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| **Institution:** University of Cumbria | | |
| **Unit of Assessment:** UOA3: Allied Health Professions, Dentistry, Nursing & Pharmacy | | |
| **Title of case study:** Improved accuracy of image interpretation in clinical practice | | |
| **Period when the underpinning research was undertaken:** 2004-2016 | | |
| **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:** |
| Dr Tim Donovan | Associate Professor in Medical imaging | 2002 to date |
| Dr Peter Phillips | Senior Lecturer | 2012 to date |
| **Period when the claimed impact occurred:** 2014 - 2020 | | |
| **Is this case study continued from a case study submitted in 2014?** N | | |

## 1. Summary of the impact (indicative maximum 100 words)

Rapid advances in technology and 3D imaging have changed the radiological task. Our research focus has developed to reflect this, specifically in measuring the performance of radiologists when undertaking the interpretation of 3D datasets, and the subsequent impact on training methods and assessment, ultimately improving accuracy. The evidence base from our work underpins clinical guidance from both the World Endoscopy Organisation and the American Association of Physicists in Medicine. This guidance is used throughout the world by clinicians, radiographers and medical physicists. In addition, the research has a direct impact on the training and development of clinical practitioners by informing the content of all taught medical image interpretation modules at undergraduate and postgraduate levels. Specialist tuition has been given to a national postgraduate programme, thus showing impact on the higher education sector as a whole. Within our own institution, research has informed the teaching of over 400 newly qualified radiographers, since 2014, being able to provide initial interpretations on clinical images.

## 2. Underpinning research (indicative maximum 500 words)

The underpinning research has been undertaken at the University since 1999 with the research group pioneering the application of eye tracking technologies in medical imaging to determine expertise related differences in searching (R1), decision making and the type and frequency of errors (R2) as well as the optimum environments for image interpretation (R3). However, because radiology is such a rapid technologically developing domain, we have continued to develop novel methods of analysing and interpreting eye tracking data in response to the rapid increase in volumetric imaging. Eye tracking studies carried out on static 2D images cannot be generalised to the 3D volumes of data from computerised tomography (CT) or Magnetic resonance imaging (MRI), which is why we have developed new ways of analysing, presenting and interpreting eye tracking data in complex visualisations where computer-aided detection can be used (R4). There is some concern that artificial intelligence (AI) will displace radiologists, but it is more likely that its role will be to augment radiologists. Radiology training needs to change to take account of this development in the implementation of AI, and we have shown that the focus needs to be on decision making rather than detection alone, to reduce the number of false-negative interpretations (R5).

A key research project has been the 'Imaging diagnosis of colorectal cancer: Interventions for efficient and acceptable diagnosis in symptomatic and screening populations'. This is a NIHR Programme Grant, collaborating with University College Hospital/University College London RP-PG-0407-10338 July 2008-June 2013: £1,458,097, of which £250,000 came to Cumbria for the eye-tracking component of this colorectal cancer study looking at the benefits of CT colonography (CTC) over optical colonoscopy. A number of outputs resulting from this project have been published. Specifically with the development of a comprehensive framework of metrics for the characterisation of visual search of 3D moving medical images (R4), our research has demonstrated that the use of computer aided detection (CAD) in CT colonography statistically significantly increases polyp detection, and that small polyps in CTC are often seen but ignored by radiologists (R5).

It is important to determine the empirical evidence for prevalent models of medical image perception, which is why the rigour of experimental psychology methods have been used to test assumptions about the way experts process complex visual information. It is well documented that expert observers are very efficient in the way they search through medical images, and it is thought that rapid scene recognition, or processing of the initial 'gist', underpins expert performance when searching for pathology in medical images. We have used experimental eye tracking paradigms that isolate the initial glimpse from subsequent search to determine whether expert radiologists do exploit the initial glimpse more efficiently than novice observers (R6), demonstrating that actually the initial glimpse may not be as integral to expert performance as previously thought.

**3. References to the research** (indicative maximum of six references)


R1. Donovan, T., & Litchfield, D. (2013). Looking for cancer: Expertise related differences in searching and decision making. *Applied Cognitive Psychology*, 27(1), 43-49. doi.org/10.1002/acp.2869.
*R1 is an empirical research paper published in a journal focussing on proper appraisal of practical implications of the research.*

R2. Manning, D. J., Ethell, S. C., & Donovan, T. (2004). Detection or decision errors? Missed lung cancer from the posteroanterior chest radiograph. *The British Journal of Radiology*, 77(915), 231-235. doi.org/10.1259/bjr/28883951.
*R2 is a full research paper published in an international journal covering clinical and technical aspects of medical imaging.*

