From our brain to the world: views on the future of neural interfaces

A public dialogue research programme conducted on behalf of the Royal Society

Executive Summary

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Preface

This Executive Summary has been prepared by Hopkins Van Mil: Creating Connections Ltd. It reflects on the issues and themes that resonated most strongly with participants in the Royal Society's public dialogue on neural interfaces, which took place in January and February 2019 involving just over 200 people. For more detail, including on the research methodology please refer to the full dialogue findings report[1].

Neural interfaces (NIs) are devices that interact with the nervous system of an individual. Used in medical settings, these devices have existed for decades to help restore motor, sensory and other neural functions. With fundamental developments in neuroscience combined with rapid improvements in areas such as miniaturisation of components and internet enabled technologies, there is now greater potential for NIs to be used in more consumer focussed applications, for example in the fields of robotics and gaming. Work is being conducted on NIs which have the potential to improve human cognition, let us interface seamlessly with technology and compete with developments in artificial intelligence.

Such fast-moving developments are accompanied by questions of ethics, governance, feasibility and cost. The Royal Society's interest in this field is in part to consider the issues which need to be addressed if systems are to be in place to approve and regulate these emerging technologies. This study feeds into the evidence base which informs the Royal Society's engagement with policymakers, industry and the research community in the UK and internationally.

The Neural Interfaces Public Dialogue was designed and delivered by **Hopkins Van Mil (HVM)** between November 2018 - May 2019**.** HVM facilitates engagement so that voices are heard, learning is shared, and understanding achieved. In practice this means finding the process by which people can explore their hopes, fears, challenges and aspirations for the future. HVM's work enables stakeholders, technical specialists, and a diversity of publics to work together as equals to make actionable, better informed, and powerful decisions.

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[1] Royalsociety.org/ihuman-perspective

1.   Desirable futures for neural interfaces

The public dialogue, together with fieldwork in the gaming community and with patient groups, has demonstrated a high level of support for NIs because of the results associated with their use in the medical sphere and potential for enhanced communication and learning in non-medical settings. Participants across the research activities considered a future in which NIs are an integral part. They felt public engagement has to be central in a desirable future and reflected on NI enabled therapies and treatments; opportunities to create a more inclusive society; and using the technologies as a route to a more inclusive society, environmental improvements and a way of enabling creativity as summarised in figure 1.

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Eradication of marginalisation	Enhancement of social cohesion	Therapies & treatment for wide range of physical and mental conditions
Enabling creativity	Increased understanding of the environment & reduced carbon footprint	Ongoing public engagement
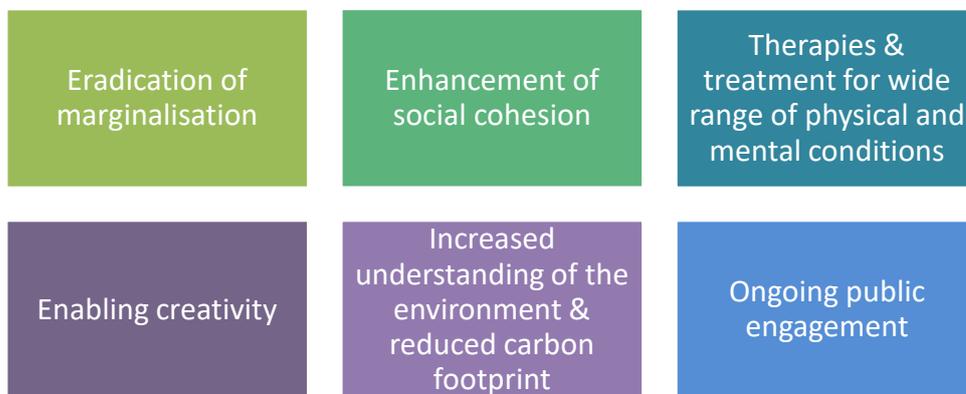
Figure 1. Elements of a desirable future for NIs

When reflecting on desirable visions for the future participants frequently mentioned a wish to use NIs to eradicate marginalisation, particularly due to disability, and to improve and enhance social cohesion. They cited a range of examples, including medical and non-medical examples for treating both physical and mental health conditions as well as for improved communication specifically as a route to understand each other's differences.

Participants reflected on a number of NI applications which might provide therapies and treatments for a wide range of mental and physical health conditions including depression, addiction, cancer, Alzheimer's disease, and dementia. The view was widely expressed that using NIs for therapies and treatments was one of the most desirable aspects for a future in which NIs are integral, in part because it was understood that NIs would have the potential to be very targeted in their delivery of treatment.

Enabling creativity was seen as an important aspect of a desirable future with integrated NIs. Participants' expectation is that NIs will make society more efficient and as such they envisaged that people are likely to be inclined to spend more time on expressing themselves creatively. They also saw developments in monitoring brain waves, in the short-term, and actual thoughts in the much longer-term as a way of opening up creativity to a wider section of society and as a route to a new creative process for artistic endeavour. It was felt that NI technology could be an important tool in

making something currently transient and intangible, such as a thought, into a concrete object or 3D representation of that thought.

