telehealth links between the optometrist and hospital-based ophthalmologist. This means a consultation can take place without the patient having to undertake a long journey (although the service may be more feasible if offered by a GP's practice that uses telehealth for other specialities as well). Attendance at the hospital ophthalmology department will then be based only on the need for a hands-on examination or treatment.

As access to health and biometric information becomes ubiquitous through wearable and mobile technology, professional help will be sought downstream for advice in application and interpretation. Customised 'automatic' reminders will be expected, but while the public will be less dependent on professionals for information, they will still want a sense of being looked after and cared for. This is still the hallmark of a civilised society.

4.3.3 Solutions

Practices need to understand local population needs and business opportunities to identify ways of best exploiting communication and education technologies. Some practices will want to remain heavily focused on retail, building links with brands and possibly lifestyle options too (see section 9). Others will want to become known for eye-health

4. Communication and education

community care, and trusted close working relationships with the local hospital. More optometrists may find themselves working in a hospital or hospital outreach setting; according to the Hospital Optometrists Committee over the past 10 years there has been a 'significant' increase in hospital eye service optometrists, although exact numbers are unclear. Other practices will be able to straddle both worlds, especially in areas where they are already the dominant provider, with strong NHS relationships.

Practices offering additional eye care services (such as LES and MECS) should find further ground for strengthening patient loyalty and confidence, particularly in suburban and rural areas where access to an ophthalmologist is a geographical challenge. Loyalty could also be enhanced by practice membership programmes (PMPs), which for a monthly payment offer discounts on services and products.

If the local practice is going to be seen as an integral part of the health landscape, improved IT connectivity between practices and the NHS will be required. This will include important improvements to e-referral and shared care via telehealth. Practices themselves will need to 'upgrade' the patient's journey with streamlined online booking and facilitate access to eye-test and eye-health records. With General Practice offering patients online booking, repeat prescription orders and access to their online GP record, optometric practice is liable to appear anachronistic over coming years unless it too enters the digital age.

Businesses should look for emerging vision testing and education apps, and online booking services that can signpost the user directly to a provider. It is essential that such services are smartphone compatible: mobile access to websites is a growth area, even if sales conversions via smartphones lag behind those of desktop computer and tablet (smartinsights.com). Within five years, the larger chains will probably offer a basic web-based vision

check as an online gateway to a full sight test. Software providers (PMS or website) catering for independents should be thinking about how to offer small practices this same facility.

Knowing about new tech and stratifying the patient database so individuals are offered relevant, targeted support (e.g. Amsler app for family history of AMD; contact lens or eye drop compliance apps) requires a small investment in time that could translate into a valuable personalised patient experience. Horizon scanning for new trends, improved automated support and patient assisting technology is essential.

Connecting with patients through social media is vital, especially through 'visual listening', using images rather than text to communicate. The most popular platforms will change over time, but finding out what is 'trending' should not be difficult. If not undertaken in-house, marketing and communication can always be outsourced, but strategies need to expertly balance eye health and retail (see also Section 9).

New communication technology offers more ways to keep in touch with patients, and in a world of increasing digital 'noise', businesses will have to find effective strategies to capture public attention. Such focus is particularly relevant to the independent practice, already challenged by the high-volume and high-visibility of the multiples, and liable to experience swift demise if it fails to harness the power of digital technology.

Legend

Vision
Vision / health
Health

Communication / education

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
Private sector							
Basic 'pre-test' apps (smartphone)	Public	Now	signposting	<1	2	Could give false sense of good eye health	Boots have already developed their own 'pre-test' app. Business potential where app links to optometric practice.
Basic (free) on-line 'pre-test'	Public	Now	Convenience; signposting	<1	2	Could give false sense of good eye health	Business potential where website links to optometric practice
Education / information apps	Prof	Now	CET; instant reference; emergency use	2	3		Useful for CET on the go, also manufacturer training modules
Digital marketing / communication platforms	Prof	Now	Business communication	8	10		Already considered business essential by most successful practices
Eye care apps & sites: education / information	Public	Now	Prevention and compliance	<1	3	Poor information from unregulated apps / sites	Expected to be increasingly utilised by contact lens wearers
PMS Online Booking / Patient Portal (eye health and vision)	Public	Now	Ease of appointment making; personal & professional ease of access	3	10	Security standards of patient portals and access	Practices will need to move towards realtime online booking systems and patient access to remain competitive
NHS involvement							
NHS Choices / NHS online services	Public	Now	Public education / information	2	4		NHS Choices (Livewell) – important educational resource; includes link to NHS optician finder and rating system
NHS Personal Healthcare Records (ePHR)	Public / Prof	By 2020	Healthcare record connectivity across primary and secondary care	1	5	Patient confidentiality	Important to parents, LTC groups and over 60s. During late 2020s full integration with PMS patient data.

5. ASSESSMENT, PREVENTION AND EARLY INTERVENTION

Introduction

Arguably the most important part of community optometric practice is associated with assessment, prevention and early intervention. By 'assessment' we mean the process of refraction and screening for eye disease; by 'prevention and early intervention' we mean the education of at-risk individuals and any action taken to detect, mitigate or control the effects of incipient eye problems or disease.

While there are optometrists working in independent practices who perform every aspect of the full eye examination, the high-volume multiple has seen many 'pre-test' or 'pre-screening' tasks, such as autorefractometry, visual fields, tonometry and fundus imaging, undertaken by technicians. The push-button design of such machines has been deliberately developed to enable ancillary staff to perform the tasks. Regulation requires the optometrist to complete the refraction process and then undertake further examination of eye health with reference to the pre-test results.

Innovation in the high street is being propelled by market forces – not by the NHS or regulation. Commercial pressures will see technology increasingly harnessed to both streamline the patient journey and raise the standards of the sight test and other eye health services, with marketing strategies including new refracting technologies and private children's services.

In this section:

- Vision testing
 - Autorefractometry and automated subjective refraction
 - Portable autorefractors
 - 3D refraction
 - VisionOptimizer: refraction innovation
- Focus on eye health
 - Optical coherence tomography (OCT)
 - Ultra-widefield laser scanning ophthalmoscope
 - Dry eye diagnostic technology
 - Objective tests for incipient eye disease
 - Pre-diabetes testing
- Children
 - Myopia control
 - Gaming technology for amblyopia

5.1 State of play: 2015

The technology available to the community optometric practice is constantly evolving and improving in design, capability, precision and speed. The last 20 years have seen significant developments and greater accuracy in the fields of tonometry, autorefractometry, corneal topography and anterior segment imaging. Added to this there is now access on the high street to digital fundus imaging and, more recently, ultra-wide field retinal imaging and swept source optical coherence tomography (SS-OCT), bringing enormous diagnostic and monitoring power to the optometrist. The optometrist also has access to a far wider range of tools to assess visual acuity, with computerised test charts incorporating contrast sensitivity, fully randomisable letter charts and shapes/characters for those who cannot read.

Optometric opportunities for community eye care services (especially monitoring, pre- and post-operation consultations and the treating of minor eye conditions) have generally widened in the UK within the last few years (2020health interviews / LOCSU), in the interests of patient access and to relieve pressure on hospital eye services.

The emergence and fast dominance of the multiples has expedited a certain uniformity of cutting-edge equipment across community optometry. The most recent technology to undergo normalisation is fundus photography – even if some independent practices in England are still charging patients extra for the service (following detailed ophthalmoscopy). According to most interviewees who expressed an opinion, the next technology in line for normalisation is optical coherence tomography (OCT).

5.2 Vision testing

The days of manual subjective vision testing on .25D measurements are surely numbered. Digital refraction systems capable of greater accuracy of measurement within a faster exam time are already finding their way into UK practices. Several manufacturers now make automated phoropters, some enabling sphere increments of .125D, and with claims of a 50% (or more) reduction in the time taken for a subjective test (VisionMonday.com, 2015). The use of pre-test baseline data, captured from autorefractors and other digital analysers, is key to reducing the time the patient spends in the optometrist's chair. Some businesses transfer the time saved to eye-health matters (further tests and/or patient education); not all simply seek a faster eye exam altogether. New forms of refraction are also emerging which dispense with the phoropter entirely (see also Sections 7.6, 8.3D, 9.3). In this section we look to the future and consider some likely developments in refraction technologies aimed at traditional providers.

A) Autorefractometry and automated subjective refraction
Autorefractometry dates back to the 1970s (Vilaseca *et al.*, 2013) and in recent years has become a standard constituent part of the 'pre-test'. In the UK, autorefractometry is typically used only as a starting point, yielding baseline results that are refined by the optometrist in a subjective refraction. Used in this way, autorefractometry can be a time saver, particularly where tests are supervised by a technician and measurements are electronically relayed to a digital phoropter.

Whilst research in autorefractometry and wavefront aberrometry shows some general agreement between automated and subjective tests, indications are that up to 10% of automated results differ by beyond +/- 0.50D (Bennett *et al.*, 2015); the subjective test is therefore still considered the gold standard by optometrists.

CASE STUDY TOPCON BV1000

In 2004 Topcon released a revolutionary piece of technology with the tagline: *Every so often something happens to change a Profession forever.* This was the BV 1000, the world's first subjective refraction system, with 'simultaneous binocular objective refraction and interactive defined subjective refraction,' with voice prompt.

It received broadly positive reviews in early trials (Dave T, 2004; Sheedy J, 2004), and yet UK providers rejected the instrument. The price may have been a contributing factor (suggested list price in the USA was \$43,000), although the notion of optometrists' livelihoods being negatively affected is presumed to have been pivotal.

In the past, UK providers have appeared somewhat resistant to (further) diminishing patient–optometrist contact time through autorefraction. There was little excitement generated by Topcon's BV 1000 in 2004 (see case study), which could have virtually reduced the optometrist's role to eye-health consultant.

Some of those we interviewed argue that automated refraction is now good enough to rely on in the testing of 'normal eyes', and certainly where there is no, or only minor, refractive error to read. The 'art form' of testing, using experience and considered judgement in the fine-tuning of refraction, is not utilised in the majority of cases. Others disagree with this position, pointing out that machines can in any case 'de-calibrate': the results can only be known as accurate via subjective testing. However, manufacturers in global markets know well the value of automated refraction – where, for example, optometric expertise may be in short supply, or profit margins are severely challenged by staffing costs and other overheads. Further improvements to autorefractors will no doubt follow.

"...as involvement in more specialised ... services becomes increasingly commonplace, the introduction of an automated refraction component to the overall eye evaluation may allow greater time taken on health assessment, imaging [and] specialist prescribing."
Optician, 2004

We may yet see a return to the autorefractor combined with patient-led refraction, so to allow a process of both objective and (rapid) subjective refraction, supervised by a technician and signed off by an optometrist. Vmax Vision's Perfectus relies on the involvement of the eye care professional, but is otherwise a step in this direction, combining subjective technology with wavefront autorefraction in one machine (vmaxvision.com, 2015). In the USA, some practices delegate largely automated refraction with autorefractor and tablet-controlled phoropter to a technician, with eye-care professional sign-off. Telehealth solutions are also on offer, using both the autorefractor and autophoropter, with remote ophthalmic technicians supervising the refraction, followed by remote ophthalmologist sign-off (20/20Now, 2015). The future will see a decreasing need for the optometrist to be hands-on throughout the refraction process.

There will always be members of the public who do not trust technology and want to retain the maximum level of professional interaction. Nevertheless, automated systems will dominate in the future, and it is reasonable to expect some kind of binocular autorefraction and/or patient-led refraction to become as reliable as the optometrist's current gold standard within the timeframe under consideration. Initially we would expect this technology used in situations of high throughput, such as the busy city-centre practice or supermarket. It may encourage regulatory changes to 'delegated

functions' (see 17.2.2), and also the advent of automated sight testing in telehealth kiosks (see 8.3E).

"The future will see a decreasing need for the optometrist to be hands-on throughout the refraction process."

B) The portable autorefractor

The portable, handheld autorefractor is not just a valuable tool for domiciliary specialists, but also for any optometrist who needs to take measurements from infants, children, the elderly and patients who cannot cooperate. Developments in this area have the potential to increase the quality of care to historically underserved cohorts.

Recent innovations include PediaVision's Spot binocular autorefractor and the slightly more compact 2Win Refractometer, both point-and-shoot, wi-fi enabled instruments capable of monocular or binocular refractions. The capturing of images is no more complex than taking a photograph, with the software providing a comprehensive analysis in seconds. The 2Win even has attachable masks, such as animal faces, to capture the gaze of the very young.

Smartphone technology is used in the pocket-sized Smart Autorefractor, SVOne, designed by the start-up Smart Vision Labs and recently made available in the US. Consisting of an aberrometer with wavefront sensor, the SVOne can be used by optometrists or even caregivers, and is intended to be affordable at the point of use by community healthcare workers (see also Section 8).

All such technologies have the potential to enhance both in-practice and domiciliary care for a range of vulnerable patients. Start-up disruption and technological development will likely induce competitive pricing and the wider use of portable autorefraction in the UK in future years.

C) '3D' binocular refraction

Practice-based 3D binocular refraction seeks to create a more true-to-life alternative to the 'false' conditions of open-eye / closed-eye testing. One of the most recent innovations in this particular space is the Paskal3D, a refraction system made public in 2014 by IPRO GmbH. By using circular polarised filters, which continuously remain before the eyes of the subject, the viewer keeps both eyes open while the acuity of either left or right is tested via optical test objects on a 3D monitor.¹⁵

Other companies to have brought such technology to the market place include Thomson Software Solutions, with its 3D Polarised Monitor and Test Chart Xpert 3Di software. Such software-generated tests of course allow a great range of sight-test options that can be continually updated and expanded.

In time, 3D binocular refraction may be offered by practices as a more suitable or even enjoyable alternative to standard sight testing. However it is highly unlikely to become standard testing method for most. 3D testing appears in part reliant on the popularity of 3D media – film especially – which is highly susceptible to swings of public preference (rollingstone, 2013; cinemablend.com, 2013). According to a survey by the American Association of Optometrists, as many as a quarter of people report eyestrain, blurred vision, dizziness, headaches or nausea after viewing 3D content (Telegraph, 2011). For some the symptoms will be triggered by motion sickness, a feature of no relevance to the 3D sight test, but an association with discomfort may remain.

D) VisionOptimizer: refraction innovation

Autorefractors and tablet-controlled auto-phoropters are not the only technologies challenging traditional methods of manual refraction. In 2014 DigitalVision created a stir at the Vision Expo West in Las Vegas with its VisionOptimizer (DVO) system, which projects images from a wavefront generator to a concave viewport mirror, where they are reflected to the patient's eyes to create a 'virtual refraction'.

¹⁵ If the right eye is being tested, the left sees only a blank screen, but only by shutting the right eye does the viewer become aware of this.

5. Assessment, prevention and early intervention

An eye and head tracking system compensates for head movement during refraction – a significant feature for children, the elderly and people whose disabilities cause involuntary movements. The system also allows the virtual try-on of eyewear, and is accordingly described as a 'vertically-integrated exam-product solution for delivering premium vision care and corrective eyeglasses'.

The manufacturer claims the technology facilitates a more precise measurement of higher order aberrations and refines prescriptions to an accuracy of 0.01D, rather than the 0.25D of a standard phoropter (or 0.125D of some digital phoropters, such as the Righton RV-II). Moreover, traditional subjective refraction often fails to replicate normal viewing conditions – rarely, day-to-day, do we read text on well-illuminated, high-contrast visual acuity charts! The aim of the DVO is to test visual acuity within 'natural viewing conditions', avoiding the restrictions of small viewing apertures and head restraints. The developers believe this technology will particularly appeal to a population accustomed to interacting with computers and gaming technology.

"In contrast to the fixed power lenses in the phoropter lens-dial, the DVO incorporates computer-controlled, continuously-variable power lenses (CVPLs) that can be adjusted to one-hundredth of a diopter (0.01D), thereby providing twenty-five times the resolution of conventional phoropters. A spatially-resolved refractometer in the wavefront generator measures higher order aberrations of the patient's visual system."

DigitalVision Systems

The optical market will no doubt be keen to see compelling results from clinical trials and early adopters of the VisionOptimizer before committing to purchase. This equipment could be commercially available in the USA within the next year or two, and we are aware of some notable interest in the UK.

5.3 Focus on eye health

A) Optical coherence tomography

Optical coherence tomography (OCT) is a non-invasive imaging technique relying on low coherence interferometry to generate in vivo, cross-sectional imagery of ocular tissues. Developed in the 1990s, OCT has slowly found its way into community optometric practice over the last ten years and has continued to evolve in capability, with higher scan density, faster acquisition and processing speed of data, and computerised image analysis (for example, Topcon 3D OCT-2000, with glaucoma analysis). The newest version of this technology is Swept Source OCT. During our project period, Topcon launched the Triton SS-OCT, which doubles the scan speed (to 100,000 A-scans/sec) of some Spectral Domain OCTs, with superior penetration through cataracts, haemorrhages, retinal nerve fibre, blood vessels and the sclera.

OCT has clinical value beyond early detection and monitoring of disease; the ability to perform volumetric and retinal thickness analysis also provides a quantitative and repeatable method to evaluate surgical and pharmacological interventions (Ophthalmic photographer society, Retinal OCT imaging). OCT is also used outside of ophthalmology, for example in dermatology and coronary imaging.

OCT is still fairly uncommon in community optometric practice. Where available, its use is chargeable within the context of a premium sight-test service, with fees of £50 to £80 typical. The lowest charge for OCT we found was just £5 extra on top of a £25 standard test.

Within optometric practice, OCT is perhaps ahead of its time. Some interviewees (both optometrists and ophthalmologists) remarked how optometrists generally lack appropriate expertise to interpret images, and far from reducing false-positive referrals to the secondary setting, high street OCT is liable to increase them. Optometrists see things unknown, or borderline images, and refer on for a specialist's opinion.

“The level of detail in OCT is inappropriate for the optometrist's role. Optometrists are not terribly good at interpreting the results, so we're swamping hospital eye departments with unnecessary referrals.”
2020health interviews, 2015

It is reasonable to expect within the next five years a multiple chain will make the decision to purchase (or lease) several hundred machines at discount: the cheapest OCT instruments after all are around £20k (ex-VAT). Considerable thought should therefore be given to education and training if OCT is going to be suitably maximised. Following low-level training, affirming that the image gained is normal should not be a problem, but the full potential of OCT imaging is only realised in disease detection and monitoring. To become confident in understanding the relevance of variations in images, to discern whether an irregularity is significant and to monitor seemingly stable patients, will require training, minimum patient volume¹⁶ and locally agreed accreditation and remuneration.

It was put to us that feedback from ophthalmologists would contribute significantly to the education of optometrists in OCT, especially following the implementation of NHS.net. For example, Southern

Observation

With rising demand from an ageing population, it would be well worth the professional ophthalmic bodies extrapolating the predicted incidence and prevalence of eye disease, so to map out service capacity and understand how suitably qualified optometrists may use OCT to contribute to patient care.

Derbyshire CCG is running a small telemedicine pilot with OCT currently, where participating optometrists who have undertaken an OCT scan have the option to send images via a telemedicine system (using NHS.net) for advice from an ophthalmologist, who then decides on the appropriate course of action. Such working partnerships can create valuable dialogue and learning, but these are for now the rare exception. We therefore believe it unrealistic to view occasional ophthalmologist feedback as an expected constituent part of OCT up-skilling among optometrists.

Perhaps a better solution to the OCT 'problem' will be some sort of specialist triage service, locally located and run by suitably trained optometrists. We consider this further in Part 4 (Education and Training).

Looking further ahead, advanced automated image grading will bring considerable screening capability to the high street, regardless of clinical expertise. The acceptance of such by the NHS is another matter (see business section, below). Before that, by around 2020, we will almost certainly see the miniaturisation of OCT to hand-held models (see Section 8). The mass marketing of the product will follow, particularly with a focus on primary care and telehealth, but the utility and commercial case will still have to be made.

¹⁶ The most recent publication on interpreting OCT images in glaucoma (Singh *et al.*, 2015) is a book to inform the highly specialised optometrist or ophthalmologist, and as with all conditions, no one will become expert unless they are dealing with relevant patients continually. As Sir Bruce Keogh, Medical Director of NHS England, said in his quality of care report (Keogh, 2013), there needs to be a minimum throughput of patients to ensure that the public are getting the level of care that they should from health professionals.

5. Assessment, prevention and early intervention

Further possibilities with OCT: 2020s

Multi-modal imaging, for example allowing simultaneous viewing of 3D OCT and 2D retinal photography, or OCT with confocal scanning laser ophthalmoscopy (cSLO), has been available now for several years. For example, the Spectralis HRA+OCT from Heidelberg Engineering is a dual beam confocal scanning system, capable of simultaneously capturing a reference image and a spectral domain OCT scan, while its 'TruTrack' software recognises the retina and tracks it as the eye moves, enabling the same scan to be taken on subsequent visits (HeidelbergEngineering.com). Such technology is expensive but may become increasingly important to providing accuracy in the monitoring of retinal pathologies.

Yet further advances are expected with the integration of adaptive optics (AO) technology, which is able to compensate for aberrations in the optical path between the object and the camera. Applied to the human eye, AO allows direct visualisation of individual rod and cone photoreceptor cells, RPE cells, and white blood cells. AO will be another technological leap forwards in the tracking of disease progression (Godara *et al.*, 2011).

Higher-resolution and wider views of retinal pathology are a safe prediction for OCT, especially once AO is integrated, possibly within the next 10 years, and with greater sophistication in multi-imaging functions within single instruments. This raises further potential for the use of OCT to track early processes of neurodegeneration in connection with Alzheimer's disease, Parkinson's disease, MS and dementia. Studies with OCT already show that degenerative changes occur in optic nerve fibres in patients with such conditions (Journal of Alzheimer's Disease, 2013). If OCT becomes the go-to technology for the detection of early onset or even pre-symptomatic screening, the community optometrist may have an opportunity to play a key role in the wider health care of NHS patients. OCT technology of the future could be used to identify new therapeutic strategies,

and perhaps even enable the detection and monitoring of the processes of neurorestoration.¹⁷

We acknowledge that detecting disease for which there is no known cure or treatment raises ethical questions. Our ability to detect the earliest presence or risk of disease is far outstripping our ability to remedy. Public consent to taking and interpreting ocular images will have to become more explicit, both to ensure complete understanding of what the test is for, but also to ensure professionals retain public trust.

B) Ultra-widefield retinal imaging

Ultra-widefield retinal imaging devices allow an optometrist to view around 82% of the retina, or 200°, substantially more than the c.60° possible with the digital fundus camera (Schalensbourg A, Zografos L, 2013). The market leader in ultra-widefield imaging is Optos, whose instruments are capable of producing high-resolution fluorescein angiogram images of the retinal periphery, clinically useful in the monitoring of retinal vascular disease. In addition, the Optos is also capable of producing autofluorescence images, which are valuable in disorders that affect the retinal pigment epithelium (Review of Ophthalmology, 2012).

Whilst this technology allows the optometrist to see more and diagnose more confidently, studies published within the last two years have flagged up widefield imaging limitations. Concerns have been expressed about different colours produced by different cameras of the same image, which can result in serious misdiagnosis (Schalensbourg A, Zografos L, 2013). Image distortion is another concern, as what are effectively 3D images become flattened to 2D representation, preventing the direct measurement of peripheral retinal structures on the image (retinatoday.com, 2014). But these challenges are being met. For example, within the last year Optos has introduced Proview software, which enables the display of its optomap in a 'consistent geometry that accurately represents anatomical features in the retina' (Optos.com).

¹⁷ This treatment is not yet possible, though a central objective of neurobiology. See: <http://www.medscape.com/viewarticle/589462>

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Opportunities for practices to recoup costs of ultra-widefield imaging are currently limited to private arrangements, and we expect it to have significantly slower uptake than OCT. A small minority of independent providers in the UK have introduced the technology as part of their gold-standard eye-care offering (not included within the cost of a standard GOS exam). A specialised UK multiple in the near future may well introduce this technology as part of an augmented exam, as OPSM (Luxottica) has done in Australia and New Zealand.¹⁸ By the early 2020s, with OCT anticipated as standard in most practices, we expect greater emphasis on ultra-widefield imaging to differentiate top-tier clinical services. The technology may be utilised in future community services in the monitoring of such conditions as AMD, retinal vasculitis (Leder *et al.*, 2013) and choroidal nevi (Zapata *et al.*, 2015).

C) Dry eye: diagnosis and monitoring

Dry-eye symptoms result from either decreased tear production or excessive tear loss from evaporation. They are experienced by a significant portion of adults, especially as we age. The issue of dry eye is important to optometric practice since its detection (ideally in the very early stages) can be critical to contact lens continuation: prevalence is reported to be up to 20% in non-contact lens wearers and about 50% in contact lens wearers (opticianonline, 2014). Moreover, with an ever greater emphasis on optometric community eye care, patients with dry eye may also present at a local optical practice through the Minor Eye Conditions (MECs) pathway, irrespective of any other ocular requirement.

Dry eye is often misdiagnosed due to its complex and varied presentation. Diagnostic tests are numerous, with a number not yet widely accepted and not reproducible (CO, 2014). Following careful clinical history-taking, procedures commonly utilised include detailed slit-lamp examination, measurement of tear break-up time, fluorescein staining and the Schirmer test. The chair time of patients can be considerable.

Diagnostic and monitoring equipment manufacturers are seeking to improve outcomes for patients. The TearLab Osmolarity System, costing around £8k, measures the osmolarity of human tears, offering a quantifiable test (using £10 test cards) that can be completed in two to three minutes. Another high-end technology is the LipiView Ocular Surface Interferometer (TearScience), which measures the thickness, variability, and stability of the lipid layer in the tear film and the completeness of the blink response, again within about two-minutes.

New technology at the budget end includes the RPS InflammDry test (Rapid Pathogen Screening) for the detection of elevated MMP-9 protein in tears. This involves a disposable test strip and small hand-held analyser, with a single test costing as little as £7.50 to the practice, taking around 10 minutes (BIB, 2015).

All these technologies of course sit within a wider battery of tests (due to the multifactorial nature of dry eye), and no single test will displace the detailed questionnaire and consultation that begins the process of diagnosis. But even the questionnaire is open to innovation: for instance, the Dry Eye Tool Box app (by Dr Heiko Pult) offers a basic patient questionnaire (based on the OSDI system) and calculates the likelihood of dry eye. It also provides treatment and management recommendations, and a 'symptomometer' to monitor effectiveness of treatment. The app conveniently enables a dry eye report to be emailed to the patient.

Such is the commercial interest in dry eye technology – essential also within the field of refractive surgery, particularly aftercare – we should expect improved diagnostic technologies and treatment regimens over coming years. This should allow practices to widen their offering to the public and ensure lower rates of contact lens drop out.

¹⁸ See OPSM's 'essentials plus package'

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D) Objective tests for incipient eye disease

As already noted, we expect an increasing marketing shift towards eye health among providers in the near future – a strategy that will make clear the unique offering of the high street versus 'self-health' culture. Over the next 10 years providers may well see the advent of clinically-proven technology that can provide objective measurements of very early stage disease such as AMD, glaucoma and retinitis pigmentosa.

Despite advances in digital imaging analysis software, subtle incipient disease requires skilled interpretation and is therefore easy to miss, while standard methods of detection used in the high street can lack precision in identifying early onset altogether.

In glaucoma assessment, manufacturers have been working on objective measurement technology that may surpass the accuracy of Goldmann Applanation Tonometry, and instruments that could in time replace standard perimetry (visual fields test), which itself cannot detect early retinal ganglion cell death.¹⁹

With an ageing population and greater public awareness of the importance of early detection, some high-end and high-volume practices may value such equipment as powerful marketing tools. Objective testing that replaces standard visual fields assessment could be especially welcome, given that subjective-response perimetry is time consuming and, according to one large provider we spoke with, generally not popular with the public (2020health interviews, 2015).

E) Pre-diabetes testing

It appears to be the minority of CCGs that are currently commissioning diabetic retinopathy screening services from (accredited) community practices. At the same time, technology is affording new opportunities for optometrists to become ever more involved in screening, monitoring, advice and even management. OCT, for example, can assist the assessment of macular thickness for management decisions and treatment of diabetic maculopathy (OT, 2013).

A very recent technology available to the optometrist is the ClearPath DS-120 lens fluorescence microscope, which is used to detect autofluorescence of the lens, caused by the accumulation of advanced glycation endproducts (AGEs). During a six-second scan of the patient's eye, the device quantifies this autofluorescence by rapidly measuring its intensity and also the scattering of light in the lens (NIHR, 2014). The test therefore requires no fasting or blood draw, and results are instant.

Freedom Meditech claims that the device provides a cumulative, non-reversible picture of a patient's uncontrolled glycaemic levels, and thus a more complete picture (than the HbA1c test) of the historic levels of control. The company also claim that a key innovative feature of the device is its capacity to identify diabetes many years before a symptomatic diagnosis is made. This 'pre-diabetes' detection has not yet been clinically proven. If it is, then the technology (currently \$34,000) may attract considerable attention from primary care providers. The high-end, services-driven optometric practice may be first in line.

¹⁹ Manufacturers in this space include Reichert (Ocular Response Analyzer G3 tonometer) and Konan Medical (EvokeDx). Seeing Machines and Maculogix are among the manufacturers developing objective measurement technologies for early onset AMD.

5.4 Children

A) Myopia treatment (non-invasive)

It is now widely accepted that progressive myopia can have a detrimental effect on ocular health, in time increasing the risk of retinal detachment, macular degeneration, glaucoma and cataracts (Nhs.co.uk; Hiraoka *et al.*, 2012). The causes of myopia are not fully understood: research suggests both genetic and environmental factors are involved. However it is generally thought that as children and young adults spend more time undertaking close work through education and engaging in screen media, and spend less time outside, reducing opportunity for healthy exercise, relaxed distance vision and, perhaps most crucially, exposure to sunlight, myopia rates will only increase (Nature, 2015).

The prevention of myopia progression is an increasing focus of the optometric profession worldwide: in some East Asian countries myopia prevalence is 70–80% among teenagers (brienholdenvision.org, 2015), while in the USA, prevalence among those aged 12 to 54 increased from 25% in the early 1970s to over 40% thirty years later (Vitale S *et al.*, 2009).

The Brien Holden Institute in Australia is undertaking research into spectacle lenses aimed at reducing the progression of myopia in younger children with parental myopia (Sankaridurg *et al.*, 2010). Already available are corneal-reshaping contact lenses: night-time wear hard gas-permeable lenses (standard orthokeratology) and, in some countries, daily-wear soft multifocal contact lenses. In clinical studies both types of contact lenses have produced about 30–50% less myopia than in control groups, in the short term at least (Sun *et al.*, 2015; Lam *et al.*, 2014; Cho *et al.*, 2012). Since longer term outcomes are unclear, the evidence base is incomplete.

Observation

There appears to be a lack of robust data on the change in prevalence of myopia in the UK, and little extrapolation of the costs of myopia related vision loss. A comprehensive study would be of great value. Myopia is both career and sight limiting, and the possibility of early intervention to reduce life-long impact is a case worth investigating.

Orthokeratology, where hard lenses are worn overnight to reshape the cornea, is well known among contact lens fitters. However in the UK less than 1% of practitioners are fitting such lenses (whether to obviate need for day-time lens wear or try and slow axial elongation in children). By contrast in the Netherlands, 98% practitioners fit orthokeratology lenses, which account for as much as 10% of CL market (Contact Lens Spectrum, 2015). The barriers to uptake include specific equipment requirements and training to fit the lenses, as well as user discomfort in wearing.

Daily-wear lenses for myopia control are worn like a traditional contact lens and are multifocal, allowing different foci of light to the retina so that there is a controlled blur to slow down myopia progression. These soft daily disposables are advertised as a practical hygienic option for children. There is no specialist training required to fit them (beyond standard lens fitting competencies), and users are expected to experience no more discomfort than normal contact lens wearers. CooperVision has such a product, MiSight dailies, available in the Far East but not yet approved in Europe or North America. Some optometrists in the UK are dispensing multifocal daily wear as an equivalent.²⁰

²⁰ CooperVision's Biofinity multifocal D lens is used by some optometrists in the UK for myopia control.

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Game-changers in this field would be in terms of a more robust evidence base that corneal reshaping is effective long term, and public awareness of, and preference for, the treatment. To encourage a parent to fit their six-year-old child with myopia slowing contact lenses (as a preventative measure) is not an easy sell, particularly with the necessary cautioning of sight-threatening microbial keratitis. Moreover, childhood stigma associated with glasses is not what it once was. Spectacle frames have become fashion items, with people wearing them who need no visual correction. Whether this will continue or fall out of favour in our image-obsessed society is unknowable.

B) Gaming technology: new possibilities for correction of amblyopia

Treatment of amblyopia typically involves the patient (usually a young child) wearing special glasses for refractive correction,²¹ and often then wearing an eye patch over their dominant 'strong' eye to ensure the 'lazy' eye receives visual stimulation to trigger neuro-visual processing. Eye drops or a frosted lens may alternatively be used to temporarily impair the vision in the strong eye (London Eye Unit, 2015). Traditional treatment programmes typically last many months. Tolerant of the eye patch varies significantly in children, especially if particularly noticed by their peers in school.

Gaming technology for the treatment of amblyopia has not yet proven comparable or superior to conventional treatments, although tests so far have been very encouraging, even among adults, in whom amblyopia is more difficult to treat (possibly due to less brain plasticity) (Li *et al.*, 2011 & 2013). Further progress in this area of treatment is important, since amblyopia is among the most common causes of visual loss in one eye (optometry.auckland.ac.nz) and has significant repercussions for potential career choices.

There are a variety of developers in this 'gaming' field, from independent start-ups to collaborative university-based research teams, most of whom appear to be exploring binocular eye training.

Eye specialists at Glasgow Caledonian University²² have used a Tetris-style game in a study involving children, who wore special gaming goggles while playing the game for an hour a day for up to 10 days. The goggles feed a clearer image to the lazy eye, as described in a study from McGill University, Canada (gcu.ac.uk, 2014).²³ Another study in Texas showed significant improvement in vision in children using an iPad application and gaming goggles, with those demonstrating improvement (all who complied with at least two hours a week for eight weeks) still retaining the visual improvement six months later (Birch, 2014). At the University of Ohio researchers have likewise explored binocular training with a Pac-Man-style game and a 'search for oddball' game, each game lasting only a few minutes to avoid problems of repetition and boredom. Working with laptops, adult participants wear red-green 3-D glasses that filter the images to each eye. A similar technology is already available in the form of the 'uncertified' smartphone 'Stereo Blocks' app, available on Google Play, which uses red/cyan or similar coloured 3D glasses, and is to be played at the owner's 'own risk'.

The long-term outcomes of gaming technology for amblyopia are not yet fully understood. Binocular training may well become the new norm in the treatment of amblyopia (something that has been asserted by Behavioural Optometrists as essential for over 20 years). NHS-funding of 'gaming treatment' will need to be evaluated, perhaps by NICE or possibly by the NHS app store. (The NHS already approves 'iSightTest' app for children with an emphasis on early detection of amblyopia.)

²¹ In some cases spectacles alone have provided a complete treatment. See Amblyopia treatment beyond the critical period. Professor Brenden Barrett: Optometry Today, 10 January 2015.

²² GCU has recently begun collaborating with the University of California, Berkeley, to launch phase 2 research.

²³ McGill University in Canada has also undertaken a Tetris study, with adult participants viewing split images through goggles: one eye sees only the falling objects, while the other sees the blocks that accumulate on the ground.

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With amblyopia affecting 2–5% of the population, high-street involvement will remain niche, especially since childhood eye complications typically lie in the domain of the hospital-based ophthalmologist and orthoptist. However, as we have seen elsewhere, community optometry has scope for developing services to children, and practices may well profit from an optometrist with amblyopia speciality, even if gaming treatment remains privately funded.

More widely, the subject of children's visual development, including eye-tracking and relationship to dyslexia and learning, has been hotly contested for decades. Behavioural Optometrists have been long convinced that vision training is effective (BABO²⁴), whilst other academics are dismissive (Handler *et al.*, 2011). Work is ongoing to identify eye movement patterns indicative of subtle convergence problems or dyslexia (2020health interviews, 2015), but either way these problems are of an order that do not become obvious through traditional screening and testing methods.

5.5 What this means for business

5.5.1 Considerations

Professionals will have the choice of many more assessment, prevention and early intervention tools at their fingertips in the coming years. The availability of this technology within community practice will in part be driven by market competition: an offering of the latest health technologies may well give a business the commercial edge over competitors. The buying power of the multiples will once again be to their competitive advantage.

Change will also depend partly on NHS remuneration for General Ophthalmic Services (GOS), as well as community eye care services that depend on new technologies. (We should not expect to see NHS England matching the £8,000 capital payment given by the Scottish government to each practice ahead of

their GOS contract change in 2006, to improve standard levels of equipment.)

Our interviewees were in broad agreement that NHS remuneration for a comprehensive eye exam does not adequately reflect professional fees and overheads, and that practices are heavily reliant on retail to realise profitability. This state of affairs may well in time encourage further consideration of a more comprehensive role for autorefractometry and other automated processes of refraction. If automated refraction in the near future can claim to offer the same standard as a professional subjective examination, then providers will be able to adopt the technology as their principal refracting method without requiring any change in regulations.²⁵

Another incentive for manufacturers to improve autorefractometry, specifically, comes from a desire to see better outcomes for those with communication and movement difficulties, young through to old. This applies particularly to the further development of portable autorefractors.

In some respects, with greater emphasis on the optometrist's role within eye health, there may be an appetite to relinquish some of the more 'mechanical' work of the eye exam. The refraction results would after all be discussed between the patient and professional along with matters relating to eye health. With a change to regulation, autorefractometry and/or patient-led refraction could be validated and signed off by the dispensing optician (DO).

The commercial considerations of binocular 3D testing and the VisionOptimizer are very different. The entertainment and utility value of these tools may well attract particular patients and prove important to business, but they are likely to sit alongside, rather than replace, conventional testing equipment. The footprint of the VisionOptimizer is of particular consideration, since many testing rooms

²⁴ British Association of Behavioural Optometrists; Bibliography of References

²⁵ The current (Opticians Act 1989) guidelines state, "You must carry out such examinations as appear to be necessary to detect signs of injury, disease or abnormality in the eye or elsewhere". Equipment required is suggested, but there seems to be no legal requirement to use a retinoscope, phoropter or trial frame and lenses.

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do not have the luxury of the minimum 8' x 10' space. This is true even of practices in the USA (2020health interviews, 2015).

Most practices take consideration of footprint and have welcomed the relative miniaturisation of equipment. Both price and footprint are in some ways of greater concern in respect of 'non-essential' equipment – that is, not mandatory to the fulfilment of the GOS contract. OCT machines have reduced in size, but price remains prohibitive for many. If OCT becomes widely deployed by a multiple in the next few years, it may become perceived by the public as a normal part of the examination and a preventative measure, thus no longer a 'non-essential', irrespective of GOS. The pressure will be then on other multiples and independents to conduct OCT testing as well.

As stated above, the optometrist will require further training to become proficient in understanding variations in the normal appearance of scans. Manufacturers can support UK universities in providing this (See Part 4, Optometry education and training), but local ophthalmologists (and possibly neurologists) need to be reassured of the utility of an expansion of the regulated sight test into more in-depth health screening.

Community eye care possibilities with OCT are interesting and very appropriate to a 'whole system' approach. During our research period we heard argument for optometrists using OCT for three- or six-month interval monitoring of potential disease. Optometrists monitoring disease with OCT in the community would typically depend on accredited schemes, such as the shared care scheme for stable wet macula patients (CAMS) in Kent. An optometrist offering OCT monitoring outside of a formal service agreement would be unwise and high risk.

Policy makers have been trying to encourage more whole system approaches to patient care for some time; i.e. coordinated primary and secondary care professionals being jointly incentivised to work together. One of the difficulties they have faced is being able to do this at the same time as championing 'choice' in the system. Now, political approval of moving to Accountable Care Organisations (ACOs) means that wider community eye care services (including shared care) are more of a possibility. An important driver for the whole system approach is the ageing population; the proportion of patients with long-term eye conditions, and indeed other neurological conditions, will increase over the next 15 years to a level that will be near impossible to sustain within the current model of labour- and hospital-intensive monitoring.

In years to come, superior computerised OCT and ultra-widefield image analysis may allow wider optometrist involvement in disease detection and monitoring in the community. However we wonder what the rate and variation of adoption will be of automated examination, given both the complexity of analysis and the varied history of automated retinal screening in the UK. Digital automated screening software for diabetic retinopathy has been around since at least 2003 with greater sensitivity and specificity than a human could achieve, but for many years it met significant resistance from the English National Screening Committee. English NHS trials were not begun until 2011 and we understand Moorfields Eye Hospital is now reviewing Medalytix auto grading software (iGrading). This software was licensed to Digital Healthcare (now part of EMIS Group) in July 2012, but it has not been deployed, even though it has been used in NHS Scotland for many years.²⁶ If quality and safety of care is the priority, automated digital screening should become the norm throughout the UK during the 2020s.

²⁶ 2020health correspondence with former CEO and product developer

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All health professionals will have to face the reality of digitisation bringing more automation in healthcare communication, diagnostics and delivery over the coming years, and make changes to their training and practice.

A number of technologies cited in this report point to the notion of the 'upskilled' optometrist. This theme extends into the field of myopia control in children and corneal reshaping treatment in adults – contact lens practices relatively unknown in the UK but well known in The Netherlands. Whilst the UK does not have the prevalence of myopia that is found in the Far East,²⁷ a rise in myopia rates may well see contact lens interventions become mainstream.

