Institution: Newcastle University

Unit of Assessment: UoA4 - Psychology, Psychiatry and Neuroscience

1. Unit context and structure, research and impact strategy

1.1 Overview

Research activity in UoA4 translates our high-quality neuroscience into health, wellbeing and wealth benefits for the UK and beyond. We undertake clinical research in causes and impacts of neurological, neurodevelopmental and psychiatric conditions, and develop effective approaches to treatment. This translational work is underpinned by a strong systems neuroscience approach using multiple animal models, notably the non-human primate (NHP), for which Newcastle is one of Europe's leading centres.

The Faculty of Medical Sciences (FMS) restructured in 2019 into three strategically interconnected research institutes: Biosciences (NUBI), Translational and Clinical Research (NUTCRI), and Population Health Sciences Institutes (NUPHSI). The vibrant, interdisciplinary research activity of UoA4 spans all research institutes and our School of Psychology. Cross-cutting research themes provide "silo-busting" opportunities for bench-to-bedside-to-population and bench-to-product collaborations across the Faculty; with key strategic NHS partners, the Newcastle upon Tyne Hospitals NHS Foundation Trust (NuTH) and the Cumbria, Northumberland, Tyne and Wear NHS Foundation Trust (CNTW); funders and industry. The award of Academic Health Science Centre status in 2020 (AHSC), one of only eight centres in the country and our NIHR Biomedical Research Centre in Ageing and Long-Term Conditions (BRC) (held since inception of the BRCs in 2007) exemplify our track record of translating basic science into clinical impact.

Our submission comprises 66 individuals (62.2 FTE), including eight early career researchers (ECRs), and 23 clinical academics who hold joint appointments with our NHS partners. Our research income across the REF period has been £78.8M. UoA4 researchers have strong interdisciplinary links to UoA1 research themes, notably in Long-term Conditions and Ageing, and Rare Diseases (including Mitochondrial diseases and Muscular Dystrophies); UoA2 in public health and primary care of neurodegenerative diseases; UoA3 with allied health professionals on neurodevelopmental disorders; UoA6 in animal welfare; and UoA11 with the School of Computing for big data analytics in areas as diverse as seizure control, connectomics and gait analysis and a Doctoral Scholarship Programme in Behavioural Informatics (*Nettle*, *Smulders*, and *Asher* (UoA6); Leverhulme Trust, £1M). We co-lead CoroNerve, the MRC-funded UK-wide surveillance study of COVID19-associated neurological and psychiatric conditions (*R.Thomas*, LancetPsych2020).

1.2 Research Strategy

Summary

We have delivered on our REF2014 objectives by investing in and developing our previously identified areas of strength and applying a greater multidisciplinary approach to tackle key research questions. These foci are captured by our Faculty research themes: **Neuroscience**, **Neurodisability & Neurological** Disorders – lead *Thiele*; **Mental Health**, **Dementia &**

Neurodegeneration – co-leads *Taylor & McAllister-Williams*; and **Behavioural Science & Psychology** – lead *Nettle* which expand on the research themes presented in REF2014 and that were reflected within the Institute of Neuroscience (IoN) where the majority of UoA4 research was housed prior to the restructure.

1.2.1 Neuroscience, Neurodisability & Neurological Disorders

Our mission is to understand how the nervous system works in both health and disease, aiming to understand the principles of information processing in the brain; how genes, the environment, diseases, and accidents impact on the nervous system; to develop tools to prevent, diagnose, and treat nervous system disorders; and address important clinical and societal needs in relation to neuroscience. Our translational work is underpinned by the selective deployment of animal models and a strong emphasis on systems neuroscience.

Discovery Neuroscience

We stimulate innovative translational studies (*e.g.* identification of a novel cooperative optogenetic tool in reversing an *in-vitro* epileptogenic phenotype, *Trevelyan*, NatComm2016); develop diagnostic tools (*e.g.* functional magnetic resonance imaging of human motor unit fasciculation in motor neuron disease, *Whittaker*, AnnNeurol2019); and inform potential clinical interventions for patient benefit (*e.g.* wearable devices for motor recovery of hand function in stroke survivors, *S.Baker*, NeurorehabilNeuralRepair2020).

As a leading European ***non-human primate centre*** we have found: how cortical state transitions relate to cognitive function (*Thiele*, Science2016) and how learning changes neuronal codes (*Thiele*, NatComm2018); thalamocortical visual pathway in primates using cell-specific optogenetics (*Schmid*, Neuron2016); cell type specific roles of cholinergic signalling in attention (*Thiele*, PNAS2019); delineation in the evolutionary origin of human language pathways (*Petkov*, NatNeurosci2020); how local field potentials can be used for biofeedback to control single cell activity in macaques (*Jackson*, FrontiersNeurosci2014); and provided evidence for a novel hypothesis of postural control (*S.Baker*, ELife2020). We have significant awards for work on: motor function (*Jackson*, Wellcome Trust, £1.8M); auditory sequence learning (*Petkov*, ERC Consolidator 2017, €2M; Wellcome Investigator 2014, £1.5M); neuropharmacology of decision making (*Thiele*, MRC 2017, £1.7M); and human auditory cognition (*Griffiths*, MRC, 2020 £2.2M). Our ***model systems*** use a variety of animals, e.g. bees (gustatory neurons, *Rind*, CurrentBiology2018) and rodents (neural substrates for flexible decision-making, *Banerjee*, Nature2020). Studies comparing ***insect and human vision*** (*Read*, Leverhulme Research Leadership Award, £1M; *Nityananda*, BBSRC David Phillips Fellowship, £1M) generated several highly influential papers (CurrentBiology2018, PNAS2019, NatComm2019), revealing convergent evolution of neural computations for stereoscopic "3D" vision.

Fundamental neuroscience studies in hearing have advanced knowledge of brainstem auditory pathways and discovered previously unknown major multisensory cortico-collicular projections (*Rees*, eLife2014; *Gartside*, *Rees*, JNeurosci2019a, JNeurosci2019b). Our work on auditory sequence learning (*Griffiths*, *Petkov*) was recognised as one of PLOS Biology's "biggest hits" of 2017.

Neurological Disorders

Our work in ***epilepsy*** exemplifies how we combine work from cells (*in vitro*, *ex vivo*, *in vivo*) across species (mice to NHP) to patients, and across disciplines to include computing and engineering.

Demonstrating our multidisciplinary strength is a 9-year, £10M Wellcome-EPSRC Innovative Engineering for Health Award for the Controlling Abnormal Network Dynamics with Optogenetics (CANDO) aimed at radical new treatments for epilepsy using light (*Jackson*, *Trevelyan*, *Whittaker*, *S.Baker*, *Clowry*, *LeBeau*), with computing UoA11 and engineering UoA12. We have extended our clinical studies on epilepsy to include mitochondrial disease (*Whittaker*, AnnNeurol2015), with work on carbon dioxide (*Forsyth*, EurJPaediatrNeuro2016) leading to a randomised clinical intervention trial of pH manipulation for treating convulsive status epilepticus (*Forsyth*, NIHR £1.1M). We use computational modelling to understand seizure pathways (*Forsyth*, *Jackson*, PNAS2020), and animal models for new insight into underlying causes (*Trevelyan*, NatComm2016), and to improve understanding of developmental disorders and epilepsy genetics (*R.Thomas*, LancetNeurol2017).

Our ***stroke*** research examines alternate motor pathway recruitment following pyramidal tract lesions (*S.Baker*, JNeurosci2018) that may be harnessed clinically post-stroke. Our research characterised the optimal treatments for stroke, including i) mechanical thrombectomy for the most severe type of stroke, resulting in a quadrupling of these procedures in five years; Impact Case Study (ICS) "*Optimising thrombectomy services to improve patient outcomes from stroke*" (*White*, JNeurolNeurosurgPsychiatry2017); ii) Investigating the impact of transdermal glyceryl trinitrate on stroke outcomes, pioneering BHF-funded placebo controlled randomised trial in ambulances (*Price*, Lancet2019a); iii) NIHR HTA-funded randomised control trial to investigate extended rehabilitation support in stroke patients which showed reduced service costs (*H.Rodgers*, *Price*, Stroke2019); and iv) finding that introducing robots to enhance post-stroke arm function did not improve recovery, NIHR HTA-funded clinical trial (*H.Rodgers*, *Price*, Lancet2019b).

We pioneered the investigation of ***motor neuron disease*** with MRI (*Whittaker*, AnnNeurol2019, William Leech Charity, £1M) and are developing novel MicroEMG intramuscular electrodes to improve its diagnosis with clinical trials starting in 2021, these developments were combined in our Wellcome Trust-funded Manufacturing Facility for First-in-Patient Complex Medical Devices.

Basu developed training materials for frontline healthcare professionals to improve early detection of infants with emerging movement disorders (NIHR career development fellowship). A WellChild-supported clinical trial on improving upper limb function in children with hemiplegia led to development of online resources for families, which proved particularly useful during COVID restrictions.