Research participants also put NIs at the heart of understanding the environment. In a desirable future they saw a role for NI technologies in accessing environments which are not practical for human exposure for long periods or are completely inaccessible currently. They imagined that NIs will enable people to have fulfilling virtual leisure time experiences, which alongside enhancements in remote working will help a future society to reduce the carbon footprint of travel.

Underlying these visions of a desirable future for NIs was a clear statement from all those involved that public engagement, consultation and involvement should be central to every step in the development of NIs. The subject was felt to be too important for the public not to be involved and there was a view that greater awareness of NI applications will lead to increased acceptance of the technology.

2.   How people make decisions on acceptable uses of NIs

Over the course of the dialogue, participants expressed a range of considerations to inform their views on the acceptability of NIs. They are summarised in figure 2.

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Ease, comfort & effectiveness of use	Restoring quality of life	Enhancing quality of life	Safety and impact of health
Internal versus external devices	Equity of access to NIs	Control, transparency and choice	Ethical framework in place
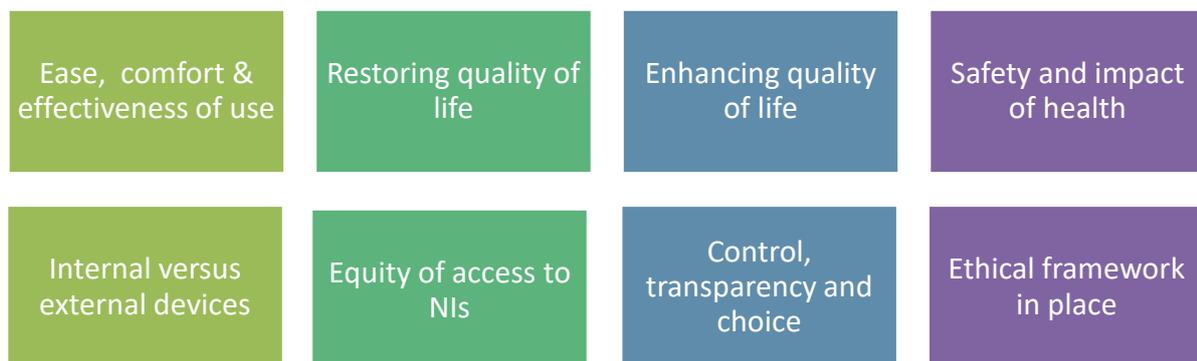
Figure 2. Considerations to inform societal decision-making on the acceptability of NIs

The considerations most frequently made to inform decisions on the acceptability of NIs were equity of access; control, transparency and choice; and the development of an appropriate ethical framework to underpin regulation of the technology. These are described in more detail below. Restoration of quality of life and safety and impact on health were seen as extremely important considerations as well with the opportunity to save life often being cited as an overriding decision-making factor. For an overview of the thinking behind all the considerations see the full dialogue report.

2.1 Equity of access to NIs
Across the locations, participants agreed that in a desirable future NIs are available to all who have a medical need for it. Out of concern for a deepening divide between people who are very wealthy and those who are very poor, participants said that applications to alleviate symptoms of high

incidence conditions/ injuries should be made available on the NHS. If prioritisation is needed due to a lack of resources, the severity of a condition and the level of discomfort and pain patients experience were seen as additional factors for decision-making. Ensuring that a wide range of people (age, gender, ability, ethnicity, faith) are involved in clinical trials for NIs was identified as another criterion for the acceptability of NIs. In all of the research groups effective regulation was mentioned as the first safeguard to ensure equity of access.

2.2. Control, transparency and choice

Given that data derived from thought and brainwaves were seen as more personal than data generated by the use of devices such as smartphones or the use of social media, there was a sense across the research groups that there is more caution required with NIs than with other technologies. Personal choice and the option to opt in or out of the use of NIs, as well as the ability to turn a device on or off, were therefore identified as key decision-making factors impacting on the acceptability of NIs. At several points in the conversations participants raised concerns about losing control over their data, particularly to companies, which led to the view that corporate monopolies need to be controlled through legislation. They discussed a desire for transparency about who is gathering data from NIs and for what purpose and emphasised the importance of clarity on the pros and cons of the applications.

2.3. Ethical framework for NIs in place

At different stages in the research the sentiment was reiterated that clear governance of the technology would offer reassurance to both researchers developing NI technologies and publics. Participants made it clear that knowing there is a regulatory framework in place that developers and users have to adhere to would ease people's worries. Some recognised that strict regulation can stifle technological developments and therefore felt that initially a code of ethics is more desirable, as that offers opportunities to test the relevance of the framework on an ongoing basis as the technology evolves. According to the research participants an ethical framework should indicate for what purposes NIs can be developed; provide safety and data protection assurances; and enable equal access to information about technology applications.

3. Implications for society

What became clear to participants is that society will need to adapt to balance the opposing forces that are likely to emerge from the development of NIs. They discussed a range of factors, including how the perceived pace of technological change might leave behind those who can't keep up, which would be counter-productive to the concept of equity of access that had been identified as an important criterion for acceptability of NIs (see 2.1). Some groups focused on the societal implications of military NI applications, including NI remotely controlled drones, robotics and cyber security systems and expressed the view that this might lead to the de-personalisation of war.