R3. Brennan, P.C., McEntee, M., Evanoff, M., Phillips, P., O'Connor, W.T. & Manning, D.J. (2007). Ambient Lighting: Effect of Illumination on Soft-Copy Viewing of Radiographs of the Wrist. *American Journal of Roentgenology*, 188(2), W177-W180. doi.org/10.2214/AJR.05.2048.
*R3 is a full research paper, with an international author team, published in the official journal of the American Roentgen Ray Society.*

R4. Phillips, P., Boone, D., Mallett, S., Taylor, S. A., Altman, D. G., Manning, D., & Halligan, S. (2013). Method for tracking eye gaze during interpretation of endoluminal 3D CT colonography: technical description and proposed metrics for analysis. *Radiology*, 267(3), 924-931. doi.org/10.1148/radiol.12120062.
*R4 is an original research/technical developments paper published in the most authoritative journal in the field of radiology.*

R5. Plumb, A. A., Fanshawe, T. R., Phillips, P., Mallett, S., Taylor, S. A., Helbren, E., & Halligan, S. (2015). Small polyps at endoluminal CT colonography are often seen but ignored by radiologists. *American Journal of Roentgenology*, 205(4), W424-W431. doi.org/10.2214/AJR.14.14093.
*R5 is a full research paper, published in the official journal of the American Roentgen Ray Society, the first and oldest radiology society in the USA.*

R6. Litchfield, D. and Donovan, T. (2016). Worth a quick look? Initial scene previews can guide eye movements as a function of domain-specific expertise but can also have unforeseen costs. *Journal of Experimental Psychology: Human Perception and Perform*ance, 42(7), 982-984.psycnet.apa.org/doi/10.1037/xhp0000202.
*R6 is a multi-experiment empirical research paper, published in a journal considering studies that increase theoretical understanding of human perception and performance.*

**4. Details of the impact** (indicative maximum 750 words)

**Impact 1: Influencing Guidelines for Clinicians and Medical Physicists**

Our work identifying missed lesions during the visual inspection of CT Colonoscopy (CTC) data forms part of the evidence base for the World Endoscopy Organisation's Consensus Statement (No.81) - (Statement 21, Rutter 2018) on post colonoscopy and post-imaging colorectal cancer (PICR), see S1. PICR is a cancer that has been diagnosed after a CTC in which no cancer was found, and means that the cancer may have potentially been missed at the initial imaging stage. A 20-member international team of clinicians produced the 21 statements that provide worldwide guidance on terminology, identification and analysis of colorectal cancer that some patients develop after negative findings from an examination. The guidelines provide recommendations for clinicians, organisations, researchers, policy makers, and patients. Statement 21 specifically recommends that if a PICRC is diagnosed it is essential that data relating to an impression of the likely nature of the missed lesion, including perceptual/reader error, should be sought. Our work on eye-tracking CTC observers, identifying lesions of varying sizes and the finding that small polyps are often seen but ignored, informs Statement 21 on the quality assurance review for a suspected missed cancer at the initial image interpretation stage (S1).

The American Association of Physicists in Medicine (AAPM) in January 2019 issued revised guidelines for display quality assurance, and our work is part of the evidence base for their new recommendations on ambient light levels. This is in sections 2.3.1.4 and 2.3.1.5, AAPM TG270 (S2). AAPM guidelines are incorporated into many national and international guidelines including the Royal College of Radiologists guidelines on diagnostic display devices. AAPM reports provide the reference standard for medical physicists, in this case for the assessment of display quality for flat-panel displays used in medicine. To make an accurate diagnosis from a medical image, the computer display must be as clear and readable as possible. This readability can be degraded by the amount of ambient light in the room. Our research identifies levels of ambient light that can maximise readability, and that a reporting room with low levels of ambient light may result in errors, such as missed pathology, when reporting medical images on a computer monitor.

**Impact 2: Improving practice for Clinical Practitioners in Diagnostic Imaging**

The first step in changing practice and reducing error rates is making clinicians aware, by using eye tracking for example, of the processes involved in reaching a decision on the presence or absence of pathology and the type of errors made. The research findings, for example, directly impinge on practice by demonstrating to practitioners that missed pathology is typically due to decision making rather than detection (or image quality) errors, with implications for the importance of understanding personal search strategies. Our experience in observer performance studies is also directly relevant for quality assurance (QA) procedures and the choice of equipment in the radiology department.

- Donovan has been an invited speaker at the Royal Marsden Hospital for the Royal Brompton & Harefield NHS Foundation Trust Chest Reporting Study Day in 2014, 2015 and 2016. In total, over the three years 360 clinical practitioners from across the UK have attended (S3). Donovan was invited to the Northern Regional Nuclear Medicine Meeting, for 30 physicists and technicians to talk about the Psychology of Medical Image Perception (23 November 2018) (S4). These events show direct amalgamation of research findings into the continuing professional development (CPD) programme of various NHS Trusts.