5.5.2 The public

It has always been difficult to engage people's interest in healthy behaviours. One only has to consider the general public's consumption of alcohol and fast food to see that preventing illness is not a daily concern. This is partly because of ignorance of the links between poor diet and disease, but also because of the perceived 'safety net' of the NHS. Gone are the days when there were memorable public health broadcasts on TV. It is easy to assume from sensational media headlines that there are few maladies for which there is no cure, so prevention has altogether become a harder sell.

On the other hand, advanced assessment and prevention technologies, such as digital retinal cameras and OCT, does impress the public. While little extra information may be gained from this within an examination of 'normal eyes', the impression will be that a more thorough test has been undertaken at a practice boasting the latest kit. And why would you then settle for anything less? The VisionOptimizer is also likely to impress; it could also appeal to employers where realistic viewing conditions are valued, such as the forces or aviation.

There are a few people who are sensitive to the smallest of refractive adjustments who would therefore appreciate or seek this technology. Perhaps above all, it may also be a way to develop a practice aimed at a younger market: 'fun' and 'sight test' are not words that normally appear in the same sentence. That could well change, especially as being entertained is such a modern obsession. Likewise with 3D testing; it could well become vogue, although such popularity is hard to predict. The technology may appeal to an important minority.

Gaming as a treatment for amblyopia could become very popular; improved compliance from a much more enjoyable therapy could reap significant rewards and gaming is an approach receiving much more attention across medicine. Trials have taken place on compliance with treatment and medication supported by gaming, including connecting similar cohorts of patients to compete against each other. Parents would respond well to a child-friendly practice offering support in this field.

Independent practices in particular will know families with a high incidence of myopia. As high myopia can have serious ocular repercussions and sometimes be career limiting, the public may appreciate advice on corneal reshaping and the offering of orthokeratology or day-time wear lenses.

On a public relations note, the name 'optometrist' still often causes confusion. And the concept of an 'optician' is understood by the public but only those within the profession understand the 'dispensing' qualifier. As the optics bodies consider adapting for the future, they must think about the public relations aspect of the profession, how to communicate their skills and promote understanding of regulated functions, especially as roles evolve.

²⁷ 60 years ago, 10–20% of the Chinese population was short-sighted; today, up to 90% of teenagers and young adults are (nature.com, 2015)

5.5.3 Solutions

There is now a real opportunity for optometrists to position themselves more strongly as visual health experts in the community. Today's and tomorrow's technology has the potential to give more information to the public in the primary care setting than ever before. Recouping the costs of much of the new technology will require a diverse overall offer to the public, and/or the willingness of NHS commissioners to pay for new models of practice. Both within and beyond urban settings there needs to be strong relationships built through community eye care services – LES, PEARS/MECs and shared care initiatives. In England, despite increasing localisation, it would be useful to see such initiatives recognised in a national framework that can be locally adopted.

Practices, as now, have the option of specialisation such as sports vision, therapeutic contact lens practice or branching out to adopt new consumer technologies such as smart glasses or other 'visual' wearables (see Section 9). Practitioners also have the option of gaining many further qualifications in prescribing, pathology, orthoptics etc., which can result in an alphabet of professional letters after their name (see Part 4, Education and Training).

In terms of developing OCT monitoring expertise in the immediate future, we see the greatest potential in optometrists becoming involved in research, using their OCT as part of a wider ophthalmological or neurological clinical trial initiative. This is still a field in which there is much to research, and with remuneration such engagement would be both financially and educationally rewarding.

Anticipating the much wider availability of OCT within a few years, Local Eye Health Networks may need to work with Health and Wellbeing Boards and other stakeholders to consider specialist triage services, where optometrists skilled in the interpretation of images filter borderline cases to avoid an upsurge of false positives at hospital eye departments.

Dry eye services have potential in particular where there is an older population. This could be a case of 'supplier induced demand', as many people experience dry eye but do not know they can be evaluated and treated. A practice that has a considerable contact lens base would also benefit from promoting such care.

It is not too soon for any practice to think about their viability and a new business model, and in doing so, we think some professionals will raise the perception of the optometrist as an essential member of the healthcare team. As shared care practitioners, there is the likelihood of more NHS salaried optometrists possibly straddling HES and community practice, or working with community ophthalmology services. Optometrists themselves could be drivers of this.

- **Whole system care**

The Secretary of State for Health has already said that his priority is transforming the quality of care outside of hospitals. This is an admirable aim and mirrors the quest for quality in the acute sector, but unless the whole system works together, quality care cannot be fully achieved. This will require further joint ventures between, and complimentary measures applied across, stakeholders – in this case community optometry and ophthalmology. Tariff reform is also needed to incentivise quality care across the 'old' boundaries. This is well known by NHS England and Monitor who have the responsibility for tariff reform; we hope this to be a focus of the new government, as without this it will be difficult to establish some of the new models of care.

Part of the argument against more care in the community has been the risk to the hospital department of losing the easier patient care that essentially subsidises the more difficult cases. A solution to this is not particularly clear, and the ACO model is still only emerging. However there are some interesting established alternatives.

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The telemedicine example below shows implementation of a skill mix and improved access (but still under the umbrella of one hospital Trust), and The Practice Group²⁸ was the first primary care company to employ ophthalmologists in GP surgeries and health centres, with optometrists working alongside. The Practice Group now holds 19 ophthalmology contracts with CCGs.

- **Public health**

It has been argued that aspects of the way the GOS Contract is implemented are contrary to public health interests, and that different approaches are needed to address eye health inequalities and to reduce preventable sight loss (Shickle *et al.*, 2014). Whilst the optical profession has known internally that their role is crucial to public health, this is not widely appreciated. Behavioural threats to public health such as smoking, drinking and being overweight all have ocular repercussions. As local and national government seek new ways to nudge and shove the public into better habits, optometrists should be sharing best-practice and early intervention initiatives that have helped support people to make better choices, such as the hypertension pilot in Lambeth aimed at younger African and African Caribbean men. This is a rare example of cultural considerations being taken into account to target resources in a more intelligent way. The Welsh smoking cessation partnership between Optometry Wales and Public Health Wales, delivered by practitioners across the country, is another encouraging example (Public Health Wales, 2014).

- **Telemedicine**

Enhanced and new digital technologies make telemedicine (telehealth) an ever safer prospect. Originally trialled in remote rural areas in Finland, Canada and the USA, both 'store and forward' (where images or data are acquired on one site and transferred to a remote analyst, doctor or grader) and real-time remote consultation approaches have found relevance in the UK, including in urban areas. The Newmedica glaucoma service in Bristol (BMJ, 2014) utilises eight mobile sites for glaucoma review appointments by an optometrist and technicians, with the optometrist's provisional management outcome reviewed and communicated to the patients and their GP within five working days. A similar approach is used for some diabetic retinopathy and retinopathy of prematurity screening programmes.

Both Scotland (Scottish Eye Care Integration Project) and Wales have established 'teleophthalmology' services, and the increased quality of images and data that new technologies will capture in the community is an opportunity for optometrists to share in such services across the UK.

²⁸ <http://www.thepracticegroup.co.uk/patients/eyes/clinics>

Legend

Vision
Vision / health
Health

Prevention / early intervention

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
Autorefractor: clinically-demonstrated, high quality refraction	Prof	2023	Time-saving; cost-saving	0	5	Not suitable for patients with higher-order aberrations	Type of binocular autorefractor most likely. Manufacturers may (re)combine autorefractor with phoropter / voice prompt.
VisionOptimizer (or equivalent)	Prof	2020	Increased refinement of refraction. Entertainment value.	0	4		Will not completely replace other forms of refraction (by 2030). Will give some practices a commercial edge.
Phoropter-3D refraction	Prof	Now	Increased refinement of refraction. Entertainment value.	<1	2	3D viewing not to everyone's taste	Cheaper option of bringing element of entertainment into refraction process
Contact lens myopia control (Ortho-K; bespoke dailies)	Prof/Public	Ortho-k: now Myopia-control dailies: 2020	Reducing risk of myopia progression	<1	3	Expensive treatment that may not be available on NHS	Culture change will take time, even with robust evidence of effective long-term outcomes
Gaming tech for amblyopia treatment	Prof/Public	Now	More efficient and enjoyable method of treatment	<1	2	Long-term outcomes not yet demonstrated	Adults/parents may access technology independently (self-care)
OCT	Prof	Now	More accurate diagnostics; earlier detection	6	10	Lack of optom expertise on what will become common technology	Market forces and competition will guarantee growth market
Hand held OCT	Prof	2020	Portability; telehealth; lower cost	1	5		Simplified version of 'desk-top' OCT, but makes OCT available to domiciliary practices, and in time GPs, pharmacy and telehealth services
Ultra-widefield laser scanning ophthalmoscope	Prof	Now	More accurate diagnostics; earlier detection	2	8		Limited opportunity to recoup costs: vitreoretinal specialists and/or high-end offering only, for some years ahead. In time, a common and expected technology.
ClearPath DS-120 lens fluorescence microscope	Prof	Now	No fasting or blood draw; enables picture of patient's glycaemic levels over time	0	2	Pre-diabetes testing capability not yet proven	Patient appeal, though limited provider opportunity to recoup costs

6. CORRECTION AND TREATMENT

While interviewees recognised new business opportunities in the correction of refractive error, by no means all felt there was significant disruption ahead. However a literature review of R&D within non-invasive correction supports the view that there could be some game-changing innovation over the next 10 years.

Interviewees were in broad agreement that technological progress in contact lens comfort would aid potential for a growth market, even if much of the work needed remains in terms of promotion and support. The 50+ presbyopia market is thought to hold great promise for the contact lens industry.

Beyond myopia control in children (see Section 5.4), we found little evidence that leads us to expect a rise of orthokeratology among adults. Varifocal liquid crystal lenses were discussed with CL manufacturers and researchers, which we consider below in relation to both contact lenses and glasses. (Smart glasses and smart CLs are discussed in Section 9.) We also note with great interest the concept of an accommodating ('autofocus') contact lens, a potential game-changer barely mentioned by interviewees – probably due to lack of public knowledge at the time of interview on the one hand, and restriction from non-disclosure agreements on the other.

It was a common view that paediatric services within community eye care are not well remunerated given the often extensive chair time involved with very young children. In the future such services may become more profitable thanks to digital dispensing, even 3D facial photography, linked up with made-to-measure spectacles.

In this section:

- Lenses (glasses)
 - Adjustable lenses
 - Dual vision liquid crystal lenses in glasses
- Dispensing tools
 - spectacle lenses
 - paediatrics
- Contact lenses
 - The digital corneal topographer
 - Presbyopia: contact lens developments
 - Liquid crystal lens
 - Accommodating (autofocus) contact lens
 - 'Zoom' contact lens
 - Drug-eluting contact lenses

6.1 Lenses (glasses)

Our interviews and research suggested few potential disruptions from lens technology in the foreseeable future. One R&D expert we spoke with considered the future of lenses to be reliant on a better understanding of the mechanisms of the visual system, rather than increased personalisation of lenses.

Recent innovations in lenses have certainly expanded options for the consumer, particularly at the mid to high end of the market with thin and compact progressives and high definition lenses. Using wave-front modelling, free form digital technology has been a revolution in lens making, and now even modest-size manufacturers are able to fine-tune prism correction, reduce thickness and have greater control over lens shape. Using micro-lens surface calculation, they have the capacity to change the curve positioning at around 40,000 points across a 65mm lens.

This technological revolution has already taken place, although we hear that not all dispensing opticians (DOs) have taken notice. There was also opinion expressed that DOs are not all considering advocating lenses specific to work or recreational activities, which is a missed opportunity from the perspectives of both patient service and business profitability.

6. Correction and treatment

A) Adjustable lenses

Lens technologies outside of conventional products should be mentioned (we have already referred to the use of glasses in myopia control trials in children – see section 5). The variable focus lens has been in existence for some years, but technology is allowing the product to become more fashion-acceptable. The company Adlens, a leader in the field, has produced two types. 'Alvarez technology' allows wave-shaped polycarbonate plates to glide across one another, thereby allowing for adjustment of power, from -6D to +3D. 'Fluid injection technology' allows for adjustment with a controllable elastic membrane, held in a chamber between rigid front and back polycarbonate plates, and adjust from -4.5D to +3.5D. Neither type corrects for astigmatism.

This kind of technology has great potential (and is already in use) in lower income countries and deprived areas, where access to corrective eyewear is poor. In 2015, Adlens began seeking changes to UK regulation to allow variable power lenses in over-the-counter sales, in supermarkets and pharmacy stores for example. Current regulation restricts such sales to fixed prescription reading glasses, 'ready readers', with identical power lenses. A change in law would represent a step towards DIY correction, for presbyopes at least, and a significant growth opportunity for adjustable focus technology. A disruptive growth market, however, would also depend on both discreet and affordable variable-power technologies: the more fashionable end of the adjustable spectacles market sees products priced at well over £500, an exclusive solution only.

A GOC Standards Committee note, following a meeting held on 8 October 2015,²⁹ suggests that regulation is unlikely to be relaxed in the near future, particularly over 'concern that the sale of these products would distract the public from regular eye examinations' (Standards Committee, 2015). This will not bar the sale of adjustable spectacles from online vendors registered outside the UK, but disruption from this technology is unlikely to be significant without specific changes in law.

B) Liquid crystal lens

The U.S. based company PixelOptics launched the liquid crystal progressive lens in 2011 and promoted it at the international Consumer Electronic Show (CES) in 2012. Beset with product design and production problems, the company folded in 2013. The original PixelOptics design, called emPower, featured lightweight composite lenses with a thin, transparent liquid crystal layer that electronically changed the power of the lenses. This could be controlled manually with a discreet switch on the frame arm, or automatically, with head tilt. The manufacturer managed to create framewear and lenses that in all aspects mirrored standard glasses. It remains to be seen whether another company brings this technology to market. As noted with Adlens products above, there is obvious commercial interest in eyewear solutions for presbyopes that offer distance and near focus at full field view.

²⁹ Note of Standards Committee discussion on adjustable focus spectacles. Meeting held on 8 October 2015

6.2 Digital dispensing tools

A) Spectacle lenses

Many dispensing opticians (DOs) still use manual procedures to obtain basic fitting measurements, and are thus regularly seen with marker pens, pupillary distance (PD) sticks and segment-height gauges to fit bifocal and progressive lenses. With the advent of high-tech progressive, individualised lenses, lens companies have created computerised measuring equipment to help ensure maximum accuracy and thereby exploit the full potential of available lens technology. This equipment can be useful to both patient and practitioner to demonstrate the impact – practical and aesthetic – of different lens options, for example photochromic, polarized, bi-focal vs personalised progressives, as well as lens thickness and anti-reflective coating.

Whilst computerised dispensing technology is not essential (currently), practices advertising the latest lens technology may appear to undermine their offer of a cutting-edge service on producing marker pen and PD stick. It is a business consideration that digital dispensing tools demonstrate an awareness and facility with technology that reassures the modern patient they are not being denied the very best service. This 'perception factor' will be a key driver of growth in digital dispensing. (See also Section 9: Dispensing fashion.)

"If a practice is embracing today's lens technology, investing in a high-tech measuring device shows patients a full commitment to advancing technology."
Eyecare Business, October 2013.

B) Paediatrics

High street paediatric services are highly variable, perhaps due to the shortage of dispensing expertise or because dealing with two 'customers' – a young child patient and the parent/carer – is sometimes time consuming and not well remunerated by the NHS. Paediatric dispensing presents its own particular set of challenges: facial features of infants and children are undergoing continued development, and frames themselves should ideally be made to measure, not made as down-sized adult ones. In short, some practices view paediatric dispensing as a loss leader or a bit of a waste of effort (OpticianOnline, 2010). Quality paediatric services can however increase the likelihood of retaining the whole family as loyal customers/patients, besides being professionally rewarding (Hughes, 2012).

Digital technology is transforming children's dispensing. Digital centration terminals, such as Zeiss Vision's iTerminal, can provide solutions for children above 120cm, or for smaller children there are tablet-based options, as now being used by Specsavers (Digital Precision Eyecare). If some dispensing opticians question the accuracy and appropriateness of this technology, it is beyond doubt that paediatric dispensing will become rapidly digitised over the next few years.

Further ahead, and importantly meeting the needs of infants, are technologies such as the 3dMDFaceSystem, currently used in hospitals for pre-operative planning (all ages). Used in an optical practice, this system could enable an optician to capture a 180 degree facial profile in an instant, with all key parameters for the fitting of made-to-measure frames calculated in just a few seconds.³⁰

³⁰ This technology is not currently advertised for digital dispensing (see 3dmd.com)

6. Correction and treatment

6.3 Contact lenses

(See also Section 5.4: myopia treatment)

Interviewees and research confirm that the contact lens market has significant scope for growth. This lies mainly in the domain of promotion and patient support, but also through technological improvements in lens design, including better management of protein and bacterial interaction with lens materials, and improved technologies associated with the diagnosis, monitoring and management of dry eye (see Section 5).

The value of the UK contact lens market in 2013 was £240m as reported by the data contributing members of the Association of Contact Lens Manufacturers (ACLM).

It is estimated that there are around 3.7 million contact lens wearers in the UK, which represents 7.7% of the adult population and approximately 12% of adults requiring a refractive correction (Baxter J, 2010). Of this group, 1.57 million people use daily disposables and 1.78 million people use frequent replacement lenses. However, it is suggested by some practitioners that there is a 24% year on year drop off rate of wearers (industry data suggest the figure may be much lower, at about 10%) (Optician, 2013). New wearers in the first three months of use are most at risk of dropping off. Practitioners feel the most common reasons for discontinuance are problems with insertion and removal, and discomfort. As detailed in Section 4, practitioners can use technology to address insertion and removal problems by making use of apps and other digital platforms to provide wearers with video instructions for general use and trouble shooting. Comfort issues also need to be addressed by manufacturer R&D.

In the ACLM survey practitioners identified daily disposable lenses as having the highest retention rate. The biggest recent advance in contact lens comfort was the introduction of silicone hydrogel daily disposable lenses in the 1990s. Work continues to

increase end-of-day comfort (and reduced dryness) of both conventional hydrogel and silicone hydrogel lenses. Recent innovations in this area include 'Water Gradient' from Alcon and 'Moisture Seal Technology' from Bausch & Lomb.

As noted above, reusable contact lenses are still worn by more wearers in the UK than daily disposables. Even with the purchasing of cleaning products, they work out cheaper. There is current research into coating contact lenses with an antimicrobial film which could result in antimicrobial contact lenses being commercially available within the next five years. Whilst eye infections from contact lenses are rare,³¹ they can be serious and antimicrobial coating on lenses will give wearers peace of mind.

A) Corneal topography

An important technology in the selection of contact lens design is the digital corneal topographer, which offers a more comprehensive evaluation of the cornea than a traditional keratometer. The devices have evolved in capability since their introduction in the 1990s. Perhaps the most advanced on the market currently is the Eye Surface Profiler (ESP) from Eaglet Eye, capable of measuring sagittal height and a diameter of up to 20mm on the eye's anterior surface. The ESP enables captured data to be translated to Sub Micron Technology machining code to create a bespoke custom fit contact lens with point-to-point curvature changes. With such technology available to optometrists and CL dispensing specialists, could we see a growth in the made-to-order CL market?

Due to the forgiving nature of CL materials and the wide options available within the standard market, it may generally remain only the small minority of wearers with irregular-shaped corneas or keratoconus who are likely to purchase what are significantly more expensive custom lens products. In this regard,

³¹ Approximately four in 10,000 contact lens wearers per year have corneal infections, and vision loss due to corneal infection associated with contact lenses affects only six in 100,000 per year. Figures from BCLA.

6. Correction and treatment

digital topography technology also has relevance in potential improvements to comfort in night-time wear orthokeratology lenses. Topographical maps are nonetheless considered valuable in guiding the practitioner to the best standard design of CL for any individual patient (Woo, S, 2014).

B) Presbyopia: contact lens developments

With an ageing population and most over 45 year olds requiring refractive correction, presbyopia describes the loss of elasticity of the lens of the eye, causing reduced accommodative ability and thus an inability to focus sharply on things close to (near vision). Presbyopes are considered a huge untapped market for contact lens wear; in the higher income countries, most of the present population will spend roughly half their lives as presbyopes (Charman WN, 2014).

Developments in monovision and multifocal contact lenses gave new options to presbyopes who would otherwise depend on glasses (from ready readers to progressives). Multifocal CLs came to market around the turn of the century and have seen significant improvements in design and visual outcomes (Optometry Today, 2011). Many eye care professionals recommend gas permeable multifocals, which keep better shape than soft CLs and are more resistant to deposits and bacteria. Some practitioners we spoke with however felt multifocal contact lens technology required further improvement to realise increased uptake.

Improvements may come in the form of extended depth of focus (EDOF) contact lenses. In May 2015, the Brien Holden Vision Institute was granted FDA clearance for an EDOF hydrogel lens designed to provide presbyopes with good vision at all distances, especially intermediate, while minimising ghosting and haloes. Intended to enable simultaneous high-contrast images regardless of astigmatism and with no loss of visual field, EDOF technology is also being explored in intraocular lenses (Photonics, 2014).

i) Liquid crystal lens technology

Looking further into the future, presbyopes may enjoy benefits from liquid crystal lenses. Alcon and Google have announced a high profile collaboration to develop liquid crystal 'smart lenses'; also competing is UltraVision in collaboration with the University of Manchester. The electronic liquid crystal contact lens will be able to be switched on and off, changing between different focal powers for near and far vision – essentially replicating the accommodation mechanism of the eye. There are different ways in which the technology may work. The Alcon-Google suggestion is that light sensors in the CLs will wirelessly send a signal to a liquid crystal, which is embedded between two layers of a contact lens. The liquid crystal would then adjust for either looking out in distance or looking in near field (Fortune.com, 2014).

Many of the large contact lens manufacturers have in fact applied for patents in the field of liquid crystal lenses, which could be commercially available by around 2020. Both Alcon-Google and Manchester-UltraVision are also exploring implantable liquid crystal intra-ocular lens technology, which could be a commercially possibility by 2025 (Novartis, 2014; Ultravision, 2015).

ii) Accommodating (autofocus) contact lenses

A comfortable autofocus contact lens could be the greatest innovation in the history of contact lens manufacturing. EP Global Communications (EPGL), Inc. has teamed up with CooperVision, Inc in competition with Google and Novartis on what has been described by EPGL as a technology worth \$10 to \$50 billion annually (prnewswire.com, 2015). Both teams claim to be making significant headway and have filed patents. Novartis recently told a Swiss newspaper it was on track for human trials in 2016 of an accommodating lens for presbyopia patients (mobilehealthnews.com, 2015): if successful, the lens could be commercially available before 2020.

6. Correction and treatment

As with the glucose-monitoring lens, questions remain about power source. A solution, developers claim, is to obtain power via an external device, perhaps embedded in to a companion wearable, which emits radio frequency radiation to the lens (Google Patents, 2015). But power and micro-circuitry are not the only challenges: unless the lenses are robust, comfortable and affordable, the technology in itself will not disrupt. If priced competitively against (successful) dual vision liquid crystal lenses, the autofocus lens may well become the 'smart' product of choice.

C) 'Zoom' contact lenses

In the future optometrists and CL opticians may also be issuing 'telescopic contact lenses', as part of their low vision services. Scientists at the Swiss Federal Institute of Technology in Lausanne hope to soon begin human trials on a zoom lens that can magnify objects up to 2.8 times. To switch between magnified and normal views, lenses need to be worn with a pair of electronic glasses. The wearer winks with one eye to make the glasses switch to a polarised filter that directs light to the telescopic part of the lenses. Winking with the other eye switches the setting back to let light pass through normally (New Scientist, 2015). Such technology could in the future be useful for patients with macular degeneration and other forms of visual impairment.

D) Drug eluting contact lenses

Drug delivery by contact lens is also a near-future possibility, although this 'possibility' has been discussed for nearly half a century. Drug eluting CLs are a popular concept since conventional eye drops are a notoriously inefficient delivery system, with much of the medicine lost as the patient blinks. The technology is generating particular excitement for the delivery of glaucoma medication, though other possibilities include treatment for dry eye and other diseases that require medication at the front of the eye.

One technology is the dissolving 'nanowafer' contact lens (NPR, Feb 2015), which is one-twentieth as thick as a standard contact lens. The CL is made from a thin resin (polyvinyl alcohol) containing tiny reservoirs that can be filled with slow-release medicines. Another possibility is a drug-eluting contact lens that additionally meets the refractive needs of the patient (Review of ophthalmology, June 2014). And further still into the future are lenses for sustained drug release over longer periods, which include drug-eluting 'smart lenses'.

Medication by dissolving contact lens could be available to the public by around 2020, but human trials have yet to commence. The more complex drug-eluting contact lens with corrective prescription has also yet to begin human clinical trials (cslbehring.com 2015).

Drug eluting lenses for steroids, anti-fungals and antibiotics are only a remote possibility due to the problems of conducting safe clinical trials. More likely in the near future will be lenses loaded with less hazardous drugs, for example anti-allergy agents, vitamins or epidermal growth factor (2020health interviews, 2015; Hsu, 2015; Schultz & Morck, 2010). For example, a lens eluting Vitamin E for glaucoma therapy (to reduce IOP) was recently trialled as a 2-day continuous wear alternative to eye drops (Hsu *et al.*, 2015). This kind of technology could be market-ready by 2025.

6.4 What this means for business

6.4.1 Considerations

Some of the innovation described in the above subsections represent niche opportunities for community practice. Some of it may barely come to market within the timeframe under review. A more wide-reaching and relevant imperative is to harness the latest glazing, contact lens and dispensing technology to offer the widest choice to patients.

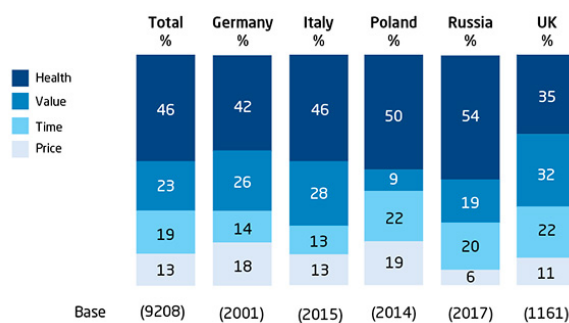
Without doubt, the most outstanding growth opportunity in vision correction lies within the contact lens market. As it developed, contact lens technology not only transformed patient lifestyle choices but also provided new ways of managing certain eye conditions and trauma. For people who had had extra-capsular lens extraction, contacts provided a huge improvement in vision and convenience, compared to thick, heavy glasses.³² The typical 45 year-old presbyope today is from a generation for whom contacts are a welcome relief from 'NHS' glasses, but there is still a perception that contacts cannot be worn later in life, either through issues of dry eyes, having worn contacts for too many years already, or the need for reading correction.

As the population ages and contact lens technology evolves, a choice of contact lens solutions will be on offer not just to younger presbyopes but also to a wider cohort of retirees with both leisure interests and disposable income.

6.4.2 The public

We live in image-conscious times and one of the 'give-aways' of ageing is the need for reading glasses. Fashion trends are powerful and the public is particularly influenced by what they see in the media. If older presenters (such as on Loose Women and BBC Breakfast) are not wearing glasses, viewers may be more inclined to solutions such as contact lenses, especially if they have seen the presenters ageing over the years and remaining glasses-free.

Figure 5. Contact lens wearers: consumer attitudes



The UK CL consumer appears to place almost as much emphasis on value for money as health considerations, looking for the best deal on their chosen product. Health priorities are even lower among spectacle wearers.

Source: Millward Brown, 2012

Liquid crystal and accommodating smart contact lenses will be marketed to a public actively seeking progressive, discreet solutions, but also increasingly adept at managing personal health and wellbeing. This principle extends to the hands-free convenience of telescopic contact lenses for those with reduced vision.

Those who opt for glasses will probably have higher expectations from technology (as they will in other areas of healthcare); they will come to appreciate the speed of digital dispensing and expect nothing 'less' for the fitting of expensive free-form lenses. Solutions that give the presbyope multi-distance full field-view, preferably without any manual adjustment, will especially appeal to an age-conscious mindset.

³² As intraocular lens replacement techniques improved, there was a reduced need for refractive correction, although in the majority of cases reading glasses are still required.

6. Correction and treatment

6.4.3 Solutions

As described in section 5, the contact lens skills of optometrists have been underutilised in the UK. There is already much ground for the taking even without further technological progress, and work needs to be undertaken to break common myths around contact lens wear. What was true of contact lenses five to ten years ago is no longer necessarily true today, even less so by the 2020s. Optometrists, especially, have opportunity to become more proactive in offering patients the option of contact lenses. Indeed, optometrists themselves may already need updated education on contact lens design: many practitioners are reluctant to fit multifocal lenses based on experiences dating back years, despite significant improvements since in materials, designs and parameter ranges. Independent practices are more likely to have a long-term relationship with their patients and this is an opportunity to offer trials to those who are already 'warm' contacts.

All digital health is benefitting from social media communication, and the advantages of contact lenses should be being communicated more frequently through these channels.

Drug-eluting contact lenses may not be available much before 2025, but for contact lens wearers taking medication via eye drop, a contact-lens drug delivery system could be an attractive alternative. This could become part of a community ophthalmology service. Optometrists would need to be IP qualified to prescribe drug-eluting contact lenses and it would make sense for them to be working closely with ophthalmologists and HES. While this option is unlikely to be offered on the high street initially, the notion of IP-qualified optometrists dispensing such a product prior to 2030 is a distinct possibility – especially in Scotland, where a substantial proportion of optometrists may be IPs.

In the past, some practices that had aphakic patients wearing semi-permanent contact lenses offered a regular removal and cleaning service. This could appeal to someone who not only benefits visually, but also from the convenience and social contact. As the domiciliary kit becomes increasingly portable, offering contact lens care in the home becomes more practical, albeit just for private patients.

Legend

Vision
Vision / health
Health

Treatment / correction

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
Computerised dispensing tools (lenses)	Prof	Now	Dispensing accuracy, speed of service	5	10	Arguably not faster than manual methods, currently	Digital-age lens technology and patient expectations will raise demand for computerised dispensing
Dual vision liquid crystal lenses (spectacles)	Public	2018	To avoid limiting of functional visual field / removal of glasses for distance vision	<1	2		Presbyopia target market. Competition from other modalities will restrict uptake
Dual vision liquid crystal contact lenses	Public	2020	Resolving problems of near/distance viewing among presbyopes	<1	3	Tech malfunction at critical moment (e.g. driving)	Competition from other modalities, such as improved multifocal CLs and accommodating smart CLs, likely to restrict uptake
Autofocus contact lens	Public	2020	Accommodating lens solution for presbyopes	<1	8	Affordability, durability and comfort? Tech malfunction.	Uptake may be restricted by cheaper multifocal CLs or liquid crystal CLs
Telescopic contact lenses	Public	2022	Helping people with macular degeneration and other visual impairment	0	1	Questions remain about comfort and ease of use among elderly population	Competition from other assistive technologies may restrict uptake
Antimicrobial contact lenses	Public	2020	Reduced risk of eye infections; CL continuance	2	10		Successful antimicrobial technology likely to be embedded in most CL products over time

NHS involvement

Drug-eluting CLs (Gradual-release / prescription)	Public	2025	Effective delivery of medication within functional contact lens	0	2		I/P qualified optom involvement only
Drug-eluting CLs (dissolving only)	Public	2020	Effective delivery of medication in a dissolving contact lens	0	2		I/P qualified optom involvement only

7. INDEPENDENCE AND SELF-CARE

There are a variety of commodities and services aimed directly at the public that require little to no engagement from health professionals: these range from ready-readers (off-the-peg reading glasses) in supermarkets to mobile apps and online visual acuity tests, eye 'workouts', and of course online spectacle and contact lens retailing.

By 2025 the UK public will be even more 'empowered' to manage their eye care needs: it will likely be possible for an individual to self-refract, design their own spectacles, upload their design to a 3D printing website and receive shipment, without even leaving home. The challenge to the high street practice is how to remain commercially viable in the face of such competition. Health professionals across the board are seeing their traditional roles challenged, and where, like the optical sector, they rely on the public's discretionary spend, they need to consider how to complement self-care and identify further skills or technologies to attract the face-to-face encounter.

The technology discussed in this section is that with which the public engages, or will engage, outside of the traditional professional or clinical setting.

In this section:

- Apps for self-care
- Glasses online
- Possibilities with 3D printing (additive manufacturing)
- Contact lenses online
- Glucose-monitoring contact lenses
- Self-refraction (app and hardware; kiosk; online)
- Non-invasive technology for the blind and partially sighted

7.1 Apps: self-care

In 2012/13 there were roughly 340 apps relating to vision and eye health (French Journal of Ophthalmology, 2013), though only a small proportion were attracting much professional or public attention. However, as apps gain greater clinical input and value, their utility in terms of compliance and self-care will only increase.

Within the space of eye health and disease management, few apps have a clinical and official stamp of approval. In the UK, NHS Choices' health apps library gives featured apps a stronger appearance of clinical worth, but there is currently only one app here related to eye-care. This is the iSight Test, a CE-marked app³³ designed for both the clinician and patient, which can be used to test visual acuity and help monitor changes in people with AMD. It is promoted as a tool for the hospital bedside, A&E, schools and the home, and is priced at £15.99 for either iPhone or iPad.

More disease-progression monitoring and medication reminder ('compliance') apps will no doubt be approved in the near future. After all, the concept of a Doctor's prescription for an app is already a reality in the USA and will very soon become a reality in the UK. For example, MyVisionTrack iPhone app from Vital Art and Science Inc., FDA-approved in the USA, enables the remote monitoring of patients with retinal disease (see Section 8). MyVisionTrack can be bought only with a doctor's prescription.

In the UK Government's *Personalised Health and Care 2020* (UK Government, 2014) the intention to make available apps by doctor's prescription is made clear:

³³ European Conformity. CE indicates compliance with EU safety, health or environmental requirements.

7. Independence and self-care

The [National Information Board] will set up a task and finish group with clinical and civil society leaders on the regulation, accreditation and kitemarking of technology and data enabled services, including apps, digital services and associated mobile devices. This is in order to support innovation, and consumer and professional confidence, including enabling GPs to be able to prescribe them. It will publish proposals by June 2015 and kitemarking of apps will begin by the end of 2015. Kitemarked services will be able to use the NHS brand and to be accessible through NHS Choices.

One app that is already under consideration for being prescribed by GPs is Sleepio, shortlisted in the AXA PPP Health Tech and You Awards in the 'Keep me healthy' category. The thinking is that several Clinical Commissioning Groups could be given permission to prescribe the app and the behavioural response from both professionals and the public, along with economic analysis, will be evaluated.³⁴

The vast majority of apps will not be considered for prescribing, since prescribing them could undermine the notion of self-care, as an individual would then be dependent on a professional for access or approval. Apps that remain relevant to patients will be those that link with medical records, or are regularly updated, or capture an individual's motivation for improving their self-care.

As mentioned in Section 4, formal endorsement of apps and digital health technologies is something that NHS England, Public Health England and NICE are looking at. However at present there is the risk of duplication of effort and expense, delaying access due to an overly complex approval process or simply due to the volume of viable apps to

be assessed. Whilst the public want to know what to trust, increasingly this will be judged by peers through social networks just as many other non-health related apps and consumer products are already. Apps for smartphones and tablets are gradually changing the way healthcare is delivered: the trajectory is towards technology as an increasingly important part of personalised health and self-care, particularly within the contexts of compliance and self-monitoring.

Blood pressure self-monitoring is an interesting illustration for this. While mercury sphygmomanometers are still considered the gold standard, digital monitors became available in the early 1970s, with a home version available in Japan by 1978. By the 2000s, buying your own home monitor was becoming more commonplace, and by 2010 they could be linked to software on the iPhone. In 2014 wireless monitors came on the market. Over the past few years there have also been several publications showing that self-management and self-medication achieve better hypertension control than when under the doctor's care (McManus *et al.*, 2010, McManus *et al.*, 2014, Bray *et al.*, 2015). It is interesting to reflect on the implications of this for compliance more generally, because evidence suggests that when individuals are given more control, the better their outcomes.

7.2 Glasses online

During the project period, online prescription eyewear retailer GlassesDirect launched a £2m TV campaign aimed at moving more of the glasses market online. Their first advert featured a woman who collapses on seeing the price of a frame in a high street practice, and is then seen outside the practice in a blizzard. Belief in the expansion of online services, with the cachet of convenience and value for money, is clearly very real for the company.

According to CMO Sven Ripper, who joined the GlassesDirect parent company MyOptique in November 2014, 'less than 5% of prescription

³⁴ 2020health conversation with Dr Martin McShane, NHS England Director of LTCs

7. Independence and self-care

eyewear is bought online. This compares to up to 20% for other retail categories. The TV campaign is a significant step in our strategy to build the category' (opticianonline, 2015).

There has been some notable media support for the online glasses market, through sites such as MoneySavingExpert.com and personal finance sections within print and online media (e.g. telegraph.co.uk 2013). This is not to suggest endorsement of all providers by any means: there are both superior and inferior services available as within any consumer sector. Industry leaders such as GlassesDirect and SelectSpecs in the UK, and GlassesShop and WarbyParker in the US, have received particularly favourable media and customer reviews. In 2015 WarbyParker was valued at \$1.2 billion: the online challenge to the high street is fully evident.

“Opt to purchase your glasses online and you can substantially cut the price as you won't be financing costly sight equipment.”
MoneySavingExpert.com

We should also bear in mind the budget stand-alone glazing options available online. The UK company reglazemyglasses.com offer glazing services from £19 and has received notably complimentary customer feedback through sites such as TrustPilot.com. Directsight.co.uk is another contender, whose services start at £15.

The growth of the online glasses market is difficult to predict. It partly depends on the ability of technology to improve the online experience of choosing glasses, and ensuring appropriate fit. Few sites appear to be utilising both webcam technology and algorithms to closely match frame to face (as Protos plans to do – see 3D printing). GlassesDirect uses webcam technology for a virtual

try on of glasses and even captures video-clip head movement left and right to show glasses from multiple perspectives. Successful image capture and processing time can take several minutes (partly depending on Internet speed), but once completed the images can be saved and reused on a return visit to the site.

Ultrafast broadband, eventually in all areas of the UK, will undoubtedly enable a refined customer journey, combining the virtual try-on of glasses via webcam with web-based software that accurately measures facial contours and pupillary distance.

The direction of travel in retail is online. In the UK in 2013/14, 64% of 25 to 34-year-olds bought clothes online (ONS, 2014). The clothes don't fit? Just return them, free of charge (e.g. via Try.com). It seems inevitable, therefore, that as consumer trends combine with faster internet connection and more efficient imaging analytics, together with a future industry of 3D printing offering the promise of customised-fitting, online glasses retailing will pose an ever greater threat to the high street. Perhaps even more so if tied in with online refraction (see below).

7.3 Possibilities with 3D printing

Disruption within the glasses market, as indicated above, will arise from 3D printing, currently confined to prototype modelling and a few niche businesses.

“While, currently, the quality of home 3D printing is arguably not yet good enough to replicate products of the same quality, precision and durability as the originals, that time will come – in about ten years, according to some experts.”

Raconteur (The Times), December 2014

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An industry concern of home 3D printing, specifically, is the infringement of intellectual property rights. Printing or distributing copied products for monetary gain is an infringement under patent law, but this does not extend to the printing of a product for personal use (Raconteur, Dec 2014). No design rights and trademark laws are broken if someone recreates their favourite frame design at home. So how real is this threat to the glasses market?

The answer depends on the model envisioned. The 3D printing of frames at home is just one part of the process; the sourcing or printing of hinges and arms for nose pads (design depending) is another step, and more complex still is the printing of lenses. Thus aside from printing a replacement frame from a 3D scan of a given product (not possible now with home 3D scanners, but probable in the 2020s even with smartphone cameras (laserfocusworld, 2015)), there will be limited options for the 3D printing of quality glasses at home without at least some help from outside services.

Initially we will see a growth industry of bespoke 3D design and print services, much of which will be online and typically working in partnership with lens manufacturing companies.

The US company Protos (protoseyewear.com) is soon to offer a range of 3D printed frames, but not personalised to customer design, and priced within the higher range. Its online service uses webcam technology and algorithms to customise frame to face. As a higher-end choice, the company poses little immediate threat to traditional frames manufacturers, but it is possible to see the concept as market-disruptive in the future. Others innovating in this space include the Australian start-up spexyme.com.

There are already a number of online companies offering 3D printing services using uploaded designs by customers (e.g. Sculpteo; sculpteo.com/en/). It is easy to imagine that the future home-based consumer will have a choice of templates for glasses

to import into their 3D modelling software program – or they may design 'in the cloud' entirely. Free frame designs (open source) will also originate from amateurs, as we see currently on sites such as thingiverse.com. Businesses specialising in 3D printed frames to order may undertake glazing, or form partnerships with glazing specialists.

3D modelling software has already proliferated, much of it free, and many secondary schools in the UK are running 3D design modules as part of their GCSE and A level Art and Design (or Design and Technology) courses. Industry should be prepared to see a new generation of independently minded customers enjoying the opportunity to craft something unique – and quite possibly only within a few minutes. The design is uploaded to a website as a computer aided design (CAD) file; the product is printed and sent on to the lens company, who return the product by post to the client within the week. This is most certainly a potential reality by 2020. (See further consideration of 3D printing in Section 9.5.)

7.4 Contact lenses online

According to reports by the ACLM and GOC, approximately 10–14% of contact lens (CL) wearers in the UK bought their lenses over the Internet in 2012–13. A further 40% of CL wearers surveyed by the ACLM had considered or researched buying lenses online.

While the volume of UK CL sales has grown in recent years, online sales have not seen the kind of growth noted in some other countries. Some experts we interviewed pointed out that savings on lenses bought from Internet providers were often marginal against buying through the sight test provider.

