House of Commons Science & Technology Committee inquiry on a new UK funding agency: response from the British Neuroscience Association

Introduction

The British Neuroscience Association (BNA) is the largest UK organisation representing and promoting neuroscience and neuroscientists. We have over 2000 members, whose interests cover the whole range of neuroscience, from ion channels to whole animal behaviour to real-life applications in the clinic and beyond.

Now is an exciting time for the UK's world-class neuroscience. The last decade alone has seen a vast increase in our understanding of the brain in health and disease and its powerful role as the key influence over our health and performance. There remains a pressing need for research into finding ways to prevent, manage and treat disorders of the brain. Brain disorders cost the UK an estimated £112bn annually.[1] Degeneration of the brain is now increasing as our population ages.

At the same time, research spending on brain disorders, such as dementia, stroke and mental illness, is grossly insufficient.[2,3] And yet, neuroscience research brings many benefits. We now have imaging technology that reveals the brain in incredible detail, new biomarkers to indicate disorders of the central nervous system and monitor the effect of drugs, and improved clinical practice. We are learning more about behaviour and emotions, our senses, learning and memory. All of these developments assist the translation of laboratory science into new treatments for the benefit of human health.

We welcome the opportunity to respond to this inquiry into the nature and purpose of the proposed UK research funding agency, for which in March the Budget allocated £800m over 5 years to fund "high-risk, high-payoff research in emerging fields of research and technology", modelled in the style of the US Advanced Research Projects Agency (ARPA).[4,5] This represents a new opportunity for the UK to invest in neuroscience that could be potentially transformative for brain disorders in the future.

For this response, we have drawn on a number of BNA members with expertise in research towards the "blue skies" area of neuroscience, and have limited our submission to key areas for the Committee to consider.

What gaps in the current UK research and development system might be addressed by an ARPA style approach?

Understanding the human brain and its diseases remains one of the greatest scientific challenges. However, in the past decade there have been advances in areas such as brain imaging, new tools to help map the brain, in addition to the increased role of molecular biology and engineering. This is

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[1] Fineberg NA, Haddad PM, Carpenter L, Gannon B, Sharpe R, Young AH et al. The size, burden and cost of disorders of the brain in the UK. J Psychopharmacol 24 Jul 2013, doi:10.1177/0269881113495118

[2] MQ. UK Mental Health Research Funding 2014-17; 2019

[3] UK Clinical Research Collaboration. UK Health Research Analysis 2018; 2020

[4] The Queen's Speech; 2019

[5] HM Treasury. Budget 2020; 2020

why a number of government-backed neuroscience initiatives have launched around the world, seeking to seize opportunities brought about through developments in this field. Within the US, this has seen both ARPA's successor – the Defense Advanced Research Projects Agency (DARPA) – and the Intelligence Advanced Research Projects Activity (IARPA) working withing a public-private research collaboration, the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.[6] Within Japan, the Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain/MINDS) project brings together different research institutes in Japan to use experimental models "to elucidate the neural circuits underlying higher brain functions".[7] While in the EU, the Human Brain Project has brought together neuroscience, medicine and computing in one of the largest projects it has ever funded.[8]

> *"The human brain is the most complicated biological structure in the known universe. We've only just scratched the surface in understanding how it works – or, unfortunately, doesn't quite work when disorders and disease occur."*
> Francis Collins, Director of the US National Institutes of Health, 2013 Announcement of the BRAIN Initiative

Funding for these sorts of longer-term projects is a gap in the current funding landscape. While the UK does not currently have its own long-term neuroscience initiative that can help facilitate investment in high-risk, high-payoff, neuroscience research, there is an opportunity for this gap to be addressed through a new ARPA-style agency, as indicated by both DARPA and IARPA's investments in this area of neuroscience in the US.

What should be the focus be of the new research funding agency and how should it be structured?

A UK ARPA should aim to identify and deliver in areas where there is the greatest need for innovation. We believe that the health needs, the gaps from historic underfunding, and the opportunities recognised by the large initiatives above that have emerged in recent years, makes neuroscience a prime candidate for additional funding by such an agency. There are a number of specific areas outlined below that we believe the UK could, with additional funding, potentially deliver transformative change.

In terms of the structure of the organisation, it is important that regulation and oversight anticipates any transformational change that could result from the research it helps to develop.[9,10] This new research funding agency should work with the recently-established Regulatory Horizons Council to ensure that the UK regulatory system is fully prepared for the potentially high impact innovation that emerges.

