Institution: University of Reading

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

Title of case study: A paradigm shift in understanding eye-focusing problems that informs cross-discipline professional education and practice.

Period when the underpinning research was undertaken:

Between January 2006 and March 2014

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

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Patricia Riddell	Professor of Applied Neuroscience, Reader, Senior Lecturer	Between 1995 and present
Professor Anna Horwood	Part-time Research Fellow/ Principal Research Fellow, Clinical Orthoptist at the Royal Berkshire Hospital	Between 2006 and present

Period when the claimed impact occurred:

Across the whole reporting period, between 1 August 2013 and 31 December 2020.

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Research from the University of Reading has provided the first laboratory evidence that individual responses to different visual 'cues' can explain the diverse treatment outcomes in patients with common eye muscle problems, which are frequently observed in clinical practice. This new concept has overturned established theories of ocular control, enabling practitioners worldwide and across different vision disciplines to better predict how patients will respond to different treatments, and to target treatments more effectively. The Reading team's findings have changed international clinical guidelines in the management of childhood strabismus. Furthermore, they have influenced the practice of leading ophthalmologists around the world, are taught to undergraduate orthoptists and optometrists, and have had a profound effect on the design and interpretation of binocular vision research studies.

2. Underpinning research

During their lifetime, at least 10% of the population will seek professional treatment for a problem associated with poor eye co-ordination, such as squint (strabismus), lazy eye (amblyopia), eye strain, focusing problems or double vision. However, clinicians have puzzled for years over why patients respond differently to similar treatments and why theoretical models, developed in the early 1900s, often do not fit with observed clinical signs. As a result, diagnosis and treatment have relied on the judgement of the practitioner without guidelines or practices built on clinical evidence.

Horwood and Riddell's early studies of ocular control development in babies [1] led directly to changes in clinical practice guidelines. However, this research raised additional questions, which formed the basis for broader studies on typical populations across the whole lifespan [2,3]. Horwood and Riddell have now investigated the relationship between directing the eyes inwards (convergence) and focusing them to overcome blur (accommodation) in older children and adults, and in different patient groups. This has demonstrated that populations with particular eye disorders use convergence and accommodation differently [4,5], and that this natural variation should be a key consideration when developing treatment plans for each group [6]. Key findings include:

- Specific profiles ('styles') in the way that cues are used characterise the onset, clinical characteristics and response to treatment of different types of childhood strabismus. This explains why a treatment, such as spectacles, helps one child, but not another [6].
- Objective responses from asymptomatic, typical young adults can be indistinguishable from those of patients with visual symptoms, suggesting that psychological factors might exacerbate mild visual problems in patients [2,5].
- Adult control groups for any research studies on convergence and accommodation need to be uninstructed to the experimental situation if any developmental inferences are to be made with observations in infants (who are equally naïve) [2].
- Simple eye exercises, which target only the convergence system, give better outcomes for both convergence **and** accommodation deficiencies compared to traditional exercises that ask patients to work on both systems at once. Importantly, the research showed that effort, instruction and placebo effects play a bigger role in the outcome of eye exercises than was previously thought. It is likely that a good therapist might be as important as the orthoptic exercise itself in conditions such as eye strain or intermittent double vision [5].

Horwood and Riddell's research has exposed errors in the scientific understanding underlying treatment decisions for patients with common visual problems. Accounting for individual differences in the balance of near-cue use, motivation, attention and effort is central to interpreting clinical observations and guiding orthoptic practice.

3. References to the research

Professor Horwood has held two competitively awarded research fellowships: the NIHR Post-Doctoral Personal Fellowship (between January 2006 and December 2009) and a GBP 566,000 MRC Clinician Scientist Fellowship (G0802809, between January 2010 and March 2014). She is currently a co-investigator on the EU Screen project. These grants resulted in multiple research papers in leading international, cross-disciplinary journals. The significance of Horwood's research contribution across clinical vision disciplines has led to international learned societies awarding Horwood with esteemed international lectureships for her contributions to the field of binocular vision and eye muscle disorders.

1. **Horwood A.** (2003) 'Neonatal ocular misalignments rarely become esotropia'. *British Journal of Ophthalmology*. **87**, 1146-1150. DOI: http://dx.doi.org/10.1136/bjo.87.9.1146
2. **Horwood, A.**, **Riddell, P.** (2008). 'The use of cues to convergence and accommodation in naïve, uninstructed participants'. *Vision Research*, **48**(15), 1613-24. DOI: https://doi.org/10.1016/j.visres.2008.04.023
3. **Horwood, A.**, **Riddell, P.** (2013). 'Developmental changes in the balance of disparity, blur and looming/proximity cues to drive ocular alignment and focus'. *Perception*, **42**, 693-715. DOI: https://doi.org/10.1068/p7506h
4. **Horwood, A.**, **Riddell, P.** (2012). 'Evidence that convergence rather than accommodation controls intermittent distance exotropia'. *Acta Ophthalmologica*, **90** (2), e109-e117 DOI: https://doi.org/10.1111/j.1755-3768.2011.02313.x
5. **Horwood, A. M.**, **Toor, S. S.** and **Riddell, P. M.** (2014). 'Change in convergence and accommodation after two weeks of eye exercises in typical young adults'. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, **18** (2), 162-168. ISSN 1091-8531 DOI: https://doi.org/10.1016/j.jaapos.2013.11.008
6. **Horwood, A.** and **Riddell, P.** (2014). 'Disparity-driven vs blur-driven models of accommodation and convergence in binocular vision and intermittent strabismus'. *Journal of the American Association of Pediatric Ophthalmology and Strabismus*, **18** (6), 576-583. ISSN 1091-8531 DOI: https://doi.org/10.1016/j.jaapos.2014.08.009