Interviewees also pointed to the direct debit and loyalty system of contact lens purchasing through sight-test providers, uncommon in many other countries. Any notion of the loss of aftercare, particularly for new CL wearers, presents a further disincentive to shop elsewhere.

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Nevertheless, the majority of interviewees commenting on online CL sales expect the market to grow. In the US, approximately 25% of all CLs are sold online; in Sweden the proportion is around 50% (Robinson, 2013). Online CL sales in the UK have been limited in part by regulation, since distance-selling of contact lenses was prohibited prior to 2005.

The Opticians Act (1989) demands that UK vendors see proof of an authorised, up to date prescription before making a sale. Such regulation perhaps constrains internet activity, although VisionDirect is able to bypass UK regulation by processing contact lens orders via its European sister site Vision Direct BV (Netherlands), where prescriptions/specifications do not need to be officially validated. GlassesDirect's sister company, LensOn (LensOn.co.uk), apply a similar strategy via Sweden.

Generational behaviour combined with higher costs of living will push more of the UK CL market online. Despite sluggish growth indicated for several years prior to 2013, we believe that CL sales online are likely to exceed 50% by 2025.

It is important to recognise UK consumer trends elsewhere in retail in order to predict contact lens market activity. A recent study conducted by RetailMeNot and the Centre for Retail Research suggests that the average UK consumer will spend £1,174 online in 2015, equating to around 15% of all retail sales, making us the most frequent online shoppers in Europe. Online retail growth 2013–14 was approximately 15%, and similar rises are predicted for 2014–15 and 2015–16 (econsultancy.com 2015). While this does not imply similar year on year growth into the 2020s (if so, the online retail market would represent 60% of all retail sales by 2025), we should nevertheless recognise the direction and momentum of travel.

Specialised multiples and supermarkets are well positioned to take greater control and share of the online contact lens market. Independent practices may consider third-party e-commerce services, or

even partnerships with online suppliers for their patients who use soft lenses; in either event, they will offer after-care as a tailored package to maintain customer loyalty. 'Specialist' practices may become more apparent as those who additionally offer CL treatment services, for example myopia control, keratoconus and ortho-k. The increasing normalisation of online purchasing, particularly where aftercare support is available, will bring confidence to the market.

7.5 Glucose-monitoring contact lenses

'Smart' clinical lenses are being developed to measure glucose levels in diabetic patients by measuring the eye's tear fluid and sending readings wirelessly to a mobile device. Such technology may appeal to those diabetics who, several times a day, draw blood from fingers with a test pen needle to assess blood glucose levels.

Human trials with glucose monitoring lenses appear to be imminent. Success is by no means guaranteed, given the challenges of powering miniaturised wireless technology and drawing accurate readings, as well as ensuring lens comfort for regular wear. With large commercial players including Alcon and Google developing this technology, these lenses could be commercially available in Europe by 2020. Google was in fact granted a patent for the smart glucose-monitoring contact lens during our project research period, March 2015 (webpronews.com, 2015); the technology is also being explored by the University of Washington in partnership with Microsoft Research Connections, and the Canadian start-up Medella.

It is anticipated that bio-sensing contact lenses will in time be used more widely for the monitoring of ocular and systemic health, further broadening the role of the optometrist (see also 8.3 A). Since the lens is not medication (there would be no drug eluting component), any UK optometrist or contact lens optician should in theory be allowed to fit bio-sensing lenses. We do not expect to see much community-based activity before 2025.

7.6 Self-refraction: outside optometric practice

Currently there is no technology commercially available in the UK that enables self-refraction. However, there are three technological platforms that may give the UK public access to self-refraction in the 2020s, and one of these even before. These are:

- (1) eye-test app and smartphone hardware;
- (2) kiosk refraction; and
- (3) online refraction.

An eye-test app with cheap smartphone hardware attachment has already been developed by EyeNetra, the Netra-G, which has, according to the developer's website, been used to perform tens of thousands of refractions 'in the field' (eyenetra.com). While the accuracy of the Netra-G is below that of subjective refraction (performed by an optometrist), this kind of technology holds particular value to healthcare professionals working in underprivileged and remote regions, where access to ophthalmic services is severely limited. The technology also has commercial potential among the general public world-wide, since the equipment can be operated by almost anyone, enabling self-refraction in the home.

However, a question remains as to whether public release of smartphone refraction would represent the best commercial exploitation of such a product. After all, virtually no one (currently) buys corrective eyewear without having first tested their prescription with trial lenses. Recent activity by EyeNetra in fact suggests a new direction for this technology, taking it into the realm of mobile vision testing services, telehealth and remote prescriptions (see Section 8). We should not dismiss the notion of personal smartphone refraction, however, not least as other technologies enabling this function, such as the eyeglass-free screen display (see Section 9.3), are likely to emerge.

Figure 6. Netra-G: smartphone refraction, early prototype



"EyeNetra aims to capitalize on the 'consumerization of health' phenomenon in the United States, where consumers are gaining access to innovative medical tools for personal use."

Ramesh Raskar, EyeNetra co-founder, 2015

A tie-in with online glasses providers, following self-refraction, is easy to imagine. This technology could also form part of a smartphone home-health kit, perhaps including otoscope, thermometer, and heart rate and blood pressure monitoring devices – all of these being already available (digitaltrends.com 2014).

Yet to be developed is kiosk refraction. In the USA, free visual acuity tests in kiosks – situated in supermarkets, pharmacies and malls – currently give an indication of the need for an eye exam only. A basic three-minute test measures distance and near visual acuity, following which the individual may be advised to undergo a full eye exam, choosing from a list of participating eye care specialists.

A future eyesight kiosk may be equipped with an autorefractor that allows subjective and objective testing. Alternatively, it may incorporate an automated phoropter or even phoropter-less

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refraction (for example, see the VisionOptimizer, Section 5.2D, and EyeNetra's Blink technology, Section 8.3D). Unless the UK deregulates vision testing, however, we are unlikely to see stand-alone kiosk refraction. Only a fully comprehensive kiosk sight test, supported by telehealth, is conceivable under existing regulation (see Section 8.3E).

Eyesight Kiosks, USA

Data gathered at eyesight kiosks in the USA have suggested that 25–30% of users have never had an eye exam (2020health interviews, 2015; Specialty Retail, 2009). The kiosk has potential as an educational and marketing tool, reaching underserved populations.

Regulation is also an important consideration for online refraction, which has recently become reality in the USA (July 2015). Opternative.com, based in Chicago, has developed a system of acuity tests and algorithms to measure near and distance vision, as well as astigmatism. The patient takes the sight test by standing several feet away from their computer screen, while responding to questions and tasks via smartphone. A fully licensed optometrist or ophthalmologist reviews the results remotely and issues a signed prescription within 24 hours, where this is legal to do so according to state legislation. At the time of writing Opternative was operating in 32 states and charging \$40 (£25.50) for the refraction. There is no eye health examination involved, and current recommended use is by those aged 18–40 and in good health.

The global market for Opternative (or its like) could be significant if user feedback endorses online refraction. But in the UK, given the availability of cheaper, comprehensive eye exams, and with people situated less remotely than in the US, online pay refraction may struggle to make inroads. Future iterations of online refraction may dispense with the telehealth element, bringing user costs down and taking the technology firmly into the realm of self-service. A computer-generated

prescription could still be used via an online retailer, who redirects orders via territories abroad to bypass regulation where necessary. This is, we believe, a likely scenario, and one that could be promoted by online retail specialists themselves.

7.7 Non-invasive technologies to assist the blind and partially sighted

The 21st century has seen phenomenal progress in enabling technologies for the visually impaired. In fact, the pace of technological development has been so rapid it has left a gaping hole in professional community support (high street practice, low vision clinics, charities), especially in terms of understanding specialist desk-top systems and software, and smartphone solutions (2020health interviews, 2015).

Among recent innovations are portable digital Braille devices with Braille output, text to speech output and wireless access to Web pages and e-mails (such as HumanWare's BrailleNote product line). The Victor Reader Stream, for both the blind and partially-sighted, is popular as a relatively affordable phone-size media player with text-to-speech and wireless capability.

The low vision magnifiers market offers substantial choice. Recent game-changing technology includes pocket-size video magnifiers (typically in the £150–£650 bracket), with HD display and enhanced colour modes to suit a range of eye conditions. Higher-end models allow viewing of text at short and medium distances (e.g. Chris Park Design i-loview HD magnifiers), therefore allowing the user greater freedom for handwriting. Magnifiers extend through larger 'transportable' digital tools to desk-top technologies with speech to text and text to speech capability, for recreational and office use.

The most rapidly developing technology is within the field of smartphone apps. Recent arrivals include TapTapSee (free with iPhone), where a double-tap on the iPhone screen enables a photo to be taken that then uploads to a server for processing. In a matter of seconds the iOS VoiceOver provides a description of items in view. A variation of this app

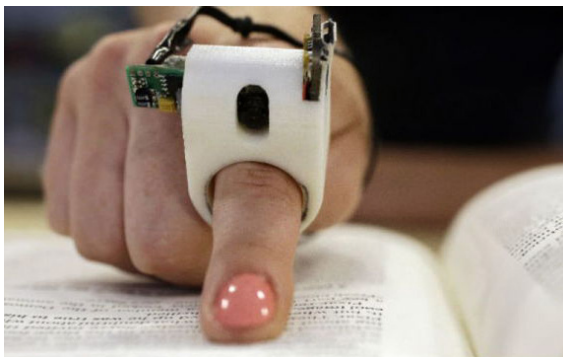
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is 'Be my eyes' (also free), where the user allows a volunteer to view their environment through the phone's rear-facing camera and perform an identification task. A reviewer for the American Foundation for the Blind reported an average connection and response time to be about 2 minutes (afb.org, 2015).

For out-and-about independence, the GPS BlindSquare app, launched in 2012, describes the user's environment, points of interest and street names. Controlled via the iOS VoiceOver screen-reader, the app links to third-party navigation apps and allows filtering to avoid information overload.

Apple has been a market leader in enabling technologies for the blind and partially sighted. VoiceOver allows the user to touch the screen to hear what is under their finger, and enables gestures to control the device. The virtual iPhone assistant, Siri, can be told to Speak Screen, whereupon all content of the page is read back. Siri has been followed by android equivalents, such as Cortana, in its ability to send messages, connect to phone contacts, schedule meetings and locate places of interest, all through voice instruction.

Figure 7. The FingerReader, MIT Media Labs



So where is technology taking the visually impaired next? There are a number of initiatives to create smart glass wear that gives the partially sighted increased independence. Dr Stephen Hicks at Oxford University has created a prototype using two cameras and a laser to identify objects, with information relayed to a computer, which then displays the objects on the glasses as simplified bright shapes. The commercial launch of the glasses may be seen within the next year, with the product priced at a few hundred pounds (ox.ac.uk, 2014). Also innovating for those with severe vision loss is the CINVESTAV (Center for Research and Advanced Studies of the National Polytechnic Institute) in Mexico, where scientists have created a lightweight smart-glass prototype combining computational geometry, artificial intelligence and ultrasound techniques. The smart-glass connects to a tablet, which enables spoken directions, sign reading, colour identification and recognition of currency denominations.

Digital reader technology also continues to develop. MIT Media Labs is working on the FingerReader, shown in Fig. 7, a finger-wearable assistive device capable of detecting and reading out loud 12-point printed text as the user scans a finger across it. Small vibrations alert the wearer to any deviation off the line.

The sight impaired could become yet further assisted by the Internet of Things (IoT). At a 'smart hotel', for instance, the blind person checking in hears information about the location of facilities from their smartphone; the menu is smartphone-searchable via voice prompt; their room's heating is smartphone controlled, as is the shower temperature, the TV, the safe's pin number.

IoT-enabled bus stops, trains, shops, supermarkets and airports can feed information to allow the partially-sighted and blind to better navigate, shop and interact with the environment – let alone be a more engaged citizen on every level (Chris Lewis Insight, 2014).

7.8 What this means for business

7.8.1 Considerations

Technologies are giving us the ability to do much more for ourselves, and in many cases this is a positive development that enables us to enhance our health. Professionals need to support this empowerment and diversify or adapt their services. New digital health advances will improve access to information about our vision, and the ideal result would be better controlled long-term conditions, such as diabetic retinopathy or glaucoma. Indications are that individuals with more control experience better outcomes.

In terms of people making their own spectacles with 3D printing, technology is not currently mature enough to pose a threat to the optical sector, but this time will come. With 3D design courses now common in schools, younger generations are well placed to exploit opportunities for home 3D design, even if 3D printing is carried out elsewhere initially. By 2025 it may be common practice for consumers to fine-tune existing templates, even design glasses from scratch, from the comfort of their own home. We believe this will be a growth market: why buy expensive 'designer' frames that thousands of others have bought, when you or a friend can design your own one-of-a-kind for a quarter of the price?

Provision of low vision assistance has been notoriously patchy across the UK. In some areas the low vision clinic has been long established and is well run; in south east London there is just one clinic, one day a week for nine boroughs. Funding has always been contentious, with the service straddling health and social care boundaries, and practices themselves struggle to make low-vision viable as part of their business model given the extended chair time involved. However, the increasing prevalence of low vision, the upsurge of assistive technology and the need for people to remain in work for longer, should amplify public demand for provision and drive the supply of support.

7.8.2 The public

If online refraction becomes available in the UK, competitively priced with user endorsement, the service may well hold appeal to individuals traditionally considered 'hard to reach'. The availability of such a service would however meet with much publicised warnings from health professionals.

The validity of any 'DIY' refraction will depend on the policy response; the risks of dissociating refraction from the internal and external eye-health examination need careful deliberation. It poses a significant challenge to the traditional role of public health, not least potentially exacerbating a lack of understanding of the importance of eye health checks among the public. If fewer individuals present for full sight tests, we are likely to see yet greater prevalence of ocular disease and preventable sight loss (beyond current predicted rises), with escalating costs to the NHS and social care.

The impact on the optometrist and business may be also significant. An automated prescription (initially from a website outside the UK) could reduce demand for in-practice sight testing, in turn affecting eyewear sales.

7.8.3 Solutions

The challenge for the sector is how to achieve balance, enabling the public whilst establishing new commercially viable services. As a countermeasure to the online sale of glasses, major optometric practices, the multiples especially, are already offering online viewing of products and ordering services, though not (yet) full e-commerce. They have the critical mass and the recognised brand advantages to keep their patients 'in-house', combining online with on-the-high-street. Their incentives include the offer of free spectacle adjustments where necessary and perhaps free nominal repairs, such as replacement screws and nose-pads. However some practices will offer this free to anyone – in the attempt to convert patients.

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There is scope for independents to expand their retail selection with an online catalogue, and some independent chains will be in a position to consider e-commerce, enabled by a digital marketing company. However the threat of cheaper spectacles from suppliers exclusively online will always remain. The challenge of maintaining patient loyalty will be better met through diversification, personalisation or specialisation, and where possible through practice membership programmes.

Frame-makers need to acknowledge potential competition from online 3D-printing companies (and later, home-based frame printing) and consider countervailing strategies. Their own offer of 3D-printed glasses, customised to the wearer's facial measurements (taken in the practice setting), could be one consideration. Manufacturers may even want to consider exploiting the same online technology, for example allowing 3D print 'co-creation' or design opportunities via the company website. This would be a step change, as since the jeweller/oculist of old stopped making the spectacle frame, there has been no public access to the wholesale manufacturers. We can also see practices themselves offering in-house 3D made-to-measure frames, with 3D printing machines sitting in the back office – or even (initially) in the shop window to advertise the innovation (see also section 9.5).

It is only a matter of time before we see virtual refraction and self-generated prescriptions in the UK. We anticipate that regulators and government will have to give this serious consideration and the profession needs to be ready with its response. It may require an extension of eligibility to 'free' NHS funded sight tests to ensure that people do attend for what is essentially a health screening. If expanded to cover people with a family history of diabetes, hypertension and AMD, then this could further emphasise the message that visiting the optometrist is much more than a test for glasses.

We anticipate that the development of 'smart' clinical (bio-sensing) contact lenses will lead to a

specialised role for the community optometrist, especially those already involved in local community eye services. The dispensing of glucose monitoring lenses would require a health professional conversant with both diabetic healthcare and contact lenses. Since the lens is not medication, those not registered as independent prescribers should in theory be allowed to fit the lenses. As trials on bio-sensing lenses have not yet begun, interested optometrists should be looking to take part in clinical studies as they have the exact expertise required. This creates further opportunity for shared care across optometric practice and the hospital-based diabetes team. Uptake by the NHS is difficult to predict. Diabetic insulin pumps for instance are used far less in the UK than in other European countries. Some individuals will simply not be interested. We expect early adopters to pay privately for the technology.

Within the hospital setting, just 30% of ophthalmology departments have eye clinic liaison officers or someone similarly qualified who is able to advise on low vision technology. Many posts are considered under threat due to the anticipated next round of budget cuts (rnib.org.uk.). This is tragic as innovation for those with visual impairment is booming; the effect on lifestyle and work of phone technology alone was described to us as utterly transformational by interviewees with sight loss.

Better community support, through commissioning pathways and up-to-date (and continuing) education of dispensing opticians and optometrists, is much needed. The high street practice has not traditionally been the place to find new low vision technology; people have relied on charities for information, but a quick review of the best known low vision charity websites revealed none of the technology we have detailed in 7.7 above. The low-vision patient-base is only set to grow. There is a need for much more assistance in helping people find and utilise the best technological support. For now this will have to be a predominantly private service, but the sector should lobby for reform of low vision services to ensure the life-transforming advances are available to all.

Legend

Vision
Vision / health
Health

Independence and self-care

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
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Private sector

Online glasses	Public	Now	Ease of access; range of choice; price	>1	5	Availability of unregulated dispensing	Online retail trends and further developments in 'virtual try-on' technology will encourage growth
Online contact lenses	Public	Now	Ease of access; price	2	9	Lack of follow-up care for those who purchase from online providers only	Multiples to gain stronger hold of online CL market
Home-based 3D frame design / web-based delivery	Public	2018	Budget-range designer glasses; fun	>1	3		Appeal to younger generations
Home-based 3D frame printing	Public	Now	Challenge; convenience; fun	>1	1.5		Appeal to hobbyists initially; limited in quality as compared with specialist services
App-based refraction	Public	2023	DIY vision test	0	3	Could give false sense of good eye health	Cheap comprehensive sight tests will restrict public interest in UK; disruptive potential remains however
Online refraction	Public	(Now: USA) UK 2020, delivered from abroad	Computerised vision test	0	3	Could give false sense of good eye health	Cheap comprehensive sight tests in UK will restrict public interest in telehealth test. Fully automated (cheaper) online test a more likely disruptive model.

NHS involvement

Assistive tech (Low vision, incl. blind and partially-sighted)	Public	Now	Increase independence, confidence and wellbeing	2 Optom / 10 LV patient	6 Optom / 10 LV patient	Effective business model a challenge for high st. practices	Rising demand for low vision tech, given ageing population
Glucose-monitoring CL	Public	2023	Effective blood-glucose monitoring for diabetics	0	1.5		Other innovative modalities of glucose monitoring may restrict uptake. NHS involvement uncertain.
Bio-sensing contact lenses (generally)	Prof/Public	2025		0	2		A natural extension of specialised services within community optometry
App-based monitoring	Prof / public	2016	Compliance and self-care	1	2.5		NHS eye-health apps may be recommended by optoms through private arrangements

8. INTERDEPENDENCE AND PARTNERSHIP WORKING

With an ageing population in the UK, the health and care labour force will be unable to meet the volume of need if we continue with a paternalistic system that holds onto personal health information, tells people what to do and does not enfranchise the public. Without enabling the public to become 'participatients', the NHS will be economically unsustainable and we will witness reductions in quality, safety and access to care.

Leaders in health understand the need for more people to have more information about themselves, to understand the data and be educated to make better choices. The health professional will have a greater role to play in public education and understanding, although there are many online health groups that offer public peer support opportunities. Increasingly we will see the individual with a condition become the 'expert patient', adapting their behaviour to make healthier lifestyle choices and understanding the importance of prevention and monitoring, all through having much more meaningful information.

The key facilitator of interdependence and clinician-patient partnership working will be the electronic healthcare record (EHR). The Veteran's Health Administration (VHA) in the USA has led the way in deployment of the EHR, with its 6.5m patients having access to a (download-friendly) online record. The NHS shares this vision, although an EHR linking primary and secondary care with full patient access is not expected until the early 2020s (and only then with significant extra investment not yet identified). The VHA is also a world-leader in telehealth, a delivery model perceived by some in the USA as the greatest potential disruptor to community optics (2020health interviews, 2015). In the VHA model, care coordinators, with nursing or social care backgrounds, do not replace specialist care, but are available to help facilitate telehealth appointments. This may play out differently in the UK, since the number of district nurses has been decreasing year on year; training places for nurses

in London, for example, have been cut by 25% in the recent years. There is no imminent prospect of them being involved in community eye care.

Manufacturers are developing miniaturised technology for worldwide markets, while start-ups, often looking at low-cost solutions for underserved populations, compete with the high-end technologies that contribute to rising costs of healthcare. Both streams of innovation challenge conventional practice and potentially put ophthalmic technology into hands outside of community optometry.

In this section:

- Practice connectivity and the EHR
- Portable optical imaging
 - Into the hands of the nurse and caregiver?
 - Hand-held OCT
 - Structured illumination ophthalmoscopy
- Technology further miniaturised
 - Glaucoma IOP monitoring
 - Smartphone monitoring
 - Smartphone autorefractor
 - Patient-led refraction

8.1 Practice e-connectivity and the EHR

The home nations are each at different stages of their NHS IT strategy with community optometry, with the aim of enabling both electronic GOS submissions and e-referral. Scotland is ahead in this respect, with e-referral more or less up and running (there are some pending issues with email attachments), although all nations are predicted to have e-GOS and e-referral in place by around 2020.

E-referral should give practices faster and more efficient communication with the NHS. Further, with practices routinely capturing digital fundus images, and with a growing number investing in OCT, there is the potential for optometrist-to-consultant telehealth, with sharing of the digital images to

8. Interdependence and partnership working

reduce the referral of false-positives. The issue then becomes one of reimbursement: this sort of shared care via telehealth is financially expedient to the NHS but requires appropriate remuneration for the community practice.

However, even without NHS payment, community practice has a business interest in seeing quality care delivered to the patient. If a patient is needlessly referred to the acute setting due to an optometrist's misinterpretation of a fundus image, the practice itself risks damaging patient confidence in its service. Optometrist–ophthalmologist telehealth links from high street to hospital will be a developing feature of optometric practice in the 2020s. The driver may well be the patient, whose loyalty to a particular practice is encouraged by service standards (driven by technology) favouring patient convenience. Alternatively, remote geography could persuade the hospital-based ophthalmologist that a consultation could be done in partnership with a more local optometrist.

The EHR

Despite all the rhetoric on electronic health records (EHR), we still have a completely fragmented set up in the UK, with different NHS Trusts using different systems, very few of which are linked to the GP, mental health, social care or pharmacy records, and none of which are currently linked to an optometry record, or are able to bring all data together in a meaningful way either to aggregate or analyse it (nowhere in the world has this yet). In another piece of 2020health's work, we found a single acute trust had nearly 500 different clinical software systems, most of which could not be accessed outside of each clinic. As we assess it, the most realistic prospect of a person having a comprehensive medical record in the near future is firstly if they compile it themselves, using one of the many available medical record apps. Both Apple's Healthkit and Google Fit can capture data from a variety of fitness technology, although

Healthkit can now be integrated with the EMIS GP record, the latter being used by about half of all doctors in the UK (according to EMIS). This also has the advantage of individuals being able to link in relevant apps to their record. The second option is if the patient lives in an area in which an EHR company, such as Patients Know Best, has a contract to integrate all health data. This is about to begin in north-west London and it estimated it will take three years to bring together data from the various sources.³⁵

This does not mean that the fundamental problem of integrated data is not being tackled. IBM announced a deal with several companies in April 2015 (including Apple) to use its Watson artificial intelligence to create a new computational model (Herper, 2015) which will link together existing computers that hold medical data. Health IT giants NantHealth, Cerner and Epic are also rising to the challenge of interconnection and analytics; for example, plans are underway to allow data from Apple's HealthKit to be displayed on the 'MyChart' patient portal of Epic. Within this matrix of interconnectivity are optical instrument manufacturers, the most forward thinking of which recognise the need for imaging equipment compatibility with DICOM: Digital Imaging and Communications in Medicine. This is already crucial for image transfer and data management within the hospital eye clinic setting (both for the EHR and Picture Archiving and Communication System (PACS)) (Strouthidis *et al.*, 2013) and will therefore in turn support efficient data flow from practice equipment to the PMS to the EHR.

8.2 Portable optical imaging

Portable digital imaging equipment is widely used but yet to become standard among domiciliary optometric services, let alone telehealth, in the UK. The reason for this lies in part with the NHS and its strict criteria for imaging equipment compliance with UK screening standards.

³⁵ 2020health communication; Mohammad Al-Ubaydli, CEO, Patients Know Best

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According to the NHS diabetic eye screening (DES) programme, fundus cameras need to have capability to detect subtle diabetic pathology, be replaced at short notice in the event of failure, and be certified to connect to approved diabetic retinopathy (DR) management software (diabeticeye.screening.nhs.uk, 2015). Cameras also need to be mounted, be capable of a 45 degree field of view, and have a fixation target. A portable instrument capable of 45 degree field of view, with high resolution and even DICOM conversion software for jpeg images, is not permitted. In Scotland, while the capturing of a fundus image can secure the high street practice an additional (£5) reimbursement within the GOS sight test for over 60s, there is no such payment available to the domiciliary practitioner. Current regulation and standards also restrict domiciliary-based community eye care services in the UK generally.

Meanwhile, some practitioners are sending portable-camera digital images via internet channels to hospital-based consultants for remote decision making. There may be no NHS reimbursement, but the optometrist's own professional standards (and good will) encourage the process.

It was suggested to us that one reason why the NHS DES programme is reluctant to validate portable imaging equipment is because there is little point in monitoring a house-bound patient for diabetic retinopathy if that patient is unable to attend hospital for regular DR treatment, typically laser surgery.³⁶

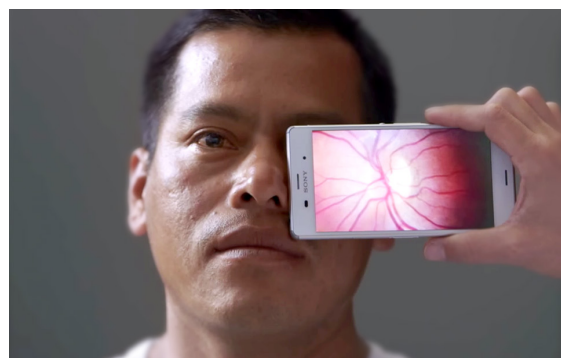
In the near future, it is likely that the UK will see a fully compliant portable digital fundus camera; or, by necessity, the NHS will readjust the criteria of equipment compliance in the interests of equality of access to services.³⁷ Regular monitoring of house bound diabetic patients can enable early action on the first signs of diabetic retinopathy – encouraging better management of blood sugar levels. And even in the high street itself, a portable camera could be useful for patients of limited

mobility who, through the support of caregivers, are able to present for screening.

A) Into the hands of the nurse and caregiver? Digital retinal imaging of the future may well transfer, at least in part, into the hands of the community health worker, caregiver or even the individual themselves. Developments in smart-phone based imaging technology are likely to bring costs of such equipment within the reach of the non-specialist.

The portable eye examination kit (PEEK, Fig.8), developed in the UK, consists of a mobile app and clip-on hardware that transforms a smartphone into a tool that can be used to 'diagnose visual impairment, cataracts, glaucoma, macular degeneration, diabetic retinopathy, and other retinal and optic nerve diseases, as well as [identify] indicators of brain tumour and haemorrhage' (Retina Today, 2013).

Figure 8. Portable Eye Examination Kit (PEEK) retinal imaging



"I see the Peek fundus camera as being a disruptive technology that will replace the ophthalmoscope because the field is bigger and it provides the opportunity to forward images to a colleague for a second opinion."

Dr Iain Livingstone, PEEK co-founder

³⁶ See for example: www.ndrs-wp.scot.nhs.uk/wp-content/uploads/2013/04/QOF-advice-on-housebound.pdf

³⁷ Portable fundus camera contenders may include the Ez-Horus 45 and Volk Pictor Plus.

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The technology is aimed at both eye care practitioners and general health workers to aid the diagnosis of eye diseases and provide a means for managing and monitoring the treatment of patients, anywhere in the world. Currently being tested in Kenya, PEEK has the potential to revolutionise the prevention of blindness in low-income countries.

The developers also see a market for PEEK in high income countries: the potential of this technology in a variety of care settings, including telehealth, is considerable. According to PEEK co-founder Dr Iain Livingstone:

The smartphone has loads of features that lend it well to ophthalmic diagnostics, and, on top of that, the ability to cascade whatever you get, whether it is information from a vision test or a photo of a glaucomatous disc, and send that material to a reading centre or to a processing cloud for automated grading, really offers something significant (Retina Today, 2013).

This affordable technology may in the future be used by caregivers or patients to send ophthalmic images straight to the pharmacist, doctor, optometrist or even ophthalmologist, as appropriate to their condition or agreed monitoring regime. It will be an important consideration for regulatory standards to consider validating the use of home-imaging through NHS channels.

Other developers competing in this space include D-EYE with its smartphone Portable Retina Imaging System, already developed and available in the USA. It is intended that eye examiners will be able to send recorded images wirelessly to the optional D-EYE ImageVault, a HIPAA-compliant private and secure cloud-based data and image storage service, for further evaluation and archiving (Wilson Ophthalmic, 2015).

The emergence of smartphone-based ophthalmic technologies is certainly being noted by manufacturers. Welch Allyn's iExaminer provides the option to attach the iPhone 4 and 4s to their PanOptic Ophthalmoscope for digital image capture. Another manufacturer, on the other hand, recently abandoned their slit lamp smartphone attachment; it is our understanding that the company considered, or forecasted, competition within the smartphone ophthalmic market to be too great. (See also smartphone autorefractor, below.)

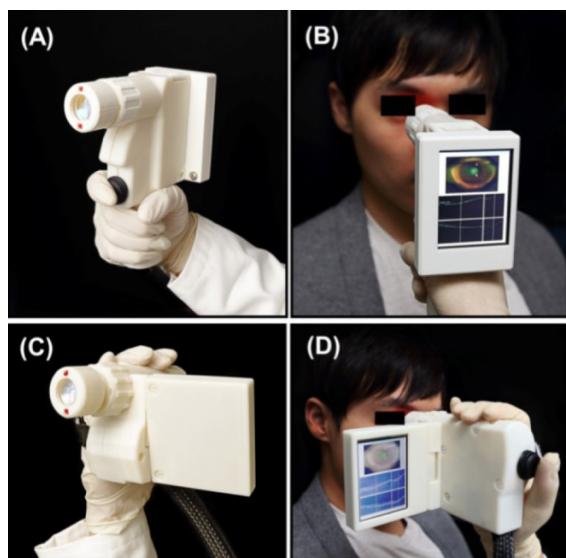
B) Handheld OCT

Detailed in section 5, OCT has become the gold standard imaging tool for the diagnosis of many retinal conditions. OCT machines have reduced in bulk since the 1990s but most remain sizeable, desk-mounted instruments, ranging in price from around £20k–£50k, or £600–£1,200 per month leased (Opticianonline.net, 2013).

In 2014, an MIT-led US-German team of scientists published research on an ultra-high speed, handheld swept source optical coherence tomography (SS-OCT) instrument using a 2D MEMS mirror (Lu C *et al.*, 2014). Prototypes of this camcorder-style device are shown in Fig. 9 (p.92).

Enabling volumetric and high definition cross sectional imaging, the handheld OCT instrument will 'enable applications in a wide range of settings outside of the traditional ophthalmology or optometry clinics, including paediatrics, intraoperative, primary care, developing countries, and military medicine', claim the developers. They also see its application in clinical specialties other than ophthalmology or optometry, dependent on the instrument being significantly cheaper than standard models. This, say the developers, could be aided by the mass-marketing of the product, but they admit that significantly reducing costs in the near term will be difficult.

Figure 9. Handheld OCT devices: two prototypes



Patient-held binocular OCT is also in development. One such device, designed by Doctor Pearse Keane (Moorfields), is intended to allow patients to capture images from their own eyes without any assistance from a clinician. The technology is planned to be multi-functional, capable of whole-eye imaging and visual acuity measurement, even refraction. Potentially available by the early 2020s, it could be used in hospital eye clinics to reduce waiting times, but also in the high street as a rapid, all-in-one 'pre-test' solution. In the longer-term, the device may allow stable disease monitoring via the local pharmacy, or even by the patient in their own home (MEH, 2015; photonics.com, 2015).

Home-based OCT monitoring, with the eye care specialist viewing images remotely, may become reality by the late 2020s. Beyond this we can see fully automated telehealth monitoring via artificial intelligence systems, with computerised image recognition and cloud-based grading activity, as well as automated triage and referral. We predict this to be a little outside the timeframe under consideration.

Figure 10. Patient-operated binocular OCT (artist's impression)



C) Structured illumination ophthalmoscopy
If mass-marketed, hand-held OCT is not imminent, then the optometrist or technician may have sooner access to a 'structured illumination ophthalmoscope' (SIO), intended to deliver 3D-imaging of the retina at a fraction of the price of commercially available OCT machines.

Developed at City University by Dr Steve Gruppeta, the device has already demonstrated proof of concept, capturing images of individual layers of the retina, although SIO will not claim the depth resolution of high-end OCT. The intention is to create an instrument that surpasses the capability of the fundus camera with 3D information to catch early stage disease. The technology could also, in theory, be incorporated into existing devices, for example giving a fundus camera additional SIO capability.

Whilst the technology could sit well within high street practice, an important objective is to make the instrument portable and easy to use, giving

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it viability in remote and lower-income regions. Such design would be ideal for community practitioners working via telehealth in health centres, or optometrists in domiciliary settings.³⁸

The timeline of bringing such a product to market is largely dependent on investor buy-in and commercial interest, including perceived competition from hand-held OCT. Otherwise there is little reason to doubt that a product could be commercially available by 2020.

8.3 Technology further miniaturised

A) Glaucoma IOP monitoring

Glaucoma is the second most common cause of blindness in the world. In the UK the disease affects around 2% of people over 40 and almost 10% of those over 75, leading to more than a million hospital visits every year (City University London, Research Spotlight). Intraocular pressure (IOP) is a primary risk factor in glaucoma patients: the higher the IOP, the greater the chance of glaucomatous disease progression through optic nerve head damage. Regular monitoring is therefore important to diagnosis and progression, but measurements taken weeks apart can be misleading, such is the fluctuation of pressure day to day.

Hand-held home IOP measuring tools have been developed, such as Icare Finland's HOME tonometer, designed for glaucoma patients for whom regular IOP monitoring has been recommended. However, the instrument is not typically used during the night, when IOP has often wide fluctuation due to body posture.

The Sensimed Triggerfish contact lens has recently made 24-hour monitoring of IOP possible, with measurements taken every 90 seconds. An adhesive antenna is placed around the eye and receives wirelessly the information from the contact lens, which is sent to a portable device worn by the patient. The equipment is highly restrictive, but designed to chart a 24 hour profile of ocular dimensional changes.

Other companies are looking at implantable devices. The German company Implants Ophthalmic Products GmbH are working on the ARGOS-IO, a pressure-sensing eye implant containing a microchip together with an external hand held device, capable of transferring energy wirelessly to the implant and receiving readings from it. The device may be durable enough to accurately sense intraocular pressure for 10–15 years (NIHR Horizon Scanning Centre, 2013).

Even with the advent of implantable IOP monitoring, it is likely a wider cohort would choose non-invasive monitoring; for example before and after a change in medication or a surgical procedure; or where fluctuating IOP is thought to be contributing to disease progression.

24-hour monitoring with SENSIMED Triggerfish is under NHS review. According to NICE: 'The technology is currently used in some NHS and private hospitals as part of research studies, and so its place in guiding treatment or improving monitoring is not clear.' It is estimated that each 24-hour use of the SENSIMED Triggerfish device costs between £424 and £549, excluding clinician time (NICE Advice (MIB14), 2014). But we are at the very early stages of this technology, and costs are likely to reduce. It is possible we will see isolated community optometrist involvement in IOP monitoring by this or similar technology within 5 to 10 years.

B) Smartphone monitoring

Smartphone healthcare apps have proliferated in the past few years, and many people are now aware of them, if not using them personally. The critical factor with apps is their ongoing relevance; the average user life is still 90 days as many are not updated and can't be integrated with an electronic health record.

The use of smartphone apps for remote eye disease monitoring is still rare. One of the best known is the FDA-approved MyVisionTrack iPhone/iPad app, which enables the remote monitoring of AMD and diabetic retinopathy between visits to the clinician. The app delivers a regular 10-minute test in which the user

³⁸ Weight of equipment has always been a significant factor to actual mobile uptake and use.

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touches odd-one-out shapes from a selection in different configurations. The clinician can view user compliance remotely, and automatic alerts are created by portal software where progressive reduced performance is detected. This app could be available in the UK within the next year (NIHR Horizon Scanning Centre, 2014).

Future remote ophthalmic monitoring will combine smartphone apps with other hardware technology. As discussed above, the NHS is already reviewing a contact lens and data recorder to measure direct IOP in glaucoma patients. Advancements to wireless remote applications could see patients self-recording IOP measurements from daytime, night-time or 24-hour contact lenses, with data downloaded to their smartphone and forwarded to the local optometrist, or indeed uploaded straight to their EHR (Ophthalmology Times, 2014). The timeframe for this technology could be similar to the glucose-monitoring contact lens, so market-ready by 2025.

C) Smartphone autorefractor

Already noted in section 5, work has been underway to miniaturise the autorefractor yet further through smartphone technology. Designed by Smart Vision Labs, the Smart Autorefractor, SVOne (Fig. 11), uses a hardware clip-on and features an aberrometer with wavefront sensor (smartvisionlabs.com). Manufacturers claim the significance of the device is that it is mobile, comparatively low cost, objective, and can be used by technicians and caregivers with fairly basic instructions. The latest version of this technology (SVOne Pro) claims a sphere range of -14 to +14 dioptres, with cylinder range -7 to +7 dioptres.

Figure 11. The SVOne from Smart Vision Labs.



Competing with high-end portable autorefractors, the SVOne represents yet another development in the growing assemblage of smartphone-based ophthalmic instruments. The SVOne was introduced to the US market in 2015 at \$3,950 with an iPhone 5s included.³⁹ This equipment is being targeted at the professional mobile eye care practitioner, initially at least, and the new the 'Pro' version should be available to the UK in 2016.⁴⁰

Shortly before going to print we noted that Smart Vision Labs were about to launch 'consumer self-guided vision testing' with the SVOne Enterprise, which they claim could play 'a crucial role in providing convenient vision exams to consumers in settings such as retail, pharmacies, hospitals, workplaces, and schools, while also delivering vision care to the underserved population around the globe.' Detailed information had not been released.

³⁹ The iPhone is intended to be used solely for the purpose of autorefraction, not to double up for personal communication.

⁴⁰ 2020health correspondence with Smart Vision Labs, 2015.

⁴¹ This range corresponds to the eyesight of around 95% of the population

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D) Patient-led refraction

We have already discussed the development of EyeNetra's smartphone self-refractor app and hardware (see Section 7.6). The company has recently taken this technology in a new direction, launching an on-demand mobile vision testing service in New York (visionmonday.com). The 'Blink' system uses the aforementioned Netra-G technology to enable patient self-refraction, measurement of astigmatism and pupillary distance. Supporting this is the 'Netrometer' to measure the patient's existing glasses prescription, and the 'Netropter', a portable phoropter capable of examining +6D to -12D.⁴¹ All three devices are smartphone-enabled. Critically, the Netropter allows the user to evaluate their prescription, which was never possible with the Netra-G alone.

Figure 12. EyeNetra's patient-led refraction technology, Blink



In the New York programme, EyeNetra's system is brought to a patient's house or office by a technician, a 'Visioneer', who ensures correct use of the technology and facilitates a telehealth link to an optometrist. (The Blink technology itself includes user support via voice prompt.) The remote optometrist views the patient's profile and results, and returns a digital prescription or, in the event of a complication, refers them for a full in-office eye exam.

Every time someone pays for a vision test with Blink (currently \$75), the company delivers a free vision test to someone in need in that same community. EyeNetra stresses that their service is intended only for patients requiring a vision test for glasses; it does not (yet) incorporate eye health exam.

EyeNetra sees opportunities in a range of foreign markets – the potential of this technology in underserved communities is certainly significant. But in the UK, any stand-alone refraction service is not viable under current regulation, which demands a full eye health exam to validate a prescription.

EyeNetra will allow practices to develop their own models of delivery. From 2016, Blink will be available for purchase in the UK at just over £700 (the full suite of three technologies available for £1,500).⁴² We could find no independent review of the technology's accuracy and utility, as compared with traditional equipment, at the time of writing. If proven comparable, it is easy to see mobile optometric services using it to deliver workplace testing within the wider context of a comprehensive sight test.⁴³ This offering may appeal to businesses that do not want to see their workforce take time off to attend sight tests. Such arrangements with established domiciliary providers exist currently (e.g. the Valli Group).

⁴² EyeNetra online store. Accessed 17.11.15 <http://store.eyenetra.com/> Price may ultimately differ owing to distributor costs.

⁴³ Both practice-based use and mobile use of patient-led subjective refraction technology may require clarity from the GOC on 'delegated functions' under current Rules: see Part 5.

