

Institution: University of Sunderland
Unit of Assessment: 11 - Computer Science and Informatics
1. Unit context and structure, research and impact strategy Unit 11, situated within the School of Computer Science in the Faculty of Technology, supports applied computer science research that invigorates the taught curriculum, enhances the student experience, and supports the needs of local industry and society. The unit has a single primary research group (ARC: Applied Research in Computing) that meets on a monthly basis plus regular informal gatherings around themes of interests. The applied research focus calls for pervasively interdisciplinary research that draws on expertise and partnerships. Impact is generated through the close working with partners, an approach that underpins the unit. Expertise developed through original research provides disciplinary inputs to projects, alongside knowledge of leading-edge research. ARC's focus has maximized research activity during the School of Computer Science's considerable reduction in size over the last decade. Existing disciplinary expertise from longstanding research groups in Intelligent Systems, HCI, and Software Engineering now combines with expertise in application areas such as Bioinformatics, Health and Wellbeing, Creative Practices, and Cybersecurity. Partnerships and collaboration within and beyond the University of Sunderland have a multiplier effect, increasing the range, resources, and impact of a relatively small group of researchers. This current focus on applied interdisciplinary research has been an effective strategic response to reduced staff resources for research. In line with this strategic response, each researcher in the school combines expertise in disciplinary areas with experience in application areas. This results in an agile responsive research environment capable of a broad range of collaborations. ARC expertise in application areas is as follows: • Bioinformatics, Health and Wellbeing: Clawson, McDonald, McGarry, Peng, Timmis • Children, Teenagers and Families: Hall • Creative Practices: Bowerman, Cockton, Hall, Jiang. • Cybersecurity: Bowerman, Irons, Jaf, McDonald • Finance/Fintech: Bowerman, Jaf, MacFarlane ARC expertise in disciplinary areas of computer science is as follows: • Data Science/Intelligent Systems/Natural Language processing: Bowerman, Clawson, Jaf, Jiang MacFarlane, McGarry, Peng, Timmis • Education: Irons • Human-Computer Interaction: Cockton, Hall, McDonald, Gandy Disciplinary and application areas provide the capability to meet future research objectives for Computer Science, which are set within a common framework for the Faculty of Technology, aligned with the University Research and Innovation strategy. These objectives are: 1. Continue to deliver sector-leading applied research through extensive interdisciplinary collaboration with strategic external partners and audiences to advance the vitality, significance, reach and relevance of the Faculty's research base. 2. Sustain a dynamic research environment by recruiting, developing, and nurturing researchers at all career stages, from PhD students to professors. 3. Leverage partnerships to develop a range of funding streams in collaboration with SMEs, and public and voluntary sectors, to the benefit of the regional and UK economies, and thus further develop centres of innovation, excellence and collaboration. 4. Deliver impact through the university's strategic focus on sector-leading applied research, innovating collaboratively with external partners and audiences.

5. **Ensure that research contributes to undergraduate and postgraduate programmes** through new research-informed curriculum content and student research opportunities.

These objectives refine earlier ones from 2016 and 2018, which in turn were based on REF2014 objectives for our former Digital Innovation Research Beacon, which had been to:

- **develop academic staff whether early career, established or aspirant** researchers, achieved by investing resources to support staff at all key career transition points through additional time, financial support, and fully funded PhDs (Section 2).
- **target SMEs to engage in research to benefit the regional economy**, achieved through partnerships with regional SMEs funded through many Knowledge Transfer Partnerships (KTPs), frequent consultancy (Section 4 below) and the CREATIVE FUSE project (below).
- **grow research in data science**, supported through appointing a Professor of Data Science (**Peng**, in 2016) and a Senior Lecturer (**McGarry**, in 2018 -- promoted to Associate Professor, 2019). Their research has applied data science to health, strengthening partnerships with City of Sunderland hospitals (**McGarry**) and Public Health England (**Peng**), and providing contextual data for investigation of research challenges. Their outputs underpin the current submission, including an impact case study.
- **feed research into the taught curriculum and involve students in research**: we have ensured that students directly benefit from our research and associated partnerships such as Sunderland Software City (below). Module leaders engage with all 4 quadrants of Healy and Jenkins' research informed teaching model. For example, **McDonald**, Cockton and Irons (2020) integrated students as both participants and researchers in a study of how usability inspection method outcomes might be improved through application of think-aloud protocols.
- **develop student research**, often to a high standard. For example, research by undergraduate students was accepted for presentation at the 2017 BCS Human Computer Interaction conference, chaired by **Hall** and hosted by Sunderland. Master's programme project-module students must now produce an academic paper rather than a dissertation. This has developed further publication opportunities for staff. Research facilities (e.g., usability lab, high-performance computing cluster) are used by undergraduates and taught Master's students (e.g., to conduct user-centred research projects).

In support of its *Impact Strategy*, the University has invested: in tracking software to record evidence of **impact**, training workshops delivered by Professor Mark Reed (Newcastle); and in an Impact Officer, who has advised staff on how to embed impact within individual research projects and applications. She has met all research active and research aspirant staff in this unit to help them to plan for research impact, mostly for REF submissions after 2021. The ability to plan impact activities has been developed via a review exercise that focuses on identification of beneficiaries, stakeholders, and metrics. The exercise guides staff to identify metrics that demonstrate the impact of their research. It also guides them to develop instruments such as questionnaires to quantify impact. The University provides dedicated financial support for impact work.

The unit has a long history of effective engagement with business, government and the third sector. Direct funding from industry and from regional, national, and European sources has supported a quarter century of collaborative research, with application in practical contexts. This engagement spans a range of activities from contract research, collaborative projects, large scale support projects for the digital sector, and bespoke training and consultancy. We have supported our relationships with public sector and industrial partners through the appointment of a number of visiting professors (see Section 2). We continue to develop new ways to engage potential partners and collaborators. For example, recent degree apprenticeships are adding new collaborators and creating new practical research project opportunities that offer new potential pathways to impact.

