Institution: University of Cambridge

Unit of Assessment: 4

a. Overview

The configuration of UoA4 matches our interdisciplinary strategy for understanding the human brain and mind in health and disease across the lifespan. Our integrated portfolio of research comprises: *Social and Cognitive Developmental Psychology*; *Behavioural Neuroscience*; and *Research in Psychiatry and Clinical Neurosciences*. Much of this work is coordinated across the *Cambridge Neuroscience* Strategic Research Initiative, representing the community of neuroscientists working in the Cambridge environment (www.neuroscience.cam.ac.uk): the 751 researchers, including 291 principal investigators, are drawn from throughout the University, embedded Research Council Units and other Institutions in Cambridge. Our submission to UoA4 (77 in category A) mainly represents individuals from the University Departments of Psychology; Physiology, Development and Neuroscience; Psychiatry; and Clinical Neurosciences; Directors of the MRC Mitochondrial Biology (MBU) and Cognition and Brain Sciences Units (CBSU), both of whom hold a joint appointment with the Clinical School; and 8 staff in category C. Additional research in cellular and molecular neuroscience is returned in UoA5 and UoA6.

b. Research strategy

Building on the research described in RAE2001 and 2008 (submitted to UoA9 and 44), we have developed the strategy outlined in those submissions over the reporting period for REF2014. This has involved delivery of the main existing research programmes and the introduction of new themes, especially in developmental psychology and social neuroscience, with reconfiguration of research groups and recruitment of new staff. Of note, previously independent departments of psychology (Experimental Psychology and Social & Developmental Psychology) and the Centre for Neuroscience in Education (previously within the Faculty of Education) are now merged as a new Department of Psychology. Elsewhere, we have brought together individuals working on cognate disciplines into the same environment (Herchel Smith Building for Brain and Mind Sciences). As a result, the return in REF2014 is described in three integrated research domains that cross departmental boundaries allowing much collaboration across themes:

- In *Social and Cognitive Developmental Psychology* we derive concepts and use methods of developmental, cognitive and social psychology from infancy to adulthood in order to understand human development and social interaction in the context of education, policy, law and clinical application;
- In *Behavioural Neuroscience* we use the theory and methods of experimental and social psychology and cognitive neuroscience to understand systems that determine animal and human behaviour, and apply that knowledge to problems in clinical medicine and population health;
- In *Research in Psychiatry and Clinical Neurosciences* we translate work on behavioural neuroscience into populations and cohorts of patients, investigate the basis for mental disorder, and develop interventions that promote mental health; and we characterise the pathogenesis of common neurological diseases that result in physical, affective and cognitive impairments and apply that knowledge to derive and validate mechanism-based strategies for limiting and repairing the damage.

Almost without exception, the 77 individuals returned in category A and 8 in category C contribute to research in more than one theme; as a rough guide to the scale of each, we assign these 85 returnees to a single theme at the head of each sub-section below. Furthermore, we only illustrate our strategy with selected research completed during the period of review, highlighting key discoveries and investigators (named in alphabetical order), and including plans to align further these three research domains. Our future research will maintain delivery of

internationally competitive research in these areas; support that work through newly established and well-funded research centres; and manage succession and recruitment to new posts (see Sections 3 and 4). All animal work is compliant with Home Office project and personal licences. Clinical work is compliant with NHS research ethics committee criteria. We follow guidelines of all relevant academic institutions: the research and development committees within Cambridge University Health Partners (CUHP: www.cuhp.org.uk) have responsibility for research governance involving patients; and the National Institute for Health Research (NIHR) Cambridge Comprehensive Biomedical Research Centre (BRC) governance structure includes an executive committee (3 members of which are in UoA4).

2(i) ***Social and Cognitive Developmental Psychology***. This domain is structured around four main groups (11 individuals in category A):

The Centre for Neuroscience in Education (Gathercole, Goswami and Szucs) focuses on the development of reading and numeracy, work that is relevant to the Technology Foresight 2008 Programme on Mental Capacity and Well-Being (see impact study). A novel approach based on electrophysiology and functional imaging tracks cognitive processes relevant to developmental dyslexia and dyscalculia. Work on developmental disorders of cognition and the brain links with the developmental neuroscience approach to education, following the appointment of Gathercole (Director, MRC-CBSU from 2011).

The Centre for Family Research (Golombok, Hughes and Lamb) studies parent-child relationships in both traditional and unusual circumstances including fatherless, lesbian and surrogacy families, and children arising from reproductive donation (see impact study); and family risk factors for maternal depression and developmental executive dysfunction. In the context of child abuse, we have shown that sensitive interviewing improves the amount and quality of information obtained from young victims, witnesses and offenders in investigative settings. These research themes will contribute increasingly to evolving attitudes on the family as these assume increasing societal importance.

The Developmental Disorders Consortium (Baron-Cohen, Davis, Hines and Plaisted-Grant) researches determinants of developmental psychopathology, including theories of how autism affects implicit and explicit learning and attentional processes. We have elucidated the consequences of congenital adrenal hyperplasia and prenatal androgen exposure for gender, and motor and socio-emotional development. Work has continued on the role of fetal testosterone exposure in influencing sexually dimorphic play, empathy, social reward learning and autistic traits in children; and on interactions between the pre-natal hormonal environment and genetic characteristics (eg *CNR-1*). Future work will combine cognitive, neuroendocrine and neuroimaging approaches to interactions between gender and cognitive development in healthy and developmentally impaired children, and will form part of the future strategy for our clinically focused programmes and the proposed Institute of Translational Neuroscience (see 2.iv).

The Comparative and Developmental Psychology Group (Clayton) translates work on animal behaviour to children. Extension of novel work with avians has led to the identification of new parallels between social and physical cognition in young children. A recently funded programme will investigate goal-state attribution and planning behaviour.

2(ii) ***Behavioural Neuroscience*****.** This domain is structured around three research clusters (27 individuals in category A; with 2 in category C):

Sensory neuroscience (Kourtzi, Mollon, Moore, Tolhurst and Welchman; with Carlyon). Work on auditory psychophysics, including the development of novel methods for enhancing spectral changes in sounds, has led to improvements in the intelligibility of speech from background noise in hearing-impaired people (see impact study). Novel genetic approaches to understanding human vision include the first genome-wide association study of normal variations in human perception; and demonstrations of tetrachromacy in women heterozygous for anomalous trichromacy. With forthcoming retirements and new appointments, this domain

will now focus mainly on vision.