4. Details of the impact

Horwood and Riddell's research has refined the way that clinicians across the different disciplines of ophthalmology, orthoptics and optometry are trained to assess and understand patients' vision, helping them to 'work smarter' and move away from a 'one size fits all' approach. Eye care professionals who apply Horwood and Riddell's approach better understand:

i. that individuals can differ in how they use cue combinations to achieve binocular vision;

ii. that 'normal' responses can be a lot more variable and apparently poorer than earlier literature research suggests; and
iii. that children's ocular control changes as they get older.

Consequently, clinicians are better equipped to differentiate normal from abnormal binocular vision and interpret test results more accurately. The approach helps clinicians to use individual differences in eye coordination to devise more accurate individualised treatment plans and, importantly, avoid unnecessary treatment. For example, to predict which children are at risk of developing double vision post-operatively or which are unlikely to benefit from wearing glasses.

Influencing orthoptists and optometrists through teaching and learning:

i. Changes to undergraduate curricula

All three UK universities teaching orthoptics (the Universities of Liverpool and Sheffield, and Glasgow Caledonian University) have incorporated Horwood and Riddell's findings into their undergraduate curricula, teaching them in lectures on typical binocular vision development, accommodative strabismus and AC/A theory, intermittent exotropia and amblyopia. Furthermore, their research has highlighted the importance of defining the population of participants, in terms of whether expert or naïve, in clinical orthoptic research studies. Researchers across the field have adopted this as standard practice as evidenced by the Universities of Sheffield and Liverpool now explicitly teaching students that participants studied in orthoptics and optometry experiments must be naïve to vision science if clinical inferences are to be made. The team's findings are also taught in the binocular vision modules of many UK undergraduate optometry curricula.

ii. Continuing professional development

Between 2017 and 2019, Horwood ran a series of training days, reaching 212 clinical orthoptists across 134 NHS and Irish hospitals (approximately 20% of the UK orthoptist workforce) to introduce techniques based on the University of Reading concept. The primary learning objective was to enable orthoptists in the clinic to determine the cues to depth used by individual patients and then to use this information to guide more effective individual diagnoses and treatment. In a survey by the British and Irish Orthoptic Society (BIOS), 96% (n=212) of all those who signed up to receive training said that Horwood and Riddell's research had been influential to orthoptic practice in general (65% "very" or "extremely"), and 94% said it had influenced their personal practice (55% "very much" or "extremely") [E1]. In a 12-month follow up to the training, a University of Reading evaluation showed that 65% of course participants were still using the techniques. Participants noted that the training:

"...has made me more confident in my management of many patients"
"...has really made a difference to my clinical practice"
"*The course was extremely useful and hospital appointments reduced"* [E2].

iii. Providing online resources

Horwood has also produced a number of resources that have been widely disseminated across the optometry profession including an online professional development lecture for UK optometrists focusing on evidence from the University of Reading team showing that certain prescriptions and intensive eye exercises, currently offered by some specialist optometrists, may not be the best approach for the patient. For example, between October 2019 and November 2020, Horwood's video 'Prisms: a love/hate relationship', produced by *Optometry Today* and approved by the General Optical Council, has been viewed over 2,000 times [E3]. The video was highly recommended by the moderator of the American Association for Pediatric Ophthalmology and Strabismus (AAPOS) listserv (the major international discussion forum for senior paediatric ophthalmologists), who commented: *"...Professor Horwood goes to the heart of how optometrists and orthoptists differ in their thought processes and approaches. Great video!"* [E4]

Influencing ophthalmologists' practice:

The team's primary approach to changing clinical practice has been through influencing leading ophthalmologists through invited lectures at major international conferences, who then pass on knowledge to junior team members. It is unusual for orthoptists to directly influence other vision professions but as Horwood and Riddell's concept is recognised for its more effective approach

to treatment, their influence has grown. This is reflected by nominations for prize lectures including:

i. Horwood's award of the **Burian Lecture 2016 (International Orthoptic Association)**, in response to which the President of the World Society of Pediatric Ophthalmology and Strabismus said: *"Our field has suffered from a lack of science and you and your lab are dragging (?pushing) science into the clinician's office and thus to the patient"… "[the traditional approach] feels like Newtonian physics, which works most of time, but we needed Einstein and others to move us further by disrupting our previous understandings"* [E5].

ii. Horwood was the first woman and the **first orthoptist to be awarded the Beilschowsky Lecture at the International Strabismological Association (ISA) Conference 2018.** The introduction to Horwood's lecture stated: *"[the award] acknowledges her numerous novel contributions to the understanding of basic ocular muscle physiology and infant vision development. Her original testing paradigms have contributed to our understanding of accommodation and convergence relationships, and these examination methods are now being applied in clinical and research centers around the world"* [E6].