Neurodevelopmental Disorders, ***Neurodisability & Autism***

We designed several ***new interventions for autism and co-existing conditions***, such as the Preschool Autism Communication Therapy (*Parr*, Lancet2016), Newcastle Blue Room Treatment (*Parr*, *J.Rodgers*, AutismAdulthood2019) and Coping with Uncertainty in Everyday Situations (CUES, *J.Rodgers*, *Parr*, Trials2019). We also developed and evaluated ***assessment tools to identify mental health conditions experienced by autistic children and adults***, *e.g.* first Anxiety Scale for Children Autism Spectrum Disorder tool (ASC ASD©, *J.Rodgers*, *Parr* AutismRes2016), now translated into 12 languages and adopted as a core outcome tool in four NHS trusts, and the Anxiety Scale for Autism-Adult (ASA-A©, *J.Rodgers*, *Parr* AutisminAdulthood2019), now translated into five languages. Our ***work with policy makers*** on transition from child to adult services influenced the NICE Guidelines and NHS Long-Term Plan (*Parr*, NIHR PGfAR £2M, BMCMedicine2018, ICS UoA2).

We are designing and evaluating primary care health checks for autistic people, managing repetitive behaviours and developing a nutritional intervention in Neurodisability (*J.Rodgers*, NIHR HTA £720K, *Parr*, NIHR HTA £3M). We lead the EU's first medication trial to treat core features of autism (Trials2020), and the first suicide prevention intervention specifically for ***autistic adults*** (NIHR PHR with MRC, and autism charities). We lead childhood autism research databases and UK autistic adult and relatives cohort studies. With 8,000 participants, these are the largest databases outside North America and support recruitment to UK research studies. Collaborating with international consortia we undertake gene discovery and translational genetics, (e.g. *Woodbury-Smith*, NatureNeuroscience2017, *Parr*, NatRevGenet-2020).

Our ***acquired brain injury in children*** research includes measuring the effects of neuro-rehabilitation treatment (*Forsyth*, NIHR PGfAR) in collaboration with leading UK and US centres. When evaluating common drugs for the treatment of drooling in children with neurodevelopmental conditions (*e.g.* cerebral palsy), our work led directly to 2016 EMA approval of two alternative proprietary treatments and their widespread use in practice (*Parr*, *Pennington*, ICS "*Approval of the first licensed medication to treat drooling in children with neurodisability*"). ***Motor learning theory*** underpins research into aspects of breath control in speech therapy; led to improvements in intelligibility of children with cerebral palsy; and informed 2017 NICE guidelines a key textbook and national undergraduate teaching. ICS "*A motor learning approach to speech therapy for children with cerebral palsy underpinned UK guidance and international teaching practice*".

1.2.2 Mental Health*, *Dementia & Neurodegeneration

Lewy Body Disease (LBD) Spectrum

Our aim in this research, covering Parkinson's disease (PD), PD with dementia and dementia with Lewy bodies, is to improve the management of patients through early and accurate diagnosis, understanding of pathophysiology, disease course and potential modifiers, and development of novel treatments, including stratified medicine approaches. We play a major role in the Newcastle BRC. In 2019 and 2020 Expertscape.com metrics ranked Newcastle as **world leaders in LBD**, majoring on the development of neurodegenerative biomarkers, imaging and discovery science.

The Newcastle Brain Tissue Resource provides clinically and neuropathologically well characterised postmortem brain tissue to national and international researchers (s3.4). We are the national coordinating centre for the Brains for Dementia Research Programme (*A.Thomas*, Alzheimer's Society/Alzheimer's Research UK £12M). Our ***neuropathological studies*** have highlighted potential pathways towards synuclein toxicity (*Outeiro*, HumMolGenet2019) and potential therapeutic targets (*Outeiro*, SciReports2020), and revealed that the anti-Parkinsonian drug apomorphine may modify amyloid deposition in PD (*Yarnall*, MovDisord2016). We discovered that predominantly cortical neurodegenerative pathology but not cerebrovascular disease may cause white matter lesions in cognitively impaired individuals (*Attems*, *McKeith*, *A.Thomas*, *Taylor*, ActaNeuropathol2017).

In **Parkinson's disease**, our Incidence of Cognitive Impairment in Cohorts with Longitudinal Evaluation (ICICLE-PD, Parkinson's UK £1.56M) study has improved understanding of clinical and biomarker predictors of dementia in Parkinson's disease. Researchers across a range of disciplines *Burn*, *Yarnall*, *Lawson*, *Pavese* and *Rochester* collaborate and have used these and other cohorts to: characterise mild cognitive impairment in Parkinson's (Neurology2014, JNNP2017); understand symptomatology in Parkinson's disease (EurJNeurol2019,

BrainSci2020); and the impact on carers (IntJGeriatrPsychiatry2016). We have pioneered using gait as a clinical biomarker for enhanced diagnosis, disease monitoring and risk prediction, showing that gait impairments are present early (MovDisorders2015), even in the prodromal stages of PD (AnnNeurol2019), can predict cognitive impairment (JGerontA2017) and risk of falls (JNeurology2017), and differentiate dementia subtypes (AlzDementia2019), and that abnormal visual fixation (BehavBrainRes2018) can be enhanced by utilising virtual reality and, via a multicentre study (VTime), reduce falls (Lancet2016, EU FP7). Partnering with NHS, bioengineering, and worldwide industry we have developed digital technology to translate this work to the clinic using low-cost wearable technology (*Rochester*, IEEEJBiomed HealthInform2016). We lead the EU Innovative Medicines Initiative (IMI) consortium, MOBILISE-D (€50M, *Rochester*), developing and seeking regulatory and health technology approval for digital mobility biomarkers. Together with researchers in UoA1 we lead the £7.4M EU-funded IDEA-FAST, a unique combination of immunology, neurodegeneration and digital research.

Our DIAMOND Lewy study (*McKeith*, *O'Brien*, *Taylor*, *A.Thomas*, NIHR £1.6M) generated **diagnostic assessment toolkits** to improve the diagnosis of LBD by more than a third (IntJGeriatrPsychiatry2018) and **an LBD management toolkit** which resulted in improvements in patient and carer outcomes (LancetNeurol2020, MovDisord2020), without increase in costs.

Newcastle research makes **significant impact on clinical policy**: developing of revised diagnostic criteria for LBD, implemented into ICD-11, DSM-5, ensuring worldwide unified diagnosis (*McKeith*, Neurology2017, >1,000 citations) and leading an international consortium to develop diagnostic criteria for prodromal DLB (*McKeith*, *Taylor*, *A.Thomas*, Neurology2020).

Affective Disorders

Utilising a novel lithium MRI technique, we demonstrated brain lithium distribution in ***bipolar disorder*** (*Cousins*, MRC Clinician Scientist Fellowship £1.1M, MolPsychiatry2018) and by characterising cognitive deficits, identified potential therapeutic targets (*Gallagher*, PsychMed2020, BipolarDiso2018). A key focus is investigating novel and re-purposed treatments in difficult-to-treat mood disorders, including anti-glucocorticoids (*McAllister-Williams*, *Watson* NIHR/MRC EME £1M) and ketamine augmentation of ECT (NIHR/MRC EME £1.1M, LancetPsychiatry2016). We have developed family-focused therapy for adolescents with bipolar disorder (*Sharma*, IntJBipolarDisord2020). Cross-disciplinarity enriches research in transcranial magnetic stimulation (*McAllister-Williams*, BMJOpen2020, NIHR/MRC EME BRIGhTMIND study £1.3M) and attentional analysis in LBD (*Gallagher*, PsychMed2015, JNeurol2019).

1.2.3. Behavioural Science & Psychology

Human and animal behaviour

Our distinctive approach comes from understanding evolutionary mechanisms that apply across widely different species. *Nettle* pioneered using starlings to study consequences of early life adversity, including food insecurity, and to develop novel biomarkers of stress and ageing (ERC Advanced Grant, COMSTAR, €2M, *Bateson, Nettle*, PhilTransRoySocB2018). Camouflage and colouration exemplifies a field requiring an interdisciplinary approach (vision science, behaviour, ecology), where *Rowe* and *Skelhorn* made highly influential contributions (PNAS2015, CurrentBiology2018, CurrentBiology2019, ProcRoySocB2020), together with insect-inspired robotics using locust neurons to investigate collision avoidance (*Rind*, EU Horizon 2020 STEP2DYNA and ULTRACEPT). Research into whether eye imagery affects human behaviour

culminated in simple, cheap measures for crime reduction (ICS "*Watching eyes: a cost-effective method of deterring undesirable behaviour*", *Bateson, Nettle,* EvolutionaryBehaviour2014).

Our commitment to Refinement, ***Reduction***, ***Replacement*** and **animal welfare** is evidenced by active research programmes in all three areas. We pioneered the use of retinal organoids for disease modelling and drug discovery (*Sernagor*, NC3Rs Crack IT Challenge, £1.1M). To monitor welfare in lab and agricultural animals we combine behavioural, systems neuroscience and ecology and have developed cross-species biomarkers of stress and welfare as well as ageing, including hippocampal structure (*Poirier*, NeuroBiobehavRev2019) and telomere attrition (*Bateson*, Bioessays2016; *Bateson*, *Nettle*, AgingCell2017, RoySocOpSci2019) and methods to reduce stress on laboratory mice (*Rowe*, SciRep2018). Such markers are used in the "ChickenStress" European Training Network aimed at improving laying-hen stress resilience in commercial settings (NU lead *Smulders* MSCA ETN €3.9M). UoA4 researchers have strong links to other welfare work at Newcastle *e.g. Asher's* (UoA6) quantifying the relationship between welfare and behaviour in dogs and chickens, and with *Flecknell*, *Leach* the "rabbit grimace scale", enabling pain to be rapidly detected enabling prompt analgesia (ICS UoA6).