The Centre for Speech, Language and the Ageing Brain (Tyler, Bozic, Marslen-Wilson and Stamatakis; with Henson) includes research that co-ordinates a cross-School consortium on neurocognitive mechanisms in ageing ('CamCAN'); this uses multi-modal imaging and magnetoencephalography (MEG) in elderly people. We have developed pipelines for advanced network metrics that test hypotheses on age-related adaptation and plasticity. This programme is complemented by research on the hemispheric control of speech comprehension in both healthy and injured brain. Future plans will incorporate a longitudinal study of the cohort.

The MRC-Wellcome Trust Behavioural and Clinical Neuroscience Institute (*BCNI*: Bullmore and Robbins) has interactive programmes linked by research themes on translation, treatments and traits defining phenotypes of normal behaviour and related clinical disorders. Research achievements include:

- Drug addiction (Bullmore, Dalley, Ersche, Everitt, Milton, Robbins and Voon): advances in the molecular, neural and neuropsychological bases of drug addiction based on the hypothesis that addiction represents devolution of behavioural control from prefrontal cortex to striatum, and from ventral to dorsal striatum, paralleling a shift from impulsive to compulsive behaviour; the demonstration of an impulsivity endophenotype in rats associated with reduced striatal D2 receptors for compulsive cocaine seeking behaviour which has been extended by genomic and imaging studies; and parallel studies in human drug abusers identifying novel neural endophenotypes for stimulant addiction and alcohol dependence. The future strategy includes the development and evaluation of new treatments including pharmacological modulation of memory reconsolidation, atomoxetine and a μ-opioid receptor antagonist (with GSK);
- Neural and neurochemical basis of cognition in animals and humans (Bussey, Clark, Clarke, Robbins, Roberts, Saksida, Schultz, Simons): work in the review period includes identification of neuronal signals for reward, risk and economic decision making in non-human primates using single unit recording of dopamine and orbitofrontal neurons and complementary human studies using fMRI; the role of modulatory influences of dopamine and serotonin on prefrontal-limbic-striatal circuitry in cognitive flexibility and anxiety in primates; behavioural consequences of hippocampal neurogenesis; novel methods for assessing cognition in rodents and in humans (see two impact studies); the role in human neuropsychology of frontoparietal cortex in subjective experience of recollection and reality monitoring; and the discovery of paradoxical false memory for objects after brain damage;
- The social neuroscience of decision-making and affect (Aitken, Clark, Kogan, Rentfrow, Robbins, Schnall): work has included the neurochemical and emotional modulation of moral judgment and well-being; the neuropsychological substrates of risky decision-making and novel studies of traits and personality;
- Brain networks and connectomics are a major focus of the *Brain Mapping Unit*. (Bullmore, Suckling and Vertes). The group plays a leading role in the technical development of graph theory methods for analysis of topological and physical properties of human brain structure and functional networks in health and various disorders. Discoveries include some general principles of nervous system organization and new network markers of brain disorders.

The present funding for the BCNI finishes end 2015. Plans for renewing and extending the BCNI form a central part of the University's strategy to support translational neuroscience within its Campaign Flagship Initiative. The proposed Institute of Translational Neuroscience (see 2.iv) will also link our developmental programmes (2.i) to our behavioural neuroscience (2.ii) and the clinically orientated research described in the following section (2.iii).

2(iii) ***Research in Psychiatry and Clinical Neurosciences.*** This domain is structured into 2 larger clusters – Psychiatry and Clinical Neurosciences, which in turn are organised into cognate research groups.

The **Psychiatry** cluster is structured around five main groups (11 individuals in category A)

linking to NHS partners in the acute sector, Cambridge University Hospitals NHS Trust (CUH: www.cuh.org.uk) and mental health (Cambridge and Peterborough NHS Foundation Trust [CPFT]: www.cpft.nhs.uk), both members of the academic health sciences centre (AHSC), Cambridge University Hospitals Partners (CUHP) and the Cambridge Biomedical Research Centre (BRC); and more widely through the Collaboration for Leadership in Applied Health Research & Care Cambridgeshire and Peterborough (CLAHRC CP: www.clahrc-cp.nihr.ac.uk).

The BCNI Clinical Behavioural Neuroscience Group (Bullmore, Chamberlain, Clark, Ersche, Fletcher, Jones, Murray, Robbins, Sahakian, Urcelay and Voon) translates behavioural neuroscience findings, largely arising from applying basic neuroscience research in the *BCNI*, to improved understanding of neuropsychological and neurochemical bases of obsessive-compulsive disorder (OCD), attention deficit hyperactivity disorder (ADHD), frontal lobe injury, compulsive gambling, anxiety, schizophrenia and depression. Research achievements include:

- Demonstration of orbitofrontal hypoactivity as an endophenotype; and enhanced habit learning and reduced goal-directed behaviour in OCD
- Prediction of substance abuse and ADHD in the IMAGEN adolescent cohort
- Elucidation of neural substrates for gambling behaviour in humans
- Discovery of aberrant prediction errors in fronto-striatal systems underlying delusion.

The Bernard Wolfe Health Neurosciences Group: (Bullmore, Chamberlain, Clayton, Fletcher, Goodyer, Simons; with O'Rahilly and Farooqi [UoA1]) combines neuroscience, metabolic and pharmacological approaches to an understanding of appetite, satiety and health-related behaviour. Attracting philanthropic, industrial and Wellcome Trust support the group has expanded rapidly since RAE 2008. Research achievements include:

- Demonstrating the importance of motivational mechanisms in the neural component of obesity and health-related decision making; and that stimulus-specific putamen/pallidal responses in obese people with binge eating are sensitive to altered μ-opioid function.