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E) Kiosk sight testing

In section 7.6 we considered the eyesight kiosk, used in the USA (supermarkets, pharmacies and malls) to assess distance and near vision, and refer users to participating eye care professionals for full eye exams. Introduced in 2007, SoloHealth's EyeSite kiosks have over time evolved into more comprehensive health stations, allowing checks on eyesight, weight and blood pressure, and giving information on diet, vitamins and pain management (KHN, 2013).

As already stated, fully automated kiosk refraction is likely in the future, but while acceptable under law in some countries, this would not be valid in the UK under current regulation since it would separate refraction from the all-important eye health exam.

Figure 13. SoloHealth's vision test kiosk, 2008, USA.



By the late 2020s, health kiosks could have commercial viability for full sight testing, with telehealth interpretation and validation of results.

A possible option for the UK under regulation is a kiosk that combines both automated refraction and eye health screening, with tele-optometrist remote viewing, so to enable a comprehensive sight test. Capitalising on miniaturised technology, this future version of the kiosk could include fundus imaging and OCT (see 8.2B), an idea that has already occurred to manufacturers.⁴⁴

Kiosk telehealth could be in real time, or tests validated within 24 hours. A prescription could be returned via email, perhaps with onward referral to a practice for further diagnostic tests where necessary. Supported by telehealth, kiosk sight testing points to a future of wider access, particularly for underserved populations, and greater competition among providers.

8.4 What this means for business

8.4.1 Considerations

Lighter, more mobile and easily accessible equipment and technology that utilises common gadgets such as the mobile phone will open up testing and monitoring opportunities. This is important for the NHS and economy as a whole, which will otherwise not manage the level of demand. Integrating information collected in the community or even in person is still not straightforward and this is currently hampering its utility. Consent and confidentiality are also issues. The public need to be confident in the security of their information, which requires robust clinical governance and a clear understanding among professionals and technicians as to who the data belongs to. Further, for improved clinical care, data need to clearly show normal and abnormal readings; simply to deluge professionals with streams of new data will not improve the quality of care, or persuade them of the usefulness of the technology.

All professionals across medicine will experience a shift in their role from having sole access and understanding of patient health data, to one of assisting in care, interpretation, signposting and

⁴⁴ For example: www.google.com/patents/US7384146

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reassurance. As more avenues open up to obtain health data, professionals should expect more information from a variety of sources. However the rise of smartphone apps that enable remote self-monitoring, for instance to check AMD progression, could mean some of the disease monitoring work will bypass the optometrist.

8.4.2 The public

There is still a debate about patient generated data. Some professionals doubt its veracity, but this is a problem that has to be overcome, as interdependence and partnership working can only thrive if credence is given to personal health data collected by individuals – and from ‘automatic’ sources. As mentioned before, over the next decade at least, only individuals will be able to compile a truly comprehensive EHR as there are so many NHS software systems that are too disparate and opaque, with hidden application program interfaces (APIs).⁴⁵

For the public, this is not such a bad thing. The ownership of property has always been central to emancipation, and owning our medical data – which after all is our intellectual property – is vital for both our involvement and safety. Many health records contain errors, uncorrected because we never see them. In one US study, 95% of the medication lists in GP notes were found to have errors (wsj.com, 2014). And if we are the arbiter of who can have access to our record, and are able to see the audit trail of access, then fears over privacy will be mitigated. Public confidence will grow as people have more record access and greater understanding of their health. They will be willing to cooperate with technology, such as the Sensimed Triggerfish contact lens or pressure-sensing eye implants, because retaining vision is so highly valued.

Added to this we have an ageing workforce. Older people with long-term conditions will remain in the workplace and they will increasingly want and need

convenient solutions to remaining well. Vision screening in the workplace and mobile phone solutions will appeal as people seek to reduce the time they spend on protracted professional healthcare interactions. Indeed, direct to workplace services (telehealth enabled or otherwise) could become ever more sought among larger employers for the wider workforce, many of whom may be entitled to sight tests at the employer’s expense (under Health and Safety Regulations, 2002) due to concentrated periods of screen work.⁴⁶

Remote self-care is particularly good news for people who are housebound. The quality of their care will improve as the greater availability of convenient tests will provide more information, vital to ensuring their visual abilities are kept optimal. Whilst some technologies will still require a technician’s involvement, innovation will mean the role of domiciliary care can be re-envisioned.

8.4.3 Solutions

Technologies that enable clinician-patient collaborative care, reducing the role of the traditional provider, will be one of the disruptive innovative challenges for optics. The public are already becoming more used to health apps, looking for watches and wearables to collect health data and finding information online. Be it called ‘citizen medicine’, the ‘emancipated consumer’ or the ‘democratisation of medicine’, people have more access to information and many will become expert patients, though most will still want to be able to discuss results with a professional.

Automated image assessment will also mean a reduced role for the optometrist. In some areas of the country, for example south London, optometrists were removed from diabetic screening programmes as they became digitised. Technicians took over the role in acute hospital diabetic clinics, but even they could now be replaced by software analysis.

⁴⁵ The set of routines, protocols, and tools for building software applications; if they are hidden then interfacing and integrating with the application is problematic.

⁴⁶ Health and Safety Regulations (updated 2002) state that employees using Display Screen Equipment (DSE), typically desktop computers and laptops, as ‘a significant part of their normal work (daily, for continuous periods of an hour or more)’ are entitled to eyesight tests on request at the expense of the employer, and even spectacles if specifically required for workplace DSE use.

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Due to the demand on community care (carers, district nurses) and the proportional reductions in adult social care budgets still to come, community health workers will not be replacing domiciliary eye care professionals any time soon. The voluntary sector's role will expand, as demonstrated by the successful 'Living Well' AgeUK programme in Cornwall (ageuk.org.uk), and there is an opportunity for optometrists to be linked into this sort of scheme which will no doubt grow throughout the UK in the future. Interestingly, AgeUK realises that at present it is not utilising technology properly to assist in its programme and is open to ideas for improving pathways through innovation.⁴⁷ Whether volunteers would be interested in training on screening devices traditionally used by the eye care professional is another matter.

An instant-access, comprehensive kiosk eye exam will probably be available in the UK by 2030. A pharmacy or supermarket chain could set up health kiosks (as already found in the USA, even if limited in function) and perhaps have staff trained to assist where necessary. Telehealth viewing of results could be undertaken by an optometrist, and a prescription returned via email, perhaps with an attached voucher, allowing the patient 20% off frames in store. Another possible location for patient-led eye exams is the large general practice or medical centre, where the patient will feel no onward pressure to buy eyewear from the provider. Such models, if supported by the NHS, could prove particularly popular among unemployed and low income groups, who cite 'pressure to buy' as a disincentive to attend sight tests (2020health interviews, 2015; Trudinger and Niblett, 2012).

⁴⁷ 2020health communication, Tom Wright, CEO, Age UK

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Legend

Vision
Vision / health
Health

Interdependence / partnership working

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
Private sector							
Hand-held OCT	Prof	2020	Greater diagnostic capability for mobile practices; equipment for other community providers	0	4		Mobile OCT may not be a deal-breaker for domiciliary patient base. Developer ambition to facilitate patient-operated binocular OCT.
Smartphone autorefractor	Prof	2016 (USA 2015)	Cheaper alternative to £5k+ portable autorefractors	<1	3	Extensive trials not yet undertaken	Lower-priced S/A potentially disruptive to manufacturers
Patient-led refraction (portable)	Prof / technician	2016 (USA 2015)	Convenience; domicile/office service	<1	3.5		Technology viable in context of comprehensive mobile eye health services. Potential to reach those underserved by optometric practice.
Kiosk sight test with telehealth	Public/ remote prof	2028	Comprehensive automated (audio-prompt) sight test with telehealth interpretation of results	0	2	Potentially unsuited to high-risk individuals	Potentially attractive to those put off by retail-driven services, especially unemployed and lower income groups. Non-traditional settings – wider access. Increased relevance in 2030s.
Smartphone imaging systems: E.G. Portable Eye Examination Kit (PEEK); D-Eye	Prof/Public	2016	Remote-region eye health; use in variety of care settings; domiciliary; telehealth	<1	4	Limited field of view as compared with desk cameras, currently	Evolving technology will improve image quality and field of view. Opportunity for community healthcare workers, using telehealth links within primary and secondary sectors.
NHS involvement							
E-Gos / voucher submissions	Prof	All nations by 2020	Time saving, reduce paper trail, clear records; reduce costs	3	10	PMS incompatibility issues: will hamper progress and uptake	Alternative methods: Northern Ireland OCS portal
E-referral	Prof	Scot: now Others by 2020	Seamless communication; patient safety; reduce waste	5	10		No need for PMS compatibility – easier solutions
Home telehealth OCT	Prof / Public	2030	Home-monitoring of eye disease progression	0	1		Financial viability of model unlikely much before 2030
Contact lens IOP monitoring	Public	2017 (UK trials now)	Home monitoring of intraocular pressure	<1	3		Uptake among elderly population uncertain
Smartphone apps for eye disease monitoring	Public	2016 (USA now)	Home monitoring of disease progression	1	4		Optom involvement in partnership care, using apps in NHS community eye care pathways

9. FASHION AND LIFESTYLE

Fashion is the major driver of trends in traditional eyewear. But it is technology that allows even a small frame manufacturer to have considerable control over product style and durability, while the internet gives opportunity to compete within a global market.

Further automation within the frame-making industry as a whole is expected. Disruption will also arise from additive manufacturing, or 3D printing, within the time-frame under review (see also Section 7). Though it will be many years before 3D printing sees significant scale and speed, it will soon allow smaller operations to respond rapidly to changes in trends, and will certainly bring new stakeholders into the space of fashion framewear.

Some interviewees cited increased business opportunities in bespoke products for recreation; for example polarized lenses for fishing or skiing, contact lenses for sports, and also computer glasses – both prescription and non-prescription. However this is nothing new; the technology has been available for some time, it arguably just needs better promotion.

Already there is increasing competition among optical practices to promote the aesthetic and brand value of their stock through technology, both with the virtual try-on of glasses and interactive product information. Such digital presentation emphasises the fashion product as modern, relevant and cutting edge.

Few interviewees expressed real interest in smart glasses or augmented reality glasses. With business generally looking three to five years ahead, perhaps there was doubt about progress in this field of wearable technology, particularly following the public's lacklustre reaction to Google Glass. Looking forward into the 2020s, we see second and third generation smart glasses and augmented reality glasses of potentially great significance to optical practices. To be ahead of the curve and not miss out on this growth market, it will benefit practices to be prepared and trained (accredited) early on.

In contrast to healthcare providers, public adoption of technology is rapid, witness the astonishing rise in social media, smart phones and now wearable tech. The balance is shifting, from a public who was dependent on professionals for direction, to citizens who are more informed, aware and focused, and telling the professionals what they want.

In this section:

- Smart glasses and augmented reality glasses
- Smart contact lenses
- Eye-glass free screen displays
- Dispensing fashion (digital tools / RFID)
- Personalisation from 3D printing

9.1 Glasses: Smart and Augmented Reality

Few doubt that the wearables market is set for rapid exponential growth. The IDC (Worldwide Quarterly Wearable Device Tracker) estimate that around 20 million wearable devices were shipped in 2014; they predict shipment of 126 million by 2019, with around 4.5 million units of eyewear (IDC, 2015).

As compared with the smartphone market, which saw 1 billion shipments in 2012 (IDC, 2014), the smart eyewear market may seem inconsequential. Limitations of technology (including battery life), unwieldy or unfashionable design and lack of style choice are currently restricting growth in the smart eyewear market. This was partly the complaint with Google Glass: unbalanced on the face, a distraction to others and ridiculed for its 'geek factor'.

But the smart and augmented reality eyewear market will no doubt flourish in the 2020s, and emerging technologies will support ever more discreet 'smart' applications in glasses of the future. This may be enabled by new materials such as graphene (see inset), but even before then, manufacturers will be able to miniaturise the technology in smart eyewear still further.⁴⁸

⁴⁸ There is still room for further miniaturisation with existing semiconductor technology (re/code, 2015).

Once the products become fashionably acceptable – as smart watches are becoming – as well as lighter, there will be no reason to doubt exponential growth.

Graphene, a carbon allotrope usable in layers of one atom thick, is unequalled in its lightness to strength ratio and could greatly enhance the performance and efficiency of materials and substances. There are challenges yet to overcome with the material, such as production on an industrial scale and the fine-tuning of its properties to suit specific functions (phys.org, 2015).

The issue has potential relevance to the high-street optician since anyone who requires a corrective prescription may well need the lenses of their smart glasses or augmented reality glasses made to order. Distributors claim that bespoke lenses can optimise the heads-up display (HUD) of smart glasses by accommodating a prescription adjustment in the field of display. There may be more flexibility with augmented reality glasses, with 'normal' lenses bringing reasonable results, but again it is possible that the equipment will only achieve optimum performance with specific lens types. And even if the technology sits (now or in the future) with regular eyewear, optical practices should be positioning themselves as leaders in the field.

The technical applications of smart glasses and augmented reality glasses will give them appeal even before they become fashion-ready. DHL have recently run a pilot study with Ricoh and wearable solutions firm Ubimax to test out the utility of smart glasses in warehouse stock management. Allowing staff to operate hands free, the glasses display aisle, product location and quantity, and have resulted in a 25% efficiency increase in the product picking process (DHL press release, January 2015).

The further capability of smart technology to create virtual instructions for general or specialised maintenance or assembly, could well give smart glasses traction 'behind closed doors', whether in industry or the home (spectrum.ieee.org, 2015). Other early adopters may be sports enthusiasts. Recon Instruments has recently released its Recon Jet HUD glasses, boasting accelerometers, gyroscope, magnetometer, altimeter, barometer and thermometer, as well as HD camera. Also developing within this space is Oakley, who have partnered with Intel to develop fitness and sports smart glasses.

9.2 Smart contact lenses

There is an ambition to see emerging smart glass technology miniaturised into the form of a smart contact lens (CL), wirelessly fed from other smart technology, which might itself be wearable. This CL technology is of a far more complex order than bio-sensing lenses, drug eluting lenses and zoom lenses (see Section 6.2), not to mention Google's 'biometric I.D. contact lens' (Optician, June 2015), the likes of which we may see in use within ten years. To compete with smart glasses, the smart contact lens would need to include such components as image projection, camera, energy production (perhaps solar-cell) and storage, and microelectromechanical system (MEMS) transducers and resonators to tune radio frequency communication (spectrum.ieee.org, 2009). The smart CL would of course have to be safe, comfortable and affordable.

Despite current media excitement around such technology, it is unlikely that we will see recreational smart CLs developed and clinically approved much before 2030. The product may appear closer to hand because much of the theory behind the technology and even some of the micro-components involved are already developed. The smart lens power source perhaps remains the greatest challenge of all. The state of play with augmented reality and smart

glasses, with their size, weight and inherent limitations, is an important marker of progress in this field.

A) Augmented reality: frames and contacts combined

Possible in the nearer future will be smart technology combining CLs and framewear. Innovega is developing a contact lens onto which images can be projected from framewear, designed to deliver 'higher performance and better style'. Called iOptik contacts, the lenses have capability to be customised according to the wearer's prescription, making them a viable replacement for conventional lenses (smithsonianmag.com, 2014). This technology, if successful and FDA-approved, could be commercially available by 2020. Applications include magnification for those with low vision, wide-field virtual reality for gaming, and both superior data capture and field of view for the military. Optometrists and opticians will have a key role to play in its distribution.

9.3 Eyeglass-free screen displays

Researchers at the University of California at Berkeley and MIT are working on 2D computer displays that compensate for the viewer's visual impairment. They have already created a prototype, taking an iPod display and modifying it with a printed pinhole screen and some advanced software that manipulates the light emitted from each screen pixel, projecting a 'pre-distorted image', customised to compensate for the viewer's refractive error. There are milestones yet to be reached with the technology. First, the corrective power thus far does not exceed a couple of dioptres. Second, for the technology to work efficiently, eye tracking software needs to be incorporated, otherwise the viewer needs to be always at a set distance from the screen. Third, the system needs to be able to accommodate viewers with anisometropia, by directing the light from the screen to left and right eyes and compensating for different refractive errors. A fourth milestone would be to make the technology beneficial to those with higher-order aberrations, whose sight cannot be improved with glasses or contact lenses.

Eye tracking software is already available and has recently been integrated into the Amazon Firephone – so it is only a matter of time for Berkeley and MIT to assimilate this into their product. And even a product that compensates enough for a user with a low prescription to pick up their phone or see their car's GPS screen without needing glasses, will generate immense interest. Thus not all these milestones need to be reached before the technology finds its way to the market. It is also of note that Vitor Pamplona of EyeNetra is competing with similar technology (Pamplona, 2012).

Through manual adjustment, such a device will in theory be able to inform the user of their refractive error (the adjustments would need to be made one eye at a time). It again points to a future where individuals may have access to prescription checking outside of the professional setting.

We do not predict great disruption to the eyewear market from this technology. People with refractive errors will still need corrective eyewear, for example to read food labels and various instructions, but it might just deter them from buying a second pair of glasses.

9.4 Dispensing fashion: digital tools of the 21st century

It is essential that the optical practice understands consumer drivers, habits and preferences. In this way it can analyse the potential market and engage with dispensing technology that responds to key drivers of consumer behaviour: health, value, price and time.

A recent survey by Millward Brown of vision-corrected men and women suggested that the UK public are among the least health-driven eyewear consumers in Europe (Optician, July 2014). An extrapolation of data from the five-nation survey suggests 43% of all eyewear consumers are health driven, while 23.5% are value driven; figures for the UK alone suggest 33% are first and foremost health-driven, and a similar proportion is value-driven.

Digital dispensing

Specsavers, in 2015, announced plans for the nationwide digitisation of their dispensing services, with tablet-based software capturing the full range of dispensing measurements required, as well as offering a computerised try-on.

The service is designed to create a more fluid patient environment, and brings an element of Apple's 'Genius Bar' concept into optics (OT, April 2015).

The time-conscious consumer also has a marked presence in the UK, notably more so than in Germany or Italy. It is however important to remember that the health-driven consumer generally accounts for the greatest proportion of spend among behaviour groups (Millward Brown, 2012). Practices need to understand where the balance lies among consumers and respond with appropriate solutions. Whatever the balance of spend, the patient's retail journey will always remain high priority and for the most part critical to practice viability.

Digital dispensing tools are likely to become ever more important to consumer experience, choice and decision-making – and ultimately to sales. We have already noted digital tools that facilitate precise measurements of the eyes and eyewear positioning, so to personalise the manufacture of free-form lenses (Section 6). Soon, similar technology will be useful for practices offering the customised fitting of 3D-printed glasses, which are surely a direction of travel for truly personalised framewear (3dprintingindustry.com, 2014).

The virtual or recorded try on of eyewear is another important digital solution. The time-honoured method of testing out frames with clear 'dummy' lenses by looking into a mirror has limited utility for those with blurred vision. The iPad, allowing the DO

to photograph or record the patient wearing a frame and play this back, represents a low-cost solution. At the higher end are free-standing products by Essilor, Zeiss and A.B.S,⁴⁹ which enable the patient to try on – virtually or otherwise – a range of frames at their own leisure. This class of product will often assist patient education, for example a review of spectacle lens treatments, a video tutorial for first-time contact lens wearers on how to insert contacts, or animations on eye health.

Free-standing (wall-mounted, table top or floor) dispensing systems are fundamentally designed to enhance patient experience; they are also intended to cut down staff time needed for the explanation and demonstration of products. In the near future we are likely to see the increase of RFID (Radio Frequency Identification) marketing solutions within this space. RFID is already emerging as a powerful tool for customer data analytics, allowing businesses to tag products and capture quantitative data on sales and consumer preferences, as well as enabling product tracking and rapid stock-taking. Smart tables allow an RFID-tagged product to be advertised to the consumer: sensors register the product and pull up relevant information, photographs, graphics and even film clips to allow the individual to self-educate themselves on the product.

We see these interactive and enjoyable solutions becoming ever more present in busy practices with high throughput. They will particularly appeal to the millennial, a person who enjoys interactive technology and self-education, and recoils at the hard-sell.

9.5 Personalisation from 3D: 'additive manufacturing'

In Section 7 we discussed the future possibility of younger generations designing their own frames at home, and uploading their Computer Aided Design (CAD) files to the Net for 3D printing by specialist (and potentially very small) companies. We also

⁴⁹ E.G. Visioffice System from Essilor; Smart Centration E-column by A.B.S;

expect to see a growing number of people using home 3D printing technology for frame-making (new or replacement), even if end products fall short of the quality achieved by specialist services.

Disruption caused by 3D printing can of course be harnessed by established manufacturers and optical practices, who will be able to extend the range of sizes of specific frame designs. Businesses may need to provide further bespoke options, since the appetite for 'co-creation' is very real amongst younger generations – Millennials especially, who seek personalised and unique experiences. Co-creation requires the manufacturer to allow customer input on design; exactly what kind of design choice would depend on the product. The Australian start up Sneaking Duck (sneakingduck.com), for example, is planning a line of 3D printed frames which can be customised according to frame colour, printed text on frames and arm length.

Practices offering 3D co-creation among their glasses range are much more likely to attract younger customers (and without any disruption to an older patient base). The independents have an advantage in this regard: they can potentially form partnerships with suppliers far more quickly and with greater flexibility than the multiples and supermarkets.

9.6 What this means for business

9.6.1 Considerations

Whilst a history of fashion can be traced through spectacle frame design from at least the 1950s, it was in the 1990s that they began to emerge as pure fashion items for those who do not need refractive correction. Technology now impacts our lives in ways unknown even a decade ago, and a hugely significant corollary of this is visual communication. We are now exposed to 'the new' in real time, and the average adult over 16 years engages with media and communications for 667 minutes a day (econsultancy.com, 2014), the vast majority being in

visual form (for under 16s it is more). YouTube, not Facebook, is the most used social platform in the world, and social media's obsession with celebrity means that the moment someone popular is seen wearing something attractive or novel, the image spreads around the world in a matter of minutes. Fashion houses know that if the Duchess of Cambridge is seen wearing one of their items, it will be sold out within hours.

Although there will always be novel materials, disruption in recreation and fashion is currently about the rapidity of changing styles. This trend is likely to continue, giving impetus to 3D printing, which compared to traditional manufacturing methods has greater flexibility to respond to rapidly changing fashions.

The combination of mobile technology and refractive correction will emerge strongly during the next 15 years. The momentum behind all wearables is that they are practically instantaneous. Though we marvel at the smartphone computer in our pocket, we are already getting impatient with the time it takes between intention and action. The essence of google glass was Google Now (wired.com, 2013), which, rather like predictive texting, can anticipate from your diary and past history what you want to know before you ask. If our sat nav is in our glasses, and it has drawn from our calendar the location of our next meeting, then it will display the route without us having to ask. Google Glass mark 1 may have bombed, but then the mobile started with a 'brick' in the 1980s.

Google Glass was the fore-runner of a trend that is gaining pace; that of incorporating technology into frames and lenses. Whether it is innovators combining optical components on frames in conjunction with contact lenses, or the incorporation of technology into frames by established optical manufacturers, the optical wearable tech market will grow over the next five years.

9.6.2 The public

Whether driven by necessity or fashion, interest in frames is not waning, except perhaps amongst those who wish to avoid reading glasses. For them, the prospect of the eye-glass free screen display will be very attractive. As eyewear emerges with applications other than for sight correction, a new portion of the population, needing no visual correction, may present themselves as potential customers of high street opticians.

Visual media matters because trends are moving fast and global communications carry them into every home. Novel technology is bought by the minority 'early adopters', but cheaper alternatives always follow. And this interest will carry on, not necessarily driven by refractive need, but by public curiosity and consumerism. In fact Forbes reported last year on new trends in eyewear, crediting social media for driving an 'Instagram' look (forbes.com, 2014).

Six themes for Gen Y / Millennials:

1. Treat me like I'm a partner, not just a purchaser.
2. Give me products that fit ME.
3. Connections are important to me.
4. I'm insecure about today, but optimistic about tomorrow.
5. I want to make a difference.
6. My life is an adventure.

IdeasToGo.com, August 2014

Generation Y and Millennials want products that reflect a greater sense of who they are as individuals. They appear to be much less influenced by advertising than previous generations, and look to personal feedback to products (consumer ratings, message boards and blogs) to judge quality and guide purchase (forbes.com, 2015). Increasingly they will be looking to fashion designers and manufacturers to allow co-creation (see insert).

But it is not just younger generations who value personalisation; we have discussed the increasing personalisation of medicine, and the general public will expect optics to be more personalised as well. Independent practices that have thrived are those who already understand the importance of individual relationships.

9.6.3 Solutions

The market in frames will remain strong, but RFID analytics, virtual try-on and social media causes us to ask whether the days of large stocks of physical frames are numbered. RFID allows the practice to swiftly respond to demand and fashion, and identify and remove products attracting little interest. Practices with space limitations may even go semi-virtual: the shop-window screen showing the latest trends and celebrity preferences, and virtual try-on in store extending choice beyond the range of displayed frames.

The offering of specialist frames for sport, work or local business could also be efficiently marketed by shop-window screens, demonstrating the latest technology and trends. The DHL case study as well as the multiple applications for the Innovega iOptik should be a spur to think about potential markets in wearables that will require the partnership of the high street practice.

The inside of an optician's practice should not look the same in 10 years' time: optical wearable tech, virtual frame choices, customisable 3D printed glasses, and connected RFID monitoring/marketing systems will mean that traditional spectacle rows will reduce to allow for lifestyle, communication and healthcare options. To reach this point high street businesses will need to forge new partnerships in uncharted territory – such is the nature of chasing the exponential curve of digital technology.

Legend

Vision
Vision / health
Health

Recreational / fashion

Technology	Target users	Availability	Purpose	Relevance index (1-10) by 2020	Relevance index (1-10) by 2030	Concerns	Comments
Private sector							
Smart glasses (heads-up display; HUD)	Public	Now	Hands-free, wearable phone/camera and computing device	1	6	Privacy considerations / photograph and filming violations	Early adopters in workplace and recreation. By 2030, common, more discreet and fashion-acceptable
Augmented reality glasses	Public	Now	Semi-immersive hands-free, wearable computing device	1	4		Like smart glasses, will become increasingly fashion-acceptable. Gaming, design and workplace appeal.
Smart contact lenses	Public	2030	Hands-free, wearable computing device	0	<1		Significant technological hurdles remain; smart CL would require clinical trials. Unlikely to make strong impact before 2030.
Eyeglass free screen displays	Public	2025	Screen media clarity without need for glasses or CLs	0	3	With tech capable of producing refraction results, users may bypass formal sight test	Corrective eyewear still necessary for many tasks, thus limited disruption only. Development of self-refraction app could be more disruptive.
Virtual / recorded try-on (dispensing aid, in practice)	Prof	Now	Fast view of multiple eyewear options	5	10		Particular appeal to younger generations; also to 'time-stretched', and patients with poor eyesight
3D print bespoke frames / 'co-creation'	Public	2018	Increased customer personalisation	1	6		Extended ranges of frame size will become standard; co-creation appeal to younger generations
RFID marketing	Prof	Now	Improving the patient journey through tech interaction, education and entertainment	2	5		Appeal to younger generations

10. DEVELOPMENTS IN OPHTHALMOLOGY

In considering the effect of technology on the optical sector, it is obviously important to recognise developments in ophthalmology and the impact that this could have on the high street. There are few nations within the European Union that have such a low proportion of ophthalmologists: only 2.3 ophthalmologists per 100,000 population in the UK (European Union of Medical Specialties).⁵⁰ However, in many European countries the profession of optometry is not well, or officially, recognised, and the greater proportion of ophthalmologists corresponds in part to their involvement in primary eye exams.

Surgical correction of vision, both corneal and lenticular, as well as gene therapy and stem cell treatment, have all received a lot of attention in the press. Progress is often reported with much excitement and optimism for further breakthroughs in the near future. In this section we review some of the latest developments and cautiously speculate forwards, mindful of what a rapidly ageing population and an increasing incidence of people living with multiple long term conditions means for the 15-year view.

In this section:

- Refractive surgery
- Eye disease
- Summary: the supportive role of optometry

10.1 Refractive surgery

Lifestyle-choice refractive surgery really took off in the 1990s. Preceded by more invasive scalpel techniques such as radial keratotomy (RK), 'lasik' emerged after laser had been introduced to replace the scalpel in RK, creating photorefractive keratectomy, or PRK. This procedure was still on the corneal surface but lasik changed this; a blade was used to cut a thin flap in the cornea, the tissue

underneath was then reshaped by laser, and the flap was replaced like a natural bandage: 'flap and zap' was born.

In the credit-easy turn of the 21st century, lasik quickly became the most popular elective procedure in the western world. Optometrists were employed to undertake pre- and post-operative care, and some still do work in laser clinics. However there was a marked drop-off in volume of surgery after the 2008 economic crash;⁵¹ off-putting videos loaded onto YouTube both from successful (but gory) and unsuccessful procedures are also blamed for the decreased popularity of lasik. Research into refining lasik continues with 'interstromal' techniques but the results are not as accurate, nor is using riboflavin with UV light to produce 'cross-linking' within bonds of the collagen within the corneal stroma. Whilst no cutting is involved, the tension (and thus curvature) change of the latter approach is unpredictable and not permanent. This technique however is the ideal first line of treatment in keratoconus as it prevents disease progression and has been available for 10 years on the NHS at Queen Victoria & Moorfields.

Whilst Lasik is usually delivered in the community and much of the procedure can be automated, the latter is not a realistic prospect because the public will still require the reassuring presence of a professional. There are still stand-alone Lasik clinics, but it is very difficult to obtain statistics on market change, and although there is growth in the sale of ophthalmic lasers worldwide, all we know from this is that more clinics are being set up in Asia and Latin America (optics.org, 2012).

Traditionally, refractive surgery was about replacing the cloudy intraocular lens with a clear plastic one to restore vision. By the early 1990s, the technique had been refined to a procedure that only required a micro-incision, together with the implantation

⁵⁰ Union Européenne des Médecins Spécialistes: www.uems.net

⁵¹ Research by Market Scope and VSDAR revealed an above 50% fall in procedures across Europe from 2007 to 2008 – 1.4 million to 600,000; their prediction for 2014 was 720,000 procedures, just 4% growth since 2011 (Market Scope; VSDAR, 2014).

of a flexible lens correctly calculated, giving excellent visual results. The outcome was now more about seeing as well as possible post-operatively without the need for correction, rather than just removing a visual obstruction in the form of a cataract. As early as 1998, studies of refractive lens exchange (RLE) in people with high refractive errors were being published (Alió *et al.*, 2014). In 2002, a five year study was published on the efficiency and safety of replacing the clear lens from patients with high myopia, with 70% needing no refractive correction post-operatively (Gabric *et al.*, 2002).

Since then the average age of those willing to undergo clear lens exchange, also known as RLE, has dropped from those in their 60s/70s to those between 40–60yrs.⁵² Vanity (not wanting to wear reading glasses with the onset of presbyopia) and possibly practicality are the main drivers as individuals want to be able to function without glasses for both distance and near vision. The most popular surgical solution is to have a reading focused lens inserted into the non-dominant eye with a distance lens for the dominant eye. Multifocal lenses (mainly bifocal) are available, though glare, halos and dysphotopsias are reported as common. Technological improvements are of course expected in the future. A new trifocal intraocular lens, the FineVision IOL (PhysIOL, Liège, Belgium), demonstrated superior outcomes in one recent study (Vryghem & Heireman, 2013) while a near future possibility (five to ten years) is an implantable liquid crystal based lens, with switchable focusing⁵³ – in essence, the implantable version of the dual vision liquid crystal contact lens described in Section 6.

Accommodating lenses for RLE are still some way off, and doubt was expressed by some we interviewed as to whether they would ever be a realistic option.

They currently do not give enough near vision, and significant surgical and technical issues remain, for instance keeping the capsular bag clear.

Optical Express, Optimax and Optegra are the main chain providers of RLE. Lens manufacturers (and some surgical providers) claim this is a growth market but there are no publically available data to back this up in the UK. However a study published in Germany in 2010 showed RLE to be growing at a faster rate than traditional cataract extraction (Schmack I, Auffarth GU, Epstein D, Holzer, 2010). RLE as a lifestyle treatment will not become available on the NHS, but if it became regarded as a desirable cosmetic treatment,⁵⁴ it could be a game-changer for optics. The reasoning could be that given the inevitability of presbyopia, as well as the likelihood of needing cataract surgery at some point later in life, there are good reasons to choose surgery while younger, fitter and not to have to endure any sight loss due to cataracts. 50% of 60 year olds have cataracts and 100% of 80 (some would say 75) year olds (Hammond, 2001). Life expectancy is expected to reach 85.7 years for men and 87.6 years for women by 2030 (Bennett *et al.*, 2015) and the strongest risk factor for cataract is ageing (Beaver Dam Eye Study: Klein BEK, Klein R, Lee KE, 1999). However, such is the perceived risk and fear of eye surgery, many will want to wait until cataract removal is essential, and 'free', on the NHS. RLE impact is therefore difficult to predict, but we may be surprised: our image-obsessed society may be increasingly willing to take the risk.

Pharmacological solutions to presbyopia still rely on constricting the pupils, which is only ever a short term solution. Whilst there has been talk of improving lenticular flexibility,⁵⁵ there seems to be little progress at present.

⁵² 2020health communication from UK ophthalmologist

⁵³ 2015 saw Devesh Mistry win the 'Industry Fellowship from the Royal Commission for the Exhibition of 1851' for a liquid crystal IOL. Work supported Eurolens Research at the University of Manchester and UltraVision CLPL.

⁵⁴ Cosmetic surgery has grown from £750m in the UK in 2005, £2.3bn in 2010 and is forecast to reach £3.6bn by 2015. Eyelid surgery is currently the second most popular procedure.

⁵⁵ For example, Encore Vision is attempting to develop such a solution. Webpage accessed 12 May 2015: www.encorevisioninc.com/product.html

Cataracts remain a problem of ageing and waste disposal (especially with no blood vessels to remove debris), and whilst they have become of interest due to their association with particular conditions (and their removal as potentially improving outcomes beyond vision e.g. in people with Alzheimers⁵⁶ (alz.org, 2014)), treatment through removal is now so straightforward there is no commercial interest in prevention. Currently, reading glasses are normally required after NHS surgery following the fitting of monofocal lenses;⁵⁷ but it is conceivable that in the future the NHS may introduce alternative lens choices that will reduce (though not necessarily eliminate⁵⁸) the need for corrective eyewear. This could be of some business impact to community optometric practice.

10.2 Eye disease

A) Age-related macular degeneration (AMD)

The breakthrough in AMD was in the treatment of the 'wet' form of the disease through the advent of treatment with anti-VegF medicine. The vascular endothelial growth factor (VEGF) protein is one reason why weak abnormal blood vessels may grow under the retina and lead to vision loss through rupture and leakage. Blocking this protein with an anti-VegF treatment injected at the back of the eye slows the growth of the abnormal blood vessels. It is important to note that this treatment buys time, and slows progression, it is not a cure for wet AMD. There has been discussion about developing anti-VegF in eye drop form to avoid injections and make treatment easier and more available. However the tissue layers of the human eye appear to be too thick to allow sufficient absorption. Oraya therapy, an X-ray treatment for AMD not yet widely available, is intended to maintain or improve vision while reducing the required number and frequency of anti-VEGF injections. Sheffield Teaching Hospitals

NHS Foundation Trust became the first NHS hospital to offer the new non-invasive treatment, in 2014. Full treatment outcomes are not yet known.

The first phase one stage stem-cell transplant for wet AMD took place in September 2015. With no obvious complications to date, replacing damaged retinal pigment epithelium (RPE) cells with those cultured from stem-cells is of great research interest but the regenerative outcomes are currently completely unknown (Medical Research Council, 2015).

Treating the much more common dry form of AMD has seen limited progress – largely because the underlying mechanism of advanced AMD remains unclear. Whilst drusen (tiny yellow or white spots seen on the retina, accumulations of extracellular material that build up between retinal layers) can be removed with the micropulse laser, leaving no scarring behind, there is disagreement on whether there is any benefit to the patient, and concern about actually increasing the risk or rate of development of AMD.

Phase 3 trials are also underway for people with geographic atrophy (GA) (amdbook.org) – a late stage of dry AMD characterised by a pale sharply delineated area of the macula – with a monoclonal antibody (MCA) fragment that binds to complement factor D (CFD). CFD is indicated in an inappropriate immune response which is thought to result in the destruction of certain cells, including photoreceptors in the eye. The phase 2 trial showed a 20% reduction in GA lesion progression in patients treated monthly with the MCA (lampalizumab) and in addition, data from a sub-population of these GA patients receiving monthly treatments and who also had tested positive for the complement factor I genetic biomarker, demonstrated a 44% decrease in the rate of disease progression (Ophthalmology times, 2013).

⁵⁶ Removal significantly improved visual acuity and quality of life, reduced decline in memory and executive functioning, and improvements in behavioural measures compared with the non-surgical group.

⁵⁷ <http://www.nhs.uk/conditions/cataract-surgery/pages/introduction.aspx>

⁵⁸ NHS Choices; Cataract surgery: Using multifocal or accommodating lenses can potentially reduce the chances of needing reading glasses after surgery, although most people will need to wear glasses in some situations after surgery regardless of the type of lenses they had fitted.

10. Developments in ophthalmology

Biomarkers are the hallmark of personalised medicine and are of huge interest in research as they can indicate an increased risk of a disease, predict or monitor a patient's response to treatment or allow an assessment of prognosis. Prevention of AMD through nutrition has been the subject of much research, but an analysis of 80 research studies in 2014 showed the greatest known benefit so far to be a healthy balanced diet (Zampatti S, 2014), not nutritional supplements. The long-term Age-Related Eye Disease Study (AREDS) undertaken by the US National Eye Institute found that taking high levels of antioxidants (vitamins A, C and E) and zinc can reduce the risk of developing advanced age-related macular degeneration (AMD) by about 25 percent, but only in those who already have the disease (National Eye Institute, 2011).

Current opinion is that the focus of research needs to look at what is aging in the outer retina and the position of debris within membrane, and trying to manipulate that to rejuvenate the system. Therapeutic agents are being developed to target inflammatory pathways, reducing oxidative stress and protecting the RPE and restoring choroidal blood flow (Hanus *et al.*, 2015). Manipulating the cleaning mechanisms for Bruch's membrane through laser 'cleansing' has allowed researchers to clean up the membrane without damaging the photoreceptor cells. Whether this will lead to restored functioning is not yet known. A treatment or prevention for dry AMD remains the Holy Grail of ophthalmic research.

B) Diabetic eye disease

The continual rise in diabetic eye disease is inseparable from the increase in obesity, now at crisis levels globally. A Scottish study in 2007 found that obesity seemed to be a causal factor in 60% of people with type 2 diabetes. Nothing less than a cohesive, long-term, comprehensive, committed central and local government response will change the fact that a quarter the UK's population are obese (in France, it is 15%). As we do not yet have a holistic strategy for obesity reduction, we can confidently predict that the prevalence of diabetes will rise in the coming years.

There remain regrettably few treatment options for diabetic retinopathy (DR), and it is thought that about half of people do not respond to the treatments that do exist. Current treatments include anti-VegF to mitigate damage from 'damage limitation' management such as laser photocoagulation treatment and when vitrectomy is indicated (Zeng *et al.*, 2015, Gupta & Arevalo, 2013). Whilst it is now thought that being short-sighted and/or having a longer axial eye-ball length are associated with a lower risk of developing diabetic retinopathy (Fu *et al.*, 2015), this knowledge does not really lend itself to a prevention strategy.

What we do know is that prevention of DR remains the best option. Intensive insulin therapy, and specifically insulin pump therapy as opposed to multiple daily injections, prevents DR in both adults and adolescents with type 1 diabetes. In patients with type 1 diabetes of longer duration, islet cell transplantation may be more effective than medical therapy (Virk *et al.*, 2015). A new class of drug for the management of diabetes – known as Sodium glucose co-transporter 2 (SGLT2) inhibitors – began to emerge at the end of 2013. Canagliflozin, dapagliflozin and empagliflozin are now all on the market, and the excitement associated with them is due to the fact that they not only improve glucose control to an extent comparable to other hypoglycemic agents, but simultaneously enable reduction in body weight, blood pressure, and cholesterol. It is too early to tell what their effect on diabetic eye disease will be. A risk indicator equation for vision loss has also been developed (Hippisley-Cox & Coupland, 2015) which it is hoped will give patients and professionals a more accurate estimate from which to make decisions on lifestyle and medication.

The direction of travel of research includes trying to prevent the death of insulin producing beta cells in the pancreas, genetics, understanding why the non-obese develop type 2 diabetes, new oral hypoglycemic agents, and insulin sensitizers like metformin.

C) Glaucoma

Glaucoma is characterised by the death of nerve fibres (retinal ganglion cells) in the eye, and is divided into several subclasses including normal tension glaucoma, primary open angle glaucoma, congenital glaucoma, and secondary glaucoma. The only treatment modality is to reduce the pressure in the eye, and the frustration has been that glaucoma can continue to progress even when this has been achieved. The molecular pathways that cause visual loss are complex, which has made modelling and developing new treatments difficult, but with it now being possible to combine multiple biological and genetic tools there is a significant amount of in-depth research being undertaken.

Glaucoma is the leading cause of acquired blindness in Japan (Nakazawa, 2015), which has been the main stimulus for a drive there to develop new 'neuroprotective' agents for glaucoma. Current activity includes clinical research to improve the classification and evaluation of glaucoma based on IOP-independent factors, pathology-based research on comprehensive gene expression analysis and the development of molecule-targeting drugs, and the development of next generation imaging enabling "big-data" analysis (see swept source OCT below).