Forensic Psychology

Our continued research into the use of polygraphy with high-risk sex offenders has increased disclosure of management-relevant information in more than 2,150 offenders since being made compulsory in 2014 (*Grubin*, IntRevPsychiatry2019). Due to its success the technique was introduced into UK 2019 Domestic Abuse and 2020 Counter-Terrorism and Sentencing Bills. Our work has also established universal standards for non-coercive police interviewing and procedural safeguards (ICS "*Non-coercive forensic interview training*").

1.3 Future research strategy

Cross-faculty Newcastle University Centres of Research Excellence (NUCoREs, REF5a 2.2.1) will further enhance our multidisciplinary and multi-professional approach, with UoA4 researchers contributing to NUCoREs in Healthier Lives, Ageing and Inequalities, Data, and Rare Diseases. In 2021, we will launch the Transformative Neuroscience NUCoRE, bringing together ~100 colleagues across the University with industrial, academic and clinical collaborators to better integrate experimental and clinical neuroscience with strengths in computational neuroscience, neuroengineering, humanities and social sciences.

1.3.1 Neuroscience, ***Neurodisability & Neurological Disorders***

We will **build our *in vivo* cellular imaging (2-photon**, **multi-photon) and large-scale brain imaging capacity** (rodent, non-human primate and human MRI/fMRI and PET) and expand the use of marmosets as a model system by investment in our breeding and holding facilities. Utilising our recent BBSRC 19ALERT Mid-Range Equipment Initiative (*Sernagor*, £579K), we will build on our high-density recording probes and extend into non-human primates, and *in-vitro* systems.

Maximising **cross-disciplinary working** in our new research themes, we will develop a primate model of dementia in marmosets; investigate the link between hearing loss and dementia using a NHP model; establish a world-first platform where human intra-operative brain tissue is cultured for studies of dementia for mechanistic and drug screening; investigate the core systems involved in mental navigation and how these underlie mental states in health and disease; undertake

fundamental research in how intolerance of uncertainty might underlie psychiatric disease; and develop rodent models of autism.

We will explore the use of **artificial intelligence in the diagnosis and treatment of neurological disorders**, bringing together neuroscientists and computational scientists *e.g.* for diagnosing/ monitoring neurological disease and elucidating neuronal networks and neuroimaging data. We will **combine institutional expertise in engineering and neuroscience** to develop radical new ways to treat and manage neurological disorders. For example **implants or external devices** to control epilepsy using optogenetics, improve motor function following stroke, or overcome spinal cord damage.

We will extend our work on *in vitro* systems to **culture human tissue and human cerebral organoids**, to study proteins linked to neurodegeneration and test the efficacy of interventions aimed at protecting neuronal function; investigate thalamocortical interactions and cortical interneuron production in human development; and use 3D hiPSC-derived laminated retinal organoids as tools for toxicology studies.

1.3.2 Mental Health**, **Dementia & Neurodegeneration

In addition to the dementia studies outlined above, we will deliver **new clinical trials in Lewy Body Disease**, including early-phase trials (*e.g. Taylor*, *Yarnall*, OACS-3 clinical trial of FXR-agonist in Parkinson's disease, £2.1M) through to large international phase-3 trials such as NIHR/NHMRC-funded trial of combination treatment (*Taylor*, COBALT £2.2M).

We will **further develop gait as a biomarker to aid differential diagnosis of dementia** (*McArdle*, AlzheimersDement2019) and exploit novel multimodal imaging to reveal neural networks involved in gait in real time (*Brooks*, *Pantall*, *Pavese*, Parkinson's UK).

We will work closely with engineers, NHS and international partners (*e.g.* Maetzler, Germany) to increase the take-up and impact of **digital monitoring to enhance outcome measurement and patient management**, driving personalised approaches to patient care. We are leveraging Newcastle's expertise in big data to apply machine learning techniques to mobility data, as a precursor to translation and scaling up for digital healthcare tools. A €50M IMI2 consortium (MOBILISE-D, *Rochester*) will deliver validated tools for digital mobility assessment in age-related mobility-limiting conditions, including dementia. Building on the significant investment, international collaboration and industrial engagement already brought by these public/private partnerships, we will establish ourselves as world leaders in digital healthcare.

We will extend our reputation for the **development of novel therapies for affective disorders**, within the NIHR Mental Health Translational Research Collaboration (*McAllister-Williams*). In particular, we lead the NIHR HTA-funded PAX-BD study in treatment-resistant bipolar depression (*McAllister-Williams*, *Watson*, £1.9M) and are investigating pramipexole and lithium vs quetiapine in depression, plus optimising response to lithium treatment in patients with **bipolar disorder through personalised evaluation**. We lead on **development and implementation of our novel lithium imaging** (7Li-MRI), establishing the technique in five European collaborating centres (*Cousins*). We are developing expertise in multicentre trials in young people of both psychosocial and pharmacological interventions (*Sharma*).

1.3.3. Behavioural Science & Psychology

We will grow research capacity in comparative cognition, behaviour and psychology within the School of Psychology by leveraging the increasing popularity of the BSc in Psychology, and MRes degrees in Animal Behaviour, and Evolution & Human Behaviour. Three new permanent T&R staff will join in 2021, while appointments in 2020 of *Clark* and *Komes* strengthened clinical psychology. These new appointments will allow expansion of our research and widen the breadth of research undertaken in the Behavioural Science and Psychology theme, particularly in humans.

We will **probe the evolutionary basis of behaviour**, across multiple species (locust, bee, praying mantis, starling, chicken, mouse), for example the correlates of emotion and attention in species including insects. We will **translate behavioural science insights into societal impact**, **targeting obesity**, **food insecurity**, **climate change**, **and epidemiology**, and build on the success of our Centre for Behaviour & Evolution and Leverhulme Trust-funded Behavioural Informatics Doctoral Scholarship Programme through cross-Faculty NUCoREs in Healthy Lives and Animal Welfare.

1.4 Impact strategy

Our research leads to impact in three key areas: 1) **health and wellbeing of people and animals** (*e.g.* identifying the best drug to treat drooling; the "rabbit grimace scale" for measuring pain in lab animals); 2) **public policy**, **law and services** (*e.g.* introduction of polygraphy in UK law); and 3) **practitioners and professional guidance** (*e.g.* speech therapy research leading to new NICE guidelines, textbook and teaching for undergraduates).

Impact has always been at the heart of the University research strategy. However, the recent Faculty restructuring has furthered collaborations between discovery scientists and clinicians by dissolving disciplinary boundaries and augmenting interdisciplinary research through cross-Institute themes.

To support the translation of research into impact, we have two UoA4 **impact champions** (*Read* and *Fitchett*) who work with the Faculty's impact officers, to identify and support research with impact potential. We encourage colleagues, particularly early career researchers, to participate in University programmes such as the Policy Academy, Global Challenges Academy and Enterprise Academy. We support and train colleagues in patient and public involvement in our research, and provide funds for partnership building and impact activities.

1.5 Research Integrity, **Reproducibility and Openness**

The University is a signatory of the Concordat for Research Integrity (REF5a 2.3.2) and has appointed *Rowe* as Dean for Research Culture and Strategy with oversight of integrity and Woods (Professor of Bioethics UoA21) as its expert convenor on research integrity. We have joined the UK Reproducibility Network, maintain policies and procedures compliant with the Concordat to Support Research Integrity, subscribe to UKRIO, and are members of the Russell Group's Research Integrity Forum.

Open access, data and code sharing are our key pillars of a positive research culture and research integrity. We have invested in a Research Data Repository, containing >345 items categorised as

Neuroscience, Psychology or Psychiatry and ePrints repository that ensures research outputs are made Green Open Access. Both are supported by expertise within our Library, with our Research Data Service supporting the development of data management plans for research proposals to ensure resulting data will be in suitable forms for sharing. We are embedding this practice into our teaching, with students encouraged to pre-register their research projects, and upload relevant data sets and outputs. For example, in *Nettle*, PeerJ2017, psychology undergraduates carried out a pre-registered replication of a published study, uploading all code and data, which showed that they were not able to reproduce the previous finding.

Nettle chairs our Faculty Ethics Committee with *Read* leading its Psychology sub-committee. The formation of our "Innovation, Methodology and Application" theme (s3.5) enhances our ability to develop and share best practice, and to provide critical input into research design and statistical rigour, significantly strengthening our commitment to research reproducibility.

2. People

2.1 Overview

Our submission comprises 66 staff (62.2 FTE), 33% of whom are women. 23 returnees are clinical academics and hold honorary contracts with our partner trusts. Further, nine NIHR Academic Clinical Fellows, six NIHR Clinical Lecturers and a broad community of 25 honorary clinical academics (REF Category C) currently contribute to our research. Of those returned, 42% are professors, 46% mid-career and 12% early career researchers (ECRs).

2.2 Staffing Strategy

We aim to have a strong career development pathway underpinning both capacity building and succession planning. To do so we have targeted recruitment at senior level; supported career progression; invested in fellowship programmes and lectureships; and supported ECRs to success in external fellowships. We are recognised nationally as a sector leader for supporting and developing clinical academics (s2.5.2).

