Institution: University of Cumbria

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

Title of case study: Improving understanding of medical image perception and enhancing interpretation in practice

1. Summary of the impact

The body of research relating to perception and interpretation of medical images has generated a range of impacts on the practice and training of radiologists and reporting radiographers, with resultant benefits for patients. Engagement with the research findings has raised awareness in clinical practitioners of the implicit strategies they use during medical image interpretation and in particular the type and frequency of errors, including the prevalence of decision-making mistakes over issues of pathology perception. Practitioners have benefited through considering their individual strategies, leading to enhanced decision making processes and reducing error rates in interpretation of 2D and 3D images.

The impact has been achieved through engagement with the sector through relevant professional bodies, practitioner orientated publications and direct involvement of the research team in training and development activities for practitioners.

The impact of the research on practitioner diagnostic strategies is applicable across all areas of radiology and diagnostic radiography, but is also being explicitly pursued to determine training methods and assessment when radiologists view 3D Computed Tomography Colonography data for bowel cancer.

2. Underpinning research

The body of research was initiated at St Martin's College (one of the legacy institutions which became part of the University of Cumbria on its formation in 2007) in 1999 by Dr David Manning (Reader, then Professor of Medical Imaging from 2005, left 2010) and is now led at the University by Dr Tim Donovan (Senior Lecturer in Radiography, 2002 to date). The research group pioneered the application of eye tracking technologies for medical imaging perception, via collaboration with psychologists (eye tracking) and statisticians from Lancaster University, and with NHS practitioners. Over the last 14 years the research has developed from describing typical patterns of search for observers with different levels of expertise, to research interventions that could improve diagnostic performance such as providing perceptual feedback, and learning from the scan paths of experts.

The statistical properties of pathologies and how they affect the visual search process on medical images has also been explored. The underpinning ethos of the group is to apply the rigour of experimental psychology methods to help understand medical image perception and decision making. This has led to the use and adaptation of experimental paradigms to enhance our understanding of observer performance and develop ways to improve the efficacy of training programmes pre and post registration. In parallel with the experimental work we have developed new ways of analysing and interpreting eye tracking data, from 2D and 3D data sets, which can be applied to improve understanding of radiological staff performance, with academic national and international take up of the work in the research community.

Other key members of the research staff team have included Dr Susan Barker-Mill (née Ethel, PhD student – eye tracking, 1999-2003), Dr Damien Litchfield (Research Associate, 2010-2011), Dr Mariusz Pietrzyk (PhD student, 2008-2011) and Dr Peter Phillips (Research Fellow, 2009-2012; Lecturer in Medical Imaging, 2012 to date). The team also includes Dr Trevor Crawford, Senior Lecturer at Lancaster University.

The key studies that have led to the development of the *model for image perception* are listed below (with researchers indicated); all results have been published and disseminated to practitioner audiences nationally and internationally.

- Effects of Prevalence on Visual Search 1999-2003 (DM/SE/TD)

- Categories of observer error from eye tracking 2002-2004, 2008-2011 (DM/SE/TD)
- Classification of Errors (Detection and Decisions) 2002 – to date (DM/SE/TD)
- Software framework for diagnostic medical image perception (PWP) – *new ways of analysing data 2004 to date (PP)*
- Effect of feedback on performance in image perception 2004-2008 (TD)
- Difference between radiologists and radiographers in interpretation (training, experience & education) 2002 to date (DM/SE/TD)
- Time-dependent observer errors 2004 (DM/SE/TD)
- Mathematical description [spatial frequency characteristics] of conspicuity of lung nodules in chest radiographs 2008-2011 (MP/TD)
- Learning from others 2008-2012 (DL/ TD)

The more recent work has been supported by 2 key grants (for financial details, see section 3)

1. NIHR Programme Grant, examining factors relevant to implementation of CTC screening in the NHS such as test perceptions, patient preparation, radiologist interpretation, experience and training, and potential enhancements such as computer-assisted diagnosis (CAD). The eye tracking project (UCL/UCH/Oxford/Cumbria) within the programme developed a novel method that allowed the tracking of observer gaze when interpreting CTC images, where pathology is both moving and changing in size. New metrics had to be developed for the analysis and used to investigate differences between experienced and inexperienced observers when asked to interpret CTC. The project also investigated the effect of CAD marks on observers' gaze.
2. Phillips Medical Grant: gaze-contingent paradigm. Funding allowed us to employ a Research Associate, Dr Damien Litchfield, who had a background in experimental psychology and eye tracking and was able to take this research forward.

This innovative body of interdisciplinary research has given a number of insights that have been taken up nationally and internationally by research groups, professional bodies and practitioners.

Key insights include;

1. Expertise related differences in searching and decision making; and that novices can learn both from viewing the search patterns of experts and by receiving feedback on their own search patterns.
2. Missed pathology is typically due to decision making rather than detection (or image quality) errors, with implications for importance of understanding personal search strategies.
3. Reporting radiographers and radiologists are equally accurate when reporting images, although there are qualitative differences in the way they view medical images.