The Life Course Neuropsychiatry Group (Coles, Holland, Goodyer, Jones, O'Brien, Rowe and Sahakian) studies clinical and population cohorts accrued since RAE2001. There are collaborations between the MRC-CBSU (including with Calder who died in October 2013 and so is not returned), the ALSPAC birth cohort and the MRC Unit for Lifelong Health & Ageing (London) on specific learning disability and developmental neuropsychiatric syndromes across the life course including conduct disorder, antisocial personality traits and depression. These elucidate genetic and environmental mechanisms in early life that influence clinical presentation, course and therapeutic response. Research achievements include:

- Very long-term follow-up of children with conduct disorder and anti-social personality (ASP) traits revealing pervasive negative impacts on health, family and social outcomes; definition of emotional processing deficits in ASP traits shared with depression presenting as an adolescent behavioural phenotype indexing high risk of violence to self and others;
- Epidemiological studies of psychosis creating multi-level models of psychosocial risk and prediction (www.psymaptic.org);
- Randomised clinical trials on cognitive therapy for at-risk mental states (multi-centre EDIE-2); MR imaging in response to psychotherapy in young people with depression; cognitive training through computer gaming in first episode psychosis; cognitive enhancement with modafinil; and brain structural end-points for a multi-centre trial of minocyline for negative features of schizophrenia;
- The elucidation by neuroimaging of a neural network for performance on a predictive memory test for Alzheimer's disease based on the CANTAB-PAL task (see impact study);
- Findings of autoantibodies to neurotransmitter receptors in schizophrenia and immune therapy resulting in remission of the psychotic syndrome with demonstration that circulating markers of inflammation in childhood predict later depression and psychosis (with ALSPAC) have led to a new NIHR BRC immune-psychiatry theme and industrial collaborations (GSK).

The *Intellectual and Developmental Disabilities Research Group* (Holland [(see impact study]), funded through an endowment from the Healthcare Foundation and forming part of the NIHR CLAHRC CP, catalyses interdisciplinary collaboration within and beyond Cambridge in biologically orientated 'syndrome-based' research and clinico-legal studies. Future plans include collaboration with the Gurdon Institute to model abnormal cellular connectivity in neurodevelopmental syndromes using stem cells.

The *Wellcome Trust Neuroscience in Psychiatry Network* (NSPN; Bullmore, Goodyer, Jones and Suckling; with UCL) is a new strategic collaboration that links the *Brain Mapping Unit* and *Life Course Neuropsychiatry Group* to characterise the decade of post-pubertal development, the period of accelerating risk for the major psychopathological syndromes of adulthood, in terms of structural and functional connectomics; and derived computational models of cognition. Extension of the approach to clinical cohorts will underpin investigation of risk for conduct disorder, affective disorders, and psychosis.

Our strategy for the **Clinical Neurosciences** cluster (28 individuals in category A; with 6 in category C) synergises with basic cognitive neuroscience in the area of behavioural neurology; and studies generic aspects of brain injury and repair relating to common neurological and neurosurgical diseases. The two themes are organised as two cognate groups now optimally aligned around the following topics: brain imaging (structural, functional and molecular), dementia, neurodegeneration, head injury, glioma biology, multiple sclerosis, stroke, plasticity and regenerative neurology including stem cell biology. The *Wolfson Brain Imaging Centre* (WBIC: Aigbirhio, Bullmore, Carpenter, Fryer, Pickard, Suckling, Williams) provides multimodal imaging facility for translational clinical science involving high acuity patients in a unique environment created by incorporation of the centre within the envelope of the neurosciences critical care unit (NCCU): work in human brain imaging supports stroke; brain injury; coma and the vegetative state; neuro-oncology; brain plasticity and connectivity; dementia syndromes; neuro-psychiatric disorders and obesity; and molecular imaging of orphan receptors. With the impending retirement of the WBIC Director (Pickard), a new scientific and technical strategy for neuroimaging, covering all the relevant imaging platforms including small animal imaging and collaborations with the MRC CBSU, is being led by the WBIC's new Scientific Director (Bullmore).

The Systems and Restorative Neurology Group (Barker, Bussey, Fawcett, Holland, O'Brien, Robbins, Rowe, Sahakian, Saksida, St George Hyslop, Spillantini; with Bertolotti, Goedert, Hornberger and Rubinzstein [UoA1]) works on dementia syndromes and Parkinson's and Huntington's disease. Research achievements include:

- The discovery of risk alleles for Alzheimer's disease; description of genetic risks and clinical predictors for early cognitive failure in Parkinson's disease; and participation in genome wide association studies for these and other neurodegenerative diseases;
- Demonstrating changes in structural and functional brain connectivity resulting from frontotemporal and other dementias, and Parkinson's disease; linking these to changes in cognition; studying mechanisms of behavioural control and social cognition from multivariate analyses of brain imaging and psychopharmacology; and investigation of beta-amyloid accumulation and brain atrophy using ^{11}C-PiB PET and structural MRI in Down syndrome as a model of Alzheimer disease;
- Showing that chondroitinase and inosine promote plasticity and rehabilitation in models of cognitive disease; and that injection of chondroitinase induces a temporary memory improvement in transgenic mice expressing human mutated P301S tau.

Future work includes the role of neuroinflammation in dementias: and focuses especially on clinical trials including a study of rilmendine in patients with early stage Huntington's disease; and a long term study on the tolerability and efficacy of fetal striatal allografting in patients with Huntington's disease.