In **Neuroscience**, **Neurodisability & Neurological Disorders** have made strategic appointments: Chair in optogenetics (*Schmid*); Senior Lecturer in adaptive decision-making (*Banerjee*); Clinical Intermediate Fellow in epilepsies (*R.Thomas*) and *UKRI* Future Leaders Fellow in sensory neuroscience (*Young*). Six colleagues have been promoted to Chair (*Jackson*, *Petkov*, *Read*, *Sernagor*, *Trevelyan*, *Whittaker*), one to Senior Lecturer (*Vuong*) and one from Senior Research Associate to Lecturer (*Soteropoulos*), with *Kumar* promoted to Newcastle University Research Fellow (NURF s2.5.1).

In **Mental Health**, **Dementia & Neurodegeneration** we have enhanced our capability across the translational pathway with the appointment of chairs in Clinical PET Research (*Brooks*); neurodegenerative disorders (*Outeiro*); Parkinson's (*Pavese*). Clinical Senior Lecturers (*Sharma and Woodbury-Smith*) have broadened psychiatry and autism research respectively. ECR capacity has expanded through appointments of NURF (*Pantall*) and Parkinson's UK Senior Research Fellowships (*Lawson*, *Reeve*). Five colleagues have been promoted to Chair (*McAllister-Williams*, *Parr*, *Price*, *J.Rodgers*, *Taylor*); two Clinical Senior Lecturers (*Cousins*,

Yarnall), and Senior Lecturer (*Gallagher*). Four NHS consultants were appointed to honorary Clinical Senior Lectureships.

In **Behavioural Science & Psychology** strategic appointments in clinical psychology (Senior Lecturer, *Clark*, and Lecturer, *Komes*) have been supplemented with additional ECR capacity: in attention-like processes, BBSRC David Phillips Fellow (*Nityananda*), and animal welfare NURFs (*Poirier*, *Asher* (UoA6)). Three academic colleagues have been promoted: Chair (*Rowe*), Reader (*Smulders*) and Senior Lecturer (*Skelhorn*).

As part of our commitment to minimise casualisation in our workforce, academic appointments are made to open-ended contracts, with the 3% of returned staff on fixed term contracts in fellowship positions who join our academic track community (s2.5) and are therefore expected to progress to academic appointments. Research staff funded entirely by external grants are offered open-ended contracts after four years. Movement between projects is facilitated by a process starting six months before funding ends with positions advertised in a redeployment pool. This is complemented by our bridging scheme, which retains key skills and prevents researchers from leaving scientific careers by providing short-term funding between research grants; 19 UoA4 colleagues have benefitted over the REF cycle.

2.3 Career Support and Development

We promote and embed a collaborative research culture, supporting colleagues at all stages of their careers to maximise both their wellbeing and scientific productivity. We are committed to the Concordat to Support the Career Development of Researchers, with NU receiving one of the first HR Excellence in Research Awards by Vitae (2010; renewed twice). We enable colleagues to develop research and leadership skills throughout their careers, evidenced by the development of our University Skills, Global and Enterprise Academies (REF5a 2.2.5), Faculty mentoring schemes, and our support for access to complementary external programmes such as the Aurora Scheme (four attendees).

Our dedicated Research Career Advisor and Organisational Development Specialist work with our Career Development Working Group to ensure that our career pathways and training reflect all needs across the Faculty. Our research themes provide critical peer support for discussing research in progress and developing grant proposals.

Personal objectives are identified and prioritised in annual review meetings (PDR) with a senior academic, with dedicated training for appraiser and appraisee. These focus on encouraging aspiration, celebrating achievements, future plans and career development together with areas of support, concern and training needs. PDRs are submitted to the Head of Unit enabling high-level oversight and identifying common needs across disciplines.

2.4 Effective Integration of Clinical Academics and NHS-employed Active Researchers

Clinical Academics are hosted for their clinical duties in our partner NHS Trusts and hold honorary consultant status. A joint job-planning process ensures balance between academic and clinical responsibilities and career development planning is facilitated by integrated University and NHS appraisal processes. We also host 25 NHS-employed honorary academics whose affiliation with Institutes enables access to facilities and support for their research. Those with honorary clinical

senior lecturer status or above have a University review alongside their NHS appraisal to recognise research commitments in their development goals.

Our Clinical Academic Office (CAO) manages the interface between the University and NHS for employed and honorary colleagues, including a joint Human Resources meeting where strategic and operational issues can be identified and resolved swiftly and effectively. The launch of AHSC is further strengthening the integration of clinical academics and NHS-employed researchers.

2.5 Supporting early career researchers

We conscientiously nurture our ECRs, encouraging them to develop advanced research and translational skills through bespoke training programmes both within the Faculty and through our Academies (REF5a 2.2.5). This includes 'PI Development Programme' (21 attendees); Policy Academy Fellowship Scheme (four attendees); in-house topic specific programmes such as on psychiatric methodology or computational neuroscience; and external courses such as NIHR Academy (four Attendees) and Future Leader Fellow Development Network (two attendees).

ECRs are personally mentored from within and beyond NU and supported to develop research funding applications as PIs or to apply for personal fellowships. They are guided from initial ideas development, through the writing, application and processes. Seedcorn funding, such as our Small Grant Scheme, enables them to acquire preliminary data to support applications (10 awards), with our Broadening our Horizons Scheme supporting the development of collaborations and exchange with other research institutions, so crucial at this career stage (44 awards). We have transparent processes for application and allocation of funding with clear criteria communicated across the Faculty.

NU and externally funded clinical and non-clinical "transition to independence" fellows are expected to progress to academic positions (2.5.1, 2.5.2). In Year 3 (of 5 year fellowships), fellows are reviewed by a panel comprising internal and external academic members. Based on transparent written criteria this panel can recommend the Fellow is offered an open-ended academic position.

2.5.1 Non-Clinical Fellows

We invest in two non-clinical fellowship schemes, open to internal and external candidates. **Faculty Fellowships** provide 2-3 years of funded scientific and career mentorship to allow early-stage researchers to prepare external fellowship applications. In 2015, we introduced **Newcastle University Research Fellowships** (NURFs) for "transition to independence" researchers as a route to non-clinical academic appointment. The scheme was extremely competitive, attracting applicants worldwide and was the basis of the pan-university NU Academic Track (NUAcT) appointments (REF5a 3.2.4, initially led by *Rowe*).

We have a **vibrant fellows' network**, supported by the Faculty Director of Non-Clinical Fellowships. Fellows receive regular updates and meet with the Director bi-monthly to share experiences, provide peer support and attend career development presentations. The success of this support is demonstrated by the award of 18 external non-clinical post-doctoral fellowships. We have appointed three Faculty Fellows and five NURFs, two of whom (*Asher*, *Pantall*) have successfully been appointed to open-ended contracts, with *Asher* promoted to Chair in 2020 and *Young* subsequently winning a UKRI Future Leaders Fellowship. Since 2014, five other colleagues

completed their fellowships; all have obtained academic positions, with *Jackson* promoted from Wellcome Senior Fellowship to personal Chair.

2.5.2 Clinical Academic Researchers

We have a strong track record of developing clinical academic careers supported by Jones (UoA1) as Dean for the NIHR Academy. We host an NIHR Academy Incubator in Clinical Education (Vance UoA23), which is fundamental to our future pathway from undergraduate to academic career (s2.7.1). Our Academic Foundation Programme was the first in the UK offering eight months protected research time during the 24-month scheme, forming the basis for programmes across the UK. Our model of cross-profession integration of training support through our Clinical Academic Office has been adopted by the NIHR Academy.

We have provided mentoring and support to 23 NIHR Academic Clinical Fellows to develop externally funded doctoral fellowship applications, 10 of whom have continued to clinical PhD fellowships in Newcastle. Seven NIHR Clinical Lecturers have been enabled to complete their clinical training while developing a post-doctoral research career. Particular highlights are the promotions from research fellows to Clinical Senior Lecturers (*Basu*, *Cousins*, *Yarnall*) and recent post-doctoral fellowships (Wellcome Trust Career Development (*Sedley*) and NIHR BRC (*Donaghy*)).

2.6 Team Science: Supporting All Career Pathways

Our Team Science ethos ensures that our technicians, technologists and methodologists have a clear career structure and are acknowledged for their contribution to research. We encourage recognition through authorship with 14% of submitted outputs including a technician as author. This commitment is deeply embedded within UoA4. *Leitch*, formerly IoN Technical Manager, now Newcastle University's Deputy Head of Infrastructure, led a university-wide initiative to support technical staff in obtaining Registered or Chartered Scientist status. Over the REF cycle four UoA4 technicians achieved RSci status and one CSci. Two studied for PhDs while successfully continuing their technical responsibilities. *Leitch* subsequently led the formation of NU TechNet in 2016. This pan-university forum enables technicians to share resources, information and experiences and provides career development support. Technicians lead the delivery of technology based training through the Skills Academy. NU TechNet has enabled Newcastle to become a Science Council Employer Champion in 2016 and founding signatory of the Technician Commitment in 2017. *Leitch's* contributions achieved national recognition through shortlisting for THES Technician of the Year 2019.