3. References to the research

- Manning, D., Ethel, S., Donovan, T. (2004) Detection or decision errors? Missed lung cancer from the postero-anterior chest radiograph.T*he British Journal of Radiology* 77: 231–235
- Litchfield D, Ball LJ, Donovan T, Manning DJ, Crawford T, (2010) Viewing another person's eye movements improves identification of pulmonary nodules in chest x-ray inspection, *Journal of Experimental Psychology: Applied*, 16 (3), 251-262
- Donovan, T., Litchfield, D., Crawford, T., (2012) Negative priming for target selection for saccadic eye movements, *Experimental Brain Research* 222 (4): 483-94
- Donovan T, Litchfield DL, (2013) Looking for cancer: Expertise related differences in searching and decision making, *Applied Cognitive Psychology,* 27 (1): 43-49 (Online first Sept 2012)

- Donovan, T. Manning, D. J. and Crawford T. (2008) Performance changes in lung nodule detection following perceptual feedback of eye movements. Proc. *SPIE 6917, Medical Imaging 2008: Image Perception, Observer Performance, and Technology Assessment*, 691703
- Phillips, P., Boone, D., Mallet, S., Taylor, S., Altman, D., Manning, D., Gale, A., Halligan, S. (2013) Tracking eye gaze during interpretation of endoluminal 3D CT Colonography: Technical description and proposed metrics for analysis. *Radiology* Published online before print February 4, 2013
- Phillips, P., Manning, J., Crawford, T., Burling, D., Chi-Leung, T., Taylor, A., (2008) Searching in Axial and 3D CT Visualisations. Proceedings of SPIE Medical Imaging 2008, San Diego, USA. February 2008. doi:10.1117/12.790424
- Manning, D., Barker-Mill, S.C., Donovan, T., Crawford, T., (2006) Time-dependent observer errors in pulmonary nodule detection, B*ritish Journal of Radiology* 79: 342-346
- Pietrzyk, M., Donovan, T., Brennan, P., Dix, A., Manning, D. (2011) Classification of radiological errors in chest radiographs, using support vector machine on the spatial frequency features of false-negative and false positive regions. *Medical Imaging 2011: Image Perception, Observer Performance, and Technology Assessment*, Manning, D. and Abbey, C. (Eds.), SPIE Vol. 7966, ISBN 9780819485083.

The rigorous methods used mean that our research is not only published in domain specific journals such as the *British Journal of Radiology* and *Radiography*, but also ones such as the *Journal of Experimental Psychology* and *Applied Cognitive Psychology*.

The research has been supported through two key grants;

1. NIHR Programme Grant, collaborating with UCH/ UCL RP-PG-0407-10338 Jul 2008 – Jun 2013: £1,458,097, of which £250,000 came to Cumbria for the eye-tracking as part of this colorectal cancer study looking at the benefits of CTC over barium enemas and colonoscopy.
2. Phillips Medical Grant: £45,000 2010-2011 to work on the gaze-contingent paradigm.

4. Details of the impact

The research impacts on the behaviours and skills of radiologists and reporting radiographers, with influence on their practice and training, with resultant likely benefits for patients through improved speed and accuracy of diagnosis. The research undertaken by the medical image perception research group has always been intrinsically applied in practice, and focussed on expertise-related differences in observer performance and eye movement behaviour as a way of gaining insight into differences in visual and cognitive processing and understanding the development of radiological expertise. The aim of the research has not been to demonstrate the effectiveness or otherwise of any particular professional group but to understand human expertise and in particular visual expertise in radiology by undertaking high quality research with direct implications for practice. The impact of the research has been on raising an awareness of observer performance studies in a real-world visual search and problem solving task, such as looking for cancer. Rather than being focussed on theory building, the research findings directly impinge on practice, stimulating individuals to consider their own practice, particularly through training activities.

The work has been disseminated and supported for uptake into practice through a wide range of invited presentations and support activities, such as meetings, study days and MSc programmes at other universities and both research and practitioner conferences. These include:

- British Institute for Radiology study day on perception in 2008, designed to update clinicians and reporting radiographers on the latest research in medical image perception to inform practice.
- Guest speaker engagement with MSc programmes at Salford, University of Central England

Birmingham and St George's Medical School. These programmes are for clinical practitioners who are taking post graduate qualifications which will allow them to report medical images in a variety of domains, such as axial and appendicular skeleton reporting, mammography, CT head, and gastro-intestinal imaging. Each course typically has 20 participants, and is run annually.

- Invited speaker at the United Kingdom Radiological Conference (UKRC) in 2012.
- Manchester Medical Society symposium March 2010, a meeting for clinical radiologists and radiographers in the North West.
- The keynote for The Medical Image Perception Society 2011, a society based in North America which brings together academics and clinical radiologists with an interest in medical imaging.
- A seminar for the Medical Physics research groups of Universities of Lund and Malmo (Sweden), September 2011.
- Experimental Psychology Society workshop on expertise as revealed by oculomotor behaviour, University of Portsmouth, 2011.
- Invited speaker to a chest reporting study day held at the Royal Marsden annually, organised by the Brompton and Harefield NHS Trust. Such training shows direct amalgamation of the research findings into the continuing professional development programme of an NHS Trust. Each year there are 120 participants, all clinical practitioners.

5. Sources to corroborate the impact

- Panel discussions and key notes at practitioner conferences; for example 2008 http://www.pacsgroup.org.uk/forum/messages/198/Sensing_the_Image_flier-_high_resoultion-40443.pdf, 2009 http://radiology.rsna.org/content/253/1/230.long, and 2011 http://home.comcast.net/~eakmips/update.htm
- Invited contributors to texts; http://knowledge.sagepub.com/view/perception/n45.xml and NHS training events, http://www.royalmarsden.nhs.uk/SiteCollectionDocuments/education-conference-centre/events/2012-chest-x-ray-imaging.pdf
- Invited speakers; for example 2012 UKRC conference, session A9; http://www.ukrc.org/userfiles/library/UKRC2012_Del_INTERACTIVE.pdf
- Invitations to collaborate with and support other research groups such as the Applied Vision Research Centre at Loughborough and the Diagnostic Imaging Research group at Salford University (email evidence).

Contact for corroboration of delivery of training to practitioners to improve service delivery, based on research:

Superintendent Radiographer, Royal Brompton and Harefield NHS Trust.

The NIHR collaborative project is due to be used within NICE guidance.