Risk factors for glaucoma are also warranting attention. Many are well established, such as family history, age, certain medical conditions, such as diabetes, heart disease, high blood pressure and sickle cell anemia as well as being short-sighted. We now know too that obstructive sleep-apnoea is a risk factor (Liu *et al.*, 2015), as are excess calcium and iron and early menopause (Lin, 2014).

Swept source OCT and glaucoma

Ophthalmologists are excited about the hugely improved resolution of the new generation of OCTs, a non-invasive way of seeing cellular level changes (e.g. Rodrigues *et al.*, 2014; Reboleda *et al.*, 2014). OCT makes it possible to see changes in nerve fibres in the optic nerve head revealing glaucomatous changes before any visual loss can be detected. Swept source OCT (SS-OCT) and newly developed

analysis software have been used in Japan to reconstruct the entire lamina cribrosa, a structure situated deep in the optic nerve head. Preliminary data suggests that alterations in the morphology of the lamina cribrosa are already present in the early stages of glaucoma. This gives researchers a new target to study, but disease prevention remains a long way off.

D) Stem cells and gene therapy

Stem cells have been in use for 10 years to improve epithelial clarity, significant pain reduction and sight improvement in those with diseased corneas. This is also considered essential ahead of corneal transplant. However, elsewhere in the eye, safety and control issues with stem cells remain, as they can migrate and mutate. The added issue is that although stem cells can be used for blood vessel repair, this approach is not patentable, and there is no commercial incentive to invest in research.

At present there is only one ophthalmic gene therapy on the market, RP65, in the US. First stage trials of gene therapy for choroideraemia in Oxford have been published (eye.ox.ac.uk, 2015) showing a positive response, although it is not known whether the effect will last.

For AMD, gene therapy in which new good cells are put into an old environment was likened by one expert we interviewed to "putting a lettuce in the desert".

There is however growing interest in genetic screening in ophthalmology: lattice corneal dystrophy and granular dystrophies are caused by gene defect on a single, dominant chromosome. Although these dystrophies are rare, the case was made to us that genetic screening could be offered ahead of corneal surgery (including Lasik and possible RLE), as the complications experienced by someone with the gene defect could mean surgery is ruled out, especially if elective. Some interviewees believe that optometrists could be gate-keepers to refractive surgery, including taking the swab for genetic screening. However there would remain the issue of

10. Developments in ophthalmology

genetic counselling, and the scenario of finding genes associated with other eye diseases would have to be considered. There is no doubt that genetic screening will continue to be promoted, with over the counter tests already available. It is a controversial area however; some feel genetic screening should only be undertaken by professionals qualified in genetic counselling, particularly as understanding tests is not straight forward. The validity and usefulness of a test are down to three accuracy criteria:

- Analytical validity – how well the test predicts the presence or absence of a particular gene or genetic change. In other words, can the test accurately detect whether a specific genetic variant is present or absent?
- Clinical validity – how well the genetic variant being analysed is related to the presence, absence, or risk of a specific disease.
- Clinical utility – whether the test can provide information about diagnosis, treatment, management, or prevention of a disease that will be helpful to a consumer.

Interpretation is often not straightforward as in many cases the tests indicate relative or probable risk. And for the major diseases such as AMD, there are far too many genes and interactions involved to be able to undertake any meaningful testing. Even where a single gene is involved, such as retinitis pigmentosa, only an optometrist with a special interest in genetics in a hospital eye service could realistically be involved. This is clearly an area that will gain more attention, but there remain unanswered concerns about associated risks (WHO.int, 2015).

E) Artificial retina

Despite a few sensational headlines, artificial retinas are still in a very experimental stage at the moment. 130m photoreceptors in a normal eye converge on approximately 1m fibres in the optic nerve. The bionic chips cannot replicate this scale to give detailed vision; in fact chips with a greater number of electrodes do not actually work for the patient as well as ones with fewer electrodes. Where the aim is to enable the perception of movement and shade (helping individuals navigate), there is greater potential and the next 10–15 years could hold major advances. This technology will remain firmly in the sphere of electrical engineering and ophthalmology.

10.3 Summary

It was put to us that there would be more eye disease in the UK as a whole by 2030, but due to improvements in detection and treatment, less loss of vision. While we would agree that advances in ocular health are a virtual certainty, this prediction is likely to apply to age-standardised prevalence rates of blindness only. Our rapidly aging population,⁵⁹ together with a predicted increase in people with multiple long term conditions, indicates a greater proportion of the UK population with both age- and health-related ocular changes, with AMD having the highest prevalence and the prime reason for irreversible vision loss in this age group. Consequently there will be a greater need for community expertise in low-vision correction and technologies (see section 7).

Pre- and post-operative care, and the careful monitoring of disease, could drive more opportunities for ophthalmologists and optometrists working together in the community. We can see this happening already (see sections 3 and 5) by way of Community Ophthalmology Services (COS), although this has been slow to grow. Historically, reluctance of hospital doctors to work off-site has included issues of:

- i) previous treatments requiring clinical back-up (much less the case now – most are done under local anaesthetic)
- ii) funding restrictions
- iii) training, which is still virtually all hospital-based, leading to a reluctance to work in the community
- iv) the need for equipment use to be maximised, requiring assured footfall; the high-street not being able to deliver the critical mass of patients
- v) costs: whereas for instance glaucoma referral refinement in the community might be a cost saving to the CCG, if too many of the 'easier' services are moved out of a hospital, it leaves the latter with more complex services that are not remunerated in a manner that sustains the viability of the unit. The current payment (tariff) is an average price only.

As outlined earlier in this report, some of these historical reasons against the movement of care into the community are less pertinent now than previously. Moreover, consultant-led COS present an opportunity for more affordable expansion where hospital departments can no longer cope with volume. Such was the case in Telford and Wrekin, where the CCG and Shrewsbury & Telford Hospital's Ophthalmology Department set up a COS in 2011 to deal with severe backlog, even undertaking cataract surgery, uncommon in COS at this present time (SaTH, 2014).

We should not however expect NHS culture change to be rapid. Commissioners have increasing demands on their budgets and there has to be a robust business case for them to change the location or model of care. Hospital overheads remain even when services are moved out, and there is no appetite to undermine the viability of a local hospital. While tariff review is possible, ophthalmology is a relatively small sector that is unlikely to be prioritised for reform.

Developments within ophthalmology will therefore impact optometric practice in different ways, some of which are difficult to predict. We can certainly expect increased optometric involvement in both community and hospital-run services, involving diagnosis, monitoring, pre and post-surgery care. Harder to predict is the impact of lifestyle-choice RLE and the potential of superior IOLs in NHS cataract surgery. The latter is essentially outside the influence of optometric practice, although we expect to see opticians countering the option of RLE with advances in contact lens technology for presbyopes. Finally, an ageing population means that reduced vision – with poorer colour discrimination and colour sensitivity – will be experienced by a greater number of people due to photoreceptor cell loss, regardless of disease. Technology will be unlikely to combat this reality before 2030.

⁵⁹ Proportion of over 65s in the population is predicted to rise from 17.7% to around 22% in just 15 years, according to ONS projections.

Foresight Project Report Part 3:

Business impact

11. DECISION MAKING ON FUTURE BUSINESS MODELS

In Part 2 of this report we examined an array of new and predicted technologies that will bring innovation and direction to optics in the next 10–15 years. In the following pages we summarise what this could mean for established businesses within the sector and also identify new business opportunities for future stakeholders. By way of introduction we briefly recall five overarching business considerations (11.1–11.5) relevant to both service providers and manufacturers.

11.1 Business

Technology will affect all tasks across the industry, increasing speed, efficiency and quality and decreasing the need for hands-on labour.

Technology will streamline eye care provider services, broaden niche opportunities, and bring new stakeholders to optics.

Manufacturing is set to become both more competitive and more automated. Disruption by web-based competition, international start-ups, smartphone-based technologies and additive manufacturing will be considerable. Job losses will follow in mainstream manufacturing.

How companies that harness science and technology survive and thrive in ambiguous market circumstances (Accenture, 2013):

1. **Predictive insight:** Routine monitoring of potential disruptions.
2. **Focus on customer value:** Primary focus on customer, then technology.
3. **Coherent business model:** Aim for a singular model for value.
4. **Disciplined investment:** Methodical approach to balancing short and long-term goals.
5. **Agility:** Being ready to adapt.
6. **Courage:** Embracing a risk-taking culture.

11.2 Demographics

Stratification of national population (manufacturers/distributors) and local population (providers), taking into account predicted changes in age distribution, racial mix and behaviour, will be essential in order to plan strategically. Key areas of growth (and need):

- children – myopia
- young people – leisure / game-culture
- adults – employment specific
- over 65s – long term condition monitoring
- over 80s – visual impairment

11.3 Location

Where eye services are based is a significant determinant of demand. Tower Hamlets in London and Birmingham's city centre may see a nominal change in the number of over 65 year olds, whereas West Somerset and Craven (North Yorkshire) could see a 36% and 48% increase respectively.

In general it may well be rural and town practices that have greatest opportunity to develop focused clinical and niche services. A concentration of younger people in large urban areas will mean that a strong, cutting-edge retail focus predominates, likely with fewer clinical service opportunities and the cost of premises remaining high.

Manufacturers and distributors will be mindful of provider opportunity in order to effectively target sales. For manufacturing itself, location may be less critical, but competition from start-ups emphasises the power of the Internet – from fundraising to remote manufacturing and direct-to-consumer marketing. Software developers can remain largely 'in the cloud'.

11. Decision making on future business models

11.4 Economy

As we write, inflation is just above 0%, borrowing is cheap but likely to increase in cost, and UK interest rates are close to achieving seven years unchanged at 0.5%. Greece's future in the Eurozone remains uncertain and during 2016 our country will vote on whether to stay in or leave the EU. These and other factors will affect the UK economy in the coming years, determining our growth, trade and prosperity, and impacting business and personal finance.

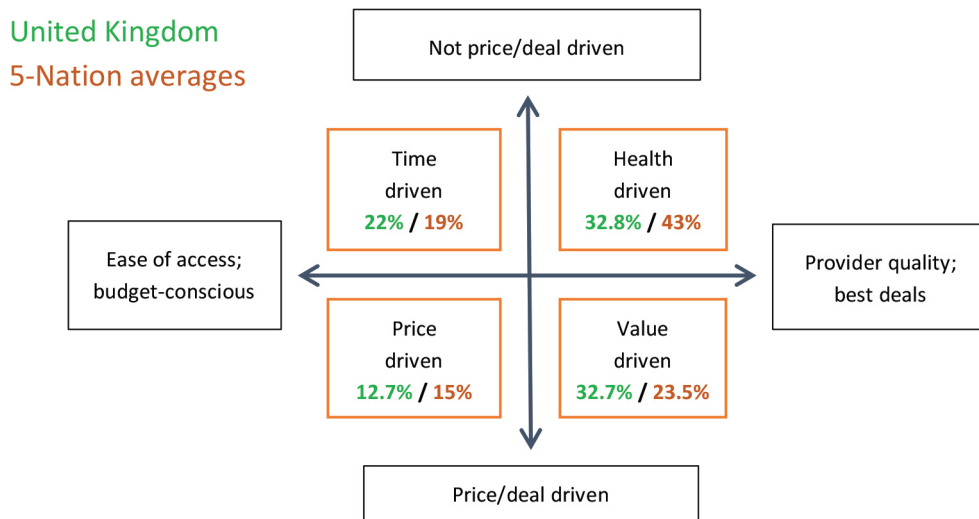
The real origins of growth are knowledge and technology. Together they can improve the way we work and arrange our lives, allowing us to harness more energy and use it more efficiently, boosting productivity and effectiveness. We can also exploit innovation from other countries, as long as our policy framework allows business to adopt new ideas and products quickly and efficiently.

The good news is that innovation can allow us to do more for less; the bad news is that we will not require the same numbers of personnel; and the uncertain news is that we do not know how the economy is going to perform in the coming years. We therefore need to identify, as a priority, the disruption that will almost certainly happen anyway.

11.5 Consumer behaviour

The British consumer of eyewear appears to prioritise value for money alongside health concerns; time considerations are also important. As Fig. 14 illustrates, UK consumer behaviour has distinct attributes when compared to various other European nations.

Figure 14. Eyewear consumer habits 2012: CL & Glasses respondents, equal weighting. Five nations: UK, Germany, Italy, Poland, Russia.

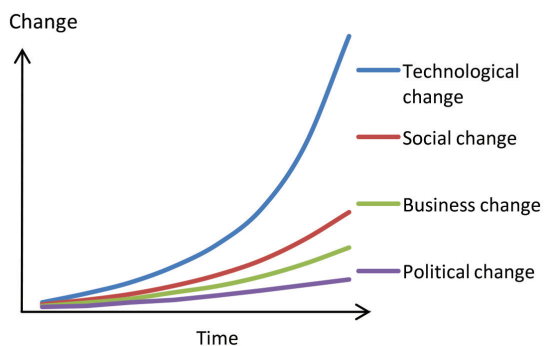


Source: Millward Brown, 2012, survey for Johnson & Johnson Vision Care (extrapolated figures)

11.6 Summary

The above themes combine local, national and even international considerations, and should be understood as interplaying with a wide host of market variables. No one knows what the Internet will be offering in 10–15 years' time, especially considering the pace of technology and the current, embryonic reality of the Internet itself. It is also immensely difficult to anticipate the rate of technology adoption, and we should remember that in our digital age, the pace of technological change far outstrips social, business and political change (see Fig. 15). In the following pages we have therefore attempted to remain grounded in terms of focusing on what is likely to happen, not on what is theoretically possible.

Figure 15. The law of digital disruption



"The law of disruption: technology changes exponentially, but social, economic and legal systems change incrementally."

Larry Downes, 2011

12. BUSINESS IMPACT: EYE CARE PROVIDERS

12.1 Independent practice

The independent practice will need to look at niche offerings to remain relevant and survive against the rising tide of chain retailer-providers. The successful independent of 2025 will be offering real-time online booking, advanced eye-health examinations with cutting-edge technologies, and fully digital dispensing; they will have a commanding and engaging website and be exploiting digital marketing strategies. E-referral will be standard by this time, but practices offering EHR connectivity or patient portals (access to personal eye health information) will be attracting the 'switched-on patient'.

The cachet of the independent potentially lies in the intimacy of the practice and customer relationships. With options in new diagnostic technologies, growing demand for low vision services and opportunities in the delivery of NHS eye care pathways, independents are well placed to cultivate a patient relationship not unlike that of a GP and patient. Multiples, and supermarkets especially, will struggle to forge such strong relationships.

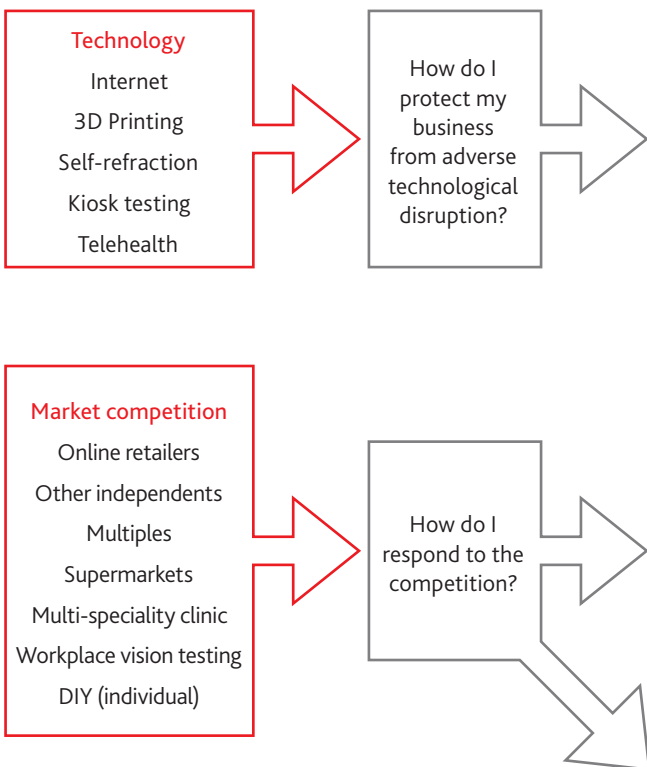
Competition from online vendors will be answered by competitive pricing, after-sales care and a strong emphasis on eye health. 'Virtual' stock and even e-commerce, facilitated by third-party digital management, could extend product range, while business-loyalty partnerships with manufacturers may enable new opportunities in online contact lens purchasing. Above all, the offering of customer loyalty programmes with attractive discounts could counter the threat of further disruption from both chains and web-based vendors, while facilitating a healthier economic balance between sight-test fees and retail. Disruption from self-refraction (online or elsewhere) will be met by concerted, cross-provider cautioning to the public of the importance of eye health checks.

The offering of both in-practice and web-based virtual try-on (glasses), 3D printing, 'co-creation', and demonstrable expertise in smart eyewear, will ensure the practice remains relevant to younger generations. Sports eyewear speciality will capture the enthusiast and enable a dynamic and relevant marketing message.

Given the current direction of travel, described earlier, two basic models of independent practice are likely to dominate. The first, and perhaps most common, will give special emphasis to its community eye care services, alongside retail and high-tech customer journey. A minority of these practices will have up-skilled optometrists (holding professional certificates) and be involved in specialised NHS care. The practice will broadly favour an older demographic, while remaining relevant to working-age individuals and children. The second model, typically city-based, will offer enhanced eye health exams, but its stronger retail and fashion focus, promoted by shop-window screen media, will emphasise trending products, extending to high-end frames and lenses, and wearable eye tech (even other wearables). It will promote a message of healthy living and specialise in recreation, sports and vocational eyewear.

The independent practice: towards 2030

Disruptions → **Considerations** → **Solutions**



Two dominant independent models: 2025

- Strong emphasis on services and eye health (NHS & private) with older demographic, but still reliant on product sales
- Retail and recreation focused (in closer competition with multiples); strong emphasis on fashion, but mindful of all age groups

Some practices straddle both worlds, but the independent practice anchored to traditional services and techniques has all but vanished.

The practice promoting eye-health services is cutting-edge and common to market towns and suburban areas. A typically quiet, comfortable environment (with low but regular footfall) finds appeal among those flustered by the high-volume multiple. Patient loyalty to the independent remains critical to success.

Tech-driven solutions

Priority:

- Increase vision and health service offering to the public via technology: e.g. high-end OCT; ultra-widefield retinal exam; ortho-k; colorimetry; 'smart' CLs
- EHR connectivity / patient portal
- Digital dispensing & virtual try-on
- Real-time online booking
- Digital content marketing and community-focused social media
- Stylish and engaging website
- Bespoke 3D printed frames

Possible:

- Partnership with online retailer (collection point / alterations)
- Extended virtual catalogue / e-commerce
- In-store RFID marketing/inventory
- In-store online checkout
- Smart eyewear specialisation
- On-line try-on of stock (e.g. via PMS software provider)
- Shop-window advertising (touch-)screen
- Customer 3D print co-design
- Gaming tech for eye problems

Business identity solutions

Priority:

- Increase loyalty levels (via membership schemes)
- Higher levels of patient service
- Staff training (up-skilling) to widen service offering
- Low vision speciality
- Community eye care services
- Niche recreation/workplace eyewear (glasses/CLs)

Possible:

- Independent prescribing
- Specialised NHS care
- Partnership with local pharmacy
- Partnership with CL manufacturer
- Domiciliary / Workplace services
- Practice (identity) refurbishment
- Independent joint venture partnership

12.2 The specialised multiple

Like the independent of 2025, the multiple will need to be offering real-time online booking, eye-health examinations with cutting-edge technologies and digital dispensing. The multiple business model, not so well suited to specialised offerings such as orthokeratology or clinical contact lenses (drug-eluting and condition monitoring), has great capacity to bring technological streamlining into practice, from which the public will expect virtual try-on, interactive RFID technology and same day dispensing. The multiples may all be using cloud-based patient records by this time, with access from any provider store across the UK; patient record access ('patient portals') may also be on offer.

Acknowledging the threat of online disruption, multiples will need to be harnessing much more of the Internet's potential by 2025. Services will include direct online purchasing and remote, virtual try-on, neither of which are available currently. With competitive pricing on contact lenses along with quality after-sales care, the multiples will be defending at least some of their business from the inexorable rise of online contact lens vendors.

The promotion of eye health will be necessary to differentiate the high street service from both the internet retailer and DIY vision testing. Multiples' advertising will shift some of the emphasis from retail to eye health, promoting the latest offering in diagnostic technology. OCT by this time may be included in all sight tests as a standard service. The offering of ultra-widefield retinal imaging will be likely in some stores.

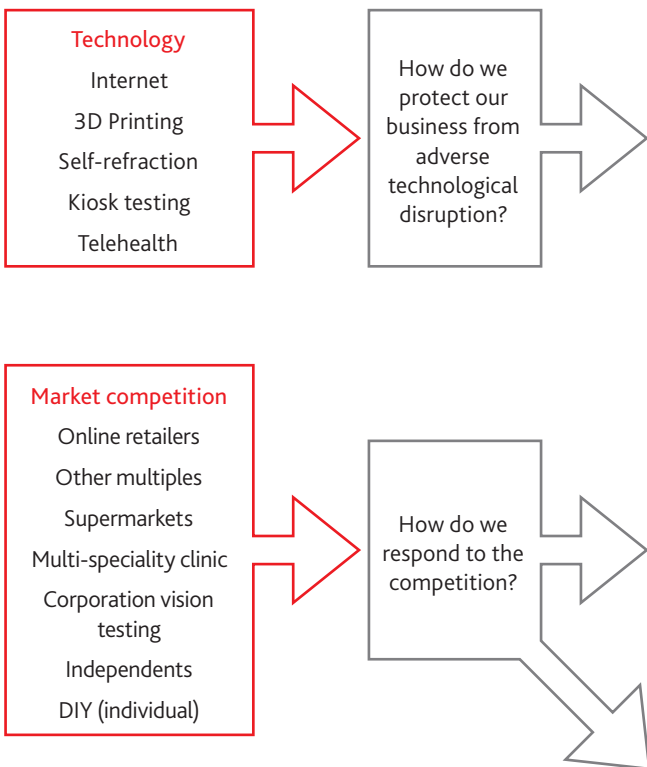
Demand for mobile vision testing will increase with an ageing population and some providers may consider new services. Vision services to businesses may also be profitable in an age where consumers seek both immediacy and convenience. Improved portable optical equipment will ensure a service comparable to the high-street.

The principal rising threat to the specialised multiple comes from the supermarket, whose ability to absorb sight-test loss-leaders while offering competitive pricing on products is unmatched. This competition will escalate significantly over the next 10–15 years. But the specialist multiple can use the latest diagnostic technology to its commercial advantage, with the supermarkets typically lagging behind in 'non-essential' technology. The supermarket is also less favourably positioned to deliver community eye care pathways, including MECs. While low vision does not sit comfortably with the specialised multiple model, we think this will be an inevitable direction of travel for some branches, lest the patient base transfers elsewhere. Again, this could become a differentiating offering. Telehealth kiosk sight tests could be a way in which multiples (and indeed supermarkets) extend their reach to underserved populations.

With a strong share of the younger market, the multiples will have turned their attention to smart eyewear, vision testing entertainment (e.g. Vision Optimiser), and be promoting products and tracking consumer behaviour via RFID technology. By 2025, smart eyewear could be offered with mobile-phone contracts from the multiples.

The specialised multiple: towards 2030

Disruptions → **Considerations** → **Solutions**



Multiple: 2025

The technologically-streamlined multiple has extended its services to both compete with niche independents and differentiate itself (further) from the supermarkets. Market town outlets, in particular, vie with independents for a loyal patient base. While their optometrists do not deliver the suite of specialised services of some independents, eye health and children's services have become a stronger priority.

Tech-driven solutions

Priority:

- Increase vision and health service offering to the public via technology
- Full digital dispensing
- CL presbyopia market
- Real-time online booking
- Cloud-based patient records
- Online try-on of stock
- Online sale of eyewear (with after-sales tie-in)
- Digital content marketing
- In-store RFID marketing/inventory
- Bespoke 3D printed frames

Possible:

- EHR connectivity / patient portal
- Sight-test entertainment (VisionOptimiser/3D)
- Digital window advertising (touch-)screen
- In-store online checkout
- Fully automated refraction
- 'Smart' eyewear specialisation
- Customer 3D print co-design
- Telehealth kiosk sight testing

Business identity solutions

Priority:

- Increase loyalty (discount schemes)
- Higher levels of customer service
- Staff training (up-skilling) to widen service offering
- Community eye care services
- Recreation/workplace eyewear (glasses/CLs)

Possible:

- Other health services
- Low vision
- Mobile services in low-access locations
- Care home services
- Workplace services

12.3 Supermarket optical services

The growth of supermarket optical services is seen as certain, even aggressive: Tesco and Asda are currently expanding services, and we should expect more from Costco, perhaps a new offering within Sainsbury's (following the collapse of Mee Healthcare) and there may yet be new entrants entirely. Independents and specialised multiples will have lost further business to the supermarkets by 2025.

The supermarkets, due to their size and extensively developed web-based services, are better insulated against online competition. They have significant opportunities to exploit internet technology through a broad retail offering alongside shop-discount and loyalty schemes (already widely used). Online they can also offer products that would not ordinarily be expected in store, including smart eyewear, as already begun by Tesco Direct.⁶⁰

Any loss of optical product sales to the internet may not be significant enough to force retreat on discounted sight tests and/or eyewear. Real-time booking should be on offer by 2025, but we would not necessarily expect a standard offer of patient portals or EHR connectivity unless there is an increase in other primary care services offered on site. Appointment booking could be an accessible feature within the store's shopper app (widely used for product scanning) – no other opticians will come close to exploiting app technology in this way.

The supermarket optical service is to a significant extent shaped by brand type, public expectation and consumer demand. A supermarket known for convenience and low-cost products will not be expected to offer the latest 'non-essential' technology (such as OCT or ultra-widefield imaging), so there will be much less business imperative to use cutting edge optical technology to attract further patients. Only when the technology becomes perceived as a standard part of the service (or mandated for NHS sight tests or eye health checks) will the supermarket need to respond, as we

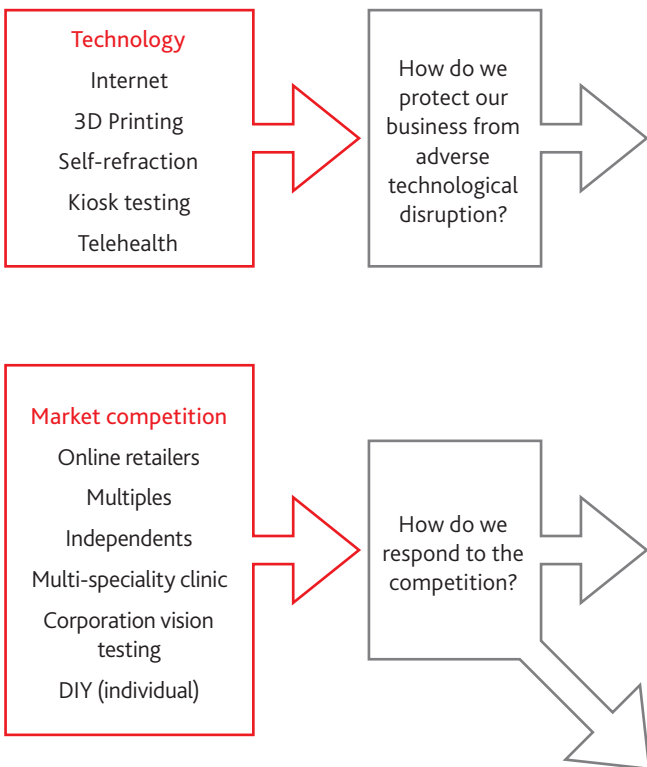
see now with digital fundus photography. A new business model, similar to that facilitated by Walmart with the 'tenant' optical service provider, could in the future present some exceptions to this general rule.

Alongside other providers, the supermarkets will emphasise the importance of eye health exams to combat the threat of online vendors and DIY vision tests. They may also (still) have opportunity for involvement in the delivery of some NHS community eye care services, although activity may be nominal. We anticipate they will show keen interest in exploiting 'gold-standard' autorefractometry and other automated refraction technologies, and perhaps later the sight-test kiosk (which itself could expand provider competition yet further in the form of telehealth). The supermarket many well become the bastion of clinically-approved automation.

⁶⁰ Recon Jet GPS sunglasses, with Heads Up Display (HUD) system

The supermarket optical service: towards 2030

Disruptions → **Considerations** → **Solutions**



Supermarket opticians: 2025

The supermarket optical service emphasises access and convenience, as well as discounted eyewear. Its customer app, widely used for product scanning, incorporates a real-time sight-test booking feature. Automated processes, including auto-refraction and even patient-led refraction, do not detract from a health-focused service, fully compliant with NHS standards. Online services allow direct purchasing of eyewear, including smart glasses, with aftersales services available in store.

Tech-driven solutions

Priority:

- Full digital dispensing
- Real-time online booking, available via desktop or (mobile) store App
- Digital content marketing
- On-line sale of eyewear (with after-sales tie-in)
- Bespoke 3D printed frames

Possible:

- Fully automated refraction
- Patient-led refraction
- Increase vision and health service offering to the public via technology
- EHR connectivity / patient portal
- In-store kiosk pre-test and refraction
- In-store kiosk full sight test service; telehealth (kiosk) in smaller stores
- 'Smart' eyewear (online store)
- On-line virtual try-on of stock

Business identity solutions

Priority:

- Increase loyalty (new discount schemes with optical services integrated)
- Higher levels of customer service
- Recreation/workplace eyewear (glasses/CLs)

Possible:

- Community eye care pathways
- Staff training (up-skilling) to widen service offering
- Audiology / other health services

12.4 Domiciliary practice

The potential patient base for domiciliary services will grow due to our rapidly ageing population and the rising number of house-bound.

Technology will give the domiciliary provider new opportunities for service provision and practice efficiency in the near future. Online information could inform a potential patient or a professional enquiring on their behalf when an optometrist is making visits in their area.

E-referral should be standard for such providers by 2025, and it will be business expedient to enable EHR connectivity or patient portals (with shared care access) for a patient base that will typically have multiple morbidities. The EHR opens up the possibilities of other provider opportunities, such as diabetic care.

Compared to high street businesses, the domiciliary provider is less exposed to disruption from internet vendors and DIY vision testing. The average patient will be typically mid to late 80s and not greatly troubled by a more narrow selection of fashionable frames, although virtual try on and an internet-based catalogue will enable far greater choice than previously. Contact lens prescribing for this age group is narrow, although it could increase with technological improvements to extended-wear contact lenses.

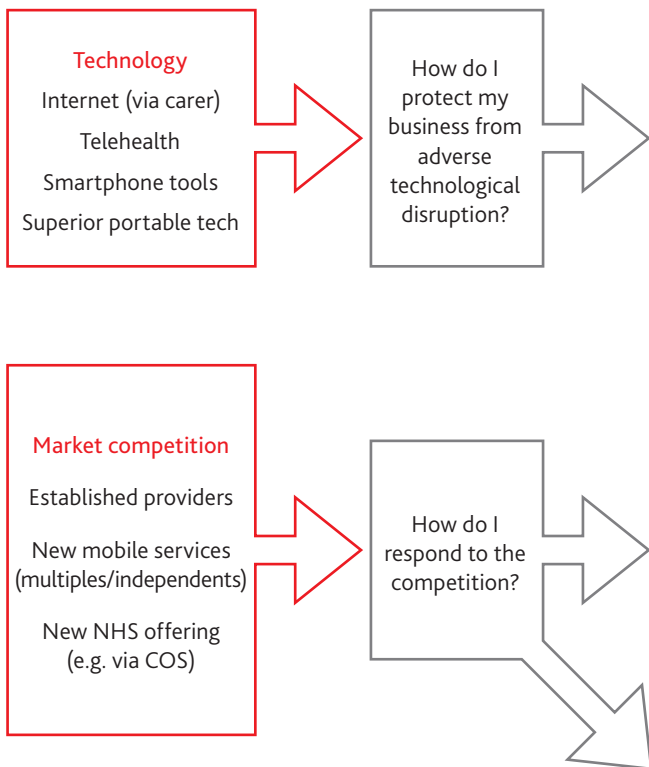
Portable technology is set to increase in the 2020s: this includes hand-held OCT and various smartphone-enabled technologies. Improvements in portable fundus cameras, together with pressure from equal access groups, may result in wider domiciliary practice involvement in diabetic eye screening.

The affordability of portable technology may encourage independent high street businesses to extend their offering to mobile services (home and workplace), thus increasing provider competition. Challenges could also arise from NHS telehealth services, perhaps situated within a local NHS consultant-led ophthalmology service (COS), elderly care, falls or multi-speciality clinic. The COS, with salaried optometrist, could even enter the domiciliary market directly and be perceived as a more 'authentic' NHS service.

The prospect of decentralised domiciliary services commissioning, with responsibility moving to CCGs, could lead to a reduction in competition if the service is put out to tender. Whilst the 'any qualified provider' (AQP) implies plurality of provision, the reality is that budgets can be better contained with a block contract given to the organisation that wins the tender. Professional upskilling, such as an independent prescribing qualification, should be considered, along with flexibility to participate in NHS community eye care services. Both small and large providers may profit from extending their offering to direct-to-workplace services where there are large local employers.

The domiciliary practice: towards 2030

Disruptions → **Considerations** → **Solutions**



Domiciliary services: 2025

Providers within the domiciliary market have diversified. NHS optometrists are also a feature of domiciliary services, including delivering eye care to nursing homes, sometimes via telehealth. Some areas have a block contracted provider. Direct-to-workplace services are now common among private providers.

Tech-driven solutions

Priority:

- Increase vision and health service offering via new technology: e.g. (portable) OCT; digital slit lamp; 'smart' extended-wear clinical CLs
- EHR connectivity / patient portal
- Digital dispensing & virtual try-on
- Digital content marketing and community-focused social media
- Bespoke 3D printed frames

Possible:

- Smartphone-based assessment/diagnostic tools
- Telehealth (remote monitoring; remote optom)
- Diabetic eye screening (using NHS-approved portable fundus camera)
- Online booking
- Partnership with product suppliers (on-line catalogue)
- Wider selection of high-tech low vision aids / assistive tech, complemented by appropriate expertise

Business identity solutions

Priority:

- Higher levels of patient service
- Up-skilling to widen service offering (including assistive tech expertise)

Possible:

- Community eye care pathways
- Independent prescribing
- Partnership with local pharmacy
- Workplace services
- Additional services (Chain provider: e.g. audiology)

Further delivery models

12.5 NHS models: HES; Consultant-led ophthalmology services (COS)

In Section 3 we discussed the consultant-led community ophthalmic service (COS), a number of which have been launched in recent years to relieve pressure on the acute sector and place 'hospital' services more firmly in accessible community settings. Both advancing technology and NHS commissioning strategy imply the possibility of new models of eye care delivery competing in the future with established services.

The COS model is flexible, in that any number of ophthalmic services may be delivered from its premises – even cataract surgery (see Wrekin Case study, Part 1, Section 3). In future the COS with optometrist staff member(s) may compete for domiciliary eye care services. We see this possibility where the COS works within, for example, a Primary and Acute Care System (PACS), operating as part of an integrated health and social care team. The same PACS could implement ophthalmic tele-monitoring services to care homes and nursing homes.

Whilst it is perfectly conceivable to see Local Optical Committee (LOC) companies working within PACs or Multispecialty Community Providers (MCPs), NHS organisations of the future could themselves offer eye testing services with a limited offering of spectacle dispensing. Already, NHS trusts run contact lens clinics (typically where there is a medical need for use), and dispense and sell products at prices set each year by the Department of Health;⁶¹ in the future we expect this to extend to clinical contact lenses ('smart' / drug eluting). In this NHS provider model, footprint is minimised while footfall is potentially guaranteed by virtue of location. The demand for such services could be seen in areas of poor access, though the business model may require NHS optometrists to be undertaking community eye care services also.

12.6 Online vendors

The inexorable rise of online retail and services will bring wider choice and increased international competition within the UK optical sector over the next 15 years. Technology will continue to raise efficiency and speed in online retail. (Amazon already offers same day delivery, and is even experimenting with 30-minute drone delivery.) The success of Warby Parker in the USA, an online vendor valued at \$1.2bn which has now launched several bricks and mortar practices (Guardian, 2015), is testament to the power of digital marketing and online sales, and indeed the lucrative potential of non-branded products. The emphasis of Internet retail will always be one of value for money, speed and convenience.

The world online also enables businesses to circumvent regulation. The authorised prescription, mandated for corrective eyewear sales within the UK, is bypassed by such companies as Sweden's LensOn (LensOn.co.uk)⁶² and the UK's Vision Direct (via the Netherlands), neither of whom request documented evidence of prescription validity. It is possible that more businesses will bypass regulation in this way in the years ahead, thereby offering the consumer maximum flexibility.

To counter such flexible and adaptable competition, UK high street businesses can offer attractive loyalty packages to retain patients (and even whole families). But so too can online vendors, as MyGlassesClub is doing already, with 0% interest on a monthly payment scheme, and with no credit check.

High street businesses will in time adjust their business model to better exploit web-based services. We think it unlikely, but not impossible, that some will set up additional operations beyond UK borders to bypass regulation. We may also see new competition from fashion houses entering the online optical market place, more confident about a

⁶¹ For example, see Norfolk and Norwich University Hospital NHS Foundation Trust. <http://www.nnuh.nhs.uk/clinics/contact-lens-clinic/>

⁶² Partner of Glasses Direct, based in Sweden and one of Europe's largest contact lens suppliers. LensOn contact lenses sold to the UK are dispatched from Sweden.

12. Business impact: eye care providers

direct-to-consumer opportunity: who would have predicted Toni&Guy Opticians ten years ago?⁶³

The competition for customers will see ever more sophisticated websites and online services. All the large online vendors will be offering virtual try-on, which will be a vastly superior tool as compared with current technology. Digital dispensing will be enabled by either webcam or app, and some websites will be offering 3D printed custom-fit products. The opportunity to share virtual try-on with family and friends (for feedback) will be made possible via social media in real time. 3D print co-design ('co-creation') and DIY websites will also proliferate, and it is conceivable that some companies may integrate an online sight test, or sight test via downloadable app.

Convenience, creativity and unregulated flexibility afforded by technology, together with superior internet speed and digital accuracy, will be such that online retail and dispensing services will hold a significant share in UK optics by 2025/30.

12.7 Direct-to-workplace optical services

The delivery of optical services direct to business is another growth opportunity, and some providers may market this as a speciality. From the business perspective, having your workforce examined on site could be a preferable option to allowing time off-site for sight tests.

Many employers are unaware of their obligation under the Health and Safety Regulations (updated 2002) (HSE, 2013), which state that employees using Display Screen Equipment (DSE), typically desktop computers and laptops, as 'a significant part of their normal work (daily, for continuous periods of an hour or more)' are entitled to eyesight tests on request at the expense of the employer, and even spectacles if specifically required for workplace DSE use.

There is a business opportunity for mobile optometrists to (1) alert businesses to their obligations, and (2) offer affordable and time-saving solutions. With the increase in quality of portable vision-testing and diagnostic technology, together with virtual dispensing, high quality mobile services of the 2020s will more closely match the high street offering.

The direct-to-workplace model could be an additional service provided by an established high street optical practice – it is a model that should be carefully considered by independents. The high street business would after all be able to offer contact lens sales (not employer-obligated) and aftercare. But direct-to-workplace will be offered by domiciliary providers also,⁶⁴ with some businesses claiming advanced expertise within the field and presenting a direct threat to the high street.

12.8 DIY model

An end-to-end DIY service model, though not a business as such, is worthy of mention as an 'industry' that is set to begin within our timeframe. This model would incorporate: (1) self-refraction, smartphone-based or online; (2) self-measurement of facial parameters, using mobile app or web-cam and online tools; (3) self-design (or open-source modification) of framewear in a 3D modelling programme; (4) home 3D printing. The appeal of this model is perhaps above all personal satisfaction and creativity.

Aspects of the DIY model will of course exist in combination with industry providers. Some people may self-refract and then use an online business to complete the manufacture of their 3D computer-aided design. Of course, any service model that diminishes the likelihood of regular sight testing, and thus early intervention on

⁶³ The original aim to establish Toni&Guy opticians as a multiple appears to have stalled; the online shop however is well developed. See www.opticianonline.net/hairdresser-toni-guy-opens-optical-practice/

⁶⁴ EyeNetra is exploring this very concept in New York with telehealth technology.

12. Business impact: eye care providers

incipient ocular problems, will concern professionals, regulators, the NHS and government.

The end-to-end DIY model, which will be shaped by the counter offer of the high street (discount enticements from the multiples and supermarkets especially), is unlikely to be a great disrupter within our timeframe. It is, rather, the individual elements within the DIY model that present key challenges to industry, which in wider definition could include any kind of virtual, automated dispensing and self-checkout via the internet.

While the future of self-refraction is uncertain for the 2020s, it is safe to predict that under any plausible economic scenario, online dispensing and 3D printing, and thus consumer choice and control, are set for significant growth.

13. BUSINESS IMPACT: MANUFACTURERS

13.1 Contact lens manufacturers

In Part 2 of this report we highlighted a range of innovation and exploration in contact lens technology, including the obvious goal of increased product comfort, all of which points to a growth period for contact lens manufacturers. This is not to suggest a proportional downturn in spectacle sales, since it is considered likely that a greater number of consumers will choose both modes of eyewear. However, the presbyopia contact lens market itself is set for growth with improvements to multi-focal lenses, new extended depth of focus (EDF) lenses and perhaps soon accommodating 'smart' lenses, while the children's market could see not just an increase of contact lens wearers, but, with rising myopia incidence, a modest growth in corneal refractive therapy.