This broad portfolio of activities with partners and collaborators, with associated access to funding, establishes sustainability and vitality. Impact is achieved in domains such as healthcare, digital government (including privacy), business solutions, media, legal services, Creative-Digital-IT, children, teenagers and families, and education. Much has been enabled by decades of involvement in collaborative networks. The unit contributes to the University's strategic society-shaping mission by making "a positive difference to industry and society through our research, innovation and practice", aligning with national agendas, as reflected in two submitted impact case studies and further impact detailed below.

McGarry's impact case study with City Hospitals Sunderland NHS Foundation Trust, Nottingham University Hospitals and Hampshire Hospital NHS Foundation emerged as a consequence of a visiting professorial appointment in McGarry's previous Faculty, Health Sciences. Kim **Hinshaw**, until recently Director of Research & Innovation at South Tyneside & Sunderland NHS Foundation Trust, introduced McGarry to doctors and physicians who needed support with statistics and modelling. The resulting collaboration led to development of a new multifaceted Disabilities Complexity Scale (DCS). McGarry's expertise in creating medical statistical models has had conceptual, capacity-building, and instrumental impacts that benefit disabled children and young people and their clinicians and families. DCS was validated against existing functional scales. Its use since 2015-16 in Sunderland paediatric disability clinics improved clinical care compliance with NICE autism diagnosis timescales. Since 2019, DCS has been used by GPs and Learning Disability clinicians. DCS's *healthcare* impact spans systematic identification of multi-faceted needs, more accurate calculation of NHS funding, increased capacity within specialist pediatric disability (three new clinical posts, need evidenced by DCS), improved clinical care and service design, and improved transition between paediatric and adult services.

McDonald's impact case study originates in a work-based MSc double module on User Experience that was developed in 2007 by **McDonald** and **Cockton** for Sage, a Newcastle FTSE-100 software company. Content from this module was repurposed and updated by Tingting Zhao (PhD 2012, supervised by McDonald) when she was a Senior User Researcher in the Cabinet Digital Office. Zhao's PhD research on improved think-aloud methods for usability testing provided important innovative content for this update. The training courses that Zhao ran for UK *digital government* gave attendees practical experience in applying her PhD research with McDonald. As a result, the underpinning research on improved think-aloud methods has directly influenced practices at the Home Office and the Government Digital Service (GDS). Practitioners who attended Zhao's training course have changed their user testing practices, which has improved the quality of the 3,000 most-visited pages on GOV.UK (11-14M visits per month), the GOV.UK search function, and the publishing tools used to update GOV.UK. In addition to this impact on *digital government processes*, Zhao's *healthcare* work with *creative digital* design agencies had positive impact on all Wellcome Trust's websites (including the Wellcome Collection, 0.25M visits per month), and the Sanger Institute (0.27M visits per month). Most recently, Habito, an online mortgage broker, improved their *business solutions* when Zhao updated their user testing practices.

In addition to the two submitted case studies, there has been extensive impact via KTPs, Innovate UK projects, the CREATIVE FUSE project (below), and industry funded projects. KTPs have been especially important for developing ECRs' understandings of pathways to impact as part of their development. In addition, researchers benefit from new datasets and software architectures for future research. **Peng** and **Clawson** developed and managed a *healthcare* KTP for *Rokshaw*, focusing on data driven intelligence for enhanced manufacture of special medications, which are personalized formulations manufactured on demand for patients with unique prescription requirements. They are increasingly in demand through need for personalised precision medicine. *Rokshaw* could only produce products after an order was received on the day. The KTP developed a cloud-based, data driven medical formulation engine (MFE) using natural language processing, deep learning, and semantic search technology. The novel NLP pipeline combined deep feature extraction with one-class support vector machine learning. *Rokshaw* were able to perform enhanced literature searches, increase shelf lives of

over 1000 products, and manufacture more than 50% of orders in advance with little wastage, thus increasing efficiencies and capacity.

Research by **Timmis** has also resulted in *healthcare* impact through the formation of a company in 2014, Simomics Ltd, that has gone on to launch the Reason product, which is used by a major personal care company to support risk assessment, and also to risk assessment tools that are now being developed as part of a major Innovative Medicines Initiative (IMI) funded by the EU working with 12 leading pharmaceutical companies.

Bowerman and **MacFarlane** are working on a *business solutions* KTP with *Proforecast* to extend financial forecasting services (balance sheet with profit and loss forecasting, cash flow, report generation) through deep machine learning driven models that help companies to manage cashflow and to decide on prospective investment, expansion, and sustainability. *Proforecast* have benefitted from a new forecasting module within their commercial suite of services resulting in a smoother, faster, more streamlined reporting process. They have installed faster servers to meet computational AI needs in line with increased demand.

Jaf's project with regional company *ProcurSmart* built on his research to develop an AI solution for procurement document classification, as part of an ERDF funded project (GX08) as part of the Newcastle-Gateshead initiative. *ProcurSmart* has adopted an AI solution to automate procurement document classification. **Jaf's business solutions** KTP on Smart Procurement and his Innovate UK project with *Distinctive Publishing* (in collaboration with Durham University) have resulted in competitive edge in the market. Distinctive publishing expanded its operation with a new branch to utilize products developed during the KTP.

As well as impact with businesses, healthcare and government, the unit's research has influenced *educational curricula*. **McDonald** and **Hall** were part of the trail blazer group for the development of the standard for a User Experience Digital degree apprentice standard.