Neurotechnologies

Neurotechnology is a rapidly developing area that is having a major impact on society, especially healthcare. One type of emerging neurotechnology are neural interfaces. Connecting the brain or nervous system to digital devices or IT systems (also known as brain-computer interfaces), neural

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[6] braininitiative.nih.gov
[7] brainminds.jp
[8] humanbrainproject.eu
[9] Wellcome. A blueprint for the oversight of emerging science and technologies; 2019
[10] Nesta. Renewing Regulation: 'anticipatory regulation' in an age of disruption; 2019

interfaces have the potential to deliver life-changing therapies, enhancements in concentration, decision-making and collaboration, as well as improvements to well-being.[11] This is a new area in neuroscience, and combines disciplines that include computer science, engineering, and applied mathematics. Initial uses of simple applications are already being tested in a number of areas including healthcare (for example, to aid movement of prosthetic limbs), education, games, pain management, fatigue-monitoring, and security applications.[12]

> **How could neural and brain computer interfaces be used in the future? (Royal Society's iHuman report, 2019)**
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> - 'Typing by brain' and use of a 'mental mouse' to control computers and devices;
> - Direct brain-to-brain communication, whether simple impulses or complex thoughts;
> - Wider medical applications, such as for Alzheimer's Disease and mental health conditions;
> - Monitoring of brain activity to support health, safety and security;
> - Augmentation of human memory, concentration and learning.

There are ethical and regulatory challenges associated with high-risk technologies such as these, and the Royal Society has recommended that the UK should seek to encourage multidisciplinary collaboration across industries to develop neural interfaces at the same time as developing an anticipatory approach to how they are regulated.

Pharmaceutical cognitive enhancers

In addition to technological enhancers, the use of pharmaceutical cognitive enhancers is another high-risk area considered to potentially deliver high-payoff results within neuroscience. Cognitive enhancers, also known as "smart drugs", are being increasingly used by people at work to improve their concentration, motivation and overall quality of their work, and in social and recreational activities.[13,14] However, there are potentially high gains for health that could be realised through further research in this area.

Potential benefits include improving cognition, functionality and wellbeing, which could be impaired in patients with particular neuropsychiatric disorders.[15] However, these also carry with them ethical risks through their potential use by healthy individuals.[16,17]

'Mind-reading'

Advances in brain imaging through fMRI have seen technology used to help interpret the contents of thoughts and mental states.[18] This in turn has raised the potential in the future to further interpret

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[11] Royal Society. iHuman: Blurring lines between mind and machine; 2019.
[12] Mudgal S, Sharma S, Chaturvedi I, Sharma A. (2020) Brain Computer Interface advancement in Neurosciences: Applications and Issues. Interdisciplinary Neurosurgery. 2020. 100694. 10.1016/j.inat.2020.100694.
[13] Brühl AB, d'Angelo C, Sahakian BJ. (2019). Neuroethical issues in cognitive enhancement: Modafinil as the example of a workplace drug? Brain and Neuroscience Advances. https://doi.org/10.1177/2398212818816018
[14] Coveney C, Bjønness J. (2019). Making sense of pharmaceutical cognitive enhancement: taking stock and looking forward. Drugs: Education, Prevention and Policy. 26. 293-300. 10.1080/09687637.2019.1618025.
[15] Sahakian BJ, Bruhl AB, Cook J, et al. (2014). The impact of neuroscience on society: cognitive enhancement in neuropsychiatric disorders and in healthy people. Philos Trans R Soc Lond B Biol Sci. 2015;370(1677):20140214. doi:10.1098/rstb.2014.0214
[16] Royal Society. Brain Waves Module 1: Neuroscience, society and policy; 2011.
[17] Mohamed AD (2014). Neuroethical issues in pharmacological cognitive enhancement. Wiley Interdiscip Rev Cogn Sci. 2014;5(5):533-549. doi:10.1002/wcs.1306
[18] Poldrack R. Neuroscience: The risks of reading the brain. Nature 541, 156 (2017). https://doi.org/10.1038/541156a

electrical activity of thoughts and decisions, and convert these into definitive knowledge of what someone is thinking. One project currently funded by DARPA, the Next-Generation Nonsurgical Neurotechnology (N^3) programme, aims to develop non-invasive "high-performance, bi-directional brain-machine interfaces" that would enable able-bodied individuals to perform operations such as control of unmanned aerial vehicles.[19]

While the DARPA project is looking at military use for able-bodied individuals, the potential medical applications could have enormous benefits for people with certain neurological conditions.