The rise of online retailing in contact lenses has served the industry well in terms of public access to products. The consumer is more inclined than previously towards contact lens wear now that reordering and home delivery have become virtually effortless. And a lost prescription is no longer the headache it used to be, when sizeable retailers such as LensOn and Vision Direct are accepting prescription details (off packaging) on 'trust' alone, bypassing UK regulation. As much as 80% of the UK contact lens market could be online by 2030, with over-counter sales reduced to first time purchases and emergency supplies.

The competition between multifocal lenses and EDFs for the presbyopia market could cause disruption that weighs against particular contact lens manufacturers. And if the more costly dual-vision liquid crystal lenses or accommodating (autofocus) lenses prove yet more effective for the presbyope, the market will become even more competitive. Lenses with antimicrobial technology will give consumers peace of mind and may become the product of choice. We think by 2030, 'smart'

recreational CLs will still be early stage and not influencing the market.

Manufacturers at the forefront of clinical contact lens research and innovation – monitoring/ data-gathering and therapeutic – include both market leaders and new niche entrants, such as Sensimed. The technology also brings new commercial giants into the optical space, notably Google (with Alcon) with interest in glucose-monitoring lenses and the 'iris fingerprint' detection system (extremetech.com, 2015).

New, powerful alliances could become a feature of the industry, enabling increased investment and innovation within the research field. Indeed, these partnerships may be the most disruptive outcome of work on 'smart' clinical lenses, since the products themselves are competing with other innovative developments. Smart glucose-monitoring lenses may compete with glucose-monitoring patches; smart drug-eluting lenses may compete with drug-loaded nanoparticle technology. The contact lens product may therefore gain only a small market share within a minority user group. Still, we expect more manufacturers to look to tech and pharma partnerships to build alliances, even if negligible disruption to standard lens production is forecasted.

Manufacturers ten years from now will remain very much dependent on the high street to promote their product and influence sales (alongside advertising and social media), since optometrists and opticians are the gatekeepers of contact lens technologies. It is in the commercial interest of practices to stimulate public appetite, and manufacturers will be doing more in the future to promote education, facilitate services, encourage loyalty programmes and support continuing product compliance via website and apps.

13.2 Practice equipment manufacturers

Manufacturers have never before seen so much opportunity in the face of so much competition, and the pace of development is staggering. On the one hand, computer power, data processing speed and diagnostic capability are opening up ever greater functionality, detail and precision within optics. And the common industrialised-nation approach to moving more care into accessible community settings has opened up new business opportunities to the manufacturer, who is now targeting the high street optician with equipment formerly the preserve of hospital eye services.

On the other hand, the manufacturer has to recognise a new market phenomenon: the start-up. Powered by venture capitalists and crowdfunding, start-ups commonly attempt to find cost-effective solutions to problems that are otherwise addressed by bigger business with often expensive technology. Much of the innovation is driven by a desire to meet the needs of underserved populations in lower income countries, hence the objective to keep product cost low and technology miniaturised for ease of portability. But benefits to providers in higher income countries will inevitably follow.

The start-up is not necessarily an anathema to established manufacturers, since the latter can always bid to purchase the product, and perhaps some of its development team. But this option may never become available; or if so, perhaps not to the manufacturer whose business is likely to be hardest hit.

The manufacturer should also be taking keen interest in university research which may directly or indirectly (or unintentionally) disrupt business. Some research teams have likewise turned to crowdfunding: the Portable Eye Examination Kit (PEEK), a collaborative UK initiative, is a prime example of this and a technology of potentially significant disruption.

While technology is expanding competition in a myriad of ways, it is also demanding greater software connectivity and compatibility – DICOM, National Screening Standards, high street Practice Management Systems and, sooner rather than later, the Electronic Health Record. This is familiar territory to manufacturers serving the US healthcare system and needs to be considered carefully for the UK market.

The 2020s will be a particularly disruptive decade, with some of the best start-up and university-based technology widely recognised by professionals. Equipment distributors are likely to play a key role in the dissemination of this technology. We will also see innovative 'virtual' methods of refraction that dispense with traditional trial lenses and phoropters. Both the DVOptimizer and the eyeglass-free screen display point to such disruption.

The small manufacturer of just a few select technologies may be particularly exposed to this competition and needs now to be planning strategically to ensure it remains commercially viable. Growth areas within primary care include self-management products, advanced diagnostic equipment, reduced-footprint technology, superior portable technology for the domiciliary practitioner, and tele-monitoring equipment.

Software manufacturers have opportunity to help further modernise the high street with on-line catalogues, real-time booking and patient portals. High-street providers' websites, particularly the independents, are typically lacklustre and underdeveloped: there are extensive opportunities here for digital services providers.

Manufacturers should be able to anticipate at least some UK disruption of the next ten to fifteen years, and not simply because, in many cases, digital is superseding manual. For example, the escalation of OCT and widefield retinal imaging on the one hand, and likely developments in portable imaging equipment on the other, will negatively impact sales of the desk-mounted digital fundus camera.

Table 3. Potential disruption from a selection of anticipated¹, emerging² or developed³ technologies, 2020s

Technology	Developer	Function	In competition with:
PEEK²	UK University collaboration	Smartphone-based retinal viewing/ imaging & visual acuity tests	Ophthalmoscope Portable Fundus Camera Portable digital test chart
D-EYE³	D-EYE (It/US)	Smartphone-based portable eye and retinal imaging system	Ophthalmoscope Portable Fundus Camera
SVOne³	Smart Vision Labs (US)	Smartphone-enabled autorefractor	Portable autorefractor Desktop autorefractor
Blink³	EyeNetra (US)	(1) Smartphone-based refractor & (2) handheld phoropter	Autorefractor Traditional phoropter Trial lenses
Corrective screen display²	Berkeley/MIT	Allows hyperopes to view screen without corrective eyewear. App-based refraction add-on?	Phoropter Trial lenses
VisionOptimizer²	DigitalVision Systems, Atlanta	'Virtual' refraction	Phoropter Trial lenses Digital test chart
Kiosk: full eye exam¹	Various	Automated-testing booth with telehealth link	Practice-based equipment (vision/eye-health)

In summary, no manufacturer should feel complacent in tomorrow's world of optics. Disruption can spring from almost anywhere, and manufacturers more than ever need to be regularly envisioning and researching nascent initiatives, from start-ups to university research departments, to remain relevant and safeguard market share.

The emphasis on technology now and in the future, given the spiralling costs of healthcare, is to do more at cheaper cost. It is a reality that start-ups and universities understand all too well.

13.3 Frame makers

Typical of other areas of manufacturing, technology has transformed the process of frame design and construction, elevating its speed and quality while reducing staff overheads and machine footprint, thanks to automation and technological miniaturisation. Frames themselves are generally lighter, stronger and more durable, and available in a greater range of materials with multiple options of treatments, coatings and finishes. This is an evolving science and one of which all frames manufacturers will be aware.

Frame making is largely located within the field of fashion, and it is on frames that many businesses make their most important profit. So while the UK manufacturing of frames is small-scale (the majority of modern frames are made in Italy, France, Germany, China, Japan and the US), the product is critical to UK businesses – something that will remain true in 2030, despite the predicted rise of contact lens wearers.

It is worth highlighting three important technological disruptions to frame makers of the future. The first is already happening – the Internet – and will continue to escalate and disrupt, allowing smaller frame companies to compete within a global market place and gain potentially exceptional traction via social media and innovative digital marketing.

“Spectacles remain essentially simple devices and, numerically speaking, the most successful have been those that provide a cheap and comfortable means of holding corrective lenses in place.”

College of Optometry:
'21st century spectacles'.

The second disruption is 3D printing, a phenomenon that has not yet dented any frame-maker's business. But this will happen. To what degree is uncertain, but 3D printing will potentially explode wide open market place competition by virtue of its predicted versatility and efficiency. New 3D-print businesses will emerge, offering greater flexibility in customised fit and introducing the possibility of 'co-creation', with consumers able to influence specific details of product design to order. Beyond this, the manufacturer will see optical practices experimenting with this technology, as well as consumers designing and ordering frames from the comfort of their own home, working from templates provided by specialised internet businesses and even amateurs themselves on file-sharing (open-source) websites, as is already happening (e.g. thingiverse.com).

Some established manufacturers may themselves consider moving into 3-D printed eyewear (including made-to-measure and co-creation design) to compete within a more diversified and competitive market. Manufacturers should also consider how their product(s) might accommodate smart technology – as explored by the manufacturer Oakley, who recently partnered with Intel. This is the third disruption – not so critical perhaps, but an important business opportunity for some. The options are integrated smart technology within the frame, or attachable technology (which will no doubt appear and multiply in the future). The latter could be optimised through partnerships with tech companies, to ensure best and discreet fit with specific ranges of frames.

13.4 Glazing companies

Digitisation has revolutionised the lens manufacturing industry. While some manufacturing has been 'lost' to the high street – mostly single vision lenses – the necessary expertise and technological sophistication required for multi-focal, progressive, free-form, ultra-thin and high definition lenses has secured continued demand from specialised manufacturers, even if many lab technicians have lost their jobs to automation. It is of note that Walmart recently abandoned in-house glazing of sophisticated lenses, due to frequent mistakes within the manufacturing process.

Further automation will however continue to impact employment opportunities within the field. As noted in the introduction to this report, one Oxford-based research team anticipates a 97% likelihood of the ophthalmic lab technician disappearing within 10–20 years. An opinion of course, but there is no doubting the capacity for near-full automation within the glazing industry.

Direct-to-consumer glazing, via online frame sellers or specific re-glazing services, has and will continue to disrupt established businesses. Again, the Internet has created wider opportunities for market competition, but recognised glazing companies could in theory shift their business model to field orders from both businesses and individuals, if needs be.

Online glazing services present a greater threat to high street businesses. Re-glazing services start from as little as £15. In one model, a freepost pack is posted to the customer who sends back their glasses; typically a week to two weeks later (depending on lens type) the glasses are returned with 30-day money back guarantee. Such services will always trump the high street on price, but not necessarily on convenience and speed. The re-glazing of a single-prescription lens is far quicker in a multiple offering a one-hour or same day service than any Internet offer, even though costs may be double.

A potentially more important disruption to established glazing practices in the future is 3D printing. In 2013 LUXeXceL⁶⁵ in the Netherlands created the world's first 3D printed spectacle lenses, inserted of course in a 3D printed frame. Its 'Printoptical Technology' enables the additive manufacturing of optically smooth surfaces and full colour structures without the necessity for post processing like polishing, grinding and colouring after printing (3ders, 2013). Printing technology by 2030 may be of sufficient quality for complex lenses, transforming not only online services and competition but, via reduced footprint, also high-street optical store glazing services. Such an event will revolutionise the glazing industry: it is a question of when, not if.

⁶⁵ LUXeXceL was selected by the Deloitte FAST50 Jury (Belgium/Netherlands) as 'The Most Innovating Disruptor of 2013'

13.5 Business models summary

Existing recognisable models: adaptations and new opportunities to 2030.

- Possible impact of deregulation: separation of refraction from eye-health test.

Supermarket	<ul style="list-style-type: none"> • Critical mass allows for deployment of technology at lower cost, higher convenience • Emphasis on automation • Strong online presence and e-commerce • Extended retail offer of wearables, online • PRESCRIPTION SERVICE • SOME FREE REFRACTION • RETAIL ONLY IN SOME STORES
Multiple	<ul style="list-style-type: none"> • Greater online presence and transactions • Streamlined eye-check with minimal chair-time • Optical e-record containing photographic and scanning records; patient access from any outlet • Extended clinical services • telehealth kiosk sight testing • FREE REFRACTION • NHS HEALTH CHECK
Independent	<ul style="list-style-type: none"> • Specialised business with niche offering (sport, orthotics, extended clinical services); telehealth / mobile offering • Strong loyalty programme with personalised services • More up-skilled optometrists • STRONG HEALTH EMPHASIS
Domiciliary	<ul style="list-style-type: none"> • Wider eye care offering • Linked or partnering with other community care services • Could be NHS-salaried if part of COS • Direct-to-workplace offering • HEALTH WILL REMAIN CORE OFFER
HES/Salaried Optom/ COS	<ul style="list-style-type: none"> • Involved in acute and community-based ophthalmology services (COS) • Up-skilled optometrists essential • Increased FT salaried positions • Closer working with other specialties, such as diabetology; MDT emphasis
Contact lens Manufacturer	<ul style="list-style-type: none"> • More lifestyle options, tying in with retail and wearable technology • Strong support for presbyopia market • Therapeutic CLs • Direct to consumer marketing and support, or via partnership with providers
Device / s'ware manufacturer	<ul style="list-style-type: none"> • Close scrutiny of start-up tech • Clear tech differentiation • 'Gold standard' autorefraction • Miniaturisation • Telehealth • Real time online booking; Patient portal (software) • Enabling consumer loyalty through image storage, apps or self-care
Frames manufacturer	<ul style="list-style-type: none"> • 3D printing • 3D custom and co-design • Wearables (technology integrated / accommodated)
Lens manufacturer	<ul style="list-style-type: none"> • Direct to consumer marketing • Direct to consumer online trade • 3D printing

New models to 2030

- Possible impact of deregulation: separation of refraction from eye-health test

Online / Virtual	<ul style="list-style-type: none"> • Direct to consumer comprehensive offer • Partnership with online pharmacy &/or GP • Global names (Apple / Facebook) etc offering convenient tie-ins with other health services and records
Frames manufacturer	<ul style="list-style-type: none"> • Direct to consumer online • 3D print bespoke products • Partnering with smart technology provider or leisure / sport retail • Fashion partnership in wearables, with clothing or jewellery • Marketed alongside wearables
21st Century Tech Practice	<ul style="list-style-type: none"> • Automated and/or patient-led refraction, photography and diagnostics • Virtual try-on of frames • Window flat-screen display of latest fashion and technology trends • Glass mounted technologies and smart-phone tie-ins • RFID inventory control
Personal DIY	<ul style="list-style-type: none"> • 3D print manufacture of frames / online dispensing • Smart-phone / online refraction • Smartphone retinal and anterior eye 'selfie' • Automated eye & blood pressure check via local kiosk • Online virtual support
Kiosk / telehealth	<ul style="list-style-type: none"> • Fully comprehensive, automated refraction and eye health exam (with voice prompt) • Telehealth interpretation • Non-retail driven model possible (e.g. at Medical Centres) • For low-risk patients only • REFRACTION-ONLY KIOSK • TIE-IN WITH IN-STORE EYEWEAR
Direct-to-workplace	<ul style="list-style-type: none"> • Core specialisation from domiciliary provider • Patient-led refraction • Patient-operated OCT (hand-held) • Potential telehealth element • OPTIONAL NHS HEALTH CHECK
Wearables	<ul style="list-style-type: none"> • High street business with specialism in wearable technology • Sunglasses, sports glasses, HUD: lenses made to patient prescription where required • Smart eyewear with phone contract

Foresight Project Report Part 4:

Education and training

14. INTRODUCTION

Regulated education and training needs to ensure a workforce fit for purpose in the here and now, meeting public, NHS and business needs. At the same time it is important for stakeholders in education to acknowledge predicted demographic shifts and business directions, as well as technologies that variously introduce new methods of testing, diagnosis and treatment, and those that replace or reduce traditional tasks in practice. Optometrists have enjoyed the position of being among the most accessible professionals to the public, but all professionals are increasingly being warned that if they remain anchored to tradition, not only will they be unable to meet demand, but the monopolies they have enjoyed will perpetuate inequalities and financially falter. Technology is enabling the production and distribution of expertise and information just in time for us to be able to exploit it, reorder our models of care and engagement, and be ready to meet the demands of an ageing population. If education and training fails to recognise technological developments, unintended consequences may result, including:

- the obstruction of appropriate professional evolution
- denial to the public of access to timely, best possible care
- barriers to the NHS of realising important efficiencies and reducing waste
- damage to businesses profitability

Our core discussion concerns the potential impact of technology on the education and continuing professional development (CPD) of dispensing opticians and optometrists. We have already set the scene by outlining various drivers of change within optics (Part 1),⁶⁶ but we also need to recognise the influence of education and training itself. Efforts to prepare tomorrow's workforce through evaluating tasks, roles and competencies can themselves encourage buy-in from stakeholders and shape outcomes.

14.1 Regional variation: overview

Space does not allow us to consider systematically the impact of technology specific to education and training in each UK region. There are multiple routes of learning and training within the UK; optometry courses are run in each of the home nations, some with post-graduate emphasis on regional opportunities (e.g. Glasgow and Cardiff). Ophthalmic dispensing is taught in institutions in England and Scotland, but not currently in Wales or Northern Ireland.

In professional accreditation for community eye care services, procedures are not yet standardised. Within England itself, the landscape is fragmented, with accreditation of services not necessarily allowing optometrists to transfer practice from one CCG to another. In time a framework should embed, since modules to support pathways have been in place for several years now, introduced and funded by LOCSU, and delivered by Wales Optometry Postgraduate Education Centre (WOPEC) to practitioners in England.

We understand that a number of optometrists in Northern Ireland have also been using WOPEC for enhanced services accreditation. In Wales itself, WOPEC delivers distance learning and practical based assessments for accreditation of Eye Health Examination Wales (EHEW) and continuing education and training (CET).

NHS Education for Scotland (NES) has been developing a structured programme of optometric training and up-skilling for all community optometrists who provide NHS care. This includes e-learning on cataract, macular degeneration, dry eye and low vision, and the facilitation of community Peer Assisted Learning (PAL) Networks, both for CET and professional networking. Practical training is available through Teach and Treat Clinics, which give optometrists exposure to acute conditions and managing a range of pathology under the supervision of an ophthalmologist (NES, 2015).

⁶⁶ Broadly: commercial/business, ageing population, NHS commissioning, public behaviour

14. Education and training introduction

Courses for CPD are also offered directly by Glasgow Caledonian University.

The College of Optometrists has developed a series of higher qualifications across three levels (professional certificate, professional higher certificate and diploma) in Glaucoma, Contact Lens, Low Vision, Medical Retina and Paediatrics. The College works with universities and other course providers to accredit its higher qualifications, with those completing these courses gaining the QAA Level 7 qualification and affix.

14.2 Digital learning environments

Online platforms have already revolutionised education and training across a multitude of professions and disciplines, and not simply to enable students to watch lectures from the comfort of their beds. Online courses have allowed organisations such as WOPEC to thrive, offering distance learning as well as practical training and assessments, with 6,000 registrants past and present. Launched in 2009, WOPEC was the first Postgraduate Education Centre for Optometry in the world.

WOPEC runs a flexible, distance-learning Masters programme in clinical optometry, and courses of this type are likely to see increased activity in the future. In Scotland, NES Optometry in partnership with the University of Edinburgh's College of Medicine and Veterinary Medicine (CMVM) and the Royal College of Surgeons of Edinburgh (RCSEd), has developed a part-time MSc in Primary Care Ophthalmology via online distance learning. The MSc programme allows optometrists to enhance their skills in diagnosis and treatment of ocular disease, with the view to taking on an ever expanding role as part of a multidisciplinary healthcare team (NES, 2015).

Digital innovation will no doubt also transform future modes of learning. Apps for undergraduate core competencies will enable learning on the go – rather like the DOCET iPhone app has been doing

for professionals since 2011⁶⁷ – while clinical education will be enhanced through virtual reality. At the University of Houston, USA, the College of Optometry has introduced a ground-breaking simulation lab that offers students 24/7 access to virtual patients. Opened in 2014, the Optometric Clinical Skills Simulation Lab (Fig. 16) is designed to better prepare students to administer patient care when they start clinical rotations. The State University of New York and Flinders University in South Australia have also recently introduced this technology.

Figure 16. Optometric Clinical Skills Simulation Lab, University of Houston



Online VR learning environments (VRLE) are an obvious and cheaper alternative (or addition) to the simulation lab, and can enable discussion and interaction across professional boundaries. Interactive learning is also supported by tablet-based systems, where students capture their thoughts and experiences (e.g. in placements) and maintain contact with their peer group and tutors, sharing both communication and learning on practical problems. Given the financial pressures on both university education and the NHS, we should expect to see digital platform innovation – VRLE, webinars, mobile platforms – as an increasingly important enabler of e-learning, CET and optometric upskilling.

⁶⁷ See www.docet.info

14. Education and training introduction

During the project period we heard that some distance-learning coursework for DOs has yet to upgrade from paper and post; but in the main, DO education appears to be exploiting digitally-enabled training opportunities, some in conjunction with on-campus residentials. DO distance learning is likely to also see increased emphasis on wider CPD, such as business management, marketing and communication.

Distance e-learning fits in well with the learn-while-you-earn model, as well as blended learning, and is the direction of travel across many professions (Guardian, 2012; Independent, 2014). However students need also to be educated in how to engage with new e-learning. Competency cannot be assumed based on their familiarity with YouTube, Twitter and Facebook.

14.3 Digital undivided

Such is the speed of development across a wide range of technologies within the optical sector, institutional courses are liable to appear out of date almost as soon as revised modules are launched. It is therefore inevitable that workplace learning via apps and online platforms will be of ever greater importance to the practitioner who wants to remain cutting edge. Manufacturers will continue to be proactive in supporting their latest products with workshop days and practice visits, but increasingly it will be through digital learning. This is particularly relevant to introductory training on high-grade optical equipment, as well as training on Practice Management Systems, contact lens technologies, frame-wear, digital dispensing, and other tablet and smartphone-based technologies.

And of course it will not only be the professionals accessing apps and online education. The internet has upended industry and knowledge is now accessible to all. Massive Open Online Courses (MOOCs), Google scholar, the emerging Facebook and Google health products will increasingly emancipate information and research once guarded jealously by the professions.

Being able to manage the amateur-thought-informed, expert patient, as well as the misinformed, confused malingerer, will be a non-negotiable skill for the optometrist and DO. Not only will this core skill have to be taught, but all individuals involved in delivering components of eye care will have to be more intentional about keeping up with technology and consumer behaviour if they themselves are going to be able to deal with the questions, tasks of interpretation and opportunities that arise.

15. OPHTHALMIC DISPENSING

15.1 Background

The impact of technology on optical practice bears considerable significance for the education and training of dispensing opticians (DOs). During the project (phases 1 & 2), two lines of thought emerged from interviewees and published opinion. One suggests the world of ophthalmic dispensing, while expanding currently, may begin to contract during the period under review. We have already noted a prediction (Frey & Osborne, 2013)⁶⁸ of a 71% chance of fully automated systems replacing the ophthalmic dispenser within the next 10–20 years.

The other camp believes the registered dispensing optician will thrive almost regardless of expected technological developments during the 2020s, largely due to regulation itself and the increasing dominance of the multiples. While optometrists are often found dispensing in the independent sector, particularly contact lenses, the multiples' high-volume model does not like to see optometrists leave the consulting room. The multiples' interest in growing its ophthalmic dispensing workforce is evident from an increase of sponsorship of DO training in recent years.

There is no question that automation and digital platforms will bring (further) 'disruption' to ophthalmic dispensing. While specific directions of travel are not easy to predict, it is certain that education and training cannot stand still. In the following sections we outline DO education pathways, competencies and CET, and then follow with a discussion of regulated activities, the impact of digital, and the 15-year view.

A) Route to qualification

To qualify as a dispensing optician, students at a minimum complete a three year course of study in dispensing optics at an institution approved by the GOC.⁶⁹ This may take the form of two years

full time study followed by a salaried work year, or three years part time study combined with suitable employment. On successful completion of the course, students gain the ABDO Diploma in Ophthalmic Dispensing. The diploma is a Level 6 qualification on the National Qualifications Framework.

B) Core competencies

The core competencies for DOs, as specified by the GOC, enable the dispensing, fitting and supply of spectacles. DOs have the training to interpret a patient's visual and fitting requirements and translate the prescription into specifications and instructions for the optical manufacturer. In this role their core competencies should ensure they can communicate effectively with the patient (and/or carer) and observe conduct in compliance with the legal, ethical and professional aspects of practice.

Core competencies give DOs the skills to dispense appropriate optical appliances to children (of any age), taking into account the development of anatomical features. The DO also has an understanding of the methods used in both ocular examination and vision testing, including instrumentation used, and an understanding of ocular abnormalities and the relevance of ocular disease. All registered DOs have skills to manage low vision patients, and at the very least have an understanding of the fitting and aftercare of patients with rigid and soft contact lenses.

C) The upskilled DO: BSc (hons)

Opticians who hold the ABDO Level 6 Diploma in Ophthalmic Dispensing (FBDO) are able to undertake further training to gain the Contact Lens Diploma and the Low Vision Aids Diploma. Some may choose this route some years after initial qualification, although others will qualify on completion of the three-year BSc honours followed by one year pre-reg.

⁶⁸ *The Future of Employment: How susceptible are jobs to computerisation?* See Part 1 of this report.

⁶⁹ ABDO College, Canterbury; Anglia Ruskin University; Bradford College; City and Islington College; City University London; Glasgow Caledonian University

15. Ophthalmic dispensing

The Contact Lens Optician is able to assess the accuracy of the specifications of contact lenses with the use of appropriate instrumentation. They can also manage the fitting and aftercare of patients with rigid and soft contact lenses.

While there is currently no legally protected title that applies to dispensing opticians (or optometrists) engaged in low vision work, the ABDO Honours Diploma in Low Visual Acuity gives the DO a specialist qualification in this area.

(See Appendix C for full list of DO and CLO competencies.)

D) Continuing education and training (CET)

CET is a points-based scheme that runs over a three year cycle to ensure that core competencies remain of a high standard and up to date. Registered dispensing opticians must gain 36 points during the three year cycle (with a minimum of 6 points per year) to remain on the GOC register. Points can be gained through a combination of learning hours, prescribed activities and reflection, and must cover all of the dispensing core competencies. If the dispensing optician is a non-specialist then all 36 points are 'general points', half of which must be obtained using interactive CET. If the dispensing optician is also a specialist contact lens optician then the 36 points must comprise 18 'general points' and 18 'specialist points'. Dispensing opticians are encouraged to participate in peer discussion but this is not mandatory. Up to half of CET points can be obtained using text-based distance learning.

E) Further professional opportunities

Beyond gaining full degree-level dispensing competencies, there are no nationally recognised upskilling opportunities, clinical or otherwise, aimed at the high street dispensing optician. Nor is there an equivalent of community care services (competency) accreditation, available to optometrists in some regions of the UK.

Further university study, Masters or PhD, is available for those interested in teaching and research. This could also provide a pathway into hospital eye services, where the DO might teach optical trainees, or undertake further specialised training in low vision clinics.

Formal study of business, communication and marketing skills is of course possible, and may be advantageous where the DO takes on practice management.

F) Demand for dispensing opticians

According to interviewees and online sources, dispensing opticians are in demand and training courses are more or less fully subscribed. It is clear that multiples and many high-volume and high-end independents see considerable value in the registered DO, particularly given regulation that stipulates specific competencies for contact lens dispensing and children's dispensing. The high-volume business model does not welcome optometrists undertaking work that DOs are very well qualified to do.

The unregistered optician, without any formal training, is legally able to dispense to most adults and offer advice on a range of products, including lenses for night driving, prescription sunglasses, spectacles for VDU use, and sports and safety eyewear

As for the skills that help 'protect' the profession under current regulation – the registered DO's 'occupational safeguards' – we should cite contact lens fitting, paediatrics and any dispensing to those registered as blind or partially sighted (commonly known as low vision services).

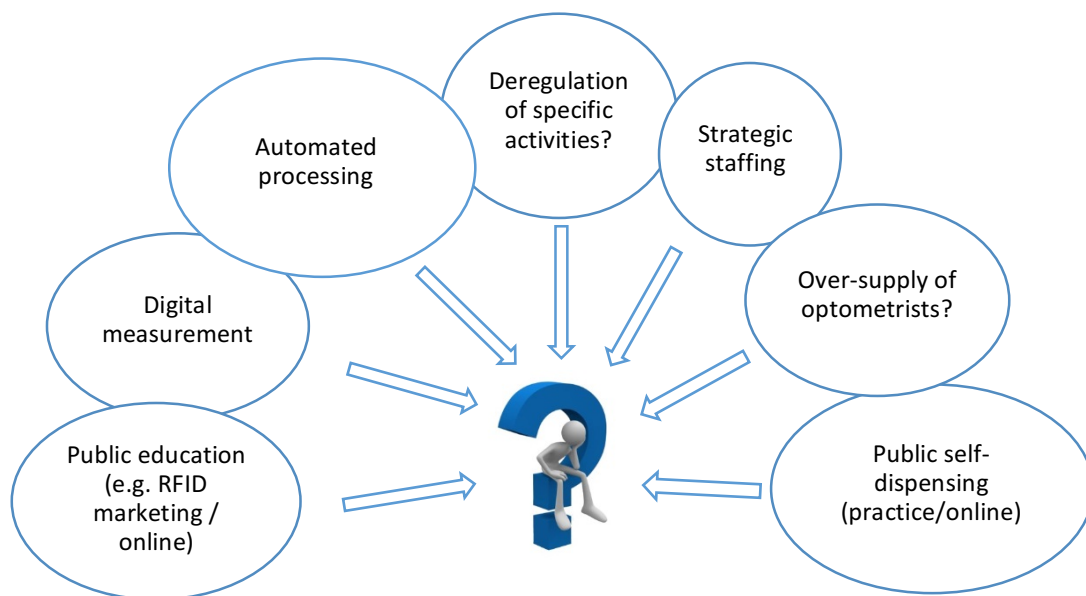
15.2 Horizon scanning to 2030

15.2.1 Dispensing optician or 'dispensable optician'?
Technologies such as in-house digital dispensing, on-line self-dispensing and checkout, and self-education websites and apps, in various ways raise questions about the traditional function of the dispensing optician.

Over the next 15 years, processes will only become more digitised and automated. Manual measurement of facial parameters will disappear, even for children's dispensing. Technology will allow faster and more accurate dispensing, with some customers choosing self-checkout dispensing even within the high street practice. Orders will be automatically processed, perhaps involving made-to-measure 3D printing services, remote or in-house. Generation-Y/ Millennials, mistrustful of the traditional sales-pitch, will be attracted to the self-education facility of RFID marketing (or other digital platform), some looking for co-creation opportunities, with or without input from practice staff.

Beyond the practice setting, public self-care and self-service undermine the DO's role entirely. Already the public can try on 'virtually' a myriad of different frames from the comfort of their own home, then self-dispense with refraction results from a high street test. By the late 2020s, we will see online virtual try-on and facial measurement-taking of far superior quality. One of the drivers will be the increasing popularity of 3D printed made-to-measure frames, which will invite greater precision in web-cam enabled measurement taking. Online contact lens purchasing and virtual aftercare will be sought increasingly in a culture of self-service and self-education. Online vision tests and apps will be well known by this time, some operating in partnership with online retailers that facilitate the circumvention of eyewear sales regulation, as needed.

So will the registered DO exist by 2030?



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15.3 Digital impact on DO's 'occupational safeguards': 2020s

The following subsections present considerations prompted by interviewees and published opinion. While cited areas of activity are regarded as the DO's *raison d'être*, and while most of these activities sit under regulation, all can be performed by an optometrist. There is no work within optics that can only be undertaken by a registered ophthalmic dispenser.

We first cite technology and potential effects on the profession. Foresight Project response to these considerations follows in subsection 15.4.

A) Complex lenses

Some believe complex lenses fall within regulated dispensing activity (2020health interviews), but this is not actually set in law. 'Complex' under GOS definition implies an appliance that has at least one lens power in any one meridian of plus or minus 10.00 or more dioptres, or is a prism-controlled bifocal lens (for which a GOS complex lens voucher may therefore be issued).

It may be 'best-practice' for only qualified persons to dispense complex lenses, but in one sense market forces regulate the activity. Poor services after all lead to the loss of clients, both directly and indirectly (via word of mouth, online feedback). Some practices may choose to involve the optometrist for the dispensing of complex appliances, where the optical assistant or unregistered optician lacks experience.

Complex lens prescribing is therefore in no way a registered dispenser's 'safeguard', although were regulation to introduce restrictions on dispensing to vulnerable adults, some complex prescribing may be captured within this cohort.

B) Paediatrics

ABDO (reference to Optician's Act, 1989)

2.6.1 Statutory regulation does not permit the dispensing of spectacle prescriptions by unqualified persons to children under 16...

Qualified dispensing opticians have full regulated competency, with mandatory DBS clearance, to dispense to children under 16 (GOC Competencies, Unit 9). If a practice does not have a registered dispensing optician, an optometrist is required to dispense to the child directly.

We heard it said that not all practices want to promote services for infants and young children, due to the effort in dealing with two clients (child and parent/guardian) and the potential of excess chair and dispensing time (2020health interviews, 2015). Given the low reimbursement of GOS, there is little incentive for some practices to cater for very young children – even with a qualified DO.⁷⁰

We understand that regulation stipulates certification for children's services due to the importance of ensuring an accurate, stable fit of glasses for the benefit of the child's development. A poor fit could impact a young child's ocular health as well as educational progress. Younger children are also less likely to communicate dissatisfaction with the supplied product (2020health interviews, 2015).

In the future, with superior digital dispensing technology, it is not impossible to imagine a relaxation of regulation for the dispensing of appliances to children, or at least adolescents (age 10 and above, by WHO definition). We are fully aware that while the industry has already seen digital centration terminals and tablet-based apps taking facial measurements of young children, there is disagreement among professionals about the quality and appropriateness of paediatric digital dispensing

⁷⁰ The multiple's high-volume business model, with use of pre-test technicians and DOs, may make seeing children more cost-effective.

15. Ophthalmic dispensing

(2020health interviews, 2015). However, as systems evolve in precision, and perhaps soon with 180-degree facial profiling technology even for infants (see Section 6.2), regulated children's dispensing could see revision in a new Optician's Act. Technology will arrive at the point where the margin of error becomes negligible, and even then, subject to simple subjective and objective tests, perhaps signed off by an optical assistant.

"Children's dispensing could be deregulated with improved automation. And even if not, paediatrics just needs a certificate – that's one semester." 2020health interviews

The teaching of paediatric dispensing will be affected not just by automation but also by 3D printing, which is set to transform made to measure eyewear in the 2020s. As with digital dispensing technology generally, there may be resistance among educators to introduce practical digital training in fear of expediting a future 'controlled' by machines. A future is conceivable where regulated paediatric dispensing is reduced to a certificated individual with mandatory DBS clearance only.

C) Contact lens fitting

Optician's Act, 1989:

25. (1) Subject to the following provisions of this section a person who is not a registered medical practitioner or registered optometrist or registered dispensing optician must not fit a contact lens for an individual.

An entry level dispensing qualification allows the DO to offer advice on contact lens fitting only.

With a Certificate in Contact Lens Fitting, or a higher honours qualification, the DO is able to both offer advice and fit contact lenses. The fully upskilled honours graduate is educated on refractive treatment and orthokeratology, as well as medical/therapeutic indications including keratoconus, keratoplasty and bandage lenses (abdo.org.uk).

Since the DO's role of contact lens fitting is regulated (due to the health dangers of contact lens misuse) and cannot be replaced by automation, it may appear safeguarded. However, envisioning to 2030, there are two principal challenges to the DO's role in contact lens fitting (discounting deregulation, which we consider highly unlikely). The first is a potential over supply of optometrists, and therefore a narrowing pay differential between the fully qualified Contact Lens Optician and the entry-level optometrist. Only around 20% of DOs are accredited contact lens fitters (GOC register, 2013) and it is not uncommon, currently, to find contact lens dispensing undertaken by optometrists. Despite employer demand for contact lens specialists likely rising over the period, questions remain as to what proportion of this need will be met by DOs and lower-paid optometrists respectively.⁷¹

The second challenge arises from online purchasing, potentially reducing the DOs role in contact lens aftercare, if not the original fitting. As already discussed, online purchasing is likely to increase significantly over the next 10–15 years. The various health hazards of contact lens misuse, including sight-threatening microbial keratitis, would be assumed more likely where users are not in regular follow-up with contact lens practitioners. But as outlined in Part 1, we should expect to see, in healthcare generally, a growing emphasis on patient self-care and self-education over coming years. Contact lens education videos have been available on YouTube and manufacturer's websites for several years now, and it is very likely that more patient education apps will emerge also. Technology is therefore being used, particularly by manufacturers,

⁷¹ Perhaps a reason for the low proportion of DO contact lens specialists is that the prospective student with academic ability to gain a DO's BSc might prefer to aim for full optometric study.

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to support self-care, and some contact lens users will consider this a sufficient and preferable (free) alternative to high street after-care. It is not a given, therefore, that rising uptake in contact lenses will see more demand for high-street contact lens aftercare.

D) Low vision services

ABDO (reference to Optician's Act, 1989, s.27)

2.6.1 Statutory regulation does not permit the dispensing of spectacle prescriptions by unqualified persons to ... patients who are registered as severely visually impaired or visually impaired (blind or partially sighted). Sales of spectacles to persons in these classes can only be made by or under the supervision of a registered practitioner.

Low vision in the UK is not defined in legislation. The Low Vision Services Consensus Group, comprising representatives from the healthcare professional bodies, the Department of Health, the voluntary sector and Social Services, has defined low vision as:

Impairment of visual function for which full remediation is not possible by conventional spectacles, contact lenses or medical intervention and which causes restriction in everyday life.

This definition includes, but is not limited to, those who are registered as blind and partially sighted.

Low Vision Services Consensus Group (1999)

Low vision services across England are highly variable from one CCG to the next. In most CCG areas, as

in Northern Ireland, low vision is embedded within hospital-run services.⁷² Low vision services in Scotland vary by region, but feedback from direct contact with optical practices suggests that low vision has become more hospital-based in recent years, not less. Wales, on the other hand, has a nationally commissioned community-based low vision service, and has even provided equipment for specific, accredited high street practices to deliver low vision care.

There was common consent among interviewees that low vision competencies of qualified dispensing opticians were generally underutilised. Unfortunately, practices located in areas without specifically commissioned high street services will rarely see business advantage in taking time to assess, dispense and educate on low vision, or deliver other practical advice, for example on CCTV, lighting positioning and types of bulb. Patients in such areas typically rely on the local hospital and low vision charities, and may therefore experience restricted access and limited support.

Low vision commissioning should ideally sit across health and social care, connecting up hospital eye units, education, social care, voluntary organisations and stroke, rehabilitation and fall teams (COptom/RCOphth, 2013). In a few places it already does, e.g. Camden and Islington. Demand for low vision services will only increase with an ageing population, and it is very likely that mounting pressure on hospital low vision clinics will in time necessitate a stronger primary care response. Such a response is not certain in all areas, nor does it automatically imply the utilisation of DOs in high street practices. The work could for example fall to (or remain with) a wider collective of the third sector and NHS outreach clinics, medical centres or consultant-led COS, and/or simply be rejected by some independents and chains on account of interference with business models.

⁷² In NI, low vision lies in the domain of NHS outreach clinics.

15.4 Opportunities in education and training

The above considerations indicate that technological developments over the next 10–15 years could undermine the status of the DO, or at least the scale of regulated ophthalmic dispensing. This would be all the more likely if encountered with unfavourable commissioning direction, disenfranchising business decisions and an oversupply of optometrists.

The question for stakeholders in education and training is perhaps not so much how to 'future-proof' the regulated profession of ophthalmic dispensing, but rather how to best position and enable education and training to meet future business and public needs, under regulation or not.

ABDO has recently reviewed and updated its national syllabus, for the first time since 2006. This has brought it up to date with new lens technologies and introduced digital dispensing theory, though not necessarily practical teaching. Other changes include a stronger emphasis on low vision work and an introduction to clinical contact lenses.

15.4.1 Fixing communication

A common concern among educators is the 'disabling' effects of technology, the negative social consequences of digital media on young people, and therefore young DOs. A generation has emerged that regularly communicates with both friends and strangers via digital media. There is some opinion that Millennials have generally lower standards of spoken and written communication, and through digital saturation, lack soft skills, behavioural understanding and sensitivity as to how patients (strangers) *feel*.⁷³

In many high street businesses the DO is (1) the welcoming party, (2) the optical dispensing expert, and (3) the sales person. They may also update the company website and be active in social media marketing. Practical dispensing skills combined with an encyclopaedic knowledge of products are of little

use if communication and soft skills do not inspire customers and patients, actual or prospective.

Educators in healthcare all face the same challenges. But ophthalmic dispensing courses will perhaps need to introduce stronger communication modules into the core syllabus to compensate for this unintended social phenomenon.

15.4.2 Digitisation and lens technologies

With digitisation, complex measurement-taking can, and increasingly will, become a straightforward, automated routine. Specsavers recently announced the digitisation of their dispensing services with a high profile advertising campaign (2015). We have already stated awareness of opinion that digital dispensing does not currently save on DO time. Some DOs describe it as 'theatre'. But digital dispensing will be soon considered the norm, and manual methods anachronistic.

Students are being introduced to digital dispensing technology, but not always trained in its use. There is an argument (currently) to leave this for the pre-reg year, building on the theoretical and practical manual skills obtained during diploma or degree, which will still be sought in certain circumstances for years to come. However, institutional resistance to digital dispensing will need to change in the very near future: the lack of hands-on training, currently, already appears behind the curve.

The eventual normalisation of digital dispensing was accepted by interviewees, but there was some strong opinion that during the timeframe under review, technology will remain reliant on the practitioner to interpret measurements and implement them in a professional manner.

Certainly, what technology struggles to provide – at least in an accessible way – is balanced information for the client in how to choose from a range of sophisticated lens options. It is relatively straight

⁷³ CIPD's Learning to Work: Developing the next generation, 2015, reports feedback from businesses and employees on a number of GenY/Millennial skillsets that often require further development, including confidence, team-working, communication and relationship-building, commercial skills and time-management.