Within our significant regional anchor institution, local impact is based on long-lived *collaborative networks* through an unbroken chain of local and regional projects and organizations over two decades: *Digital Media Network* (1999-2003, directed by **Cockton** and **Hall**), *CODEWORKS* (2003-2012, initial CODEWORKS NITRO regional university support directed by **Cockton**, with significant support for SMEs/startups from **Hall** and **McDonald**), *Digital Knowledge Exchange* 2006-2008 (HEFCE CoKE project, Sunderland lead **Cockton**), *Sunderland Software City* (2006 onwards, initial support and direction from **MacIntyre** as Dean and **Hall**, and during this REF period from **MacIntyre**, now PVC, and **Irons** as Dean), and industry led regional *Dynamo* network (2012 onwards, founding board member **Irons** - the unit hosted the 2015 and 2017 Dynamo conferences). Together, these projects and organizations have kept the School of Computer Science at the heart of regional support for the software sector.

Sunderland Software City (SSC) was a focus of a REF 2014 impact case study. Since then, **Hall** developed SSC activities and led on KTP projects related to Sunderland Software City, involving more than 20 academic staff, and generating over £600k research income. SSC Chief Executive David Dunn based his 2016 University of Sunderland Professional Doctorate on resource requirements and impact of Sunderland Software City and related regional projects. His thesis identified close local links between industry and education, including research, as important to the success of the software cluster. His Professional Doctorate is one example of the unit's continued support for Sunderland Software City (www.sunderlandsoftwarecity.com).

Hall is Institutional Lead and Co-Investigator in CREATIVE FUSE, a collaborative project across five regional universities (Newcastle, Durham, Northumbria, Sunderland, and Teesside) focused on research-led growth in the *Creative-Digital-IT* (CDIT) industries of the North East England region and funded by AHRC, ERDF and the Arts Council. CREATIVE FUSE explores the economic and innovation value of the CDIT sector in the region, and delivers direct engagement with creatives, freelancers, and SMEs in the sector, identifying opportunities for innovation, growth and cross-sector collaboration with other industries and the wider economy. CREATIVE

FUSE's purpose is to identify how the region's CDIT sector can grow and contribute greater impact for the regional economy and facilitate growth in other sectors.

Sunderland's interdisciplinary applied approach and expertise has been most effective in CREATIVE FUSE, with input from HCI (**Hall, McDonald**), Artificial Intelligence (**Bowerman**) and Data Science (**Peng**). Several *creative companies* (including software service and hardware companies) have benefitted from collaborations within Creative Fuse. Innovation Pilots funded by Creative Fuse have delivered value to industry beneficiaries. For example, in the words of its director, **Bowerman's** support for *Wordnerds*, a local Data Science and AI SME, "accelerated Wordnerds' product immeasurably ... at the end of the project, the team have delivered... a proof of concept of something we didn't even think possible at the outset of project." Similarly, **Peng** collaborated on an Innovation pilot to support *Shoes2Run* in their development of a novel wearable technology sock. An AI algorithm was developed and tested, providing support for evidenced claims for the product for when it is taken to market. **Hall** worked with Jupiter Artland sculpture park on mixed reality experiences of places for children's working. Her Evaluation workshop led to Jupiter Artland changing their approach to audience evaluation from a questionnaire to a single question.

Worth-focused design approaches developed during **Cockton's** NESTA fellowship on value-centred design (2005-2008, with publications to 2009) have continued to be disseminated during the current REF period through courses at major HCI conferences (NordiCHI 2014 and 2016, CHI 2016 to 2019 inclusive), and courses for postgraduates across Europe. Publications and courses have led to worth-focused approaches being used for innovative *business solutions* in France (Orange: Family Pack app and services; Colibri: Viseo planning product), in-house developments in Finland (Finnish Golf Union), business development in the Netherlands (support for a creative entrepreneur) and for current *national digital policy work* in Germany (*Privacy by Design* programme). All have benefitted from Cockton's novel concurrent design methodologies for strategic creative innovation.

The unit's HCI and AI research is inherently **interdisciplinary**, with collaborations within areas such as creative technologies, healthcare, and cybersecurity. These collaborations have always underpinned the sustainability and viability of the unit's research by providing access to funding, data, collaborators, systems infrastructure, and practical challenges that require advanced research approaches and have led to foundational contributions to computing, such as **Cockton's** interdisciplinary research on evaluation methods that has been continued by **McDonald**.

Hall's work on multi-setting evaluation approaches with *children, teenagers, and families*, includes collaboration with the Jupiter Artland sculpture park (above). Before this, her EU funded EMOTE project supported children's learning through interaction with empathic robot tutors. Her *Technological Family* project explored the future of technology in the home and family. It combined Rapid Evidence Assessment, expert interviews, a Delphi study, parents' questionnaires, and workshops involving over 130 teenagers. More recently, her SMART project (Google Digital News Innovation funding) with **Jaf, MacFarlane** and Price (Journalism), combines journalism research with HCI, AI and Data Science to track and visualise real-time and historical trends in social media to pick up abuse, trolling, and more general behaviour patterns. A SMART app is being developed for journalists to explore how social media can be used more effectively to support stories and news, and to investigate and report stories about abuse and hate speech on social media. Hall's KTP with *Quantum Law* has also added *legal services* to the mix of application areas, with the Associate on this project pursuing a PhD and publishing. Other KTP projects apply research for a Utilities' supplier (Start Energy), digital marketing (Brown, Beer, Nixon, and Mallon), print quality (Imprint Wearables), and portable air sampling (Franks Portlock). CREATIVE FUSE sponsored and supported a creative track at the 2017 BCS-HCI conference, directed by **Hall**, that focused on the intersection between HCI and the creative sector. CREATIVE FUSE collaborations between Computer Science and New Media, and across diverse sectors from freelancers to large corporates and the public sector, have added a new interdisciplinary area to applied research (complemented by **Cockton** since his return).