2.7 Postgraduate Research Students

2.7.1 Overview

We have a vigorous and well-supported postgraduate research student (PGR) community which contributes significantly to our research environment. UoA4 researchers have supervised, or co-supervised 127 PhD students to completion since 2014, with 148 ongoing. Our PGR population is diverse with 62% women and 29% from BAME backgrounds. Our students, 16% of whom are international, benefit from our doctoral training programmes (DTPs), specifically our BBSRC and MRC DTPs; Leverhulme Trust Doctoral Scholarship Programme and our Wellcome Trust Clinical PhD Academy and DTP in Systems Neuroscience. Further PhD student cohorts have been supported by the Newcastle Biomedical Research Centre and Faculty. In addition we host clinical academics by offering MDs (nine students) and DClinPsy (112 students).

We invest time in developing a pipeline of future researchers by hosting budding scientists from school age onwards, for example through the Nuffield Summer Science Bursary. Our undergraduate teaching has an emphasis on laboratory-based research projects and we host placements including through the Princeton International Internship programme and an annual Neuroscience Summer School.

This provides an excellent basis for progression of intercalating medics and science students to a range of focused MRes programmes. 363 MRes students have spent six months working on research projects, with 91% reporting overall satisfaction with their programme (PRES 2019). This training "pathway" generates a pool of well-qualified, research-motivated postgraduates who can compete successfully for studentships.

2.7.2 Recruitment

Studentships are advertised widely and awarded in open competition. Applications are reviewed by our PGR Coordinators to identify supervisors with matching research interests, with candidates shortlisted against explicit criteria and interviewed by a panel of at least two selectors. Our UKRI DTPs pioneered the redaction of identifiers at project selection and student short-listing stages. Furthermore, 38% of PhD students in our BBSRC 2018 and 2019 cohorts are first-in-family at university, comparing favourably with Newcastle's 37% undergraduate widening participation rate.

2.7.3 Progression, monitoring and support

We provide multiple layers of pastoral support to every PGR student thereby empowering them to choose who they judge as most appropriate to deal with specific problems. Students agree their training and development needs with supervisors when initiating their studies, and record these in a personal development plan. Academic Performance Reviews (APRs) are independent of the supervisors, performed by academics drawn from the Faculty to reflect on research study progress, training and skills development. We have clear expectations of PGRs and supervisors and pay careful attention to the expertise and experience of supervisory teams.

2.7.4 Skills development

Students are supported by a comprehensive skills development programme (>100 topics) which aligns with the Vitae Researcher Development Framework and promotes research-specific and generic skills. Since our UKRI-sponsored DTP students benefit from additional training, we have provided additional funding to widen this access to all students. Students are encouraged to gain teaching experience; take part in outreach; participate in the North East Postgraduate Conference; and to organise scientific events *e.g.* NeuroPalooza 2016, a Wellcome-funded Neuroscience Students Conference.

PGRs are members of Faculty research themes and encouraged to present their work at work-in-progress meetings and events. An active student-run support group allocates new students 'buddies' to provide peer support, with final year PGRs having a 'writing up buddy'. Access to our Broadening our Horizons Scheme (s2.5) demonstrates our commitment to research dissemination and fostering external collaborations. The quality of our training is reflected in authorship on 24% of submitted papers; front covers (CerebralCortex2017); and prizes (AnatomicalSociety2018).

We recognise the vulnerability of PGR students to the effects of COVID-19 and have implemented measures to mitigate the impact where possible (REF5a Annex). These include fee-free extensions and investment in a COVID-19 Impact Scholarship scheme to provide additional stipend support where needed.

2.8 Equality, Diversity and Inclusion (EDI)

Our research strategy is underpinned by a collective commitment to values and practices that cultivate a supportive, inclusive, fair research environment, and provide freedom and opportunity to succeed. We hold **Athena SWAN Silver**, with Institute of Neuroscience awarded Silver Status (2015) later consolidated into a **Faculty Silver Award (2019)** led by *Rowe*.

We embrace the University Equality Strategy (REF5a 3.4.1) with its membership of the **Advance HE's Race Equality Charter**, the **Business Disability Forum** and position as **Global Stonewall Diversity Champion**. This provides a framework for our approach, alongside important policy initiatives, which we champion at UoA4 level with *Shoaib* chairing the NU Black, Asian & Minority Ethnic Advisory Group; *Rowe* co-chairing the 'For Families' project to make NU more family-friendly and co-leading with *Petkov* a **Wellcome Trust Diversity and Inclusion award** to develop a Research Leaders EDI toolkit. UoA4 researchers also champion EDI nationally and internationally, five of whom are members of the ALBA network to promote EDI in brain science research (*Banerjee*, *Petkov*, *Smulders*, and ECRs Alberio, Luna).

Our physical workspaces are configured for colleagues with sensory and physical access requirements and our buildings have baby changing facilities and designated breastfeeding rooms. Flexible working is accommodated; pre-COVID some colleagues chose to work remotely part of the week or had flexible or compressed working hours to accommodate their personal circumstances. Meetings and seminars are arranged around flexible work patterns, religious needs and ensure a gender balance of presenters.

We have robust support and funding, for example through our Returners Support Programme (four colleagues supported) to enable colleagues to return to work following a period of extended leave and accelerate them back into their research programmes. Broadening our Horizons funding (s2.5) supports those with caring responsibilities to attend conferences and meetings. We have transparent processes for application and allocation of support with clear criteria communicated across the Faculty. With mental health an increasing issue, our Psychology School has developed innovative student support services with our **HEFCE Catalyst-funded project #Wellbeing4All**.

Women continue to be **role models** and have key roles within the Faculty and University. *Rowe* as Faculty Director of EDI led the Faculty Athena SWAN submission and is now University Dean of Research Culture and Strategy. *Reeve* (Parkinson's UK Senior Fellow) is Faculty Director of EDI (as job share), *Hurlbert* is University Dean of Advancement and *Hurlbert*, *Chrzanowska-Lightowlers* former Institute Directors.

We monitor gender and ethnicity at each career stage to inform our recruitment and career development activity. Only 22% of promotions have been women, and 33% of those to personal Chairs, which is below the Faculty average, as is the proportion of female clinical academics. Our **future EDI strategy** focusses on this, the relatively low proportion of BAME colleagues (9%); on

supporting and enabling colleagues to declare disabilities; broadening our processes and accessibility to diverse applicants; further improving our gender balance and encouraging all colleagues, particularly females, to seek promotion. Although a Global Stonewall Diversity Champion we do not currently monitor this protected characteristic. To enable critical scrutiny of our recruitment processes, "blind" triaging of NUAcT applications is now undertaken; subsequent monitoring will determine whether it effects meaningful change. We will continue to work on University initiatives to create research cultures, activities and environments where people from varied backgrounds can thrive.

We have embedded **EDI considerations in our submission** through an open process whereby outputs were self-nominated using our Research Management System and evaluated anonymously by at least two other senior academics (with both an indicative score and reasons). The REF lead moderated the scores across disciplines. Selection of the return was by paper, not author, in line with our code of practice.

2.9 Recognition and Reward

Formal recognition happens via our annual promotions round, an open process which encourages all staff to submit their case. NU signed the Declaration on Research Assessment in 2018 and does not base promotions or evaluations on journal impact factors. Achievements are based on quality evaluations and non-contextual citations. Successful career support is reflected in 19 of our 66 returned staff being promoted at least once since 2014.

More informally, our Vice-Chancellor holds Celebrating Success Ceremonies three times per year to celebrate staff and student achievements. Our Dean of Research and Innovation hosts a Celebratory Lecture twice a year spotlighting research and impact achievements with ECRs as keynote speakers. Post-doctoral successes are celebrated at an annual symposium, organised by our Post-Doctoral Committee, with *Nityananda* winning the best paper prize and being ECR keynote speaker at the inaugural symposium.

3. Income, Infrastructure and Facilities

3.1 Income

Total income to UoA4 since the last REF was £78.8M, averaging £11.2M per annum, representing an increase from £10M per annum from REF2014, from a varied portfolio of major awards across UKRI, UK government, European, charitable and commercial sectors. We highlight significant income from UK based Charities (31%, notably Wellcome Trust, Alzheimer's Research UK, Parkinson's UK), 27% UKRI and 22% NIHR. We participate in 20 European-funded projects, leading the EU IMI consortia MOBILISE-D (€50M, *Rochester*) developing and seeking regulatory and health technology approval for digital mobility biomarkers for use in clinical trials and clinical management. Our UK top 10 performance in relation to translational funding from MRC was specifically highlighted in the 2019 MRC evaluation report on Translational Research, 2008-2018.

3.2 Infrastructure supporting translation and impact

We have a strong pathway to support close working between clinical and basic science researchers, identify translational opportunities and achieve "pull-through" of research. We have strengthened significantly our infrastructure in the "near-patient" end of translational pathway through our national infrastructure investments and pump priming funding such as MRC Confidence in Concept, and more recently added commercial expertise through a Wellcome Trust-funded Translator in Residence (*Athey*) to specifically support earlier phase translation. Expertise in our Funding and Business Development Teams links researchers to key infrastructure and guides onward applications; for example, an Innovate UK ICURe award to support commercialisation of our ASTEROID vision test (s4.3). This priming support for early translational concepts has led to onward projects (including DPFS, NIHR EME & HTA programmes); is evidenced by day-to-day clinical impact of our research and recognised in the award of externally-funded infrastructure, facilities and centres (Table below).