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forward to choose a single vision lens with anti-scratch coating – as the billion-dollar online glasses retailer Warby Parker would no doubt attest. But decision making on a range of lens coatings and tints, free-form, high definition, photochromic or polarised lenses, taking into account vocational/recreational needs, is best guided by an experienced optician.

Not all providers, however, consider DOs sufficiently up to date with the latest lens technologies. And we must not deny that multifaceted decision making on lens types might be guided in the future by computerised algorithms, even if a digital process of lens selection will not suit all customers.

Practices need to sell eyewear – it is the only way to stay in business. The DO needs the ongoing drive to self-educate as part of their CPD, since CET does not demand proof of expert knowledge of latest technologies. Businesses themselves will therefore have to facilitate and signpost such training, whether delivered through CET or by manufacturer's own marketing material.

15.4.3 The realities online

Perhaps lacking in DO education is a full appreciation of the impact online platforms may have in the next 10–15 years. Public experience of online eyewear is not nearly as poor as many DOs and educators would like to believe. We were given anecdotal information of clients returning to practices saying 'never again' to their online experience. But we have to weigh this up against GlassesDirect's TrustPilot rating of 9.4 from nearly 30,000 reviews; Visiondirect.co.uk scores 9.5 from nearly 9,000 reviews. These are outstanding scores, significantly higher than those achieved by a number of high street providers and well-known online clothing stores.

There may be few people ordering complex varifocals online even in 2025, but the DO stands to lose, by stealth, a client base that may not even hear the message of superior eyewear options.

There are three responses here for institutional education, providers and CET:

1. Train DOs in how to communicate available superior options, glasses and contact lenses, bearing in mind behavioural differences among generations. Younger generations (for example) are wary of sales-people and averse to the hard-sell. The Millennial wants to self-educate, at best be gently influenced, but never coerced.
2. Instil in the student a greater interest in ongoing self-education in cutting-edge technologies. As noted above, it is unrealistic to expect institutional courses and national education bodies to implement prompt response to the fast-pace world of optics, so this needs to be undertaken through CET and voluntary CPD.
3. Prepare students for the rising threat of online platforms, retail and refraction. Educators need to create awareness and communicate the risks posed by such disruption: risks to business, risks to eye health. The DO can then think strategically about countermeasures (as explored earlier in this report), and at the very least be ready and equipped to advise customers on potential hazards of DIY eye care.

15.4.4 Low vision

ABDO, in its new syllabus, has increased the emphasis on low vision competencies. In fact for some years ABDO has foreseen low vision as an ever expanding role for its members (ABDO, 2005) and has provided the opportunity for DO upskilling in this area through its low vision honours course. Considering the lack of DO involvement in low vision currently, this is certainly a forward-looking strategy.

While the diploma introduces students to assistive technologies, CET has a vital role to play in updating DOs in low vision apps, which are evolving at a rapid pace (see Part 2, Section 7.7). It was remarked to us by patients and experts that DOs and optometrists – and even low vision charities – are generally well behind the curve on assistive technologies for the blind and partially sighted.

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Our research suggests that some chain providers, even with low vision commissioning in the high street, may want to resist low vision services due to the disruption caused to business models. It will be disappointing, in terms of access, if this is to be the case. However, such will be the demand for services in the future, chain opticians will be liable to lose an important patient base to practices that are providing services. The practice that supports health needs of older family members may gain the younger family members also. This direction of travel has already been observed with (national) low vision commissioning in Wales, where branches belonging to specialised multiples (Specsavers, Boots, Vision Express) have joined the low vision scheme, for example in Cardiff, Swansea and Aberystwyth (Eyecare Wales).

“Low vision equipment needs to be demonstrated one to one with the patient. There could be savings on low vision resources through qualified DOs spending time with patients. Aids are liable to end up sitting in the patient’s drawer otherwise, because they can’t gain benefit from them.” 2020health interviews, 2015

Though many CCGs in England are unlikely to commission low vision from the high street in the immediate future, it is probable that more of this work will be undertaken by DOs in the medium to longer term (see also Part 1, Sections 2 & 3, on ageing population and NHS commissioning). ABDO is future-proofing the workforce to be better-placed to take on this work where it arises. It would be valuable to ensure that CCGs are abreast of developments in this area: the very knowledge could encourage commissioning decisions.

15.4.5 Paediatrics

The future is bright for paediatric dispensing. Technological progress in digital dispensing to the very young will in time make services more profitable, with patients benefitting from a growth market in 3D printed made-to-measure frames. The current lack of made-to-measure frames for young children is a frustration among DOs and customers alike.

“Children are time consuming. But if you treat the younger and older members of the family well, you stand better chance of getting the whole family.”
2020health interviews, 2015

Though we heard of misalignment between educators and business needs in terms of teaching on communication skills, lens technologies and contact lenses, this was not so much the case with paediatric dispensing. DO training on paediatrics has in the past been challenging since children are not allowed to be part of the examination process. But in recent years the DO has been able to train on anatomically correct heads, with realistic skin and features. Models have also been made for children with Down’s syndrome, and work is underway to extend the range to different nationalities (2020health interviews, 2015). Registered DOs will generally remain the most informed and experienced practitioners in children’s dispensing,⁷⁴ and any partial deregulation for dispensing to adolescents will not alter the fact.

Education might also in time enable wider opportunities in paediatric public health, including school vision screening services. This could even involve upskilling into certain areas of orthoptics, checking for evidence of reduced vision, squint and binocular double vision.

⁷⁴ DOs have to acquire a specific competency in paediatric dispensing under regulation; optometrists have to acquire the competency to dispense appropriate optical appliances to all clients (GOC competencies: Stage 2, Unit 4), but there is no specific competency demanded of them in paediatric dispensing.

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DO education and training may soon need to respond to the introduction of daily-use myopia control contact lenses. If combined with a pharmacological agent, the optometrist will need further involvement, but contact lens care and fitting can be delivered by the contact lens optician (CLO), who with clinical understanding of myopia control could be the professional that advises and educates the parent.

The specific fitting of orthokeratology lenses, whether for the avoidance of daily CL wear or myopia control (the latter not yet proven long term), would require upskilling of the CLO, since the technology is taught only as theory, to both CLOs and optometrists. This may prove a modest growth market in the 2020s and something that universities might offer as a follow on course. Important considerations relating to clinical interaction between professional and parent are discussed further in Section 16.2.1 (C).

Another area that could involve DO upskilling is tablet gaming for amblyopia (see Part 2, Section 5.4). This would be a partnership undertaking between optometrist and DO, with the latter explaining and demonstrating the gaming technology to the child and parent. It could be a useful practice builder, though something perhaps inconsistent with business models where the optometrist is undertaking sole responsibilities. Training could be delivered via interactive CET and perhaps peer review activity.

15.4.6 Contact lenses

Given the predicted rise of the multiples, industry emphasis on cutting edge DOs and contact lens technology, together with a growth presbyopia market, we believe that business models will support a rising number of contact lens opticians in the 2020s – even in the event of an oversupply of optometrists in some areas.⁷⁵ Education and CPD will play an important role in supporting the industry, with more direct involvement from manufacturers expected.

Provider and manufacturer dissatisfaction with current contact lens education appears to be largely focused on the optometrist (rather than the CLO), who is the first line of contact for a discussion of appropriate eyewear (2020health interviews). Part of the current stasis of contact lens uptake in the UK is blamed on education and a lack of understanding of business needs in an increasingly competitive and capricious market. It is argued that education needs to instil in the optometrist a greater awareness and desire to begin the contact lens conversation. On the other hand, not all practices have found contact lenses to be profitable due to high discontinuation rates, and have subsequently not invited the discussion with clients in the first place.

In Part 2 of our report we highlighted some emerging CL technologies and discussed the potential growth of the contact lens market in the 2020s (see Section 6.3). Technologies emerging in the 2020s could include the accommodating 'smart' contact lens, the liquid crystal dual focus lens, and glucose-monitoring lens. Students are already introduced to the 24-hour IOP lens (Sensimed *Triggerfish*), though not trained in fitting.

Some educationalists have suggested that the glucose-monitoring contact lens will not require CLO 'upskilling'. While it is true that all registered DOs have an 'understanding' of symptoms and treatment of diabetes (GOC Unit 8 competencies), the contact lens technology as a monitoring system will be for some diabetics a quantum leap from regular (or irregular) finger pricking for blood samples. Specific training will be needed on how the patient should manage and respond to a constant flow (or availability) of data. For diabetics used to a continuous glucose monitoring system (wearable), the transition may be less disruptive.

Continuous wear IOP CL technologies, capable of data transfer to smartphone device, may also emerge during the 2020s. Though sitting within optometric care, the technology could invite CLO upskilling for coordinated care within the practice setting.

⁷⁵ Such circumstances could see proportionally lower wages for CLOs, but not necessarily fewer employment opportunities.

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15.4.7 Refraction: new paths?

The refracting optician is a role familiar to a number of countries with very high standards of healthcare, including the Netherlands, Switzerland⁷⁶ and Canada (specific provinces only, including British Columbia, Alberta and Ontario).⁷⁷ In the UK, laws governing the delivery of the sight test would need to change in order to allow refraction by a suitably upskilled optician for the purposes of issuing a prescription. The legal 'delegation of refracting responsibilities' to the DO need not undermine legislation that requires an eye health exam (by an optometrist) as part of the sight test.

Arguments for DO upskilling in the area of refraction – a subject already taught in the DO syllabus – seem to have currently only marginal force in terms of business needs. We heard very little from businesses themselves of the desire to see refracting opticians. Arguments presented against included the view that higher end practices would not consider the refracting optician as conducive to their offering. Multiples, potentially the obvious contenders, may not wish to see the patient journey dissected in new ways that could result in public confusion. Moreover, the upskilled DO would expect higher remuneration, and savings made from this model may be at best marginal.

Counter arguments within business, looking to the future, include the need for cheaper refractionists to free up time for the optometrist, who will likely have greater involvement in community eye care services. And without major changes to GOS, an older demographic means reduced profits to practices, owing to longer chair time.

In terms of the patient journey, it might well be argued that to follow an eye health consultation with DO refraction could in fact streamline the patient journey where there is need to proceed to eyewear. These considerations may in time effect change to regulation. However, it was suggested to us that if

DOs want to gain refracting rights in the future, they would be best positioned to seek legislative change having already introduced full practical refraction into the syllabus. To seek change without demonstrating the skillset is a harder sell. In Part 5 of this report we take these considerations further as we look at arguments on the strategic benefits and potential hazards of separating the vision test from the eye health exam entirely. We should emphasise that regulatory change to allow the full delegation of refraction to the DO, is a separate consideration to the deregulation of the vision test.

15.5 Conclusion

There is undoubtedly an occupational threat to regulated ophthalmic dispensing from technology. DOs therefore need to seize educational and CPD opportunities in cutting edge lens technologies, paediatrics, contact lenses, low vision work (including expert knowledge of digital mobile solutions), business communication and IT skills. We may yet see opportunities for DO upskilling into areas of orthoptics, and the notion of the 'refracting optician' is a possibility within the timeframe under review.

Regardless of the future efficiency and ease of digital automation, most members of the public will still value advice and reassurance from professionals. The DO has thus to ensure s/he remains an essential guide and adviser to the public: the older, experienced DO needs to understand the Millennial mind-set, while the younger DO needs to develop soft skills to instil confidence in older generations.

We have in Section 9 described new opportunities for education and business in wearables. Smart and augmented reality glasses (work, recreational, sports) is a growth area for DOs, but training and manufacturer/distributor accreditation needs to be sought. DOs need to become the recognised experts of smart technology for all those requiring corrective eyewear. Similarly, condition management with

⁷⁶ The refracting optician in Switzerland can only undertake refraction for dispensing purposes for clients already using corrective eyewear. Initial access to corrective eyewear comes via the ophthalmologist.

⁷⁷ Refraction is fully deregulated in British Columbia.

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contact lenses might present niche opportunities, and emphasise a strong clinical understanding to the public. This may also extend to public health awareness and advice, even if remaining exclusive to private business. The DO will in any case need commanding communication skills to raise public awareness as to the potential hazards of unregulated online services, without resorting to hyperbole and scaremongering.

The best way to combat the assertion of a 29% survival chance for the registered DO in the next 10–20 years is to recognise the disruption pre-emptively, and do everything to harness it for successful progression.

16. OPTOMETRY

16.1 Background

In Part 2 of this report we outlined and predicted a range of technological developments that have implications for the profession and role of optometry. Some of the disruption empowers the optometrist, in terms of improved diagnostics, real-time monitoring, and even introducing an element of entertainment into the vision test. But disruption will also bring into question the optometrist's traditional role and the tasks they still need to perform. As binocular objective/subjective autorefraction and rapid screening devices (from multi-modal machines to patient-operated OCT) combine to increase automation, client-optometrist contact time may be reduced. Other technology is moving optics out of the practice setting altogether, enabling members of the public to self-refract, self-dispense, self-monitor and even self-diagnose.

Driving change alongside technological progress is our ageing population and the commissioning imperative to deliver accessible health care at lower cost. In eye care, this is currently seen as achievable through a greater utilisation of the community setting. As outlined in Part 1, we believe community eye care opportunities for optometrists are likely to increase – in some places significantly – during the period under review. This may not always translate to city centres, however, where consultant-led Community Ophthalmology Services (COS), staffed by multi-disciplinary teams, could emerge as a preferred model. Even there, openings for NHS optometrists will likely expand.

As stakeholders (including universities, commissioners, DOCET,⁷⁸ the GOC, clinicians and policy makers) consider the future of optometric education and training, it is essential they maintain focus not just on expanding community and hospital-based opportunities, but also on high street businesses. What do the principal employers of

optometrists need from the profession? What would be the argument for upskilling the entire workforce if city-centre practices and supermarkets in England see scant involvement in clinical services outside of the GOS contract (as it stands, or revised)?

In this section we give a brief summary of optometric education and CET, then draw together both technological and demographic considerations to assess future implications for education and training. Since this report takes technological disruption as its starting point, we organise our discussion under relevant technological and digital themes.

A) Route to qualification

To qualify as an optometrist students must first graduate with at least a 2:2 honours degree in optometry, with Stage 1 core competencies, from a GOC approved university.⁷⁹ Graduates are then required to complete salaried pre-registration training, carried out under the supervision of an optometrist member of the College of Optometrists, or a supervisor approved by the University of Manchester. Work-based assessments and a final Objective Structured Clinical Examination (OSCE) tests whether trainees have achieved Stage 2 Core competencies. The majority of trainees complete pre-registration training within 12–15 months.

Following qualification, optometrists have to fulfil continuing education and training (CET) requirements, including accruing a minimum number of CET 'points', to remain on the GOC register.

B) Core competencies

Stage 1 core competencies give the trainee optometrist the ability to measure and assess visual function of patients, to identify and quantify variations in vision (ametropia), and to use appropriate ocular drugs diagnostically and to aid refraction. Dispensing proficiency is acquired for the

⁷⁸ Directorate of Optometric Continuing Education and Training

⁷⁹ Anglia Ruskin University, Aston University, University of Bradford, Cardiff University, City University, Glasgow Caledonian University, Plymouth University, University of Manchester, University of Ulster. The University of Hertfordshire launched a four-year Optometry Master's degree programme in 2015. It can only gain full GOC accreditation following the first wave of graduates (2019).

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fit and supply of spectacles, low vision aids and contact lenses. Stage 1 also gives training on problems of binocular vision, the ability to examine for ocular diseases or abnormality, the ability to assess pupil reflexes (and to select and use safely ophthalmic drugs and diagnostic stains), and detect problems with general health, including high blood pressure and diabetes.

Stage 2 competencies are gained in the practice or hospital setting. Core competencies of Stage 2 are largely the same in description as Stage 1, though here the pre-registrant actually manages patients of all ages and (ideally) with a wide range of needs, and under an approved supervisor, as noted above. Stage 2 is therefore largely a refinement and consolidation of learning from Stage 1. (See Appendix C for a full list of core competencies, Stage 1 and 2.)

Unless the optometrist trainee is undertaking a Masters in Optometry (MOptom) with pre-registrant training included (Manchester or Hertfordshire), they will typically have no formal ties to the university of their undergraduate study during the pre-registration year.

C) Continuing education and training (CET)
Continuing education and training (CET) is a points-based scheme that runs over a three year cycle. CET enables practitioners to maintain up to date skills and knowledge; it is not a means for upskilling as such. All optometrists must gain 36 points during the three year cycle (with a minimum of 6 points per year) to remain on the GOC register.

Points can be gained through a combination of learning hours, prescribed activities and reflection. The points must cover all Stage 2 optometry core competencies, although one CET activity may cover more than one competency area. If the optometrist has an independent prescribing (IP) qualification they must gain 36 CET points and 18 further IP-specific points.

At least one point must be obtained for participation in a peer review group or peer discussion event.

Half of the 'general points' requirement must be obtained using interactive CET.

D) Further professional opportunities

Additional accreditation has been offered for over 20 years to allow optometrists to take part in more direct patient care. Greater clinical engagement with patients is very satisfying for practitioners, but this remains driven by personal interest, not the lure of a pay-rise. Unlike some professions, e.g. medicine, there is no pay-progression for those with higher qualifications.

As noted in Section 14.1, accreditation for participation in eye care services outside of the GOS contract is not standardised across the UK. Even so, an increasing number of professionals are seeing opportunity for involvement in community eye care pathways (formerly 'enhanced eye care services', in England), which by and large draw on core competencies. The same holds for Minor Eye Conditions (MECs) or Primary Eyecare Acute Referral Scheme (PEARS). Community pathways are supported by distance learning, followed by a practical assessment of techniques.

Higher Professional Certificates allow formal recognition of specific skillsets. The College of Optometrists has been developing national standards for higher qualifications so that all institutions are geared towards the same learning outcomes, with optometrists adhering to the same levels. Since 2011/12, the College has awarded over 450 certificates in total via accredited providers (universities), with more than 300 in glaucoma. Nearly 30% of all certificates, which include Low Vision and Medical Retina, have been awarded this year alone (2015), suggesting rising interest among professionals (2020health interviews, 2015). The College also sets the therapeutic prescribing exam: there are just over 300 optometrists registered as independent prescribers in the UK currently (the largest proportion by far in Scotland), with most practicing within the hospital setting or community clinics.

In the community setting, where specialised shared care opportunities arise for the optometrist, a local consultant ophthalmologist will often decide on the appropriate route to participation, regardless of any higher qualifications or specific experience the optometrist may have already acquired (2020health interviews). We are still in the early years of the 'upskilled optometrist', so this situation may remain for a number of years to come.

E) Demand for optometrists

There are currently nine GOC-accredited universities delivering optometry courses in the UK. Hertfordshire (10) launched in 2015, and there is a possibility of Portsmouth and Central Lancashire starting courses in the near future. A petition to prevent Hertfordshire opening its optometry school gathered nearly 2,700 signatures in 2013 (Change.org, 2013). The petition organisers maintained that there was a shortage of pre-registration places and the current job market could not support more graduates.

During our interviews we heard conflicting opinions from stakeholders on workforce supply. Some felt there were already too many optometrists in the UK and that salaries, in real terms, had fallen in recent years as a consequence. Though not identifying cause, research by the GMB Trade Union suggested a 27.8 per cent drop in optometrist salaries between 2007 and 2011 in real terms, taking in inflation over the same period (Optician, 2012).^{80,81}

Others felt more optometrists were needed, particularly looking forward into the 2020s, in the expectation that a greater emphasis on community eye care commissioning would increase workforce demand. That the industry is seeing a shift away from full time employment, possibly due to a proportional rise in female optometrists,⁸² suggests future oversupply is in no way certain (2020health interviews, 2015).

Demand and supply should also be discussed from the perspective of public access. Unfortunately, since practices are commonly located well beyond deprived neighbourhoods (a consequence of underfunded GOS, in the minds of some), many people in the UK are underserved. Lower income groups appear to be less inclined to pay to travel to an appointment and are perhaps more fearful of the cost of buying spectacles at their visit, even if the test itself is free – up to 27% cited this as main reason for not attending in one survey (2020health interviews; RNIB, 2007). A phrase quoted to us was that such communities are not so much "easy to miss" as "easy to ignore". Practice profitability in deprived areas is an enormous challenge.

There is also an acknowledged lack of optometrists (and fewer practices) in certain regions of the UK – in the south west, for example. The optometry course at Plymouth University was launched in 2011 to meet 'a long-time need for a training centre in the south west of England' (COptom, 2015). Optometrists of course need practices to join in the first place, and will otherwise relocate. A local course is only half of the solution.

We heard of the strategic desire among some to see a greater emphasis on patient experience (at university clinics or the local hospital) within the BSc degree course itself. This was indeed a common theme amongst recent graduates we spoke to, some having felt under-prepared for the 'real-life' work of their pre-reg year. It could therefore be argued that more widely-placed courses around the UK might profit student-patient contact time, particularly in the HES, while encouraging the growth of an optometric workforce in underserved regions. Courses accommodating hundreds of optometry students at any one time will struggle to offer increased student-patient experience.

⁸⁰ Salaries fell from £44,568 in 2007 to £38,982 in 2011, according to GMB Trade Union.

⁸¹ Some believe a rise in part-time working among optometrists has been a contributing factor to reduced salaries (2020health interviews, 2015).

⁸² Data for Britain show that women are significantly more likely to be in part-time employment than men. equalityhumanrights.com, 2013.

16.2 Horizon scanning optometric education and training to 2030

16.2.1 Four essential technological trend considerations for optometric education and training
The four areas of technology below have been selected for their disruptive potential and particular point of interest in relation to education and training. Our discussion is far from exhaustive, but these were the areas that stimulated the most comment and opinion among interviewees and other Foresight participants.

A) Technology in the hands of the public

Optometric education needs to recognise shifting trends in consumer behaviour, and a direction of travel that will see reduced public dependency on traditional high street services. These threats arise not only from the online dispensing of all types of eyewear (both within and outside of UK regulation), but also, in the future, from online refraction and a host of smartphone-based technologies. Looking a little further ahead, the possibility of telehealth kiosk services situated in general practice or pharmacy chains, may take further business away from the traditional setting (see next section).

Refraction, currently the preserve of the high street optometrist, could become a familiar activity for some members of the public, rather like self-selecting 'ready reader' correction is now. While it is unclear as to how common this will become in the 2020s, this 'empowerment' will make some individuals question the rationale for paying for (what they perceive to be) a similar service in the high street, one that may yield precisely the same results. The consideration of an eye health exam may not even occur to them.

The public are not generally prevention-conscious. The promotion of eye health (and to a certain degree systemic health) is therefore a key role for the optometrist if s/he wishes to retain patients in a future of digital self-service, since in recent years the high street has placed very strong emphasis on vision

testing and fashion. The risks of fewer people attending for regular sight tests are significant in terms of later diagnosis of sight-threatening conditions, as well as increased costs to NHS and social care.

Another technology that could be in public (and technicians') hands is smart-phone based retinal imaging. Innovators in this field, including Cupris Health (cupris.com), D-Eye (medgadget.com, 2015) and the Portable Eye Examination Kit (PEEK), are creating technology capable of reducing the cost and ease of digital retinal imaging significantly. Some accessories also cater for cataract imaging (for classification) and acuity testing. Whilst doctors and mobile eye care professionals are the initial target market, there will be nothing to stop the public from acquiring this technology. With rising incidence of cataracts and retinal eye disease among an ageing population, informal carers may be using smart-phone imaging in the future as a cheap and accessible diagnostic tool, with telehealth links to primary care for onward referral where necessary.

Self-monitoring apps, DIY refraction and smart-phone retinal imaging represent very different forms of disruption. DIY refraction, in particular, is an important consideration for universities and CET. Professionals will need up to date knowledge of such public-facing technology and will also need to recognise the ease in which online digital platforms can allow the circumvention of UK regulation. Whether the technology delivers reliable results or not, the optometrist needs to be aware of potential dangers and pitfalls presented by new 'health-seeking behaviours', and become mindful of how they can contribute to public health information and awareness, and thereby drive solutions.

B) Further into the realm of automation

Automated refraction by the mid-2020s is a distinct possibility for perhaps the majority of sight testing in specialised multiples and supermarkets. If technician-supervised automated refraction

(with optometrist sign-off) demonstrates itself as reliable as traditional manual methods, it will present a significant cost-saving and will be difficult to resist. Drivers of increasing automation will derive from challenges to profit margins by online competition, rising business overheads, the extended chair time of an ageing population and growth of less profitable community eye care services.

'Autorefractometry is not there yet', is a common view among optometrists. Judging from our interviews and experience at optical events, it is the small minority of professionals that believe autorefractometry is currently sufficient to be the principal method of refraction for patients with minor refractive error. By 2025, technology is likely to have evolved to the point where autorefractometry (probably binocular, with subjective elements) is clinically recognised as a reliable tool for a much wider cohort, even if this stops short of those with binocular vision problems, low vision or eye disease.

By this time the digital phoropter-head (the lens-containing testing device) will be commonplace, with the process of subjective refraction largely computerised; we may also be seeing phoropterless refraction in the high street (Part 2, Section 5.2 (D)), not to mention on our smartphones. There is also the question of deregulation: will dispensing opticians by this time have upskilled as refracting-opticians, as found in a number of European countries?⁸³ Increasing automation within refraction, as well as public access to DIY refraction, will raise questions about maintaining this activity under regulation as optometry-only.

Another challenge to traditional refraction methods comes from the US start-up EyeNetra. Patient-operated, smartphone-based refraction will be marketed in the UK in 2016. The obvious use of this £700 technology, which can be combined with a portable phoropter for under £1,200, is in the mobile clinic, although telehealth possibilities are also being trialled in the US (Section 8.3 (D)).

In the not so distant future we may also see patient-operated diagnostic technology. Patient-held binocular OCT (also a potential visual acuity testing device) would be a further step towards the 'high speed' eye exam (see Section 8.2 (B)). In combination with patient-led refraction, such technology could encourage the dislocation of eye examinations from the high street to poly-clinics, or to new telehealth services, delivered from pharmacies via sight test kiosks. By around 2025, technology could be sufficiently advanced, miniaturised and affordable to enable a comprehensive eye exam, as currently described in legislation, from a kiosk with telehealth interpretation, for the majority of low-risk adults.

Education strategists will need to think about how they can position optometrists to remain relevant and valuable in an increasingly automated and patient-controlled future. Automation and patient-led refraction (not to mention DIY refraction, discussed above) will bring into question the relevance of traditional manual refraction education as it currently stands. Manual skills will still be required, since methods described will not be suitable for all patients, but traditional refraction and associated modules may in time condense for Stage 1. The number of people requiring the attention of a fully trained optometrist with their foundational understanding of refraction will surely decrease.

C) Contact lenses

We heard it said by newly qualified optometrists, eye care providers and (not surprisingly) manufacturers, that university-based contact lens education does not always meet the demands of the high street business. Concerns were raised about the lack of practical hands-on experience, education on contact lens options (for example hard (RGP) lenses) and fitting differences, also on communication skills and patient contact opportunity during the BSc.

Arguably it is not the role of university optometric courses to drive growth and profit in the industry. The mandate is to deliver a science-based degree worthy of its title, and educate students to Stage 1

⁸³ The Netherlands and Switzerland, for example.

competencies according to regulation. Contact lens knowledge and fitting skills can then be further refined during the pre-registration year. However, students, now paying 'customers' of the university, will expect to be educated to be fit for purpose in the optical industry.

It is through continuing professional development (CPD) that professionals will acquire the necessary skills to remain cutting edge. However, such is the speed at which lens technology is progressing, a minimum acquisition of CET for CL competencies will still leave a significant proportion of optometrists out of touch with the latest products.

Contact lens companies have already taken proactive steps in CL education with their own courses and workshop days, promoting best practice and delivering CET on not just contact lenses but a range of optometric skillsets. One manufacturer has also produced an eye education mobile app covering a range of General Optical Council (GOC) competencies – including contact lenses – signalling the future of manufacturer-sponsored CET 'on the go'.⁸⁴

Whether peer-discussion, interactive or text-based learning, CET is the obvious vehicle for updating optometrists and contact lens opticians on new technologies. Manufacturers are likely to want increasing involvement in this area in order to drive growth.

i) Myopia control

Myopia control contact lenses, both dailies and orthokeratology (discussed in 5.4 (A)) and indeed pharmacological interventions such as atropine, are taught only as theory at UK universities, since questions remain about the long term effectiveness. (Adult ortho-k for temporary corneal reshaping, allowing the subject to be free of eyewear during the day, is taught to optometrists at undergraduate level, but students do not gain the ability to fit the lenses.)

While there are no approved myopia-control daily lenses available in the UK, some practices are using

a substitute multifocal lens for the treatment, and we know of myopia control ortho-k in practice also (2020health interviews). Ortho-k education can be gained through CPD, but we can only assume that practices involved in myopia control are making clear to parents the limitations of trials to date.

In the future, imagining an approved technology in myopia control, we see important questions arising not so much around training on lens fitting (since daily wear is worn as per normal lenses), but around patient advice and education. To persuade a parent to commit their young child to a myopia control programme is a difficult conversation – and not just due to the substantial costs involved. Myopia control lenses are typically prescribed to children as young as eight who are already myopic (OT, 2014a). They could also be prescribed to a child who does not yet need corrective eyewear to see: for example a six-year-old might be prescribed lenses with only fractional strength of -0.25D. The parent would be told that with myopia control lenses the child should progress no further than (say) -2.00D, rather than -5.00D without.

Optometrists will need specific training in the discussion they will be obliged to have with parents. Not only do they need excellent data to show long term effectiveness, they are also obliged to warn the parent that their child has a remote chance of developing sight-threatening microbial keratitis. The decision has to be made by weighing up the immediate risks against the long term risks of developing ocular health problems later in life. (The advantages of contact lenses over glasses for some recreational and sports activities is a further health and wellbeing consideration.)

Training on communication can be delivered via CET or by manufacturers themselves. But with the direction of travel in optometry being increasingly clinical, we believe interpersonal skills will become of ever greater importance to optometrists' fundamental training. This is true for all health professionals. Being able to share expertise,

⁸⁴ DOCET launched its own CET 'on the go' with an iPhone app in 2011.

interpret patient-generated data, provide reassurance and signpost appropriately will become core competencies for medical practice.

ii) Smart clinical contact lenses

Educational considerations on glucose-monitoring contact lenses have been already noted in Section 15.4.6. The co-working of optometrist and DO in this area could well be key to business models; otherwise dispensing of 'smart' clinical lenses – a private activity in the years immediately following commercial availability – may prove financially unrewarding.

Practical education on clinical contact lenses will remain specialised. Drug-eluting contact lens education will in time sit within therapeutic prescribing education, while pressure monitoring contact lens expertise will need to be developed within the College of Optometry's professional certificate in Glaucoma, perhaps also within the Professional Higher Certificate in Contact Lens practice.

Next-generation lenses will necessitate close co-working between those who understand the ocular or systemic medical condition, and those who can fit lenses and supervise after-care. Certainly within the NHS setting, new multi-disciplinary team working will need to emerge depending on the condition and the need, with potential roles for the ophthalmologist, specialised optometrist, upskilled CLO and ophthalmic nurse. Also of consideration should be courses run by other establishments which would enhance the professional's competence in relevant areas. An example is the Warwick Certificate in Diabetic Care, a course on systemic diabetes designed for front-line healthcare professionals. The specialised clinical optometrist (see below, 16.3) will be more able to provide holistic care for a patient using a new glucose-monitoring contact lens if done so with a deeper understanding of the disease as a whole.

D) Imaging technology: eye health and community services

As noted previously in this report, cutting edge imaging equipment such as optical coherence tomography (OCT) and ultra-widefield retinal imaging has so far been purchased by practices purely for private health services and commercial advantage. Apart from pilot programmes or research, we know of no NHS commissioning in the UK involving OCT or widefield imaging within community schemes, even though some Trusts have recently begun to sub-commission imaging services from experienced and trusted optometrists (2020health interviews, 2015).

Interviewees estimated that around 15–20% of providers now have OCT. This is a powerful example of the industry creating its own momentum in new offerings through private marketing; at the same time it positions itself for wider opportunities in NHS community services in the future, for example in improved glaucoma management.⁸⁵ But the lack of optometric skillsets in the interpretation of OCT images remains a problem. Software algorithms may indicate disease, while nerve fibre analysis will automatically track progression and compare measurements, but OCT currently requires the clinician to interpret results and decide on appropriate action. This is likely to remain the case for some years ahead.⁸⁶

Private courses in OCT are run by leading manufacturers⁸⁷ from which optometrists can pick up CET points for lectures and workshops attended. Some feature renowned experts in advanced imaging – both ophthalmologists and university based researchers. But while catering for both newcomers and those familiar with OCT, workshops and short courses are not enough, in themselves, to upskill optometrists to a level where they can confidently interpret borderline pathology.

⁸⁵ OCT is used in anterior chamber angle evaluation for glaucoma diagnosis and management.

⁸⁶ Computer-aided grading methodology will in time evolve to full cloud-based grading, and mature under artificial intelligence as clinicians (and optical technicians) use it. Cloud analytics has already arrived (for example, IBM's Watson), though the elimination of the human OCT triage probably sits beyond the timeframe of this review.

⁸⁷ E.g. TopCon University, Heidelberg Academy

With OCT expected in the majority of practices by the very early 2020s, we think it likely that triage services, hospital or community based, will need to be set up by CCGs and other regional health commissioners, so to compensate for the lack of advanced imaging expertise among optometrists generally.

Formal education

Optometric training for OCT triage services could begin on university post-graduate courses, but not before. Most universities have no more than two or three OCT machines (due to cost) and it is unlikely that they will be able to keep abreast with the speed of technological development and deployment. In the event of cheaper mass-marketed, miniaturised OCT, this could change, but we are unlikely to see this as viable until well into the 2020s.

While a higher qualification can include education on OCT interpretation (e.g. the College of Optometrists' Professional Certificate in Medical Retina: Cardiff, City, Ulster), specific training for OCT triage is likely to occur within the hospital setting under the supervision of an ophthalmologist. Optometry-led triage services could then be located in the high street (individual practices) or with a Multispecialty Community Provider, or NHS outreach clinic or consultant-led COS. The triage service could assess images from both routine sight testing and community eye care services.

Though comparatively few optometrists will ultimately specialise in OCT interpretation (due to necessary training and patient volume), universities need to strive to be the key point of introduction to cutting-edge imaging technology and give students more hands-on experience. To be practice-ready in the future, students will need an introduction to not just OCT retinal imaging, but also anterior segment imaging, valuable for diagnosis of corneal

disorders and for a variety of pre- and post-operative assessments (2020health interviews, 2015; Grulkowski *et al.*, 2012).

New optometric technology in post-operative assessment extends further, for example in the managing and monitoring of dry eye disease following cataract and refractive surgery. Much equipment of this kind draws on core competencies and requires minimal training, often delivered by manufacturer online videos and written literature. Ultra-widefield scanning laser ophthalmoscopy, clinically useful in the detection and monitoring of central and peripheral eye disease, is also gaining ground within commercial optometry and will likely be in greater demand in the 2020s. Users report that instrument software is typically intuitive and the basics of patient management and image capture can be learned in one short tutorial. Images (flattened and compensated) and pathology may be familiar to those conversant with retinal photography, particularly those who have recorded autofluorescence. However, upskilling and regular clinical exposure are necessary for expertise in interpreting and predicting patterns of disease and progression, and further education would be valuable on specific conditions affecting the retinal periphery. In the future, community services with this technology may include the monitoring of AMD, retinal vasculitis (Leder *et al.*, 2013) and choroidal nevi (Zapata *et al.*, 2015).

Yet another technology of relevance to the future of shared care could be corneal confocal microscopy (CCM) for the monitoring of corneal nerves for signs of diabetic neuropathy. High street opticians could perform this screening for both retinopathy and neuropathy, with data share among GPs and HES. A Manchester pilot is underway currently, with four practices each monitoring 100 patients (AOP, 2015). We foresee this area as sitting principally within the domain of the specialist optometrist.

A number of institutions are running upskilling courses that use advanced technology to aid the identification and monitoring of ocular disease. Aston's Investigative Ophthalmic Science is one example, run as a distance e-learning course and drawing on a suite of technologies including OCT, wide-field scanning and confocal microscopy, for the examination of the anterior and posterior eye (aston.ac.uk). Such courses will be increasingly sought by practitioners looking for wider opportunities in community pathways and co-management, either under individual contracts or as part of an LOC, or through private sub-contractual arrangements with the local hospital trust.

It is our impression, talking to stakeholders, that challenges to the uptake of training are less about cost⁸⁸ as about the time commitment to undertake the training, relevant patient exposure once accredited, and worthwhile remuneration for services. The scenario is somewhat chicken and egg: to obtain the confidence of ophthalmologists, optometrists need to demonstrate experience and training; in order to undertake education and gain experience, optometrists need an assurance of patient throughput, which is usually determined by agreements with local ophthalmologists. There is a role here for LOCSU and LOCs in determining the opportunities and way forward.

16.3 Directions of travel?

"This could be an opportunity for innovation in optometry. It would be helpful to think about what future Optometry graduates might be asked to do and develop a competency profile based on that."
2020health workshop, Nov 2015

We are perhaps witnessing the evolution of a two-tier, even three-tier, optometric profession, driven by clinical opportunities. This could be all the more pronounced by 2025, even if not formally recognised.

The internal demographics of the profession, with increasing part time involvement, together with the business models of city-centre practices and supermarkets in England, suggest both occupational and business demand for the 'generalist' optometrist. There will also be generalist optometrists working alongside those involved in community eye care services, particularly in the multiples: businesses do not need each and every optometrist to perform the same set of tasks.

At the other end of the spectrum is the specialised clinical optometrist, responding to the needs of an ageing population and increasing pressures placed on Hospital Eye Services. This person will typically practice in the hospital setting at least part time, as only a minority exclusive to the high street will have the necessary exposure to pathology, or be able to keep abreast of advances in technology. S/he holds higher professional qualifications and certificates, and perhaps a clinical masters and/or a therapeutic prescribing qualification.

Technology will help shape the direction of education for both optometric archetypes, and for those in between – a middle tier of high-street optometrists with substantial experience and involvement in MECs/PEARS and a range of community eye care services.

The distribution of optometric skillsets in the community is unlikely to be consistent across the UK for some years to come, due to commissioning variation. Community eye care pathways and low vision services are already well established in Wales, and NHS Education for Scotland is currently unique as a national body in supporting the therapeutic prescribing qualification.

16.3.1 University education

Universities, as the profession's starting point, will need to consider how to best adapt and align their course content to remain relevant to future business, NHS and public need. This may extend beyond the consideration of generalist vs clinical, BSc vs

⁸⁸ E.g. Private, NHS Trust or regional Health Education

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post-grad upskill, towards specific pathways that enable optometrists to graduate with skillsets better suited to either the commercial sector (e.g. IT, contact lenses, communication skills) or clinical work (e.g. soft skills, more patient contact time, OCT interpretation, introduction to therapeutic prescribing).

Universities generally have little capacity to squeeze in more learning and modules into their syllabus if they are still to meet GOC requirements for Stage 1 competencies, while delivering a BSc qualification worthy of its title. It is not uncommon for optometry students to already have a 9 a.m. to 5 p.m. teaching day, five days a week.

As demands on the profession evolve over the next 10 years, there will be broadly four ways in which universities might respond, some conditional on GOC and political review:

1. Acknowledge technological developments and new opportunities (theory), but retain current course structure; leave upskilling to post-graduate education and CPD.
2. Extend the course to a 4-year BSc or Masters to accommodate additional learning, such as further communication skills, NHS commissioning and delivery models; introduction to therapeutic prescribing; advanced ocular imaging; new refraction technologies.
3. Define and run two types of optometry degree: generalist (3 year) and clinical (4 year)
4. Retain 3-year degree programme, but with modifications:
 - i. condense teaching on specific areas of reducing relevance to optometric practice (perhaps depending on archetype: generalist/clinical);
 - ii. expand teaching in areas of rising demand by NHS and/or business (as per response 2, above).

Interviewees acknowledged that it is easy to forecast new demands of the profession, much more difficult to predict response.

Scenario 1 is the path of least resistance.

The optometrist can always refine and upgrade their skillset through post-graduate education and CPD, and will continue to do so in the future, with or without changes to the undergraduate programme.

Scenario 2, a four year BSc or Masters, might be off-putting to prospective students on account of cost and/or relevance to envisaged career path, but it could solve the problem of skillset demand without compromising core teaching. This programme is closer to the Australian model, typically a five year course with pre-registration placement included. Australia has recently seen legislation introducing the requirement of limited therapeutic prescribing competencies for all optometry trainees. Educational reform has therefore sought to upskill the entire workforce at entry point (OT, 2014b).

Scenario 3 could be a combination of 1 and 2, or 2 and 4.

Scenario 4 retains a three year programme of study, but with condensed and expanded topics, depending on a generalist or clinical route. The scenario could of course dispense with any notion of generalist vs clinical, and evolve the whole optometry programme with a clinical bias exclusively. Either way, this approach is likely to provoke heated debate and would in some circumstances require regulatory involvement. Table 4 presents a number of 'pressure points' that are likely to be discussed in this scenario, bearing in mind three career pathways.

Table 4. University optometric education: envisioning 2020s

Study area	Domiciliary optometry	General optometry	Clinical optometry
Reduction (✓): examples			
Traditional methods of refraction		✓	✓
Practical spectacle dispensing		✓	✓
Optical history	✓	✓	✓
Mathematics modules	✓	✓	✓
Ophthalmic lens theory	✓	✓	✓
Expansion (✓): examples			
Communication and interpersonal skills	✓	✓	✓
Introduction to counselling: 'breaking distressing news'			✓ (clinical setting only)
Commercial awareness and practice management	✓	✓	
Contact lens education (possibly in time including myopia control)		✓	✓
New refracting technologies	✓	✓	✓
New technologies in detecting pathology	✓		✓
Patient contact time	✓		✓
Therapeutic prescribing	✓		✓
Multi-Disciplinary Team working	✓		✓
Orthoptics (elements of)			✓

We do not suggest that any of the study areas in the first part of Table 4 will be dropped entirely, even in 2025, only that they will be considered for reduction in the event of a review. But such topics will in fact need to be discussed in part or whole by universities contemplating scenarios 2 and 3, not just 4. And some of these arguably demand review at this present time, not in five to ten years.