Overall, Hall's interdisciplinary applied research has supported applications in law, culture, and media.

Timmis' work on computational modelling involves working with both clinical and experimental immunologists, to help reduce, refine, and replace animals in research. One focus has been on disease areas of Leishmania, producing a virtual laboratory to reduce and refine animal experimentation. The simulations replaced the use of animals in one set of studies to investigate monotherapy treatments, which would have taken three years and used over 3,500 animals. The best hits from the model output were validated using just 62 mice within a matter of days.

A further example of interdisciplinary research is **McGarry's** support for the late Prof Roz Anderson as bioinformatics and statistical advisor to her PhD student Jill Jobson (PhD awarded in 2015), who was funded by the Cystinosis Foundation Charity. McGarry supported exploratory proteomic investigation of cystinotic fibroblasts and proximal tubule epithelial cells using SILAC with his guidance and support on data pre-processing and cleansing, calculating summary statistics, post processing t-tests, and data visualization. The latter gave more visual prominence to significant proteins.

Jaf has applied his research on advanced machine learning algorithms (deep learning) to many natural language tasks, including language syntax processing, automated text generation, language identification, and natural language inference. He has also contributed to cybersecurity in the areas of intrusion detection, advanced persistent threats, and botnet detection. Lastly, **Bowerman** has applied his research in Data Science, AI, Natural Language Processing, and Machine learning/deep learning to cybersecurity (fraud and terrorism detection), financial projection, health informatics, social network analysis, and marketing.

As required for an **open research environment**, the University's 2015 *open access mandate* requires all authors to deposit final peer-reviewed manuscripts, where this is permitted by the publisher, to our open access repository (SURE) within 3 months of acceptance for publication. Our strategy is to encourage authors to submit articles to Journals with Green Open Access routes. Where funded projects maintain a website, this enhances the accessibility of the unit's research. Computing research active staff now follow a policy of sharing code for reuse on fora such as GitHub.

A key aspect of **research integrity** is for all research projects to be compliant with institutional commitments to the *Research Integrity Concordat*. **McDonald** served as the ethics representative for the greater part of this REF census period and has been involved in assessing individual applications. The University has invested in an online submission system (*epiGenesys*) to support staff through a single approval process, with access to legacy data on approvals and submissions. Ethics training is provided to all staff and research students via the University's staff development programme.

2. People

The School of Computer Science is committed to developing and promoting existing staff (**Bowerman, Hall, McDonald, McGarry**). Commercial and consultation activities are supported through work loading, e.g., time allocated for KTPs and other externally funded work. The appraisal process also directs staff to engage in external work. An annual university research conference provides further support along with a new Professoriate forum. Both facilitate knowledge exchange and interdisciplinary opportunities.

Since REF2014 the host Faculty for unit 11 has seen significant changes in both staffing and structure. Our strategy has been to replace some departing research leaders through internal promotion to professor (**Bowerman, Hall, McDonald**). **McGarry** joined us from the Faculty of Health and Wellbeing as a senior lecturer and was promoted to Associate Professor. To achieve the first REF 2014 Objective, the unit has also made external appointments at both senior and early career levels: **Peng** was recruited as Professor of Data Science in 2016. His appointment was followed by further four appointments. Of these **Jaf**, an ECR appointment (2019) has

submitted outputs. The other three have been focused on teaching, with external collaborations as a route to developing high quality research bids and publications (**Clawson, MacFarlane, Jian**).

In May 2019 **Timmis** was appointed as Deputy Vice Chancellor (Commercial). Following Peng's departure in March 2020, Timmis has contributed research leadership in Artificial Intelligence and applied health computing. **Timmis** is leading technology development in a spin-out he co-founded, Simomics Ltd, working with leading pharmaceutical companies such as AstraZeneca. He also leads work on intelligent robotics in EPSRC funded collaborations across the UK. Also, **Cockton** returned to Sunderland on a fractional contract in April 2019. His publications since include two books, a PACM EICS paper, an invited JUS essay and book chapter, five ACM Interactions issues (as Co-Editor-in-Chief), and a CHI course, panel, and workshop papers. He has rejoined **McDonald** on evaluation method research (building on Woolrych's 2012 PhD jointly supervised by **Cockton** and **McDonald**). His two books have advanced worth-focused approaches initially developed from 2004 to 2009, through a creative and strategic design context that he developed at Northumbria University's School of Design.

The profile of returned staff is thus 77% F1 (**Bowerman, Cockton, Hall, Irons, McDonald, Peng** and **Timmis**), 11% IO (**McGarry**), and 11% J0 (**Jaf**). Jaf is an ECR (13% of active submitted staff). They are supported by the University's Visiting Professor and Fellow scheme. Six Visiting Professors extend the unit's range of partnerships, develop 'critical mass' in line with University strategy, and support teaching and research through their expertise, experience and access to partner organizations. Russell **May** (4n6 Investigation and Training, Computer and Network Forensics) has presented school research seminars and master classes and weeklong programmes to students; Dr Adrian **Davis** (International Information System Security Certification Consortium, (ISC)²) has supported teaching and the unit's relationship with (ISC)²; Stuart **Lynn** (former Executive Vice President and Chief Product Officer, Sage) chairs the Faculty Industrial Advisory Board and has provided a range of support, including input to strategy on Fintech; Simon **Roberson** (former Regional Partnership Director North East, BT) provides support as a board member of Dynamo, industry-led regional network for digital industries; Giselle **Stewart** OBE (Director of UK Corporate Affairs, Ubisoft) is Vice-Chair of Dynamo and has guided development of degree apprenticeships as a pathway to impact; and Anne-Marie **Imafidon** MBE (CEO Stemettes) has engaged School researchers in Stemette activities, represented the Faculty and University at a number of DYNAMO events and gave an Institute of Coding 2020 keynote as a University of Sunderland, which promoted the Faculty's equality and diversity agenda.