The Brain Injury and Repair Group (Ban, Barker, Bevan, Coles, Compston, Czosnyka, Fawcett, Hutchinson, Jones [J], Kotter, Kwok, Lorber, Markus, Martin, Menon, Pickard; Pluchino; Sahakian; Sawcer, Smielewski, Spillantini, Watts and Zeviani; with Coleman, Kirkpatrick and Warburton) works on the aetiology, mechanisms, clinical phenotype, biomarkers and novel treatments in head injury, stroke, multiple sclerosis and neuro-oncology. Research achievements include:

- *Aetiology*: identification of 110 risk variants for multiple sclerosis with ongoing functional genomics for two risk alleles; and description of several genetic susceptibility alleles for stroke and related cardiovascular pathologies
- *Mechanisms*: characterisation of the lactate, glycolysis and pentose phosphate pathways in the response to acute brain injury (see impact study); description of the role of mitochondrial dysfunction in Parkinson's disease; establishing striatal synaptic pathology as an important factor in the early development of Parkinson's disease and other alpha-synucleinopathies with cell-based models of tau phosphorylation and aggregation; studies on immune depletion and reconstitution in multiple sclerosis; and the molecular signatures of proliferation and migration, and the stem-cell origin of malignant glioma cells
- *Biomarkers*: development of databases and improved surrogate outcome measures for clinical trials with an emphasis on imaging acute plaque activity using statins in stroke, and tissue indicators of time from stroke onset to improve applications of thrombolysis
- *Phenotype*: characterization of the profile of post-traumatic neuronal loss following head injury using multi-modality measurements of brain function and ligand-based PET with structural brain imaging and connectivity analysis; and assessing sentience in the persistent vegetative state with development of computer-brain interface methods of enhanced communication and action in the intensive care setting (see impact study)
- *Repair*: showing that chondroitinase and inosine, and nanotechnology-based electrical interfacing with direct nerve impulses, promote plasticity and rehabilitation in models of spinal cord injury; the demonstration that microtubule-associated protein tau related neuronal death can be rescued by transplanted neuronal precursor cell derived astrocytes; and the use of stem-cell derived vesicles and RNA nanoparticles to promote cell-cell communication and repair in this context
- *Clinical trials*: completion of the SILVER study of reduced external drain infection in hydrocephalus; initiation of a phase 2a study of acute hyperoxia in acute brain injury; a phase 2a trial of human recombinant IL-1 receptor antagonist in head injury, and of vigabatrin; completed recruitment for the RESCUEicp trial; and initiation of RESCUE-ASDH (primary decompressive craniectomy) in head injury; participation in the ProSavin® gene therapy trial in patients with Parkinson's disease; completion of a phase 2a study of autologous mesenchymal stem cells in progressive multiple sclerosis; and conclusion of Phase 2 and 3 studies of Alemtuzumab with a product licence for first-line treatment of active relapsing-remitting multiple sclerosis granted by EMA in September 2013 (see impact study).

Future work maintains the emphasis on mechanism-based therapeutics and includes the development of stem cell-based therapies, nanoparticle delivery of growth factors and novel agents that target mitochondria to effect repair in animal models of Parkinson's and Huntington's disease; the CADISS trial and a novel von Willebrand inhibitor in stroke; first-in-man studies of keratinocyte growth factor for reducing secondary autoimmunity after Alemtuzumab; and a phase 11a study of Bexarotene (retinoic-X-receptor gamma agonist) to promote remyelination in multiple sclerosis.

2(iv) Future strategy Our future strategy for our three over-arching research themes (2.i to 2.iii) is to support existing teams in obtaining long-term financial support from diverse sources; recruit strategically to vacant and newly established positions; align research teams optimally; and accommodate them in purpose-built facilities. The vision of *Cambridge Neuroscience* is to create internationally-leading, interdisciplinary and interactive twin-hubs for neuroscience on the Downing Site and the Cambridge Biomedical Campus (see 4ii) over the next REF period, to consolidate our existing structures, including the cross-School BCNI. This will evolve into an *Institute of Translational Neuroscience* that drives advances in developmental, cognitive/behavioural and

systems neuroscience. This will inform a parallel evolution of existing strengths in psychiatry and clinical neuroscience that, through knowledge of disease, provides a vehicle for the application of new therapeutic approaches to neurodevelopmental, psychiatric and neurodegenerative disorders. The structures we are planning will build on existing University strengths in experimental neuroscience and clinical medicine as the basis for understanding and treating mental health and brain disorders. We are confident of obtaining major capital from the NHS Trusts, benefactors and the University via its Campaign Flagship Initiative. To realise this ambition, we are planning a coordinated series of programmatic and strategic award applications to RCUK, charities and industry, together with requests for major equipment including high resolution MR, PET, MEG and other modalities for both animal and human studies.

c. People:

c(i) Staffing strategy and staff development

We work on two main campuses (see Section 4) with involvement both of basic science and clinical staff on each. Considering technicians and nurse practitioners, and both established and un-established staff, we employ 313 research-active individuals of whom 52% are women.

We have responded to retirements and other departures, strategic new research opportunities, and educational objectives with new senior appointments from 2008; and will continue this policy during the next REF reporting period. The recent appointments of Kourtzi and Welchman secure work in sensory neuroscience (retirements are Moore, 2014; Mollon, 2014; Tolhurst, 2016; and Alcantara to a College teaching post). Milton strengthens animal models of addiction and memory (retirements include Everitt, 2014). We have recruited Marslen-Wilson (ex-Director of the MRC-CBSU), and appointed Bozic to strengthen language and cognitive psychology, linked to ageing, following the departure of Miozzo (to USA). The relocation of Goswami and Szucs adds work in cognitive development to *The Centre for Neuroscience in Education*. The merger with Social and Developmental Psychology brings together Aitken, Clark, Kogan, Rentfrow and Schnall. We have consolidated research with non-human primates (Clarke, Robbins, Roberts and Schultz); and in animal behaviour and learning (Clayton, Urcelay and one future appointment; with Thornton having recently moved to Exeter and Dickinson, retired 2011). Succession planning is in place for Russell (2015) and Robbins (2017). In Psychiatry, Croudace moved as professor to York; and Lennox (replaced by Murray) as Lecturer in Oxford. We established a professorship in old age psychiatry (O'Brien; from Newcastle). Succession planning includes Huppert (University Lectureship, retired); Holland (psychiatry of learning disability: 2015); and Goodyer (child and adolescent psychiatry: 2017) where we will reinvest in developmental psychiatry. In Clinical Neurosciences, Baron, Hodges, Chandran and Nestor moved as professors to Paris, Sydney, Edinburgh and Marburg, respectively. We appointed Markus (St George's London) as professor of stroke medicine; and appointed professorships in ophthalmology (Martin) and stem cell medicine (Franklin from 2014: now UoA6). Succession planning includes Pickard (neurosurgery, 2013); and Compston (neurology, 2015). We have established professorships of neurological rehabilitation (2013) and neuroimmunology (endowed by Genzyme, 2014), and two professorships of experimental neuroscience (each endowed by the John and Lucille van Geest Foundation, 2013).