Bioelectric medicine

Bringing together neuroscience, molecular biology and engineering, bioelectrics is an emerging field beginning to create new devices aimed at modulating the body's neural networks to help tackle a number of diseases.[20,21]

There are a range of high-risk areas that bioelectric medicine is active in. DARPA has invested in this via their Stimulating Peripheral Activity to Relieve Conditions (SPARC) programme for example, where electrical stimulation of the vagus nerve has been trialled as a way to treat patients with rheumatoid arthritis.[22] In another application, miniaturised neural stimulators that could be scattered through the nervous system (described as 'neural dust'[23]) may in the future be able to work together in therapeutic settings.[24]

Neuro-regeneration

Since induced pluripotent stem cells (iPSC) demonstrated the ability to convert one cell type into another, the application of this as a treatment to repair damaged cells in the brain has been targeted by neuroscience researchers. However, iPSC therapies are still in their infancy, and despite the potential high rewards the risk profile and costs associated mean that substantial funding remains necessary to ensure that cell therapies in the future are safe, cost-efficient, reproducible and workable.[25,26]

This is an area of research that continues to demonstrate promise for neurological disease – most recently in highlighting reprogramming of cells into neurons as a potential regenerative approach for

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[19] www.darpa.mil/program/next-generation-nonsurgical-neurotechnology

[20] Academy of Medical Sciences. The mind-body interface. FORUM report; 2017

[21] Peebles L. Core Concept: The rise of bioelectric medicine sparks interest among researchers, patients, and industry. Proceedings of the National Academy of Sciences Dec 2019, 116 (49) 24379-24382; DOI: 10.1073/pnas.1919040116

[22] Koopman FA et al. Vagus nerve stimulation inhibits cytokine production and attenuates disease severity in rheumatoid arthritis. Proc. Natl. Acad. Sci. U.S.A 2016. 113, 8284–8289.

[23] Deloitte. Neuroscience Innovation Report; 2018.

[24] Piech DK, Johnson BC, Shen K et al. A wireless millimetre-scale implantable neural stimulator with ultrasonically powered bidirectional communication. Nat Biomed Eng 4, 207–222, 2020. https://doi.org/10.1038/s41551-020-0518-9

[25] Sebastian S, Hourd PC, Chandra A, Williams D, Medcalf N. The management of risk and investment in cell therapy process development: a case study for neurodegenerative disease. Regenerative Medicine 2019 14:5, 465-488

[26] Doss MX, Sachinidis A. Current Challenges of iPSC-Based Disease Modeling and Therapeutic Implications. Cells. 2019;8(5):403. Published 2019 Apr 30. doi:10.3390/cells8050403

stroke and Parkinson's disease.[27,28] An ARPA-style organisation could be well placed to move cell-based therapies towards becoming a high-impact innovation in the future.

Sleep

Sleep and problems associated with a lack of sleep have become more important with a demanding modern 24/7 lifestyle. Recent years have seen a significant increase in patients reporting hypersomnia, insomnia, or circadian rhythm disorders.[29] This has developed alongside new technologies to help to monitor sleep. We have started to discover the complex relationship sleep has with neurodegenerative conditions and mental health, and there is an increasing need to improve our understanding of how sleep impacts more broadly on public health.[30]

There is a gap in definitive and rigorous research on sleep across the lifespan, which research via an ARPA-style agency could address. DARPA has, for example, been examining the impact of non-invasive stimulation of the brain during sleep in order to boost long-term memory.[31] Extra funding channelled towards sleep research could yield potentially transformational results for health, well-being, and executive functioning.

What benefits might be gained from basing UK ARPA outside of the 'Golden Triangle' (London, Oxford and Cambridge)?

The BNA represents neuroscience across the UK, with members in over 40 local groups. Basing UK ARPA outside of the 'Golden Triangle' would help to ensure that institutes from a broader range of UK locations are more able to engage with the agency – increasing the expertise, knowledge, talent and ideas for its work. We note that BEIS also intends to publish a UK R&D Place Strategy later this year, and this presents an opportunity for the UK ARPA to form part of that through its proposed location.

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[27] Livingstone J, Lee T, Daniele E et al. Direct reprogramming of astrocytes to neurons leads to functional recovery after stroke. bioRxiv 2020.02.02.929091; doi: https://doi.org/10.1101/2020.02.02.929091
[28] Qian H, Kang X, Hu J, et al. Reversing a model of Parkinson's disease with in situ converted nigral neurons. Nature. 2020;582(7813):550-556. doi:10.1038/s41586-020-2388-4
[29] Walker WH, Walton JC, DeVries AC et al. Circadian rhythm disruption and mental health. Transl Psychiatry 10, 28 (2020). https://doi.org/10.1038/s41398-020-0694-0
[30] Freeman D, Sheaves B, Goodwin GM, Yu L et al. The effects of improving sleep on mental health (OASIS): a randomised controlled trial with mediation analysis. The Lancet. Psychiatry 2017, 4, 749 - 758.
[31] Ketz N, Jones AP, Bryant NB, Clark VP, Pilly PK. Closed-Loop Slow-Wave tACS Improves Sleep-Dependent Long-Term Memory Generalization by Modulating Endogenous Oscillations. The Journal of Neuroscience. 2018 Aug;38(33):7314-7326. DOI: 10.1523/jneurosci.0273-18.2018.