In line with the University's Research and Innovation strategy (2017), the unit supports staff through the allocation of additional research time, purchase of equipment and travel to national and international conferences through a annual *Individual Research Plan* (IRP) commencing 2017/18. This is linked to yearly appraisals and staff development initiatives. IRPs are part of the university's transition to comprehensive, institution-level planning and resource allocation for research. The IRP process asks staff to: identify their yearly research goals during appraisal; link them to university objectives; and request resources (time, training, equipment, travel, PhD registration) to fulfil those goals. Since IRP inception in 2017 the unit has increased funding to research active staff to £20,250, supporting personal travel and small equipment purchases. Investment has increased year on year as research staff become familiar with the process (2017/18: £3700; 2018/19 £8049; 2019/2020: £8500). This financial support has been supplemented with additional workload allocations to staff through the university's framework for academic work loading, each equating to c.150 hours per year. There have been seven such allocations since 2017, with the university providing £27,000 of support for staff time to the unit.

Researcher development training is provided centrally, often seeding collaborations across the university. Courses include "How to be an effective researcher" and the "Principal Investigator development programme". The University has also collaborated with Northumbria and Teesside universities to develop and pilot a HE Leadership Foundation funded programme "Leading on Research Excellence" for Readers and Professors across the region. **Hall** and **McDonald**

attended this programme before their promotion to professor in 2016 and 2019 respectively.

In addition to the IRP process and training, we follow the University's inclusive approach spanning established and developing researchers:

New colleagues are allocated a research mentor who provides one-to-one support ensuring that new colleagues have access to relevant training opportunities (e.g., grant writing workshops, training in PhD supervision). We seek to integrate new colleagues into existing research structures, for example PhD supervision teams to help them establish their own research profile. For example, **Cockton** has provided research development support for **Jaf. Peng** and **Bowerman** have mentored **Clawson**. **Hall** is mentoring an ECR, **McFarlane** in her KTP work, and in line with the interdisciplinary focus of research in this unit, also providing interdisciplinary mentoring of ECR and mid-career staff elsewhere in the university.

Existing, research aspirant, student facing staff are offered mentorship support from the professoriate, waiver of fees for part-time PhD study, and involvement in colleagues' research. For example, **Gandy**, a senior lecturer with 18 years' teaching experience, registered for a PhD supervised by **McDonald**, on a part-time basis, and is now publishing. Experienced professionals who are not active researchers currently make important contributions to partnerships for research active colleagues.

Staff seeking promotion through high quality research are supported to develop a career path to Associate/Professor positions. The review framework for promotion is transparent, audited (including regular Equality Impact Assessments) and subjected to external review. Colleagues pursuing merit-based promotion to Associate Professor or Professor can access a mentor and workshop support from previous successful candidates in developing applications. For example, **McGarry** (mentored by **McDonald**) was promoted to Associate Professor in 2019. **Hall** mentors **Clawson**, who has now successfully developed her work and is submitting to high impact journals and leading on funding bids with local healthcare trusts.

Contracts were reviewed for Professors and Associate Professors in 2019 as part of the university's ongoing strategy to better support research. To ensure these staff have the necessary time for research activity, face-to-face teaching hours are capped at no more than 10% of work-loaded activity without the need to bid for research hours through the university's IRP process. This follows recent changes to the University's leadership.

Equality and Diversity considerations in relation to recruitment, promotion, and research support are monitored by the Faculty Senior Management Team and Athena Swan Self-Assessment team chaired by **McDonald**. The Faculty recently became a signatory of the Tech Talent Charter which seeks to drive greater inclusion and diversity in the technology sector and is pursuing Athena Swan bronze level recognition with a bid being submitted in 2021. We have supported individuals with protected characteristics to undertake research. For example, by purchasing equipment and providing additional time for **Gandy** (an ECR with limited mobility) to undertake her research on computer-based detection of horse-rider asymmetry.

The output profile reflects a good balance of E&D characteristics with 6 (35%) outputs associated with female staff and 2 (12%) from staff of non-Caucasian ethnicity. Also, there is an even male-female split for promotions within this REF period.

Alongside externally funded students, recruitment of **doctoral students** has focused on development of home-grown talent, establishing an effective pipeline from our undergraduate and taught master's programmes to MPhil and PhD. Current research student ambassadors in the unit support Faculty recruitment by presenting their work to undergraduate and taught postgraduate students. Fully funded studentships are available for suitable applicants. In line with the applied interdisciplinary focus of research in this unit, **Hall**, **Irons**, **McDonald** and **McGarry** co-supervise PhD students from other UoAs.

The unit's Research Student Manager **McGarry** oversees end-to-end management of research students. Staff student liaison committees are held each term and the unit has a PGR representative from the student body. Once registered, doctoral students have an annual monitoring review each year from month 9 of year one.

PhD students, in collaboration with their director of studies, are required to complete a personal development plan. Training workshops such as preparing to teach are offered to all students and we provide students with the opportunity to support module delivery to gain teaching experience. We encourage students to apply for recognition as Associate Fellow (Higher Education Academy) and have several students recognised at this level (Willis, Balloochzadeh, Button). PhD students are encouraged to submit to doctoral consortia, and have been accepted e.g., at the British HCI conference.

The university organises Research Fridays for PGRs at Institutional level, which **Hall** started and ran successfully for 3 years until 2016. In addition, the university's Graduate Research Support Office created hubs at three campus locations as social spaces where they can also work alongside each other. Computing PGRs benefit from the hub on St. Peter's Campus, which brings them together as a cohort, promotes peer support, strengthens PGR research culture, and stimulates cross fertilisation of inter-disciplinary ideas. Post-docs and PGRS are also invited to the biennial university research conference, professorial lectures, and faculty seminars.