University support for staff development: Our culture embraces the Concordat to Support Career Development of Researchers, and Athena SWAN. We have a balanced portfolio of staff that includes young investigators, emeritus staff and those with voluntary research agreements or equivalent (n= 9, from 2014) after the retirement age, in order to enable appropriate staff turnover and opportunity for new appointments. Recruitment complies with University policy and procedures, employment law and equal opportunities legislation. Heads of Departments undergo Equality and Diversity education before participating in new appointments. Job descriptions and person specifications are designed to avoid discrimination; and further particulars provide prospective applicants with information on the benefits of working in the University. Applicants for professorships present their work to relevant Departments, whose views are represented on boards of electors or statutory committees, chosen also to provide

appropriate national and international expertise, and gender balance. Meetings scheduled during core working hours support parents of young children. Under its *Special Leave Policy* the University has generous systems for flexible working options (including participation in the Daphne Jackson and Dorothy Hodgkin Fellowships), annual leave, maternity/paternity leave (45 individuals took maternity and 22 paternity leave in the review period) and family-friendly policies, including the salary sacrifice scheme for childcare and a graduated return to work plan; no requests for flexible working for family reasons were refused. University Teaching Officers are entitled to one term of sabbatical leave on full pay for each 6 terms of continuous service; 29 periods of sabbatical leave have been taken by 24 staff during the period of review for REF2014; 12 members of staff were granted unpaid leave for various reasons. The University has recently introduced a new Returning Carers Scheme for women and men that buys-out teaching and/or administrative duties to help staff resume research on return to work following a career break arising from caring responsibilities. The University Gender Equality Group aims to reconcile gender-related unequal pay; the WiSETI scheme supports women academics working in STEMM subjects. The University is fully engaged in the programme. Advice for women is available at http://www.training.cam.ac.uk/cppd/theme/women?providerId=36612 and http://www.training.cam.ac.uk/cppd/course/cppd-perdev3. The University won a number of awards in 2011-12 for work in engaging with staff, being ranked 11th (the highest for any UK higher education institution) on the Stonewall list; and winning an award from the *Employers Network for Equality and Inclusion*. The University received the European Commission's HR Excellence in Research accolade in recognition of its work fostering career development for researchers. As part of this process, the University launched an Employment and Career Management Scheme (2011), providing induction, probation and appraisal of contract research staff including initial career management review (http://www.cam.ac.uk/research-staff/employment-and-career-management/employment-and-career-management-scheme). We support academic staff at key career transition points, including promotion to personal professorships, readerships and senior lectureships based on significant international research reputation and strong external support run through an annual competitive exercise; final decisions are made by a committee chaired by the Vice-Chancellor (http://www.admin.cam.ac.uk/offices/hr/ppd). Promotions in the review period include: Barker, Bussey, Czosnyka, Hughes, Roberts and Sawcer (to professor; two women); Dalley, Rowe and Saksida (to readership; one woman); and Aitken, Clark, Davis, Rentfrow, Schnall, Simons and Szucs (to senior lecturer; one woman). The University encourages applications from women for promotion to senior academic positions. In support of women academics, the senior academic promotions curriculum vitae scheme, co-ordinated and evaluated by the University's WiSETI Project Officer (http://www.admin.cam.ac.uk/offices/hr/equality/wiseti/cv/), provides advice on promotion. Departments represented in UoA4 were included in the most recent successful application from the Clinical School, awarded Athena SWAN silver status in September 2013.

Early career researchers: we take responsibility for career development of young academics by mentoring potential applicants for research fellowship schemes or grant-supported post-doctoral posts; supporting applications for appropriate positions elsewhere; and advancing careers locally by managing progression up the local career structure pathway (see above). We have accommodated 79 post-doctoral or clinical research training fellows in the last period including: Royal Society (4); British Academy (2); MRC (10); BBSRC (1); ESRC (3); Wellcome Trust (14); Marie Curie (5); and College research fellowships (3). Based on evidence for partial independence as a principal investigator, post-doctoral workers are promoted to the senior research associate grade (15 in the review period; of whom 10 are women), principal research associate (2) and director of research (1). Cambridge provides a comprehensive range of training schemes for early and mid-career staff, covering all aspects of research, teaching, administration and leadership. The University Centre for Personal and Professional Development has programmes that support career planning, including training in interview techniques, communication and presentation skills, lecturing performance, and supervision of students. CUHP has education as a priority. The University Careers Service is available to all staff and students, offering careers advice for contract research staff and post-docs. The 'Postdocs of Cambridge Society' represents post-doctoral fellow on career development and employment conditions (http://groups.ds.cam.ac.uk/pdoc/).

c(ii) Research students

All graduate students associated with UoA4 are affiliated to the University Graduate School for Life Sciences. They are recruited on the basis of personal application to prospective supervisors. Each is interviewed through one of five graduate training streams: cognitive and behavioural neuroscience; social and developmental psychology; clinical psychiatry; neuropsychiatric epidemiology (linked with the epidemiology MPhil); and clinical neurosciences. These subtend distinct but overlapping training courses and websites. Studentships are funded through a variety of sources including the highly competitive Marshall Scholarship and Gates scheme run by the University for US and international applicants; the Cambridge International Scholarship Scheme and Cambridge Home EU Scholarship Scheme; Industry CASE studentships; Cambridge Trust, and Commonwealth scholarships; Research Council doctoral training accounts (ESRC, BBSRC, MRC); direct allocation of Research Council (RC-UK) studentships (74 started during the review period); collaboration with the National Institutes of Health (NIH) and Janelia Farm Howard Hughes Institute (US); the Cambridge MB/PhD programme; the Pinsent Darwin Fund; and Cambridge College studentships. We also benefit from participation in a Wellcome Trust PhD programme for clinicians; post-doctoral clinical fellowships for ex-MB/PhD graduates; and a PhD and MPhil Translational Medicine and Therapeutics (TMAT) programme jointly funded by the Wellcome Trust and GSK. All graduates are admitted into Colleges where they receive personal mentoring from graduate tutors, supporting our intention to develop further mentoring and career development for graduate students outlined in returns to RAE2008. Approximately ten per cent of applications are awarded.

