

Institution: University of Reading
Unit of Assessment: 4 Psychology, Psychiatry and Neuroscience
Title of case study: Improving the diagnosis and management of common childhood binocular vision problems.
<p>1. Summary of the impact:</p> <p>Coordination between the eyes is vital for children's visual and motor development, yet it often fails to develop properly. Horwood and Riddell's research has had important implications for the clinical management of binocular coordination, particularly for infant squint and childhood long-sightedness. They have demonstrated that most newborn infants (approximately 75%) have intermittent misalignment (i.e. sometimes point their eyes in different directions), but after 4 months of age only 3.25% continue to squint and it is only these children that require intervention. As a result, concerned parents have been advised appropriately and unnecessary appointments with GPs and specialists have been reduced. Horwood and Riddell's findings have also led to a substantial change in the management of long-sightedness, from which about 5% of children in the UK suffer (i.e. approximately 300,000 children between 5 and 14 years of age). Traditionally, children with long-sightedness have been provided with glasses that under-correct their vision. Our findings, however, have (i) demonstrated that some long-sighted children choose not to focus on near objects, and (ii) informed clinicians that full correction of focussing is often required to ensure clear vision, for instance, when reading. In both areas, Horwood and Riddell's research has led to changes in clinical guidelines, training, and practice and the advice given to concerned parents.</p>
<p>2. Underpinning research:</p> <p>The team's research at the University of Reading has led to key insights into how children's use of depth cues changes during development with important clinical consequences for the treatment of infantile and childhood strabismus (squint) and hypermetropia (long-sightedness). Binocular vision depends on the ability to align the eyes on a single target (convergence) while focusing on that target so that the image of it is clear (accommodation). Eyes must be able to change focus and direction rapidly as objects of interest move in depth. Accommodation and convergence need to be accurately co-ordinated, using cues from the visual environment to drive both systems in tandem. Failure to develop good, coordinated, binocular vision results in squints which can be associated with focusing problems (particularly long-sightedness) making glasses necessary. Squints and long-sightedness are very common in children. At least 8% of all children will need NHS treatment for these conditions before the age of 7 years.</p> <p>Assessment of the development of binocular vision requires the measurement of convergence and accommodation in very young infants. The Infant Vision Laboratory (IVL) at the University of Reading was set up in 1997 by Dr Patricia Riddell (Lecturer 1995-1999, Snr Lecturer 2000-2007, Reader 2007-2012, Professor 2012-) in collaboration with Dr Anna Horwood (P/T MSc Student 1994-1996, P/T RA/PhD student 1997-2001, P/T Research Fellow 2006-2013, P/T Principal Research Fellow Nov 2013-), a practicing orthoptist. This collaboration has resulted in unique, clinically driven research which has changed clinical practice, attracted prizes from the international clinical community, and been funded through research council grants and prestigious fellowships (DoH 2006-9 and MRC 2010-13). The group was one of the first in the world to measure accommodation and convergence simultaneously when these were evoked by different depth cues in very young infants, incorporating a novel method, namely remote haploscopic photorefracton (1-7). The visual system uses a number of cues to estimate the position of a target, including disparity between the positions of its image on the retina of each eye (retinal disparity), target blur (whether target is clear or blurry), and changes in size as the target moves in depth. This method allows naturalistic measurement of the response to each of these depth cues through image processing of a video of the eyes. It is suitable for all ages since the procedure is non-invasive and the head does not need to be stabilised. Horwood and Riddell have used this method to test over 800 participants aged from 1 month to over 60 years of age to assess typical development (1,3,4) and a range of clinical conditions (5-7). They have determined typical cue use at different stages of the development of binocular vision (7) and have applied this information to address clinical problems. Key insights from Horwood and Riddell's underpinning research include the following:</p> <ol style="list-style-type: none"> 1. Until the age of four months, intermittent misalignments of the eyes are common (73.2% of infants show misalignments in the first month of age) and these misalignments result from inability to use cues that determine the position of objects when they move backwards and forwards in depth. Persistence of misalignment after this time is indicative of abnormal visual

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development (pathological squint or, in some instances, neurological disease) (3).