Table: Externally funded, infrastructure, facilities and centres
H2020 MECHIDENT/ERC Consolidator Award Neural networks and mechanisms for identifying individuals 2017-2022
EU MOBILISE-D Connecting digital mobility assessment to clinical outcomes for regulatory and clinical endorsement
EU COMSTAR The effects of early-life adversity on cognition 2015-21
EU ChickenStress European Training Network 2019-2023
MRC Brain Bank 2013-2018 **renewed** 2018-20
MRC Dementias Platform UK MR-PET Partnership 2016-19
MRC UKDP: Integrated DEmentiA research environment (IDEA) 2015-16
MRC Lifelong Health and Wellbeing Centre in Ageing and Vitality 2014–19
BEIS/MRC National Innovation Centre for Ageing NIC-A 2018-onwards
MRC/EPSRC Molecular Pathology Node 2015-19
MRC NU Single Cell Functional Genomics Unit 2015–18
MRC Human Developmental Biology Resource 2018-23
NIHR Innovation Observatory 2017-22
NIHR Clinical Ageing Research Unit / Clinical Research Facility 2012-17 renewed, 2017-22
NIHR Biomedical Research Centre (BRC) Ageing and Long-Term Conditions 2012-17, **renewed** 2017–22
NIHR Applied Research Collaboration (ARC North East and North Cumbria) 2019–24
NIHR Newcastle In Vitro Diagnostics Co-operative IVDC 2018-22
NIHR Research Design Service – North East North Cumbria 2012–18 renewed 2018–23
NC3Rs Crack It Challenge 2017-21
Wellcome Trust Manufacturing Facility for First-in-Patient Complex Medical Devices 2019-22
Wellcome Trust - Neuromuscular Junction Research Facility 2017–20
Wellcome Trust Translational Partnership 2019–21
Training/DTPs
MRC Doctoral Training Partnership (DTP) - Discovery Medicine North (DiMeN) (2016-2021)
BBSRC Doctoral Training Partnership (2010, **renewed** 2015, 2020)
Wellcome Trust DTP: Systems Neuroscience: From Networks to Behaviour 2012–18
Wellcome Trust 4ward North Academy 2017-22
Leverhulme Trust Doctoral Scholarship Programme Behavioural Informatics 2018–23

3.3 Infrastructure

To strengthen our infrastructure, we purchased the **Campus for Ageing and Vitality** (CAV) site in 2019 from our partner NHS Trust (£8M). Together with the purpose-built Henry Wellcome Building (NHP housing and laboratory facilities, opened 2012) on our main campus, and the Sir James Spence building, these enable delivery of our academic programmes and support collaboration with our NHS partner trusts, underpinning our impactful translational research.

The CAV site is core to the future strategy of our AHSC, involving strong citizen engagement, and providing space for academic collaborations with industry and the public. CAV builds on existing infrastructure including clinical research activities from our NIHR Biomedical Research Centre, Newcastle Brain Tissue Resource, Clinical Ageing Research Unit (CARU), Centre for In Vivo Imaging and Wolfson Research Building, engendering a vibrant "near-patient" translational ecosystem.

We have made significant investment in buildings and equipment including development of the flagship Catalyst Building, bespoke £44M accommodation for our National Innovation Centres in Ageing (NIC-A) and Data (NIC-D) and the National Institute for Health Research Innovation Observatory (NIHRIO), providing a national horizon scanning function (*e.g.* upcoming trials in dementia to inform NIHR Translational Collaboration in Dementia activity).

With our partner trust NuTH, we have made significant investment in repurposing offices in the **Sir James Spence Institute** to provide specialist research laboratories for work with children and young people. The recently opened **Dame Margaret Barbour Building** (£36M) houses our School of Psychology facilitating cross-disciplinary working through co-location with our sports and exercise science facilities in our School of Biomedical, Nutritional and Sport Sciences. This bespoke building offers state-of-the-art facilities, including a forensic interviewing suite, media and behaviour lab, clinical consultation rooms and psychological testing cubicles. This investment crucially facilitates our strategy to expand research within our School of Psychology and enable interdisciplinary research.

3.4 Facilities

3.4.1 Comparative Biology Centre (CBC)

We are one of the very few Universities in the UK that enables research from rodents to marmosets to macaques to humans. Under the directorship of *Murphy*, the CBC has facilities for a diverse range of species including rats, mice, guinea pigs, rabbits, pigs, cattle, chickens, wild birds, zebrafish, marmosets and macaques. Together with direct collaboration with NCL clinicians, this bench to bedside model provides for a collaborative and innovative approach. Facilities include small-animal imaging as well as the non-human primate fMRI (described below); cell line derivation from primary tissues; histology tissue processing and DNA/RNA extraction; tissue and blood products; aseptic surgical procedures, routine blood sampling and dosing by any route, as well as a fully equipped and staffed theatre suite.

This state-of-the-art, multi-species facility enables collaborative research investigating disease pathologies, mechanisms of action and novel treatments, assisting the development of new *in vivo* models where necessary. Working closely with the Home Office and NU Animal Welfare Ethical

Review Body, CBC ensures the principles of the 3Rs – Replacement, Reduction and Refinement – are applied to all animal work conducted by staff and students. We offer tailored training and competency to individual researchers, together with Masters-level workshops in Laboratory Animal Anaesthesia and Perioperative Care, and Pain Assessment and Alleviation. The Centre and our animal husbandry practices have underpinned our national and international recognition for animal welfare research.

3.4.2 Newcastle Brain Tissue Resource & Newcastle Biobank

Our Newcastle Brain Tissue Resource established for over 30 years, is one of only four MRC-funded brain banks in the UK. It underpins key Newcastle discoveries (defining dementia with Lewy bodies; identifying mitochondrial DNA defects in Parkinson's; protein-protein interactions defining dementia phenotype, *e.g.* ActaNeuropathologica2017) as well as fuelling ~50 national and international studies per year. As part of the UK Brain Bank Network and Brains for Dementia Research Network it collects/manages human brain tissue for neurodegenerative diseases research. Collectively these contain over 3,400 brains (both fixed and snap frozen); the majority of donations are notably rich in ante-mortem phenotypic data.

We also access extensive well characterised human tissue samples in the Newcastle Biobank which incorporates >12 registered NHS Research Ethics Committee-approved tissue banks and have access to the archives of NuTH surgical pathology through the Cellular Pathologies Biobank. These biobanks have supported numerous studies *e.g.* on the development of the human thymus (Science2020).

3.4.3 Neuroimaging

The Centre for In Vivo Imaging (CIVI) is a multidisciplinary and cross-faculty research centre spanning NU's imaging research portfolio **encompassing both MRI and PET research imaging**. Since 2014 we have expanded our MRI capability through a second, multi-nuclear clinical 3.0T scanner, supported with additional core research posts (£1.5M). These facilities, used nationally and internationally in 233 projects, have led to over 300 papers, including identifying grey matter and metabolic changes to aid early detection of cognitive impairment in Parkinson's (*e.g. Burn*, *Lawson*, *Yarnall*, Brain2015). A further £5M joint investment by the MRC Dementia Imaging Initiative and NU has provided a 3.0T PET/MR scanner as part of the Dementias Platform UK initiative to accelerate dementia research with well-defined patient cohorts. Located on the CAV site the facility's capability will be augmented via NU investment of £1M in a PET Tracer Production Unit to enable on-site production of clinical grade PET ligands by end of 2021.

CIVI also operates the Preclinical In Vivo Imaging Facilities, located within the Centre for Translational Systems Neuroscience (see below). This hosts the **only vertical bore non-human primate scanner (4.7T) in the UK** and one of the **few in the world**. It has an ideal magnetic field strength for scanning awake, behaving non-human primates, forming an important part of a global international initiative on primate MRI open data (Neuron2020). We are one of the largest contributors to awake primate data and provide high-quality and high-resolution structural and functional MRI data, and support external contracts, *e.g.* high resolution tissue scanning, and national and international collaborations. The scanner has generated impactful discoveries, including the discovery of a human language pathway precursor in the primate auditory system (*Griffiths*, *Petkov*, NatNeurosci2020). We are developing a 7T small bore scanner for small primate neuroimaging, as part of a broader university strategy for *in vivo* imaging for rodents, primates and humans.

3.4.4 Bioimaging

Our bioimaging service provides autonomous or supported access to cutting-edge microscopy, imaging equipment and expertise. Available technologies include brightfield, phase and DIC microscopy; widefield fluorescence microscopy; confocal and multi-photon microscopy; light-sheet imaging; super resolution microscopy (SIM, STORM and STED). The new experimental platform funded by the BBSRC 19ALERT equipment grant will become part of the Bioimaging unit, providing opportunities for combined high density multi-electrode array recordings with *in vitro* imaging.

3.4.5 Digital and Bioengineering Infrastructure

NU has major strengths in computing and leads IDEA-FAST (*e.g.* neuro-prosthetics, optogenetic-microelectronics). We are a member of the Alan Turing Institute, we host the National Innovation Centre for Data and an EPSRC Centre for Doctoral Training in Big Data. Links to optogenetic technology have been fundamental to delivering our Wellcome Trust/EPSRC CANDO programme. Big data analytics is core to IMI MOBILISE-D and our work on machine learning from NHS data such as NIHR AI Health and Care award “Optical Coherence Tomography Automated Heuristics for Early Diagnosis via Retina in Ophthalmology and Neurology” (OCTAHEDRON).