PGR research skills development is provided through the institution's Virtual Learning Environment with courses designed to support processes and the research degree – for example literature review processes, presentation and performance skills, ICT skills. Different workshop sessions are offered in a block teaching mode. A four-day induction programme is provided, which facilitates networking. Students can also access relevant modules on Masters programmes. The Graduate Research School provide several courses tailored to the students' year of study. For example, **McDonald** organises a Getting Published workshop for mid-stage students and another course prepares students for their viva. A training repository is provided via the institutional learning environment. Our subject specialist librarian offers a research buddy programme to support research students with literature searches and additional training courses e.g. How to get published with IEEE led by Ed Wong.

We have an ethnically diverse group of PhD students and our promotional material has a gender positive focus. We have supported our female doctoral students to attend events such as the Hopper Colloquium which features women speakers presenting their research. Two students Balloochzadeh (2014) and Willis (2015) were finalists for the Colloquium's spotlight on research competition.

The University's performance in the Postgraduate Research Experience Survey (PRES) placed it 2/63 institutions in 2018 and 11/103 in 2019.

3. Income, infrastructure and facilities

In alignment with the university focus on applied research, grounded in three decades of computing research that has engaged extensively with the private, public and third sector, research income for this unit is primarily from funders of collaborative research projects.

These include 11 Knowledge Transfer Partnerships funded by Innovate UK (PIs: **Hall** – 5; **Irons**; **McDonald**; **Peng** – 2; **Irving**; and **Edwards**), with further KTP work subcontracted from Durham University (**Jaf**). KTPs support research in several ways, including funding from the KTP with Quantum Law for the Associate's PhD. Company contributions complement the Innovate UK funding (e.g., Cellular Solutions, Momenta).

A good proportion of research funding comes from highly competitive sources. **Timmis** has three current EPSRC projects. CREATIVE FUSE Phase 1 was funded by the Arts and Humanities Research Council, the European Regional Development Fund, and Arts Council England's Local Growth Fund. Phase 2 (to 2022/23) is funded by the Arts and Humanities

Research Council and the European Regional Development Fund. CREATIVE FUSE funded 12 collaborative projects at Sunderland, with 5 in this unit of assessment. These included a £25000 project with *Wordnerds* (Bowerman), one with *Shoes2Run* (Peng, £5000), one with Southpaw Dance (Hall, £5000), and one involving ECR **Jiang** (*AdaBee*, £5000, a robot for teaching coding). As with KTPs, these small projects have provided researcher development opportunities for ECRs such as Jiang. **Hall** was also a consortium partner in an EU funded research project (EMOTE).

Other funders include Public Health England (**Peng**), Google (**Hall**), Huawei (**Hall**), Northern Health Science Alliance (**Bowerman**) and the Higher Education Academy (**Irons**, NTF scheme). Hall's *Technological Family* project was in partnership with Internet Matters and funded by Huawei. Her SMART project is funded by the Google Digital News Innovation scheme. In all cases, attracting partners and funding is due to the sustained practical impact of the unit's research. Creative FUSE collaborations have enabled successful research bids, e.g., with Google (**Bowerman**, **Hall**, **MacFarlane**) and a KTP with Proforecast (**Bowerman**), a company founded in 2014 that moved to the Sunderland Software Centre in 2019. In addition to regional collaborations, international ones include **Cockton's** role as an international expert in the Academy of Finland ETAIROS project (Ethical AI for the Governance of the Society), his third collaboration with a Finnish national project that draws on his past NESTA fellowship work at Sunderland. **Timmis** worked extensively with DSTL through funded grants and PhD students, developing robotic mounted, anomaly detection systems used to identify potential roadside chemical-based threats. Work with AstraZeneca (AZ), led by Timmis, formed underpinning technology to accelerate the development of virtual laboratory technology for Simomics Ltd, leading to EU funding for Simomics and AZ and a successful series A funding round to grow the company to at least 30 people by 2022.

The overall strategy is to focus on funding for collaborative projects that leverage the unit's track record of applied research supported by prior foundational research. The approach of the unit's single Applied Research in Computing (ARC) group here is distinctive and has supported both submitted impact case studies, as well as further impact described in Section 1 above. The university's IRP process (Section 2 above) provides the necessary investment in the foundational and exploratory research that underpins the unit's collaborative projects. University support for research and impact comes from the Research Office (within the Enterprise and Innovation Directorate) supported by the Research and Innovation Group, a committee of Academic Board.

In line with the University's strategy, common use is made of a shared infrastructure for research, collaborative outreach, and teaching. Applied research in this unit does not require use of major research facilities in the UK or overseas. These are supported by faculty-based facilities and technical staff, university support for impact activities and partnership-based grant writing, IT infrastructure and support, and the university library (for journal subscriptions, inter library loans and book purchases). ARC researchers have access to Augmented Reality and Virtual Reality facilities in the university's Industry Centre. In addition, a total investment of around £200,000 has been made in local resources within the Faculty of Technology. This includes: investment in infrastructure changes since 2014 (total value around £40,000); a Dell R920 multicore server plus SMART GPU processing server used for data science (£26,000 - **Peng**, **Jaf**, **McGarry**); an Eye tracking lab with related user testing hardware (move to new room £10,000 - **McDonald**, **Cockton**); a Games Lab (£50,000 - PS4's, VR devices, specialised PCs - **Jiang**); a networking lab with specialised PCs and CISCO equipment (£50,000); a Forensics/Cyber Security lab (£20,000 - **Irons**); specialist setups for individual research projects (e.g., Meta2 AR headset; Raspberry Pis for **Gandy's** PhD on posture support for disabled riders, plus further PCs, CISCO networking kit for other projects). **McGarry's** and **McDonald's** impact case studies were supported by specific specialist facilities for their research within the Faculty. Tingting Zhao's PhD with **McDonald** made extensive use of an existing usability laboratory. The underpinning research for McGarry's ICS was supported by a university Digital Beacon grant for hardware (laptop) and travel (Value £3,000).