- Departmental graduate education committees supervise mentoring and assignment of advisors to each student; complement the role of research supervisors; monitor progress across 3-4 years by assessment of a first year report; arrange registration for the PhD degree upon satisfactory performance; collate subsequent annual reports, sometimes with interviews; and consider regular reports from supervisors registered on a secure website (camSIS).
- Graduate education committees are responsible for organization and monitoring the cognitive neuroscience graduate course (collaboratively with the MRC-CBSU and the Departments of Psychology and Psychiatry); the Department of Clinical Neurosciences graduate programme; and the MPhil in Social & Developmental Psychology.
- The Graduate School of Life Sciences provides education in research methodology, technical workshops and statistics, augmented by teaching on entrepreneurism, informatics, computing and transferable skills such as writing and oral presentation.
- In addition to regular Departmental seminar series, including the Zangwill Club, and biennial symposia organised by *Cambridge Neuroscience*, there is a seminar programme for first-year graduate students; and a thematic Spring School in neuroscience with international speakers.
- There are additional opportunities for graduates to present orally or by poster, with critical feedback, including annual poster days, laboratory lunch-clubs, and the annual away-days and *Cambridge Neuroscience* seminar.

We aspire to a 4 year PhD programme in neuroscience extending by 3 years the existing MRes course, organised by *Cambridge Neuroscience* from October 2012, consisting of two laboratory rotations (1 academic and 1 industrial), lectures covering the themes of *Cambridge Neuroscience*, research methods, and statistics. We will establish a complementary one year MPhil course in Translational Neuroscience from October 2014.

Career progression for successful PhD students: The majority of our PhD students proceed to further post-graduate scientific positions or training in clinical medicine, or seek positions in related professions. We have awarded 220 PhDs (Department of Psychology and related staff,

98; Department of Psychiatry, 29; Department of Clinical Neurosciences, 60; and MRC Units, 33), the number of awards made annually increasing from 33 (2008) to 58 (2012: last full year statistics) and with an 87% completion rate within 4 years. We have awarded 125 MPhils in the review period. Our graduates published 535 first authored papers in peer-reviewed journals. We have had recent awards of two Sir Henry Wellcome and one Sir Henry Dale Fellowships. Three of our recent PhDs have won College Junior Fellowships; one was awarded the first Frith Prize from the Experimental Psychology Society; and, among many post-doctoral academic appointments, three have been appointed to Lectureships at King's College, London, and at the Universities of Oxford, and Hong Kong.

d. Income, Infrastructure and Facilities

The Departments represented in UoA4 have grant income totalling £95M comprising 652 awards from 217 independent sources in the review period, excluding those credited to host Institutions.

d(i) Grant application policy, equipment and facilities including; donations and sponsorships. Our aim is to maintain a portfolio of research that draws on a diversity of funding sources; maximises success in response mode funding opportunities; and prioritising sources that bring full funding including research overheads. We have funding from each of the relevant Research Councils, the Wellcome Trust and other major charities, EU-frameworks, NIH, NIHR, and industry. Major equipment awards are managed annually through each School and provide core facilities in imaging, genomics, data-basing, microscopy, and human electrophysiology. Significant awards during the review period include:

- **NIHR**: Barker (programme, £720k); Barker, Bullmore and Compston (BRC [renewal)], £3.5M; Compston (BRC [initial], £2.9M); Compston and J. Jones (capital award with MRC, £1.8M); Goodyer (NSPN, £2.6M); Jones (CLARHC CP, £9.5M; renewed as CLARHC East of England, £9.9M; and programme, £1.9M); Pickard (Health Technology Cooperative (£800k); St George-Hyslop (Biomedical Research Unit in Dementia, £2.8M);
- **Research Councils-UK programme or equivalent grants**: Clark (gambling, £600k); Coles (multiple sclerosis, £900k); Compston (with Chandran and UCL, multiple sclerosis, £800k); Dalley (addiction, £900k); Everitt (addiction, £2.36M); Fawcett (brain plasticity, £1.9M and £800k); Golombok and Lamb (family research, £981k); Goswami (cognitive development, £1.52M); Holland (amyloid imaging in dementia, £983k); Moore (hearing, £2.02M); Roberts (primate behaviour (£1.4M), Szucs (dyscalculia, £600k); Timofeev (traumatic brain injury, £1.2M); Tyler (ageing, £4.2M);
- **Wellcome Trust and AMRC**: Bullmore, Goodyer and Jones (Neuroscience in Psychiatry Network, with UCL, £5.5M); Compston and Sawcer (with many others, WTCCC2, £16.3M); Compston with Coles, Pluchino and Spillantini; and Franklin [UoA6], MS Society, £3.3M); Fletcher (strategic award, £2.5M; with O'Rahilly, UoA1); Fletcher and Rowe (senior fellowships, £999k and £1.30M); Golombok (senior investigator award, £1.03M); Hutchinson and Kirkpatrick (with Brown [UoA1] BHF, £955k); Robbins and Bullmore (MRC-Wellcome Trust BCNI, £3.5M); Robbins (programme, £1.5M); St George-Hyslop (principal research fellowship, £4.2M; MRC-Wellcome Trust Neurodegenerative Disease Consortium, £5.5M); Schultz (principal research fellowship, £4M);
- **European Union** grants (FP-6&7) and other networks include: Baron-Cohen (EU-AIMS and EU-Inclusion, €925k); Barker (TRANSNEURO, €3.5M; and Neurostemcell Repair, £3.5M); Clayton (CAUSCOG €2.1M [from 2014]); Fawcett (PLASTICISE, €2.4M; and AXREGEN Marie Curie training, £600k); Hutchinson and Menon: EU-TBIcare (€4.2M) and Collaborative European Neuro-Trauma (€30M); Marslen-Wilson *ERC-NEUROLEX, £1.45M); Pluchino (ERC,€1.2M); Robbins, Bussey and Saksida (Innovative Medicines Initiative and NEWMEDS, €1M); Schultz (ERC, £2M); Tyler (PERCEPCON, £1.8M);
- **International** collaborative funding includes: Compston and Sawcer (with others, NIH $16M); Fawcett (with others, Christopher and Dana Reeve Foundation International Consortium £863k); Golombok (NIH, $1.15M); Rowe, Simons and Szucs (James McDonnell Foundation Scholarships, each $600k);