3.4.6 Translational and Clinical Research Infrastructure

With NuTH we co-manage four Clinical Research Facilities across the city, including the Clinical Ageing Research Unit on the CAV site, focussing on studies in older people, notably in Lewy Body Disease spectrum disorders, and housing our Human Movement and Visual Perception Laboratories. These facilities are equipped to investigate gait, balance and mobility including an instrumented walkway, floor-mounted AMTI force plates, exercise treadmill, rehabilitation stairs; wireless system for collecting muscle activity data and motion capture systems together with APDM wireless body-worn motion analysis system with integrated accelerometers, gyroscopes and magnetometers. The site also includes: **NIHR Biomedical Research Building** featuring NHS-run innovative **CRESTA clinics** (*Clinics for Research and Service in Themed Assessments*) integrating one-stop, multidisciplinary clinics centred on the needs of older patients with complex multiple disorders and **Wolfson Building**, which co-houses our mental health and affective disorder research, the Regional Affective Disorders Service and where a CRESTA-style Care Pathway Enhancement clinic in depression is being developed (2021).

Our Wellcome Trust and University-funded **Centre for Translational Systems Neuroscience** (CTSN, established 2012) located in the Henry Wellcome Building (main campus) houses laboratories for translational research in human motor, sensory and cognitive systems. The CTSN’s multi-user neuro-imaging equipment includes high-resolution EEG and functional Near InfraRed Spectroscopy (fNIRS). It also includes equipment for motor systems research and human movement analysis, including guided transcranial magnetic stimulation and transcranial direct current stimulation, electromyography, multi-camera tracking, treadmills, and accelerometers. Perceptual and cognitive systems research facilities include eye trackers, auditory and visual psychophysics stations, behavioural experiment booths, and a mock fMRI scanner. Laboratory space is flexible and may be reconfigured. Studies within the CTSN have included a combined fNIRS/EEG study of cortical and motor activity during walking (*Pantall*, IntJPscyhopysiol2019); metaphor comprehension in individuals with schizophrenia, using eye-tracking (*Watson*, SchizophrResCogn2019); and an EEG study of visual object recognition (*Vuong*, JCognNeurosci2018).

3.4.7 Analytics Hub

Eight core scientific facilities deliver key analytical technologies and technical expertise in light microscopy, electron microscopy, flow cytometry, proteomics and protein production, genomics and sequencing, bioinformatics support, bio-screening and access to the Cat3 laboratory. The >£9.4M Hub also hosts the MRC-funded Single Cell Functional Genomics Unit. These facilities have 18 core staff and directly underpins a breadth of biomedical research, encompassing over 600 projects from over 200 research groups across the Faculty and University, facilitating over 754 publications, including papers where technical expertise contributions were recognised with co-authorships.

3.5 Methodological Infrastructure

Our recently introduced Innovation, Methodology and Application theme brings together academics, methodologists and technicians whose research delivers new underpinning technologies and contributes to the issue of research integrity through establishing a culture of best practice in data generation, annotation, analysis and presentation.

We lead the NIHR Research Design Service NE & North Cumbria (*Hancock*, UoA1), with strong Methodology Research Groups (UoA2) in Biostatistics, Health Economics and Evidence Synthesis, which provide advanced methodological expertise to interventional and other trials. The UKCRC-registered Newcastle Clinical Trials Unit (NCTU) has a trial portfolio that crosses clinical disciplines and from public, commercial, and charitable funders. Over this REF period the NCTU has supported numerous trials with the current portfolio comprising 33 active international trials, and has supported trials in stroke, Parkinson's Disease and affective disorders.

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

4.1 Collaboration

We encourage individual national and international links and the vast majority of UoA4 researchers are involved in one or more collaborative networks. These are frequently longstanding and highly impactful interactions (*e.g.* Cambridge University - ICICLE-PD study to determine clinical biomarkers predicting cognitive impairment in Parkinson's (*Burn*, *Lawson*, *O'Brien*, *Rochester*, *Taylor*, *Yarnall*) with over 20 joint outputs to date; Iowa University on the evolutionary origins of language (*Griffiths*, *Petkov*); Columbia University to reveal hypersynchronous activity in the seizure focus and patterns of propagation (*Trevelyan*); Aarhus University for novel functional imaging studies to evaluate the noradrenergic system in Parkinson's disease (*Brooks*). These collaborations utilise complementary approaches (*e.g.* carbon-11 PET tracers, peri-surgical monitoring of epileptiform activity) and resources (*e.g.* carefully phenotyped patient cohorts) to enhance research. The FMS Global Committee has distributed membership, ensuring effective bidirectional communication and awareness of international research collaborations. Our Pro Vice Chancellor Global oversees international collaborations, including the approval of memorandums of understanding. As evidence of our widespread collaborative work, 61.6% of outputs submitted in UoA4 have international co-authors, while a further 22.6% have co-authors from elsewhere in the UK.

Clinical networks include: the Dementia with Lewy Bodies International Consortium (lead; *McKeith*), which produced revised diagnostic criteria, implemented into ICD-11 and DSM-5,

ensuring worldwide unified diagnosis; a UK network of 19 stroke centres that evaluated clinical and cost-effectiveness of an extended stroke rehabilitation service (EXTRAS) following early supported discharge (*H.Rodgers*), and found it to be an affordable addition to improve stroke care.

Several of our researchers hold visiting fellowships at other institutions: *Alter* Senior Visiting Fellowship, Oxford University, honorary associate at Tuebingen University. *Griffiths* Adjunct Professor in Neurosurgery at Iowa University. *Nettle* Visiting Professor at Groningen. *Brooks* professorial appointment with Aarhus University. *S.Baker* collaborates with the Institute of Neurosciences, Kolkata, *e.g*. on post-stroke motor recovery.

In 2018 we instigated The North East England South Asia Mental Health Alliance, (*Sharma*, *J.Rodgers*) a jointly-funded (British Council, CNTW and NU) partnership between academic, clinical and policy making partners from across North East England and six South Asian countries (Bangladesh, India, Iran, Nepal, Pakistan, Sri Lanka) aligning aims with WHO's mental health action plan of improving mental health research, education and policy.

We lead numerous research networks on behalf of government and charitable bodies that facilitate collaboration and are associated with patient benefit; *e.g. Rochester* is Speciality Cluster/Alliance National Lead for the NIHR Clinical Research Network (CRN) for five specialties (ageing, dementia, neurodegeneration, neurological disorders, genetics) and leads the national NIHR CRN on increasing participation in clinical trials amongst under-represented patient groups; *Burn* is Director of the NIHR Translational Research Collaboration for Dementia, worked with the NIHR Mental Health Network on COVID-related neuropsychiatric complications, and is President of the Association of British Neurologists; *A.Thomas* is National Director for the Brains for Dementia Research network which collects and manages human brain tissue for research into neurodegenerative diseases; Honorary Professor *Walker* is clinical lead for the Parkinson's UK Excellence Network; *Parr* is Chair of the Strategic Research Group for the British Academy of Childhood Disability.

We have played major roles developing evidence-based guidelines. In addition to leadership of revised diagnostic criteria for classification for dementia with Lewy Bodies, outlined above, other examples include: International guidelines to improve mobility and reduce falls (*Rochester*), into NICE Guideline NG71 and the European Physiotherapy Guidelines (*Rochester*); autistic adults are now recognised in NICE guidelines as a high-risk group for suicide prevention (*J.Rodgers*) (NICE Guideline NG105); *White* is on the NIHR Hyperacute Stroke Research Centre Oversight Group. *McAllister-Williams* led the development of nationally-utilised British Association for Psychopharmacology guidelines related to affective disorders and led international consensus on the identification and management of difficult-to-treat depression (*McAllister-Williams*; *JAffectDisord*2020).

4.2 Contribution to the Research Base

Close integration with our NHS Trusts, clinical and allied health professional colleagues is essential to our strategy of translation. We have 21 clinical academic colleagues, together with 25 NHS consultants as honorary staff, who actively lead our research and teaching programmes. Honorary colleagues are supported in the same way as substantive members of staff, with our Clinical Academic Office having active oversight of their research careers. Integrated in our formal

structures and active participants, they set relevant and searching clinical questions and complete the bench-to-bedside-and-back cycle of research. Our integration with NuTH and CNTW has been further cemented by our Academic Health Science Centre award, through which we have developed research satellites, initially in Diagnostics, Rare Diseases, Advanced Therapeutics and Robotic Surgery, creating new linkages and outputs for research.

Our colleagues shape and influence national and international research bases in their specific fields. We have four Fellows of the Academy of Medical Sciences (*Brooks*, *Griffiths*, *McKeith*, *Burn*) and three NIHR Senior Investigators (*McKeith*, *Burn*, both Emeritus, *Rochester*). Our returned researchers hold editorial positions on 21 scientific journals, including Science, Brain and Proceedings Royal Society B. *Petkov* and *Attems* are Editors in Chief, respectively, of Current Research in Neurobiology and Acta Neuropathologica and we have guest edited >10 special issues. *Forsyth* is editor of the 3rd Edition of the OUP Paediatric Neurology Specialist Handbook.