2. Long-sightedness is usually under-corrected in children on the assumption they will use their focussing ability to “make up the difference” (Farbrother, 2008). The team’s research suggests that many such children do not focus appropriately for near targets, and therefore function with blurred vision for many tasks. A major implication of these findings is that these children will in fact benefit from full correction of their long-sightedness rather than under-correction (5).

3. References to the research: A total of 17 academic papers have been published in peer reviewed journals based on this research. In recognition of this body of work, Dr Horwood was awarded the Roger Trimble Memorial Lecture in 2013 - an award to major international paediatric ophthalmologists at the annual British Isles Paediatric Ophthalmology and Strabismus Association Conference.

1. Horwood, A.M. et al. (2001) Variations in accommodation and convergence responses in a naturalistic setting. *Optometry and Vision Science*, **78**, 791-804.
http://journals.lww.com/optvissci/Abstract/2001/11000/Variations_in_Accommodation_and_Convergence.9.aspx. Funded by MRC G9608874N (£200,757, 1997 – 2000; Development of reciprocal linkages between vergence and accommodation in human infants). Squint Forum Prize for best presentation by a non-consultant UK researcher at any strabismus meeting, 2001 *Web of Science citations (November 2013): 12*
2. Turner, J.E. et al. (2002) Development of the AC/A ratio in human infants. *Vision Research*, **42**, 2521-2532. DOI: 10.1016/S0042-6989(02)00268-7. Funded by MRC G9608874N (as above). *Web of Science citations (November 2013): 18*
3. Horwood, A.M. & Riddell, P.M. (2004) Can misalignments in typically developing infants be used as a model for infantile esotropia? *Investigative Ophthalmology and Visual Science*, **45**, 714-720. DOI: 10.1167/iovs.03-0454. Funded by MRC G9608874N (as above). *Web of Science citations (November 2013): 9*
4. Horwood, A.M. & Riddell, P.M. (2010) Independent and reciprocal accommodation in anisometric amblyopia: a case report. *Journal of the American Association of Pediatric Ophthalmology & Strabismus*, **14**, 447-449. DOI: 10.1016/j.jaapos.2010.07.003. Funded by NIHR (£225K, 2006- 2009; Cues for Vergence & Accommodation in Typical & Atypical Development). Margaret Fitton Memorial Prize for best British paper. XIth International Orthoptic Congress Antwerp 2008; International Orthoptic Association Research Award in recognition of Outstanding Scientific Contribution to the Orthoptic Profession awarded 4-yearly at the XIth International Orthoptic Congress Antwerp 2008.
5. Horwood, A.M. & Riddell, P.M (2011). Hypo-accommodation responses in hypermetropic infants and children. *British Journal of Ophthalmology*, **95**, 231-237. DOI: 10.1136/bjo.2009.177378. Funded by NIHR (as above).
6. Horwood, A.M. & Riddell P.M. (2012) Decreased accommodation during decompensation of distance exotropia. *British Journal of Ophthalmology*, **96**(4), 508-513. DOI: 10.1136/bjophthalmol-2011-300138. Funded by NIHR (as above).
7. Horwood, A M, Riddell, P M, 2013, "Developmental changes in the balance of disparity, blur, and looming/proximity cues to drive ocular alignment and focus" *Perception* **42**(7) 693 – 715. Funded by NIHR (as above) and MRC Medical Research Council Clinician Scientist Award G0802809 (£566,000, 2010-2014, Typical and atypical ocular accommodation and convergence characteristics and relationships over the lifespan).