- Modern radiographic systems use the exposure index (EI) as a metric of radiation exposure. EI (and therefore patient radiation dose) has traditionally been hard for radiographers to comprehend. Phillips delivered two presentations on the relationship between dose and image quality using modern digital diagnostic systems and displays, at the UK Radiological and Radiation Oncology Congress (2016, 2017) (S5). This is a multidisciplinary meeting with more than 3000 delegates for all professional groups within diagnostic imaging. In addition, Phillips delivered two CPD activities for 18 Diagnostic Radiographers at Blackburn and Burnley hospitals (part of the East Lancashire Hospitals NHS Trust) relating to the new indicators of image quality and patient dose. This has resulted in an improved standard of radiography by radiographers with fewer unnecessary repeat examinations (S6).

**Impact 3: Benefits for the national higher education sector**

Phillips and Donovan deliver a module (MEDN83900 Assessment of Image Quality) on the Higher Specialist Scientist Training (HSST) programme, Medical Physics, University of Manchester, UK, doing so in 2018 and 2019 (2020 postponed due to Covid-19). This is a prestigious five-year workplace-based training programme that provides opportunities for clinical scientists to train to become eligible to apply for available consultant clinical scientist posts, and leads to a professional doctorate (DClinSci). The module has 13 medical physicists each year, with each one working clinically in separate NHS Trusts across the UK, hence extending the reach of their learning. The assignment on the choice of image monitor for image display in the clinical department has specifically influenced physicists when deciding on the type of monitor suitable for displaying the perceptual content of clinical images. Feedback from the module indicates that the physicists found it ‘really interesting and useful’ (S7).

**Impact 4: Influencing Education Standards for Undergraduate Radiography Students**

The research has an impact on the ability of newly qualified radiographers to detect pathology on medical images. In this REF period 428 3rd year radiography students have graduated with the ability to flag up pathology on images of the axial and appendicular skeleton after completing an image interpretation module and assessment. On qualification, radiographers must meet certain standards of proficiency, and their scope of practice can include identifying pathology when working in clinical situations. Our research informed teaching has had an impact on their awareness of the visual and cognitive processes and potential errors in image interpretation (S8), with newly qualified students quickly practising as autonomous professionals. Image interpretation by radiographers is an essential component in the current technological evolution and transformational changes required of today's radiology services, and our research is helping to contribute to these changes (S9).

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

S1. World Endoscopy Organisation’s Expert Working Group ‘Right-Sided Lesions and Interval Cancers’ of the Colorectal Cancer (CRC) Screening Committee (initiated in 2012) on their website at https://www.worldendo.org/about-us/committees/colorectal-cancer-screening/ccs-testpage2-level4/right-sided-lesions-and-interval-colorectal-cancers/. The published Consensus Statement (2018) is available at https://www.worldendo.org/wp-content/uploads/2020/06/CRC_Consensus_Statement_2018.pdf. Our research (R4) is reference no. 81.

S2. Report of the American Association of Physicists in Medicine Task Group 270 on ‘Display Quality Assurance’, Bevins et al, January 2019. https://www.aapm.org/pubs/reports/RPT_270.pdf. The report refers to R3 (Brennan et al. 2017) on page 13.

S3. See programme for Chest Study Day at Royal Brompton & Harefield NHS Foundation Trust Programme 2014, referencing Donovan’s session – ‘Assessment patterns in chest x-ray analysis’. Programme provided as PDF.

S4. See programme for Northern Regional Nuclear Medicine Meeting on 23.11.2018 at Cumberland Hospital, Whitehaven, referencing Donovan’s session – ‘The psychology of medical image perception’. Programme provided as PDF.

S5. Email with audience feedback from the session delivered at the UK Radiological and Radiation Oncology Congress (UKRC) 6-8 June 2016. Sent by the UKRC President on 15.08.2016.

S6. To support claims in improved radiography practice, further details available from Clinical Tutor Radiology Department, East Lancashire Hospitals NHS Trust [Corroborator 1].

S7. To support claims on participant feedback, further details available from HSST Programme Administrator, Medical Physics/Clinical Biomedical Engineering, Faculty of Biology, Medicine and Health, The University of Manchester [Corroborator 2].

S8. To support claims on teaching impact, further details available from Programme Leader BSc Diagnostic Radiography, Medical Sciences, University of Cumbria [Corroborator 3].

S9. To support claims on the research contributing to development of radiography as a profession, further details available from Diagnostic Radiographer and member of Allied Health Professional forum for Scotland, the Scottish Council for the Society, and College of Radiographers [Corroborator 4].