- **Industrial grants** made up as 33 awards from 14 separate sources in the reporting period (section 5) are £4.59M in the reporting period for REF2014.
- **Endowment income:** the impact of our work in clinical medicine lends itself to benefactions; those received in the review period (£10.46M) have been used to fund studentships and post-doctoral positions and (with one earlier benefaction) to endow three research professorships in perpetuity. Each arises from nurtured working relationships with benefactors with regular meetings and engagement with research progress. These include benefactions from John and Lucille Foundation (£16M in total and £5.5M in the review period) and Genzyme Corporation (£2.45M in the reporting period).

d(ii) Alignment of staffing strategy and research strengths in the context of physical environment. At the outset of the reporting period we were largely accommodated in Departmental buildings that did not well support our interdisciplinary strategy. We have reorganized and now have arrangements that cut across Departments and Schools both on the Downing Site and the Cambridge Biomedical Campus (http://cambridge-biomedical.com/), with some staff at Douglas House close to the MRC-CBSU, and representation of certain groups on more than one site. Travel is enabled by cycle routes and the University Bus 4.

Our research is advantaged by access to several cross-cutting facilities such as the Wellcome Trust Clinical Research Facility, NIHR BioResource, the Cambridge Clinical Trials Unit, the GSK Clinical Unit, and the Biomedical facility (animal houses, including the Innes Building). The new Department of Psychology has reconfigured accommodation bringing together research interests in social and affective neuroscience and developmental psychology at the *Centre for Neuroscience in Education* and *Centre for Family Research*. In 2013/4 we will consolidate yet more activities in the refurbished Craik-Marshall Building; and adjacent space including the Psychological Laboratory next to the Physiological Laboratory, Combined Animal Facility and Sir William Hardy Building where the *Centre for Speech, Language and the Ageing Brain* and the BCNI are mainly located. Visual neuroscience (Kourtzi and Welchman) will be accommodated in refurbished space, with new equipment provided by the School of Biology. Non-human primate work is housed in a special facility (Innes Building) on the Clinical Veterinary School site where imaging facilities will be upgraded as part of the planned *Institute of Translational Neuroscience*. The plan is to accommodate preclinical behavioural neuroscience (excepting the Innes Building) and most of the Department of Psychology in adjacent new buildings on the Downing Site.

Reconfiguration is also occurring on the Cambridge Biomedical Campus. This is focused on the University Forvie site and adjacent NHS and University buildings including the WBIC and the John van Geest Centre for Brain Repair (divisions of the Department of Clinical Neurosciences). The Herchel Smith Building for Brain and Mind Sciences, refurbished and established in 2009, accommodates principal investigators from each University department returning in UoA4, the BCNI, and MRC-CBSU. Funded through an NIHR capital award, departmental reserves and capital contributions from MRC, this includes a multi-user clinical research facility, together with neuroimaging and data storage facilities managed by the WBIC. The West Forvie Building for Phenomics and Molecular Imaging (opened in 2009) provides small animal imaging and high performance computing networks, supported by the University Computing Service, for data transfer to servers in the *BCNI* and *Brain Mapping Unit*. The Department of Psychiatry is partly located in the main Addenbrooke's Hospital block; the CLAHRC, Wellcome Trust Neuroscience in Psychiatry Network and the Autism Research Centre are based in Douglas House (refurbished in 2008). The Department of Clinical Neurosciences is widely distributed across the Addenbrooke's Hospital A&B, F&G and R blocks; the John van Geest Centre for Brain Repair, the Herchel Smith Building, the West Forvie Building and (from 2014) one floor of the former MRC Laboratory of Molecular Biology. At present, the University Forvie Site comprises the John van Geest Centre for Brain Repair; the Herchel Smith Building for Brain and Mind Sciences; the University Department of Public Health (incorporating the MRC Biostatistics Unit, UoA2); and the West Forvie Building (Anne Maclaren Laboratory of Regenerative Medicine and the Phenomics and Molecular Imaging Centre).

We have a well developed plan to consolidate all research that relates to translational

neuroscience by 2018. This will be enabled by building a new Stem Cell Medicine Centre elsewhere on the campus by 2016 and rebuilding part of the former MRC-LMB to accommodate Public Health at which stage buildings vacated by these moves will be reassigned to create a research community committed to brain and mind sciences - the *Forvie Brain Village* that will accommodate part of the Institute of Translational Neuroscience.

e. Collaboration or contribution to the discipline or research base

The broad membership of *Cambridge Neuroscience* and the newly merged Department of Psychology provides many opportunities for collaborations, locally (taking advantage of the great breadth of Cambridge-based institutions), nationally and internationally, including:

- **Local**: Dalley, Robbins and Milton, with Paulsen (UoA5: optogenetics); Roberts with Ferguson-Smith (UoA5: marmoset genetics); Coles, Compston, Pluchino and Spillantini with Franklin (UoA6: multiple sclerosis); Holland with Livesey (UoA5: neurobiology of intellectual disability); Fletcher and the *BCNI* with O'Rahilly and Farooqi (UoA1); Golombok with Mathur (NHS, not returned: *in vitro* fertilisation). Hughes with Ellefson (UoA25, education and cognitive development); St George-Hyslop with Dobson (UoA8: molecular chemistry of beta-amyloid); Rentfrow with Mascolo (UoA11, computing and mobile sensing devices). category A researchers returned in UoA4 interact with NHS staff and those in local Institutions: some are returned as category C (Bertolotti, Carlyon, Coleman, Goedert, Henson, Hornberger, Kirkpatrick and Warburton); others are based in the MRC-CSBU; the Sanger Institute; the Babraham Institute; the MRC-LMB2; and MRC Units in Epidemiology and Mitochondrial Biology;
- **National and International**: Aigbirhio (radiochemistry: centres in USA, Norway, Germany and New Zealand); Barker (stem cell therapies: centres in Sweden, France, Italy, Austria, Germany and Canada; and on Parkinson's disease, with Newcastle); Bullmore (NIH human connectome project) and also with Dalley, Ersche and Robbins ([ICCAM] with Imperial College in the MRC Addiction Initiative); Bussey and Saksida (neurogenesis, Salk Institute); Clayton (comparative developmental cognition, with University of Washington); Compston and Sawcer (International Multiple Sclerosis Genetics Consortium); Czosnyka and Pickard (neurosurgical devices: centres in France and Germany); Dalley (novel electrodes, Janelia Farm); Everitt (addiction, University of Poitiers and INSERM); Fawcett (spinal cord injury: Christopher and Dana Reeve Foundation consortium); Goodyer with Bullmore and Jones (NSPN, with UCL); Jones (CLAHRC, University of East Anglia), with Murray (North Finland birth cohort, University of Oulu) and with Suckling (BeneMin schizophrenia trial, Manchester); Mollon (visual psychophysics, Pavlov Institute of Physiology); Hines (paediatric endocrinology: UCL, Bristol, Kuopio, Finland and Toronto); Lamb (forensic psychology: NICHD, University of Southern California, Police Agency Japan); Markus (International Stroke Genetics Consortium); Robbins and Sahakian (MRC Translational Initiative projects with KCL and UCL, London & Manchester; and obsessive-compulsive disorder with UCL); Rowe (5-HT ligand PET, Copenhagen); Sahakian (imaging and depression, NIMH); Schultz (neuroeconomics, California Institute of Technology); St George-Hyslop (Alzheimer's disease genetics consortium; and neurodegeneration with Universities of Toronto, Tokyo and Peking Universities and Bonn); and Spillantini (fronto-temporal dementia genetics consortium);
- ***Cambridge Neuroscience*** has established a programme, funded by the Hotchkiss Brain Institute at the University of Calgary Faculty of Medicine, enabling reciprocal visits whereby scientists interact with the Calgary Programme in Neuroscience; this has moved from attendance at the annual *Cambridge Neuroscience* seminar and visiting lectureships to sabbatical leave (Sawcer) funded, in part, through the programme;
- **Industry**: Aigbirhio and Carpenter (imaging and radiochemistry: Merck, Wyeth, Siemens and GE Healthcare); Bullmore (GlaxoSmithKline [GSK]; secondment as vice-president @ 50% *wte*); *Cambridge Neuroscience* (neurodegeneration and multiple sclerosis: AstraZeneca); Coles and Compston (multiple sclerosis: Genzyme, Eisai and Sobi); Czosnyka and Pickard (neurosurgical devices: Codman and various US and Swiss companies marketing); Fawcett (spinal cord injury: GSK, Novartis and Accorda); Fletcher, Everitt and Robbins (*μ*-opioid

receptor antagonist: GSK); Jones and Sahakian (schizophrenia, GSK); Markus (stroke: Archemix); Martin (glaucoma: Phytypharm and Bausch and Lomb); Moore (hearing devices: Phonak and Bruel & Klaer); Pluchino (stem cell therapy: Reneuron); Robbins (Innovative Medicines Initiative: Eli Lilly; and *Cambridge Cognition*); Sahakian (schizophrenia, Johnson and Johnson); St George-Hyslop (Alzheimer's disease: GSK, AstraZeneca and Pfizer).

Contributions to the research base: Most of the more senior members of our faculty provide scientific leadership and contribute to the research base through:

- M**embership of grant review panels:** for example, Barker, Marslen-Wilson and Sahakian [European Research Council Grants Committee]; Gathercole, Sahakian and Rowe [MRC Neuroscience and Mental Health Board]; Jones [NIHR programmes panel]; Menon [MRC Translational Medicine Board]; and O'Brien [MRC Fellowships]);
- **Research policy**: for example, Golombok [Nuffield Council Bioethics Working party on Donor Conception and Advisory Committee for the Human Fertilisation and Embryology Authority]; Goodyer [NIHR Strategy Group]; Goswami and Sahakian [UK Government Technology Foresight Projects]; Lamb [ESRC Council]; Pickard [Home Office animal procedures committee; and Ministry of Defence review of neurosurgical care]; Robbins [MRC neurodegenerative diseases review group] and Sahakian [MRC Mental Health review group];
- **Editing journals**: for example, Barker (*Journal of Neurology*) Compston *(Brain*); Everitt *(European Journal of Neuroscience*); Fletcher (Neuroimage); Holland *(Intellectual Disabilities Research*); Lamb [*Psychology, Public Policy & Law*]; and Robbins *(Psychopharmacology*);
- **Presidencies of Societies:** Compston (Association of British Neurologists [2010-11]); Marslen-Wilson (Experimental Psychology Society [2008-2010]); Robbins (British Neuroscience Association [2009-2011]), and Sahakian (British Association of Psychopharmacology [2013];
- **Recognition of the research contributions** made by individuals returned in the reporting period includes past or recent elections to Fellowship of the Royal Society (9: with Clayton and Spillantini elected since 2008); the British Academy (4: Baron-Cohen and Goswami elected since 2008); the Academy of Medical Sciences (15: Bullmore, Fletcher, Holland and Spillantini elected since 2008); and the Institute of Medicine of the National Academies of the USA (2: Compston elected since 2008). Fifteen members of our faculty have received 20 international prizes or awards in the reporting period (Baron-Cohen, Compston [3], Everitt [2], Fawcett, Goswami, Lamb [3], Menon, Mollon, Moore, Robbins, Rowe, St George-Hyslop, Schultz, Simons and Szucs); and Robbins was appointed CBE (2012).

University support for collaborations and contributions to the research base come in many forms. The Research Services Division dedicates resources to manage European Union and other complex collaborative networks. Collaborations may also receive advice from the International Office. Overseas visits or workshops promoting collaboration are supported by sabbaticals (see above) and travel and accommodation funds from diverse University sources. *Cambridge Neuroscience* maintains awareness and effects international visits; and advertises and hosts a rich programme of guest lectures, symposia and workshops that enable Cambridge to provide intellectual leadership by promoting scientific discussion and initiative in psychology, psychiatry and neuroscience.