4. Details of the impact:

Horwood and Riddell’s research has been recognized for its impact in many clinical areas relating to paediatric vision, but two clear examples are the management of early infantile squint and long-sightedness. These vision problems are common, treatment takes many years throughout children’s early development and uses NHS services intensively. The team’s research has improved diagnosis and treatment of these conditions, affecting the practice of clinicians specialising in children’s eye care (ophthalmologists, orthoptists, optometrists) and improving information for concerned families. Clinicians: Before Horwood and Riddell had documented the frequent occurrence of squint in early infancy, the exact time at which squint could be diagnosed as pathological was not known (e.g. Burian and von Noorden, 1974 state: “Whether this type of deviation is ...present at birth...has never been truly determined”). Concerned parents of infants who are observed to squint before the age of 4 months of age will often consult their GP or health visitor who would, in the past, refer children to

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specialist ophthalmology services. Follow up of these children was common until 3 years of age (over 3 to 4 appointments) in order to rule out a pathological condition. Clinical textbooks [1] and Royal College of Ophthalmologist guidelines [2] written since the publication of the team's work recommend, however, that infants should not be referred for assessment or treatment of squint before 4 months of age. In addition, this implication of the team's findings has been documented in professional advice for concerned parents [3]. Data on referrals for infant squint has not been recorded in detail, but an estimated 30% of infants taken to a GP or health visitor as a result of an intermittent squint would have been referred to an orthoptist, resulting in approximately 17,000 hospital appointments per year in the UK [4]. As misalignments occur in 73% of infants in their first month, and in less than 3% after 4 months of age, a reasonable estimate of the effect of changing referral advice (to delay referral until 4 months) is that the number of children referred to specialist care may have been reduced by about 90%. This amounts to a reduction of an estimated 15,000 hospital appointments a year, or at least £1,500,000 per year [5] in the UK alone.

About 5% of children have long-sightedness (Tarczy-Hornoch, 2007), which corresponds to approximately 300,000 children in the UK between 5 and 14 years of age. These children have traditionally been provided with glasses that under-correct their vision, on the assumption that because children physically *can* partly compensate for long-sightedness by changing their focus, they definitely *do*. Horwood and Riddell's research suggests, however, that children often do not change their focus, and under-correction may result in blurred vision when focusing on near objects, for example when reading and that a different approach to treatment (full correction) is required in this context.

The clinical insights from the team's research have been incorporated into clinical training in orthoptics and optometry in the UK, the USA, Canada, the Netherlands, Norway, Sweden and Australia (in total approximately 500 orthoptists each year [6]), equipping future clinicians around the world with clear guidance on the management of infantile squint and childhood long-sightedness. This has been achieved through active dissemination of the research findings to clinicians working with paediatric vision problems in the UK and internationally in a number of ways including (i) publishing the findings in the most widely read journals among practicing ophthalmologists and optometrists in this specialist field (the *British Journal of Ophthalmology*, the *Journal of the American Association of Pediatric Ophthalmology and Strabismus* and *Optometry & Vision Science*) and (ii) presenting the findings and their implications for practice at clinical conferences in 12 countries, reaching over 5000 practitioners since 2008. Notably, Dr Horwood has been invited to give eight keynote or named lectures at international clinical conferences in the USA, Australia, Europe and the UK in the past four years [7]. In order to assess how much the team's research has led to changes in the clinical management of childhood vision problems, Horwood and Riddell conducted an online survey of UK senior orthoptists and paediatric ophthalmologists in 2012 [8]. Of the 130 respondents, 80% (100% of ophthalmologists) said the team's work was "very" or "extremely important" in their field, and 77% said it had changed the way they manage their patients. Paediatric ophthalmology consultant training is delivered by international opinion leaders, so by influencing them, the team's work and its clinical implications also reach junior doctors in this field [9, 10].

Children with binocular vision problems and their parents: In addition to the beneficial effects on families of improving the management of childhood squint and long-sightedness, Horwood and Riddell's work has changed the information that is directly available for parents, particularly in relation to infant squint. 95% of websites providing advice for parents who notice that their infant has a squint now state that infants often squint before the end of the third month, but squints persisting beyond this should be checked by a professional [11]. Horwood and Riddell are the only authoritative source of this information, being the only group to have published on the topic. The reach of their findings to the general public has been expanded through coverage in radio and newspapers [12]. Horwood and Riddell have provided information for parents who want to know if their infants have problems with their eyes through educational articles in popular parenting magazines [13]. Similar to the education of general practitioners described above, this reduction of anxiety about squint among parents is likely to have resulted in a significant alleviation of pressure on the NHS in this area.