The predominance of collaborative applied research projects brings many benefits in kind, including access to collaborators' expertise, networks, data, sites, and facilities, and is one of the primary origins of the unit's visiting professors. **Gandy's** research is in partnership with the *Riding for the Disabled Association*. McGarry's impact case study benefitted from access to healthcare data and application contexts.

4. Collaboration and contribution to the research base, economy and society

We have research collaborations within the UK, Europe, Africa, Asia and the Middle East. **Hall's** EU funded projects complement her collaborations with north eastern universities. For example, EMOTE (2012-16) partners spanned the UK, Germany, Portugal, and Sweden. **Jaf** collaborates with researchers in Durham, Czech Republic, Dubai, Iraq, Pakistan, and China. **Bowerman** collaborates with researchers in Abu Dhabi and India. **Irons** has twice been a visiting scholar at the University of Cape Town. **Peng** set up a Joint Lab for Research and Innovation in Data Science (JLRI-DS) with Sichuan University China, with funding from the China Scholarship Council and British Council. **Cockton** continued collaborations from the 2009-2013 COST TwinTide action in work on agile practices with researchers in Iceland, Poland, and Sweden, resulting in a submitted output. **Timmis** has active collaborations in York, Bristol, Sheffield, Surrey and Napier, as well as overseas in The Free University Amsterdam and The University of Sydney.

The unit continues to engage with a broad range of communities and publics. Within the North East region, **Irons** is a member of the boards of DYNAMO (from 2013) and the North East Fraud Forum (from 2004), Elected Chair, BCS North East Branch (from March 2016), and was a member of Digital Leaders North East Advisory Board (2013 – 2017) and chair of the BCS Cybercrime Special Interest Group (2015 – 2018). He is also a Trustee of the North East Futures University Technical College (from September 2018). **Bowerman** is a member of the regional steering board Satellite Catapult. **Hall's** work within CREATIVE FUSE engaged with regional creative and digital companies in over 30 interdisciplinary innovation pilot projects alongside a wider and aligned innovation support programme and enabled a growing network of over 1000 local stakeholders through over 30 'CAKE' (Collaboration and Knowledge Exchange) events. CREATIVE FUSE has also supported industry support activities at Sunderland Software City. Its creative track at BCS HCI 2017 included a Digital Make-Believe Hackathon in the University's FabLab. The winning team received seed funding and the event was disseminated through a hackumentary.

Hall's EMOTE project was selected as one of 5 exemplary projects showcased in the Lisbon ICT 2015 Pavilion by the European Commission, resulting in engagement with policy makers, EU Commissioners, SMEs, researchers, and the general public, with over 7500 people visiting our exhibit, along with significant television and press coverage. **Hall** led the Dissemination and Exploitation work package, resulting in significant coverage in the press and TV in the UK, Portugal, Sweden, and Germany (2015-16). There have been articles in the Huffington Post and local press related to twitter analysis related to Meghan Markle from the SMART project and **Hall** was interviewed on her research into sex with robots reported in a Czechoslovakian publication in 2019. **Hall's** research into academic-industry engagement was highlighted by the Times Higher (Academics shun engagement with industry, January 12th 2016) followed by an interview on the challenges of engaging academics in external engagement (Big drop in academics commercialising their research, February 25th 2016).

An important partnership for the unit is the Institute of Coding (IOC), a UK national programme which brings together members from industry, HEIs (England and Wales only) and outreach partners to bridge the digital skills gap. As well as the design of new courses such as the MSc Apprenticeship in Digital and Technology Solutions, the IOC has enabled the development and delivery of CPD and taster short courses (Coding, Cyber Skills and Data Science) for staff, students and industry with events aimed at bridging the skills gap between students / graduates and industry such as Digital Bootcamps. **Peng** delivered a data analytics workshop with over 30 SMEs and contributed to the development of a series of short courses in data analytics. **Jaf** developed a short course (June 2019) as an introduction to Machine Learning. The institute has also supported the academics **McGarry** and **McDonald** in identifying partners for a UKRI bid.

Bowerman, Irons and **Clawson** have been involved in Great North Care Record (GNCR) discussions around developing a regional trusted research environment for hosting clinical data and facilitating patient-facing service enhancement via collaborative applied research activity. GNCR is a way of sharing patient information and involves universities and health/social care organisations in the North East and Cumbria (spanning an overall population of 3.6m). One aim of GNCR is to establish a shared trusted research environment (TRE - specifically a secure, ISO certified and NHS approved repository) to receive health and other key data. **Clawson** is a Steering Group Member for the GNCR TRE and is presently involved in scoping a project with Sunderland City Hospital.

Timmis has provided consultancy on mathematical modelling of immune reactions for a major multinational personal care company. **Cockton's** courses have engaged with researchers, students and professionals in Reykjavik, Eindhoven, Helsinki, Gothenburg, Jyväskylä, California, Colorado, Montreal, and Glasgow, and through invited keynote addresses (below). He has developed relationships with key research users and professional beneficiaries through social media, conference courses, PhD summer schools and postgraduate teaching (1-3 per year 2014-2019). His research has integrated creative and strategic practices from design and business into software development and has been influential across a range of business and public organisations (e.g., design agencies, consultants, in-house teams), who have applied his approaches to structuring, tracking, and planning design work.