According to the Senior Paediatric Ophthalmologist at The Hospital for Sick Children in Toronto: *"[Horwood's] results have forced the strabismus community to revise decades-long basic science principles that guide clinical practice"… "I personally have benefitted from her innovations, and I have changed some of my testing and treatment of children's eye muscle problems by applying data from her laboratory. Almost every day I pass on some pearls she has taught us to my residents (registrars) and fellows in the clinic."* [E7]

As a result of influencing leading ophthalmologists' clinical practice, Horwood and Riddell's research on binocular vision and concomitant strabismus is also quoted in most current paediatric ophthalmology and orthoptics textbooks (for example: Hoyt and Taylor, Ansons and Davis, Rowe and Kushner) which are recommended to undergraduate orthoptists and trainee ophthalmologists worldwide (evidence from the UK, Netherlands, Canada and Australia). Horwood has also contributed material to two online chapters of the open access American Academy of Ophthalmology Knights Templar Pediatric Ophthalmology Online Education Center, which provides resources for trainee paediatric ophthalmologists worldwide (together totalling 3,422 views between June 2019 and November 2020) [E8].

Professional influence:

As a result of her world-leading research, in 2015 Professor Horwood was appointed as the Research and Innovation Director of BIOS, the professional body for orthoptists. She subsequently led the development of the BIOS curriculum framework – the first since orthoptics became a graduate profession [E9]. The framework lays out which core skills orthoptists need to know and at what level, providing guidance to the three UK universities that offer undergraduate programmes in orthoptics. The framework has also:

- provided the foundation for the development of a European diploma for orthoptists being prepared by the Orthoptistes de Communauteé Européenne
- been used by the Health and Care Professions Council (HCPC) to determine professional training in the UK.

As an expert in the use of photoscreening, Horwood was invited to collaborate in the EU Screen research project, which is evaluating public health screening across 48 countries.

Enabling better care and advice for patients and their parents:

Horwood and Riddell's early finding – that intermittent misalignment in babies is normal – formed the basis of their 2014 REF impact case study, reporting a change to UK Royal College of Ophthalmologists' clinical guidelines, whereby infants with suspected strabismus should not be referred before the age of four months. Since then, this recommendation has gone on to influence the American Academy of Ophthalmology's 2017 clinical guidelines on the management of childhood strabismus, which are used by clinicians around the world [E10]. The recommendation has also become mainstream advice on health and parenting websites, including Bounty, UK; Raising Children, Australia; and Healthline, USA.

Horwood and Riddell's body of work is proving to be fundamental to understanding many aspects of children's vision. What is more, it has highlighted that convergence and accommodation sit at the heart of understanding typical and atypical vision development. The overarching concept that variation in cue responses can better explain clinical presentation has rewritten the textbooks, helping to prevent unnecessary treatment and improving treatment targeting. According to the Senior Paediatric Ophthalmologist at The Hospital for Sick Children in Toronto, who sees approximately 3,000 children each year from across Canada, the widespread impact of Horwood and Riddell's research across the associated eye care professions is that: *"It has changed how strabismus experts use glasses and prisms to treat eye muscle conditions. In addition, the surgery planning now requires a more detailed analysis to predict the impact of the surgery on both convergence and accommodation links."*

"It is difficult to determine the number of practitioners and individuals world-wide who have benefitted from and been influenced by her innovations. However, given her international reputation, among those who have been exposed to her work… [it is] *at least 5,000-6,000 strabismus specialists, several hundred orthoptists, as well as several thousand optometrists. In turn, their cumulative patient contact would include hundreds of thousands children and adults per year."* [E7]

5. Sources to corroborate the impact

[E1] 2016 BIOS survey of prospective retinoscopy course attendees – anonymised.

[E2] University of Reading 12-month follow-up survey of retinoscopy course attendees.

[E3] 'Prisms: a love/hate relationship', available on Optometry Today's YouTube channel.

[E4] email from moderator AAPOS listserv.

[E5] email from President of the WSPOS on Burian lecture.

[E6] Introduction to the 13th Beilschowsky Lecturer, 2018.

[E7] Testimonial from Senior Paediatric Ophthalmologist at The Sick Children Hospital, Toronto.

[E8] AAO Knights Templar Pediatric Ophthalmology Online Education Center chapters on typical-atypical alignment and clinical examination of ocular alignment and binocular vision.

[E9] BIOS Curriculum Framework.

[E10] AAO Preferred Practice Pattern Guideline 2017 – Esotropia and Exotropia.