We contribute to UKRI, Wellcome Trust and charitable body peer review processes, as well as several UK training panels and other international grant awarding bodies. *Blamire* is on the REF2021 sub-panel 4. **Chairs**: MRC/EPSRC Hearing Aid Initiative (*Griffiths*); Neuroscience Panel for the European Research Council Advanced Grants (*Brooks*); Action on Hearing Loss International Grant Panel (*Rees*); Research Council of Norway Evaluation Panel (Ecology/Evolution) (*Rowe*); **Members:** EPSRC Healthcare Technologies Panels (*Blamire*, *H.Rodgers*, *Hurlbert*)**;** Wellcome Trust Expert Review Group (Cognition and Mental Health, *Petkov*); MRC Neuroscience and Mental Health Board (*Griffiths*, *Jackson*); MRC Senior Fellowships in Hearing Research (*Griffiths*); MRC Clinical Training and Career Development Panel, Wellcome Trust Peer Review College and UKRI Future Leaders Fellowship Panel (*McAllister-Williams*); Alzheimer's Research UK (*Brooks*, *Attems*, *Outeiro*, *Taylor*); Stroke Association UK Grant award committee (*Price*); College of Optometrists Research Committee (*Read*); UKRI-BBSRC Neuroscience and Behaviour Working Group (*Rees*); BBSRC Committee A, NC3Rs Grant Assessment Panel, and UKRI-BBSRC People and Talent Strategy Advisory Panel (*Rowe*); Academy of Finland Evolution panel (*Skelhorn*) and Neuroscience panel (*Sernagor*); ERC Advanced Awards (*Bateson*); EU FP6 and FP7 LIF Panels for Marie Skłodowska-Curie Actions (*Racca*).

We provide extensive formal and informal advice for external organisations that lead both the science and patient interests for specific conditions. *Parr* chairs the Scientific Research Committee of Research Autism, is external advisor to the National Autism Project; NIHR Paediatric Neurosciences advisory group member and Trustee of The Castang Foundation. *Parr and Basu* are members of the Paediatric Neurology Association Research Committee. *Forsyth* is Secretary of the European Paediatric Neurology Society and Trustee of Child Brain Research. *Yarnall*, *Pavese are* Parkinson's UK College of Experts members; *White* is a Stroke Association Research Panel member; *Outeiro* Chairs the Movement Disorders Society's Task Force for the Biological Definition of Parkinson's Disease. *J.Rodgers* is patron of SPARC (Support for Parents of Children with Autism and Related Conditions), co-led the James Lind Alliance Priority Setting Partnership on Suicide in Autism and chaired the first International Summit on Suicide in Autism (2018).

Several of our researchers have been recognised for research contributions via awards or through prestigious invited lectures. *Brooks* - Ramon Y Cajal Award of the Spanish Academy of Medicine and the Alzheimer's Award - Danish Alzheimer's Research Foundation, *Griffiths* - NHS Silver

National Merit Award. *A.Thomas* - Senior Investigator Award of the International College of Geriatric Psychopharmacology, *McKeith* - European Grand Prix for Alzheimer's Research and Lifetime Achievement Award from the American Alzheimer's Association. *Burn*, *Pavese* elected Fellows of the European Academy of Neurology and *McAllister-Williams* Fellow of the European College of Neuropsychopharmacology. *H.Rodgers* won the NIHR New Media Competition Prize, *Parr* received a NIHR/MQ Involvement award. UoA4 colleagues were shortlisted for Times Higher Education STEM Research Project of the Year (*Nityananda*, *Read*) and Outstanding Technician of the Year (*Leitch*). *R.Thomas* gave the Linacre Lecture of the Royal College of Physicians (2017) and *Read* delivered the Geoffrey J Burton Memorial Lecture of the Applied Vision Association (2018).

4.3 Wider Contributions to Society and the Economy

Researchers have delivered impacts in diverse areas through collaborations with multiple different individuals and organisations which have enriched our research environment (examples below).

4.3.1 Public policy and clinical practice

We work with Northumbria police force on colour vision tests for recruits (*Hurlbert*), psychological approaches to deter crime (*Bateson*, *Nettle*: ICS "*Watching eyes: a cost-effective method of deterring undesirable behaviour*"); and forensic training (*Oxburgh*: ICS "*Non-coercive forensic interview training*"). We worked with the Home Office and Ministry of Justice to implement mandatory polygraphy to help manage high-risk sex offenders in 2014, which subsequently led to the introduction of polygraphy into the 2019 Domestic Abuse Bill and 2020 Counter-Terrorism and Sentencing Bill (*Grubin*). *Basu* gave evidence to the All-Party Parliamentary Group on cerebral palsy, to inform on management of this condition.

We lead several annual conferences that enhance and disseminate good clinical practice, bringing together academic researchers and clinicians in our areas of strength including the North East Epilepsy Research Network Meeting and Three Rivers Parkinson's Disease Meeting (13th year). Our Practical Cognition course (12th year) provides a national training for junior doctors, trainees and consultants to develop skills in cognitive assessment, while our researchers contribute to medical CPD courses around the UK.

4.3.2 Commerce and the economy

Interactions commonly involve pharmaceutical and device manufacturing companies. Notable examples include working with 13 companies to deliver MOBILISE-D in a European Consortium (*Rochester*) to develop digital mobility biomarkers. We lead and co-designed, with Intercept Pharma, a clinical trial of an FXR-agonist aimed at improving cognition in Parkinson's (*Taylor*, *Yarnall*). The study arose from patient involvement in our cross-disciplinary research into Primary Biliary Cirrhosis (*Jones*, UoA1). We led work with GSK to evaluate the effect of camicinal, a gastroprokinetic, on the absorption of l-dopa and symptoms of PD (*Burn*, MovDisord2018).

Our research has attracted over £1M industry funding from companies including Eisai, Magic Leap, Takeda and Neurexpert Ltd, in areas including user experience with smartphones (*Hurlbert*, *Read*), novel visual displays (*Read*), and the function of brain networks (S.*Baker*, *Cunningham*, *LeBeau*). The Newcastle Blue Room Virtual Reality programme (*Grahame*, *Parr*, *J.Rodgers*) led to the formation of a spin-out company, XRTherapeutics, in July 2020. Our auditory research links to Autifony Therapeutics for work on tinnitus (MRC CASE Award). Our ASTEROID game, testing

binocular visual function in children (Health Innovation Challenge Fund Award, £1M *Read*) developed by combining researchers, computer game designers and the public is used in research labs across the UK, Europe and North America and has been licensed to a Canadian company.

4.3.3 Society and culture

We strive for our science to be of transformative value for the general population, epitomised by research on misophonia reported by CNN, New York Times, BBC Radio 4, BBC online (read by 1.7 million; no.1 video online), Wired, Time, other national and international media. The publication elicited >175 emails from people thanking or offering to participate in future studies. Regular contributions to national radio and television, for example explaining popular illusions such as the "Yanny/Laurel" auditory illusion (*Rees*, James O'Brien's LBC radio show); "gravity hills" (*Read*, BBC2, ZDF); and #thedress (*Hurlbert*, BBC4, Gogglebox). On Radio 3's annual Free-Thinking Festival, *Bateson* discussed group behaviour and *Petkov* created an interactive experiment to illustrate music's influence on the brain. Praying mantis stereo vision research was featured on BBC Breakfast, Radio 4, with reports in National Geographic, Nature Research and Wired (*Nityananda*, *Read*), and the role of stripes in camouflage (*Rowe*, CurrBiol2019) was highlighted in the Sun newspaper. *Hurlbert* was a Scientist Trustee of the National Gallery (2010-2018), co-created its "Making Colour" Exhibition (2014) and serves on its Scientific Consultative Group; she was profiled on Radio 4's "The Life Scientific". The Northern Centre for Mood Disorders (University/NHS collaboration) ran regular events discussing mental health and advances in research (depression, addiction, suicide). We hosted celebratory and annual public events with Autistica, Epilepsy Research UK, Parkinson's UK, Alzheimer's Research UK, disseminating latest research.

Our strong tradition of active participation in public engagement continues, with annual events such as Pint of Science, Brain Awareness Week, and Soapbox Science. We collaborated with local CIC Palace of Science on two science festivals (2018, 2019), each attracting over 200 people; helped establish the art-science-design group Colour Collective UK; worked with local science hub International Centre for Life to create their permanent Brain Zone exhibit; and presented four flagship Holmes public lectures, aimed at 10-14 year-olds, covering Animal Vision, Human Vision, Pain and Brain Imaging. Wellcome public engagement awards (CANDO project *LeBeau*) fund a dedicated public engagement officer, supporting innovative collaborative events including *Illuminating the self* with artists Aldworth, Carney. We contributed to the Great Exhibition of the North, worked with theatre companies staging/producing plays/short films about OCD (Bizarre Love Triangle, *Nettle*), insects (Six Legs, What's Your Favourite Insect? *Nityananda*), and brain implants (Deep Mind, *Jackson*). *Basu* advised the Dame Vera Lynn Children's Charity for "Anything you can do, I can do" book for children with hemiplegia.

Our affective disorders group led the development of online mental health support during the COVID-19 pandemic that has been taken up by both HEI and NHS organisations.