5. Sources to corroborate the impact

1. Textbooks that cite our work on infant misalignment:
 - Lorenz, B & Borruat, F-X, (2008) *Pediatric Ophthalmology, Neuro-Ophthalmology, Genetics*. Springer-Verlag: Berlin, Germany.
 - Levene, M.I. & Chervenak, F.A. (2009) *Fetal and Neonatal Neurology and Neurosurgery*.

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Elsevier Health Sciences: Philadelphia, PA.

Martin, R.J., Faranoff, A.A., Walsh, M.M. (2010) Fanaroff and Martin's Neonatal-Perinatal Medicine: Diseases of the Fetus and Neonate. Elsevier Health Sciences: Philadelphia, PA.

Ansons, A.M. & Davis, H. (2013) Diagnosis and Management of Ocular Motility Disorders. Blackwell Science: Oxford, UK

Hoyt, C.S. & Taylor, D. (2013) Pediatric Ophthalmology and Strabismus. Elsevier Saunders: Edinburgh, UK

2. Clinical guidelines provided by the Royal College of Ophthalmologists (RCOphth) <http://www.rcophth.ac.uk/page.asp?section=451§ionTitle=Clinical+Guidelines> (**Guidelines for the Management of Strabismus in Childhood 2012**) and
3. Advice for parents provided by the Royal College of Ophthalmologists (RCOphth) <http://www.rcophth.ac.uk/page.asp?section=488§ionTitle=Patient+Information+on+Paediatric+Eye+Conditions> (**Parent information on Squint/Strabismus 2013**).
4. To corroborate the estimated number of infants referred to orthoptists: Chair of the British and Irish Orthoptic Society (*)
5. To confirm the approximate cost of outpatient paediatric eye clinic appointments: http://www.cuh.org.uk/cms/sites/default/files/publications/PIN2705_orthoptic_dept.pdf
6. Letters on file (available on request) from leaders of undergraduate and postgraduate clinical orthoptic and paediatric optometry courses, confirming that our work is used in clinical teaching at the University of Sheffield; University of Liverpool; Buskerud University, Kongsberg, Norway; Dalhousie University, Halifax, Canada.
7. Example of international clinical conference at which Dr Horwood was a keynote speaker: 2013 Australian and New Zealand Strabismus Association Meeting.
8. Spread sheet of Survey Monkey Survey of the impact of our work within the UK paediatric ophthalmology community, circulated to the mailing list of the British Isles Paediatric Ophthalmology & Strabismus Association (available on request).
9. To confirm the influence of the team's work on international opinion leaders: Letter from the Chairman of the International Orthoptic Association confirming the impact of our work. The Chairman of the US-based Pediatric Eye Disease Investigator Group (60 sites and 120 investigators) has also given permission to release contact details for further corroboration if necessary (*)
10. To confirm the influence of our work on international opinion and training: Co-ordinator of the European Early vs Late Infantile Strabismus Surgery Study Group (*) and First Vice President of the International Strabismological Association and founder member of the Australian & New Zealand Strabismus Society (*)
11. Websites that contains quotes from our work on neonatal intermittent squint: <http://www.squintclinic.com>
<http://www.patient.co.uk/health/Squint-%28Childhood%29.htm>
<http://www.patient.co.uk/doctor/Squints.htm>
(patient.co.uk was named as the No1 Health website by The Times on Jan 26th 2013)
12. Examples of radio and newspaper coverage of our research and its implications: BBC Radio Berkshire interviews (25th July and 30th Oct, 2012)
Reading Post (24th Oct):
http://www.getreading.co.uk/lifestyle/health_and_beauty/s/2122963_eye_research_helps_reduce_false_referrals
13. Example of educational article written for a popular parenting magazine:
Copy of magazine article in "Mother & Baby" magazine August 2012 (available on file)

(*) Contact details provided separately