A) Study areas for review: examples

It is our understanding that students with a recent background in mathematics find year one subject teaching in these areas of no advancement on A-level study (2020health interviews, 2015). Another area cited for consideration is ophthalmic lens theory. Within this sits geometrical optics – a subject that includes Snell's law, light as rays, construction rays, thin lenses and cardinal planes. A significant minority (38%) of recent graduates in a 2009 survey claimed they could not agree with the statement 'What I learnt during my studies [on geometrical optics] has been useful for me professionally'. The students in question undertook around 24 hours of teaching on geometrical optics specifically, in addition to teaching on both physical optics and visual optics (UMIST survey, 2009).

The optometric core competency of ophthalmic dispensing may be considered an area to condense in the near future. Even now, many optometrists have barely any involvement in hands-on dispensing of spectacles, since the predominant high street business model promotes an environment where each staff member works at the top of their skillset. We are, moreover, faced with a future of increasing automation within dispensing itself.

(We wonder whether the industry believes that the undertaking of minimum CET points alone is sufficient to enable the optometrist with potentially no involvement in practical dispensing to practice efficiently and professionally in this area?)

Such considerations may not however apply to the domiciliary service practitioner, where optometrist and dispenser can be the same person. And though

some optometrists rarely use their contact lens dispensing skills, contact lens fitting is probably not an area to condense for any prospective model, unless the proportion of specialist contact lens opticians was to rise substantially (c.20% of DO workforce currently).

If in the future dispensing opticians upskill to become refracting opticians (regulation permitting; see Section 15.4.7), there will of course be even less demand for optometrist involvement in dispensing, since there would be no post-refraction handover to the DO with discussion of prescription considerations.

Setting aside the notion of refracting opticians, soon educators will have to address the course time devoted to traditional refraction techniques, given emerging disruptive technologies. We have cited six distinct technological challenges to professional subjective refraction, the majority of which will be likely available in the UK by 2025: (1) high quality binocular objective/subjective autorefractometry; (2) automated subjective refraction; (3) DVS Vision Optimiser; (4) smartphone-based patient-operated refraction; (5) online refraction; (6) smartphone/tablet refraction via subjective-correction screen display.

We maintain that traditional methods of refraction will still have a place throughout the 2020s, but educators should be acknowledging now new technologies and new opportunities ahead.

As already noted, increasing training on communication and soft skills would be useful to students, the NHS and industry alike. For the clinical specialist, education on 'how to break distressing news', could be valuable.

Contact lens skills, particularly for those entering practices with significant CL patient bases, appear to be lacking in many graduates. It is our impression that high street businesses, as both employer and trainer of pre-registrants, would like to see wider familiarity with lens options, together with the appropriate communication skills to enable confident and informed discussions with patients. The more

clinically focused optometrists – particularly hospital optometrists – will soon need advanced contact lens education that emphasises problem-solving and the new pathology oriented lenses, especially since ophthalmologists are not involved in contact lenses.

A number of interviewees cited increased patient contact time during the undergraduate study period as a highly desirable change. This would be ideally combined with wider interaction with other professions and multi-disciplinary team learning. While the ideal is more hospital-based opportunities, virtual reality and live webinars may in the future help facilitate such interaction.

One of the most oft-cited additional study areas was therapeutic prescribing. Interviewees acknowledged regulatory restriction as a barrier to graduating with prescribing competencies, and most suggested a four-year course as more appropriate to the inclusion of the subject, taught as theory.

Some of the knowledge bases and skillsets proposed look towards the Australian model (noted above) and US model of optometry. The US model is a seven-year programme (Bachelor's degree plus four-year post-grad degree)⁸⁹ that has for some years seen optometry students gaining wider education to undertake primary care evaluation and systemic disease management; for example being taught how to check respiratory function, blood pressure levels, blood glucose levels and cholesterol levels; even perform urinalysis and heart monitoring, and analyse laboratory reports to help evaluate a patient's systemic health. The aim is not to treat, but rather to help identify those patients at risk (Primary Care Optometry News, 2002).

B) Practicalities

Educators will need to work with both clinicians and policy stakeholders to carefully consider core competencies and the required knowledge base, so that content of undergraduate optometry courses can adapt to the evolving needs of businesses, the

NHS and the public in years to come.

It is perfectly possible to see Ulster, Cardiff and Glasgow tailoring undergraduate courses with specific considerations of clinical opportunities from devolved, national commissioning. If so, Glasgow and Cardiff, in particular, have more reasons than most to evolve courses with stronger clinical emphases, and sooner rather than later.

Universities have wide educational objectives in terms of enhancing student capacity for self-learning, problem solving and critical thinking; at the same time optometry degrees are highly vocational. Looking across to examples of Allied Health education and training, it may benefit both university–business and university–hospital alignment if pre-registration training was integrated into spring and summer holiday periods of a three-year BSc, or more flexibly in a four-year BSc or masters. Hertfordshire (launched 2015) is integrating pre-registration into a four-year optometry masters, and Manchester makes this available for a select number of masters students currently.

With integrated pre-registration, closer relationships can be fostered between stakeholders in education and training, while the university retains oversight of student development to full qualification. Australia's Deakin University has even condensed its five year masters into an 'accelerated' three-and-a-half-year trimester programme with pre-reg incorporated.⁹⁰

“Ophthalmologists think optometrists train too much on healthy eyes.”
2020health workshop

Finally, some interviewees felt that universities could already do more to support clinical learning by switching optometry from the Life Sciences Faculty to the Medical Faculty. As not all the universities

⁸⁹ A first degree followed by a four-year, doctoral-level degree

⁹⁰ Integrated pre-registration training is typical of optometric education in Australia

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that currently offer optometry have a medical school, this would require some significant adjustment in course positioning. But if optometry was aligned to medicine in the way that dentistry is already, clinical learning would be facilitated alongside medical students, and there would be at source a wider, pan-healthcare knowledge and appreciation of optometrists' competencies resulting from stronger ties to medicine. This could expedite the closer working of optometrists with ophthalmologists, even as their roles and functions evolve, and would address the perennial objection from ophthalmologists that optometrists do not know enough about eye disease. Universities would thereby support the evolving culture of shared care and even incentivise, through increased confidence and understanding, commissioner decision-making on the expansion of community eye care pathways.

16.4 Conclusion

No profession will be untouched by technology. Every institution involved in the training and education of health care professionals is going to have to adapt to accommodate the different demands that will be placed upon it. Skills of interpretation, understanding, communication and signposting will be required across healthcare as the consumer is enabled by technology to become a participant and, when ill, a 'participatient' in their health needs. But as we have described, a significant driver of this will be increased demand from an aging population with a higher prevalence of eye disease, and currently insufficient access to appropriate expertise. Technology has arrived in the nick of time for us to be able to both design new systems and improve ways of managing demand. By colluding with the traditional 'we've always done it this way' approach, we risk increasing health inequalities as the need for treatment and monitoring will outstrip our ability to supply timely and appropriate interventions.

Foresight Project Report Part 5:

Regulation

17. REGULATION AND TECHNOLOGY

17.1 Background

Regulation of health professionals arguably began in 1518 when the Royal College of Physicians was founded to grant medical licences to practice, and punish malpractice. Other bodies followed, with the Spectacle Makers Company of London emerging in 1629, whose ordinances included the authority to whip any apprentice who brought the Society into disrepute, and whose minutes, in 1671, detail the destruction of spectacle 'wares' that were not up to standard. Not until 1858 was the General Medical Council established as a stand-alone regulator for all doctors, medical and surgical. The (now) Worshipful Company of Spectacle Makers introduced qualifying exams for opticians in 1898, in response to the establishment of the British Optical Association in 1895 and their examinations. These remained optional but increasingly expected until the creation of the General Optical Council (GOC) in 1958, ten years after the formation of the NHS.

In the 1990s, several trends had emerged that prompted a review of the status of health professional regulation (Regulating the Health Professions, Allsop & Saks). There was discernible public discourse about deference towards, and trustworthiness of, professionals; at the same time the government was considering health and allied health professionals who as yet did not have regulatory bodies (leading to the establishment of the NMC in 2002 and HPC in 2003) as well as standards of existing bodies. The government was also considering the flexibility, continuing education and responsiveness of the traditional professions, and was likewise mindful of the global market place and increasingly cross-border mobile labour within the EU.

There are now nine health profession regulators overseen by the Professional Standards Authority which advises all four UK governments. In 2014 the Law Commission published its 455-page review into all nine regulators, *Regulation of Health*

Care Professionals and Regulation of Social Care Professionals in England, containing 125 recommendations and a draft bill for the government to consider. Recommendations include the removal of outdated and inflexible decision-making processes associated with current legislation; greater consistency across the regulators in some areas where this is necessary in the public interest (such as fitness to practise hearings); the introduction of a clear and consistent legal framework to better enable the regulators to uphold their duty to protect the public; and greater autonomy to the regulators to be able to deliver their functions in a way suited to the profession concerned (lawcom.gov.uk, 2014).

The Government responded in January 2015 saying that they would accept most of the recommendations and would enact a new Bill when parliamentary time allowed. In the interim they are "taking forward secondary legislation to improve the regulatory bodies' processes in order to enhance patient protection and improve public confidence. In addition, the Health and Social Care (Safety and Quality) Bill, presented by Jeremy Lefroy MP, seeks to drive up public safety, professional standards and public confidence by proposing that regulatory bodies and the Professional Standards Authority have public protection as their over-arching objective" (DH, 2015). Jeremy Lefroy's Bill became law in March 2015.

To have public protection as an 'over-arching objective', Regulators need to be able to give assurance on the trustworthiness, safety, quality and integrity of professional practice. One of the challenges for regulation and standards, however, is that clinical information is set to become increasingly a two-way street. Whilst the public still need to be able to trust and rely on professional care and interpretation, the professional now has to face the reality of clinical knowledge originating from technology owned or accessed by patients themselves (See Part 1, Section 1.2, for wider context). A new responsibility emerges. Professionals will have to discern what

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patient-generated-data (PGD) to trust, as judged by its quality and reliability. To dismiss it regardless of the source could be seen as paternalistic and Luddite. Technology introduces the potential of para-clinical practice, where the public become 'participations', possibly reflecting the early professionals themselves a few centuries ago, who through peer networks, self and formal education, acquired the latest academic and research knowledge and began to make decisions on healthcare and appropriate interventions.

17.1.1 GOC and legal framework

The General Optical Council (GOC) sets and regulates the standards of professional education and conduct, which include the approval of qualifications and provider institutions, maintaining the register of practitioners and investigating fitness to practice cases.

The GOC is a very rare example of a National Board regulating a country's optical profession. In most countries the profession is regulated either by Government (e.g. France, Sweden, Spain, Italy), or by regional authority (e.g. Switzerland, USA, Canada, Australia), or simply 'by law'⁹¹ (e.g. Netherlands, Denmark, Norway).

The Optician's Act 1989 sets out the legal framework for the profession and gives the GOC powers to make orders, rules and regulations in relevant areas, subject to approval by the Privy Council. The Act was amended in 2005, bringing in several changes to legislation, including the introduction of mandatory Continuing Education and Training (CET) for full registrants, and the introduction of registration for student optometrists and dispensing opticians (GOC, 2015).

Dating back even further, The Sale of Optical Appliances Order of Council 1984 stipulates legal restrictions for the dispensing of optical appliances to the blind and partially sighted, to children under 16, and on the fitting of contact lenses.

17.1.2 Acts and Orders: relevance today

Since the 1980s we have seen the rise of the Internet, smartphone culture, manifold advances in practice-based technology, and the fast-track phenomenon of the digital 'start-up'. Of these, it is public-facing technology (sometimes powered by start-ups) that presents the greatest challenges to regulation, since it can enable public involvement in activity otherwise restricted to the optical professions.

This is particularly true of the virtual space of the Internet, sitting beyond the reach of regulation that governs on-shore, physical optical practice. Providers beyond regulated borders can, via online technology, deliver products and services that would otherwise fall foul of UK regulation.

UK regulation appears strict by international standards (2020health interviews; ECOO, 2008). Countries such as the Netherlands, Sweden and Denmark, while boasting health services of world-class quality, have less strict regulation governing optical practice. In the Netherlands, for example, spectacle dispensing and contact lens fitting is unregulated.

Businesses registered abroad are entitled to dispense remote services to the UK as compliant with their own national legislation, but not the UK's. The Internet has facilitated this practice to the point where it is no more difficult to buy eyewear online from the UK than it is from one of our close European neighbours. Remote eye-testing services delivered by, for example, a dot-com business would similarly stand outside of UK regulation if registered abroad.

While many within optics complain of an outdated Optician's Act, it has in some ways remained 'future-proofed'. For example, it stipulates the undertaking of key eye-health examinations but does not specify precise methods involved, or the process of refraction. Many technological developments highlighted in this report, such as 'virtual' refraction

⁹¹ See ECOO Blue Book, 2015.

(i.e. without trial lenses), are therefore not prohibited on account of an Act written at a time when such a development was almost unimaginable. However, new technologies and delivery models that do not obviously flout legislation may nonetheless require regulatory action, in the interests of public safety.

17.2 Introduction to subject areas

We have already touched on competencies taught at UK universities and highlighted questions on the future relevance of specific competencies under regulation, or even the demand for identical competencies of all optometrists, given evolving technology, business models and roles within the profession (see Part 4: Education and Training).

In the following sections we move on to examine technological developments, both material and virtual, that pose questions and important challenges for regulation. Where possible we forecast on future developments.

17.2.1 Sale and supply of contact lenses online

The Internet has enabled the rise of both illegal practice and the loophole exploitation of UK regulation in the sale of contact lenses, which can be bought without proof of a valid prescription and supplied without appropriate consideration of user requirements and aftercare. Regulatory restrictions also cover prescription spectacles, but the consequences of contact lens misuse are far greater, potentially leading to sight-threatening disease.

Among the challenges for UK regulation are suppliers based in countries that operate under less strict regulatory standards. For example, a web-based company with domain suffix co.uk is able to route eyewear orders via outlets abroad without evidence of a patient's authorised prescription, so long as they abide by that country's regulatory standards. Preventing such practice would effectively require the harmonisation of standards across Europe, if not the wider-world.

The GOC has been working with stakeholders⁹² to develop a voluntary code of practice for online contact lens suppliers to make it safer for people to buy contact lenses over the Internet. The GOC hopes that the code of practice will help protect the public by:

- improving the practice of those online suppliers signing up to the code that are not subject to UK legislation;
- promoting safe and effective use of contact lenses; and
- encouraging online customers to have more regular eye examinations and aftercare appointments.

It is intended that the code, in some form of kite-marking (endorsement logo), will also indicate that the vendor is in agreement not to supply substitution contact lenses (e.g. changing material, size and brand) to fulfil the sale.⁹³

Endorsement would demand that vendors request assurance from the customer that they (or the person they are buying for) has been fitted with the specified contact lenses by an eye care practitioner, and that the prescription/specification is less than two years old (GOC Consultation, 2015).

In the future, regulation within Europe on the sale of contact lenses may be strengthened by a digital prescription system, where a code identifying contact lens specifications receives automatic approval by online vendors operating according to regulation. The ID code could mean that the customer would not need to enter any data beyond the ID code itself, nor even scan in proof of a valid prescription (2020health interviews, 2015). However, since practices are obliged to pass on to the customer their prescription details, providing this *only* in code could breach consumer rights.

⁹² Consumer groups, optical representative bodies, education providers and retailers and online suppliers

⁹³ Substitution is not covered by UK law as it stands (GOC, 3 August 2015). See also report by Europe Economics (2013): *Health Risk Assessment of Illegal Optical Practice*.

“Around 715,000 people in the UK bought prescription contact lenses online in 2013. Based on discussions with the professions, the GOC believes that a significant proportion of these people would have used a supplier that does not comply with UK law.” GOC, 2015. Consultation: Voluntary code of practice for online supply of contact lenses.

Efforts to ensure the maximum public protection in contact lens buying and wearing are far reaching across the industry. It is in the interests of no one to see contact lens misuse resulting in complications and/or sight loss. It is important to note that the GOC through consulting on a voluntary code of practice is not attempting to restrict the use of online services in the interests of high street business. Rather, it is attempting to ensure, as far as possible, public safety through the promotion of best practice.

17.2.2 Public self-refraction

Public access to self-refraction, either as a stand-alone online service or smartphone-enabled activity, presents significant challenges for the regulators. Self-refraction is likely in at least two digital modes in the UK by 2025 (See Part 2, Section 7.6).

Where self-refraction is followed by online purchasing (via foreign territories), UK regulation is fundamentally undermined. Since the vision test is not a full eye health exam conducted by an appropriately qualified professional, in accordance with the Opticians Act 1989, the results are considered unacceptable for the purchasing of corrective eyewear within the UK itself. It is of course not known how fast self-refraction will develop in the UK, but the more extensive its use, the more the public will look to services that allow use of patient-generated refraction data.

How will regulation respond?

Within the public sphere, self-refraction undermines UK legislation that has always sought to conjoin vision testing with an eye health exam in the interests of public safety.

Such technology may contribute in part to the regulatory separation of the vision test and eye health exam. However, there is certainly little reason to expect deregulation based on this technology alone. Regulation itself sends a public health message. As noted above, the GOC is seeking best-practice kite-marking of online contact lens suppliers: it is not suggesting deregulation based on the fact that UK regulation can be easily bypassed.

If strategists decide that unbundling refraction and eye health would work against the interests of public health (and the NHS purse), we can guarantee no change to policy (see below 17.2.4).

Delegated functions

Both public self-refraction and increasing in-practice automation will bring into question GOC Rules governing delegated functions. The GOC’s statement on the meaning of section 24 of the Opticians Act 1989 reads as follows:

“Refraction for the purpose of issuing a prescription is an essential part of the sight test. As such, refraction for the purpose of sight testing is restricted and can only be conducted by a registered optometrist, a registered medical practitioner or a student optometrist under supervision. No part of the sight test can be delegated to a dispensing optician or contact lens optician, even under supervision.”
GOC, 2013

If technology, in the future, enables accurate self-refraction by members of the public, will the legislation restricting the delegation of sight testing within optical practice remain relevant?

The delegation restriction is more directly challenged by patient-led refraction within the practice setting, or by mobile eye care services (see for example Part 2, Section 8.6).⁹⁴ A practice using patient-led refraction would need to 'delegate' an important process of subjective/objective refraction to the patient. Does legislation⁹⁵ therefore imply that patient-led refraction would not be allowed in UK practices?

Technician-supervised autorefraction is a delegated function of sorts, though not a full delegation, since it is normally used as a starting point for subjective refraction. Results from other pre-test delegated functions, for example fundus photography and visual fields, are interpreted by the optometrist, and such practice has not been found to present direct risk to patients.⁹⁶ Patient-led refraction could be similarly treated: the 'delegation' thus not a full delegation of that specific area of the sight test. It is then in the optometrist's jurisdiction to decide how to validate the results.

It is difficult for regulators to assess a new model before it has been defined in practice (unless of course the model unequivocally and seriously flouts regulations). But given apparent regulatory acceptance of the pre-test model, it follows that providers may consider supervised patient-led refraction acceptable under regulation, so long as an optometrist takes responsibility for, and in some way validates, the results.

17.2.3 Autorefraction: full vision testing in 2025?

There are few more divisive subjects than autorefraction within optics, but in fact we need not address arguments about the current suitability of the technology for direct dispensing.

It is inevitable that superior technology will exist in ten years' time, probably in combination with automated subjective testing. Manufacturers (and indeed start-ups) have an incentive to improve the technology, not just for territories where eye care professionals are in short supply, but also for businesses that are seeing rising commercial challenges within the optical sector. As noted previously, in the UK these challenges include: (1) the loss of profit to online retailers; (2) rising overheads, especially due to the higher costs of commercial real estate; (3) the ageing demographic with its extended chair time; and (4) the growth of less profitable clinical services. Mounting pressures will therefore force practices to consider streamlining and automating the patient journey yet further.

We wonder whether all practitioners in the sector are clear about Regulation and Rules governing autorefraction. As already noted, the Optician's Act does not specify methods of refraction within the sight test. The Act (Section 26) demands such procedures as necessary 'for the purpose of detecting signs of injury, disease or abnormality in the eye or elsewhere', while Section 36 (2) (interpretation) of the 'testing of sight', Section 24, states that the sight test has the objective of:

.....
'determining whether there is any and, if so, what defect of sight and of correcting, remedying or relieving any such defect of an anatomical or physiological nature by means of an optical appliance prescribed on the basis of the determination.'
.....

Some kind of refraction is expected of the optometrist, therefore, and would be required in order to produce a prescription (and gain NHS GOS reimbursement), but processes involved are left to the optometrist's discretion.⁹⁷

⁹⁴ The challenge assumes that such equipment secures results comparable to the optometrist-led subjective exam.

⁹⁵ Testing of Sight by Persons Training as Optometrists Rules 1993

⁹⁶ Europe Economics, 2013. Optical business regulation. P.11: "No evidence of direct risk has been found in relation to delegated functions."

⁹⁷ For example see: Opticians Act, 1989; The Sale of Optical Appliances Order of Council, 1984.

Some commissioners and LOCs have published statements acknowledging this lack of specification within the sight test, and have accordingly attempted to make clear NHS expectations of GOS protocol (See Case Study, below).⁹⁸

Case Study: GOS protocol, NHS Trafford*

A GOS sight test should normally include:

- ocular history and symptoms, including relevant general health and family ocular history
- determination of best spectacle correction and visual acuities
- basic binocular vision assessment
- external ocular examination
- intraocular examination through undilated pupil
- field screening for patients judged at risk by the optometrist/OMP
- tonometry for patients judged at risk by the optometrist/OMP
- maintaining records that show the results of the examination
- issuing the prescription or statement
- giving verbal advice
- writing a referral letter if required

*Undated. See: www.loc-net.org.uk/media/1636/opt_011t_sight_test_protocol.doc

AOP members, see also: www.aop.org.uk/advice-and-support/regulation/england/sight-test-guide-in-england

There are consequently no barriers in legislation or even NHS expectations, as far as we can tell, to the adoption of autorefractometry as the principal method of discerning a patient's prescription. Practices could be doing this now. With improvements to technology, some may be doing it for a significant proportion of patients in ten years' time.

17.2.4 Technology and the deregulation of vision testing

In section 15 of this report we touched on the notion of changes to regulation to allow dispensing opticians to undertake refraction within the context of a full sight test, with the optometrist undertaking the assessment of ocular health. By the 'deregulation of vision testing', however, we mean the complete uncoupling of refraction from the eye health exam, which would, amongst other things, enable the public to receive a prescription and purchase eyewear following a refraction alone.

Under current UK regulation, a prescription cannot be issued by an optometrist or ophthalmic medical practitioner unless a full sight test has been undertaken 'for the purpose of detecting signs of injury, disease or abnormality in the eye or elsewhere' (Opticians Act 1989, Section 26).

The question of deregulation arises within the context of technological developments of the next 10 years because within this timeframe the UK is likely to see opportunities for DIY self-refraction (online or with smartphone-based technology), together with the possibility of customer-led refraction in practices or via mobile eye care services, and superior autorefractometry and possibly fully automated objective/subjective refraction.

There are different notions of what deregulation itself could look like. In the Netherlands, for example, vision testing is unregulated to the point where anyone can undertake refraction and dispense spectacles or contact lenses.

⁹⁸ EG Kent and Medway Local Optical Committee; NHS Trafford PCT. 'There is no precise definition as to the procedures to be included in a GOS sight test'.

There is also the notion of partial deregulation, where the law still demands a qualified practitioner to undertake (or at least validate) the refraction, but no eye health exam is required for the issuing of a prescription and purchase of optical appliances.

We do not believe that technological developments alone will be enough to drive changes in regulation. Indeed, setting aside technology, we can summarise two points of view on partial deregulation, against and for, as informed by interviewees and other discourse on the subject:⁹⁹

1. **Maintain regulation.** If refraction and prescription eyewear purchasing are disassociated with the eye health exam, fewer people may present for eye exams than currently, since prevention and early intervention on eye disease is not embedded in the mind of the public. Fewer opportunities to catch early stage ocular problems would lead to a greater prevalence of eye disease and preventable vision loss, and increased costs to the NHS (2020health interviews, 2015). The very act of deregulation could send a confusing message to the public on the importance of eye health.
2. **Deregulate the vision test.** The pressure high street practices place on customers to purchase eyewear (sales being essential for practice viability) is itself reducing public inclination to seek sight tests. A stand-alone eye health exam, entirely divorced from refraction and product sales, could in fact see increased uptake and greater disease prevention overall. The public needing prescription eyewear would then pay less for it, since products will no longer be subsidising eye exams. This in turn would allow high street practice to better compete with Internet providers, helping to safeguard access to services.

These arguments are far from exhaustive, and those desiring to see deregulation might well point to technology, with increasing automation, as one of the drivers for change (CMAJ, 2010).

We should also point out that many who support current regulation recognise that pressure on patients to purchase eyewear is likely reducing the number presenting for sight tests. Research has acknowledged the negative impact of pressure-to-buy on sight test attendance,¹⁰⁰ which in turn supports the industry-wide argument to see fairer remuneration of the NHS GOS exam (particularly Eng/Wal/NI), which would result in less dependency on product sales in order to maintain business viability.

How would partial deregulation work?

It has been suggested that in order to facilitate a separation of refraction from eye health examination, optical practices could be paid a per capita sum (like General Practice) to deliver eye health exams and a variety of community eye care services (opticianonline, 2014). However, a realistic funding-model, whether some kind of block contract or Payment by Results (PbR), is unclear. Does the NHS pay for all eye health exams (similar to the Scottish system), or does the system retain the current eligibility criteria? And if there is a full separation, do NHS-eligible patients then pay for refraction services?

Some believe that deregulation requires all members of the public to pay for refraction (though some practices would no doubt provide it for free), while full GOS value, as it stands, should be transferred to eye health. There can be no NHS eligibility for refraction services because otherwise the NHS is simply paying out more money for eye health and refraction than it is currently. It is tantamount to providers simply asking the NHS for more money for services – exactly the present scenario.

In this case, the 'deregulation of the vision test' would very likely be seen as synonymous with the 'full privatisation of the vision test'.

⁹⁹ For example, see: www.ncbi.nlm.nih.gov/pmc/articles/PMC2882486/ (also <http://www.opticianonline.net/moneo-4/>)

¹⁰⁰ For example, see: Trudinger, D and Niblett, V (2012). The barriers and enablers that affect access to primary and secondary eye care services — Hackney site report.

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We question whether a £21.31 GOS fee (England, Wales, NI; 2015),¹⁰¹ perhaps together with community eye care service payments, would actually cover service delivery costs for eye health alone? If not, practices also offering refraction services may still need to look to eyewear for cross subsidy. Deregulation would only truly enable a separation of eye health from commerce if there was geographical separation of eye health testing and vision testing, or if remuneration for eye health exam was significantly increased beyond the present GOS payment – and then for what the NHS would consider to be a reduced service (unless the examination was extended to include certain systemic screening/testing).

Where refraction is offered as a stand-alone service, fees could be reimbursed on purchase of eyewear, as some providers (typically multiples) do on occasion with full private exam fees now, or be waived altogether. But discounted refraction would encourage 'pressure to buy', precisely one of the problems deregulation would be attempting to address.

The partial deregulation of refraction, in its most likely scenario, indicates costs to at least some individuals who were formerly NHS-eligible for free eye care services; and added to this is the potential risk of fewer people overall presenting for eye exams and thus lower detection rates of early stage eye disease. This is a hard sell to policy makers and NHS commissioners, since despite being very aware of providers' dissatisfaction with GOS payments, they are not seeing high street businesses going out on strike. Access to primary eye care services, when compared with almost all other services in the NHS, is extremely good in most regions of the country. Many people can even book and receive a test on the same day. Why, then, change the system?

We believe, on balance, that most stakeholders will advise policy makers to resist deregulation within the timeframe under review. There may be examples of separated eye health and vision testing in Europe (in the Netherlands, and to a point in Switzerland, for

example), but these systems have generally evolved, and not resulted from an 'unbundling' of eye care services through deregulation. The specific deregulation of sight testing in British Columbia, Canada (cba.ca, 2010), is a very rare example, and one that policy makers elsewhere will no doubt watch for learning. If in time it proves itself to be of no real risk to public health, cost-efficient and popular with the public, then of course opinion might change. This data will need to be robust and unequivocal to encourage deregulation elsewhere.

In the meantime it is worth remembering that a great deal of technology cited in this report points to a faster eye exam of the future. Practices will want to look to this technology to automate the patient journey in ways that do not compromise quality. For now, we see this as a more likely solution to the maintaining of affordable eye care services than deregulation.

17.3 Conclusion

As technology enables the public to bypass professional healthcare activity, which remains protected in statute, we need to think about how both professionals and regulation should respond. Every professional carries the responsibility, under regulation, for deciding how to interpret clinical findings and what action to take as a result. Currently no tasks as detailed in legislation can be delegated by a professional to someone without the appropriate qualifications. But when technology allows the public to undertake their own testing, or lower-level staff to supervise important testing or diagnostic processes, we are forced to reconsider traditional delivery models, especially when the NHS is straining under the rising demand of patient care.

Regulation and Standards protect the public and ensure quality services, but these will need to be reviewed at more frequent intervals in the future, given exponential evolution in digital technology; otherwise, affordable digital solutions may well be prohibited on account of outdated operating frameworks, specifications and criteria.

¹⁰¹ NHS England General Ophthalmic Services Contracts (Payments) Directions 2015

There are a number of technologies cited in Part 2 of this report that could have been discussed above: from the comparative simplicity of adjustable focus reading glasses (available only online in the UK, at present)¹⁰² to the validity of smartphone-based mobile eye-health equipment, and even ultra-widefield retinal imaging, currently not accepted by the NHS diabetic eye screening (DES) programme as a method of image capture for diabetic retinopathy screening.¹⁰³ Future models of telehealth sight testing with remote optometrists will also need careful scrutiny. Obtaining the right balance of public safety and public interest is becoming ever more complex.

Questions that require consideration include:

- What are the assurances required for professionals to be able to accept and see the public as active participants in their care?
- Do we need to devise a new form of consent that allows the willing public to take more responsibility for their health?
- What are the assurances required for regulators to be able to accept the delegation of specific responsibilities to technicians and technology?
- How can regulation enable digital technology to free up health professionals to operate to the top of their licence?

The optometrist, in particular, has for many decades played a hugely important role in the public's health, with both ocular and systemic disease being detected through examination of eye health. Building on this should be the aim; thinking about how public interest and technology can be harnessed to improve public health and outcomes across the board. The sector is now thinking about how the high street professional may become an integral part of a multi-disciplinary team, extending their offering to a number of public health services. Involvement in advice on smoking cessation (Lawrenson *et al.*, 2014), obesity and falls prevention, and checks of blood pressure, glucose and cholesterol levels, are among the future possibilities for optometrists and registered DOs (2020health interviews, 2015).

Policy, education, regulation and standards will see pressure to not just appraise 'disruptive' technologies but also facilitate evolving roles in the near future. And as we have highlighted throughout this report, those evolving roles extend into the public domain. Safety, trust, integrity and quality all remain the goals, but technology will increasingly move people out of the stands and onto the pitch with professionals, and the terms of refereeing will need to be reviewed.

¹⁰² At the time of writing the manufacturer Adlens was making the case for amendments to the portion of the Opticians Act 1989 that prohibits over-the-counter sale of adjustable focus eyewear. See article: <http://www.opticianonline.net/adlens-wins-landmark-case-arizona/>

¹⁰³ For a list of approved equipment see: www.gov.uk/government/publications/diabetic-eye-screening-approved-cameras-and-settings/diabetic-eye-screening-guidance-on-camera-approval

Appendix A

Table of acronyms and abbreviations

ABDO	Association of British Dispensing Opticians
ACLM	Association of Contact Lens Manufacturers
ACO	Accountable Care Organisation
A&E	Accident & Emergency
AMD	Age-related macular degeneration
AO	Adaptive Optics
AOP	Association of Optometrists
APIs	Application Program Interfaces
AREDS	The long-term Age-Related Eye Disease Study
AQP	Any Qualified Provider
BYOD	Bring Your Own Device
CAD	Computer Aided Design
CAMS	Care scheme for stable wet macula patients
CCEHC	Clinical Council for Eye Health Commissioning
CCGs	Clinical Commissioning Groups
CES	Consumer Electronic Show
CET	Continuing Education and Training
CFD	Compliment Factor D
CL	Contact Lens
CLO	Contact Lens Optician
CMO	Chief Medical Officer
CMVM	College of Medicine and Veterinary Medicine
COptom	College of Optometrists
COPD	Coronary Obstructive Pulmonary Disease
COS	Community Ophthalmology Services
CPU	Computer Data Processing Unit
CPD	Continued Professional Development
cSLO	confocal Scanning Laser Ophthalmoscopy
DBS	Disclosure & Barring Service
DICOM	Digital Imaging and Communications in Medicine
DIY	Do it yourself
DO	Dispensing Optician
DOCET	Directorate of Optometric Continuing Education and Training
DR	Diabetic Retinopathy

DSE	Display Screen Equipment
DVO	Digital Vision Optimiser
ECOO	European Council of Optometry and Optics
EDOF	Extended depth of focus
EHB	Eye Handbook
EHEW	Eye Health Examination Wales
EHR	Electronic Healthcare Record
EPGL	EP Global Communications
ES	Enhanced Services
ESP	Eye Surface Profiler
FDA	Food and Drug Administration
FoI	Freedom of Information
FMO	Federation of Manufacturing Opticians
FODO	Federation of Ophthalmic and Dispensing Opticians
FOMO	Fear of Missing Out
GA	Geographic Atrophy
GOC	General Optical Council
GOS	General Ophthalmic Services
HD	High Definition
HES	Hospital Eye Services
HUD	Heads Up Display
IOP	Intraocular Pressure
IoT	Internet of Things
IP	Independent prescribing
IRIS	Intelligent research in sight
ISD	Information Services Division (Scotland)
IT	Information Technology
LES	Local Enhanced Services
LOC	Local Optical Committee
LOCSU	Local Optical Committee Support Unit
MCA	Monoclonal Antibody
MCPs	Multi-speciality Care Providers
MECs	Minor Eye Conditions
MEMS	Microelectromechanical system

MOOCs	Massive Open Online Courses
MOptom	Master of Optometry
NES	NHS Education for Scotland
NI	Northern Ireland
NICE	National Institute for Health and Care Excellence
OCT	Optical coherence tomography
PACS	Primary Acute Care Systems
PACS	Picture Archiving and Communications System
PAL	Peer Assisted Learning
PbR	Payment by Results
PCG	Patient generated data
PD	Pupillary Distance
PEARS	Primary Eye-care Acute Referral Scheme
PEEK	Portable Eye Examination Kit
PHE	Public Health England
PMP	Practice Management Programmes
PMS	Practice Management Systems
PRK	Photorefractive Keratotomy
RCGP	Royal College of General Practitioners
RCOphth	Royal College of Ophthalmologists
RCP	Royal College of Physicians
RCSEd	Royal College of Surgeons Edinburgh
RCTs	Randomised controlled trials
RFID	Radio Frequency Identification Device
RK	Radio Keratotomy
RLE	Refractive Lens Exchange
RPE	Retinal pigment epithelium
SIO	Structural Illumination Ophthalmoscope
SS-OCT	Swept source optical coherence tomography
VAT	Value Added Tax
VDU	Visual Display Unit
VEGF	Vascular endothelial growth factor
VRLE	Virtual Reality Learning Environments
WOPEC	Wales Optometry Postgraduate Centre

Appendix B

Steering/Oversight groups, readers and interviewees

Steering Group (Chairman: Alan Tinger)

- Henrietta Alderman, Chief Executive AOP
- Simon Rodwell, General Secretary ACLM
- Alan Tinger, Chairman LOCSU

Oversight Group (Chairman: Alan Tinger)

- Henrietta Alderman, Chief Executive AOP
- Sir Anthony Garrett, General Secretary ABDO
- David Hewlett, Chief Executive FODO
- Ian Humphreys, Chief Executive College of Optometrists
- Chris Hunt, Chairman OC
- Bryony Pawinska, Chief Executive FMO
- Simon Rodwell, Sec. Gen ACLM
- Alan Tinger, Chairman LOCSU

External readers

- Victor Chong, Consultant Ophthalmic Surgeon, Clinical Senior Lecturer in Ophthalmology (University of Oxford)
- Paul Hodgkin, GP & Founder of Patient Opinion
- David Napier, Professor of Medical Anthropology, University College London
- Eric de Silva, Associate Director for Research & Development, UCL Institute of Biomedical Engineering
- Angela Thompson Director of Nursing, East and North Herts NHS Trust

Interviews

The Foresight Project interviews engaged 91 experts and stakeholders, whose names are known to the Oversight Group members listed above. Most interviews were conducted one-to-one, spanning business, IT, manufacturing, start-ups, commissioning, policy advice, representative bodies within the optical sector, ophthalmic dispensing, optometry, ophthalmology, scientific research, university education and CPD, and regulation. Predominantly UK focused, our interviews also engaged experts from the USA, Canada, Switzerland and Germany within the fields of research, education, start-ups and industry.

Appendix C

Optical profession core competencies

Dispensing optician

The core competencies for Dispensing Opticians specified by the GOC can be summarised under the following headings:

1. Communication: The ability to communicate effectively with the patient and any other appropriate person involved in the patient's care.
2. Professional conduct: The ability to comply with the legal, ethical and professional aspects of practice.
3. Methods of ocular examination: An understanding of instrumentation used in the examination of the eye and related structures
4. Optical appliances: The ability to dispense an appropriate optical appliance.
5. Contact lenses: An understanding of the fitting and aftercare of patients with rigid and soft contact lenses.
6. Low vision: The management of low vision patients.
7. Refractive Management: An understanding of methods of assessing vision, refraction, binocular status and visual acuity in all patients.
8. Ocular abnormalities: An understanding of the relevance of ocular disease.
9. Paediatric dispensing: The ability to dispense an appropriate optical appliance, taking into account the development of anatomical features.

Contact lens optician

A dispensing optician can subsequently qualify as a contact lens optician by studying on an ABDO approved contact lens course or a contact lens honours course. Once the specialist training is completed and competence assessed, practitioners must register their specialty with the GOC. The core competencies for contact lens opticians specified by the GOC can be summarised under the following headings:

1. Communication: The ability to communicate effectively with the patient and any other appropriate person involved in the patient's care.
2. Professional conduct: The ability to comply with the legal, ethical and professional aspects of practice.
3. Methods of ocular examination: The ability to perform an examination of the external eye and related structures.
4. Verification and Identification: The ability to assess the accuracy of the specifications of contact lenses including the use of appropriate instrumentation.
5. Contact lenses: The ability to manage the fitting and aftercare of patients with rigid and soft contact lenses.

Optometry Stage 1 core competencies

The Stage 1 core competencies for optometrists specified by the GOC can be summarised under the following headings:

1. **Communication & Professional Conduct:** The ability to communicate effectively with the patient, make a patient feel at ease and informed, take a history, keep and interpret patient records.
2. **Visual Function & Ametropia:** The ability to measure and assess visual function of patients, to identify and quantify ametropia and to use appropriate ocular drugs diagnostically and to aid refraction.
3. **Optical Appliances:** The ability to advise on, order and to dispense the most suitable form of optical correction, to adjust a spectacle frame or mount and measure and verify optical appliances.
4. **Ocular Examination:** Ability to examine for abnormalities of the external eye, surrounding structures, the cornea, the iris, the crystalline lens, the vitreous and fundi. The ability to use tonometers to measure intraocular pressure and analyse and interpret the results. The ability to assess pupil reflexes, to select and use safely ophthalmic drugs and diagnostic stains.
5. **Ocular Abnormalities:** Ability to take a structured ophthalmic history, to assess visual function and appearance of the eye, to interpret signs and symptoms of ocular abnormality and to make an appropriate management plan.
6. **Contact Lenses:** Ability to take an appropriate history, to assess anterior eye health, to quantify corneal shape and size, and pupil. The ability to select and fit the optimum lens and to teach a patient to safely insert, remove and care for contact lenses. The ability to monitor and manage the anterior eye health of contact lens wearers.
7. **Binocular vision:** Ability to take an appropriate history and to assess eye alignment, eye movements, sensory fusion, stereopsis, oculomotor function and accommodation.
8. **Visual impairment:** Ability to take an appropriate history, to accurately quantify visual impairment and relate it to the underlying pathology and functional consequences and to advise on the use of optical and non-optical aids.

Optometry Stage 2 core competencies

The Stage 2 Core competencies for optometrists specified by the GOC can be summarised as follows:

1. Communication: The ability to communicate effectively with the patient and any other appropriate person involved in the patient's care.
2. Professional Conduct: The ability to comply with the legal, ethical and professional aspects of practice.
3. Methods of Ocular Examination: The ability to perform an examination of the eye and related structures.
4. Optical appliances: The ability to dispense an appropriate ocular appliance.
5. Contact lenses: The ability to manage the fitting and aftercare of patients with contact lenses.
6. Ocular disease: the ability to identify and manage ocular abnormalities.
7. Assessment of visual function: The ability to assess visual function in all patients.
8. Assessment and Management of Binocular vision: The ability to assess and manage patients with anomalies of binocular vision.

Appendix D

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