Irons is Chair of the British Computer Society (BCS) Academy Board and Vice President of BCS (from 2020, Member of BCS Academy Board 2014 – 2017). **Peng** is Chair of IEEE Big Data Taskforce for Computational Intelligence Society, a founding member of the Technical Committee on Big Data of IEEE Communications Society and IEEE Special Interest Group (SIG) on Big Data for Healthcare and Medicine, and an advisory board member for the IEEE SIG on Big Data for Cyber Security and Privacy. **Timmis** is a Board Member (from 2018) of the National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs Part of Medical Research Council), and NC3R's Crack-IT Chair (from 2019).

Timmis had a Royal Society-Wolfson Research Merit Award (2011-2016) and a Royal Academy of Engineering Enterprise Fellowship (2015 – 2016). He is Distinguished Visiting Professor at Fudan University, Shanghai, China and Visiting Professor at the University of York, UK. He has undertaken extensive public engagement including talks at the Edinburgh Fringe Festival in 2013, Edinburgh Science Festival in 2015, The Royal Society Summer Science Exhibition (schools talks) in 2014 and 2015 and The Royal Society Lates Event in 2015. In 2015, Timmis was technical chair of the European Conference on Artificial Life. **Timmis** reviews for a number of IEEE Transactions journals, Nature and Frontiers family of journals.

Hall chaired the 31st British Human Computer Interaction Conference in July 2017 (hosted at Sunderland). She is Secretary of the BCS interactions SIG and was CHI 2019 Sponsorship Chair.

Cockton is an ACM Distinguished Speaker, and a recipient of the 2020 ACM SIGCHI Lifetime Service Award. He is on the Editorial Boards of the Quality and User Experience journal and two Springer International Series (HCI, Design Research Foundations). He was Co-Editor-in-Chief of ACM Interactions magazine (2016-2020), and a BCS Advisory Board representative for selection of a new Editor-in-Chief for the BCS Interacting with Computers journal (of which he is an Editor Emeritus). He is a founding member of the Editorial Board of the Journal of Usability Studies. He has presented invited keynotes to ACM EICS 2017 (Portugal), WUD 2018 (Armenia) and WUD 2019 (Estonia).

Hall was an invited keynote speaker at BCS-HCI 2018 and at the RIDERS Storytelling Workshop at the University of Sheffield in 2016. She has reviewed evaluated proposals for EPSRC, HEA, Cyprus Research Agency and EU Horizon 2020, and has been an expert reviewer for EU FP7 projects. Hall is on the editorial board for Transactions on Edutainment

(Springer) and the International Journal of Technology Enhanced Learning. **Hall** has also reviewed for journals such as IEEE Transactions on Human-Machine Systems, Intelligent Systems; Applied Artificial Intelligence, Interacting with Computers, Interaction Studies, ACM ToCHI, Virtual Reality, Cognition, Technology and Work, AI & Society, Porn Studies, IEEE Transactions on Affective Computing, and for conferences including CHI, INTERACT, ACHI, British HCI, India HCI, Intelligent Virtual Agents.

McDonald has reviewed for CHI; BCS-HCI2017; Interacting with Computers; ACM ToCHI; Behaviour and Information Technology; and Journal of Software and Technology. She was invited to be panel member for Innovate UK Health competition in 2015. **Jaf** has reviewed for a broad range of AI conferences and journals. **Peng** is an Associate Editor for IEEE Transactions on Big Data, IEEE Access (special section Data-enabled Intelligence 2019. Human-Centered Smart Systems and Technologies 2018) and co-guest editor of Journal of Applied Science (MDPI) on “Recent Developments in Smart Healthcare” (2019) and Journal of Applied Systems Innovation on “Healthcare System Innovation” (2018).

McGarry has reviewed proposals for BBSRC Tools & Resources fund, EPSRC, MRC grants, NIHR grants, Diabetes UK, and the Israeli Ministry of Science and Technology. **Timmis** is a panel member for The Royal Society Partnership Grants and fellowships (from 2014) and for Royal Academy of Engineering Enterprise Fellowships (2018). **Timmis** and **Cockton** are EPSRC peer review college members. **Timmis** reviews for the EPSRC, BBSRC, MRC, NC3Rs, NSF and EU and is on the editorial board for journal Theoretical Computer Science and reviews papers for Nature, Science, various IEEE Transactions journals, amongst others. **Cockton** has reviewed proposals for ERC, EPSRC and Belgian (FWO) and French (ANR) research bodies. He has been a referee for ACM Awards (CHI Academy, ACM-W Rising Star), served on the programme board/committee of ACM PACM EICS and RoCHI (Romania), and reviewed for a broad range of HCI, Design and Computing journals and conferences.

McDonald, **Timmis** and **Cockton** have also served as external examiners for PhDs. **McDonald** has been an examiner for Aalto University and for two UK universities (Teesside, Kingston). **Timmis** has examined several PhDs during the review period, including Durham, Kent, Aberystwyth (x2), Cambridge, Sheffield (x2), Queens, Loughborough, Herriot-Watt in the UK, and in New Zealand (Auckland) and Australia (Sydney). **Cockton** has twice been a public opponent in Finland during the current REF period (Jyväskylä, Tampere) and an external examiner in Belgium (Hasselt), France (Grenoble, thesis in French), the Netherlands (TU Eindhoven) and Sweden (Stockholm), as well as for five UK universities (UCL, City, Teesside, UWL, Heriot-Watt). **Hall** was the external for the validation of the Professional Doctorate programmes at UCLan (2018), and on the committee for the British Computer Society Human-Computer Interaction 2020 Doctoral Consortium (held online July 2020). **McDonald** delivered two doctoral training workshops for the ESRC NPIF Accelerating Business Collaboration. **Cockton** has been an invited lecturer and tutor at PhD summer schools in Helsinki (Aalto Arts, 2015) and Jyväskylä (2018), and for Professional Doctorate students at TU Eindhoven (2016, 2017).