The themes that resonated most with participants in the context of societal implications were productivity and efficiency, crime and punishment, NIs as a quick fix for societal ills and technological dependency.

3.1. Productivity and efficiency

Participants felt that NIs are uniquely placed within the context of emerging technologies to impact on productivity and efficiency in the workplace. Discussions demonstrated that it was clearly understood that developments in artificial intelligence and machine learning could also have a significant impact in this area. But NIs, by potentially enhancing people's cognitive and motor functions, were seen as potentially having a specific and significant role. The opposing forces summarised in figure 3 in turn demonstrate the range of implications raised by participants.
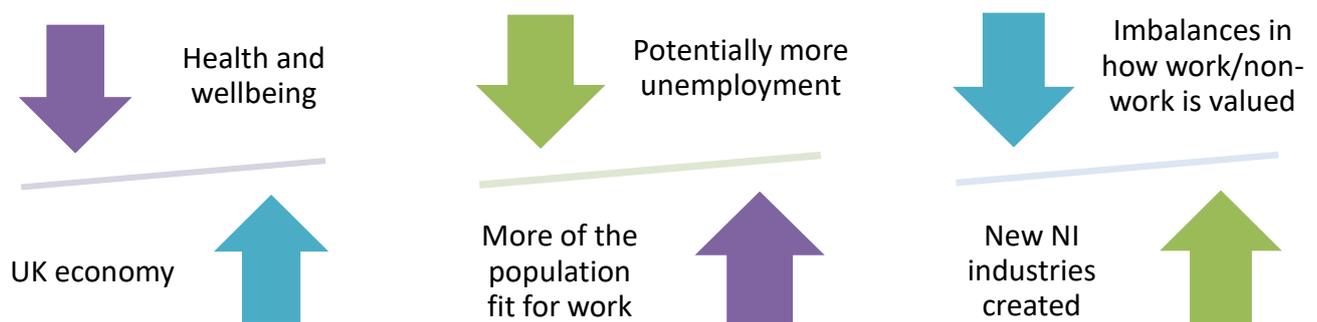

Figure 3: Opposing forces within productivity and efficiency

Participants identified that NIs can have a positive impact on the UK's Gross Domestic Product (GDP) and the national and global economy. Although they recognised the benefits of greater productivity, there was concern that people might be forced into the position of having to work harder, faster and longer, which could impact negatively on their health and wellbeing, the opposing force. There was a clear warning that this should be guarded against.

A significant point raised by groups in all locations was the idea that as NIs become increasingly used to treat paralysis and disease, more and more people will become fit for work. This was seen as positive for many reasons, both for the individuals themselves who feel well and able to contribute more fully within society, and for society because less money would be needed for disability benefits and the NHS. However, this could also be problematic as the growing work force might potentially outnumber the jobs available, which could lead to higher levels of unemployment.

The third set of opposing forces illustrates the challenge of balancing the wide number of new industries and roles that might be created. These were seen as jobs that we haven't as yet thought of, which will be required for all the NI applications that are yet to be imagined. This is set against a concern that this new society will have to think seriously about what it means to work, how work is remunerated and how we value or recognise non-work activities when people have more time for leisure pursuits.

3.2. Crime and punishment

Participants in each location saw that legal systems, criminal activity, policing methods, and how we define crime would all need to be reviewed in a society in which NIs are an integrated part. They reflected on the potential for NI technologies to be developed over the next 50 to 100 years which could mean that a thought we have becomes a criminal offence. In some groups this led to discussions on criminals being able to hack other people's brains and nervous systems and take over their bodies to make them commit crimes on their behalf. Participants found it difficult to construct a system which would enable the police to track this type of NI-enabled crime. One reflection was that if NIs were in widespread use, then the police could use the same technologies for surveillance purposes to read minds and track criminal activity. Exercising caution in this area and not overstepping a reasonable line which society has decided is ethical, and does not infringe human rights, was seen as essential.

3.3. NIs as a quick fix for societal ills

A view was consistently expressed across each element of the research fieldwork that society may come to rely on NIs as a quick fix for everything that society finds challenging or costly to manage. For example, participants considered the potential impact of using highly targeted electroceuticals[2], to treat chronic disease. It was felt that this new form of treatment may reduce people's personal responsibility for living well and do all they can to prevent health conditions from occurring. They saw a future where society would be using NIs in a consistently preventive manner so that people didn't have to get health treatment, potentially causing them to become complacent about their lifestyle choices. There was also concern that the quick fix NI route may divert science away from looking at the root causes of diseases and drive businesses to invest into highly profitable NI developments, rather than others which might tackle a more challenging disease affecting fewer people statistically. They thought this might have a positive outcome, to get more effective technologies to market sooner, but there was a fear that very serious diseases and research into the root causes of conditions such as Parkinson's would not get the investment required.

3.4. Technological dependency

Another high priority implication for society for research participants was a concern that people will become overly reliant on NI technology. Although they were clear that there is a tendency towards this currently across all forms of new technology, participants felt strongly that in an NI enabled society this dependency is likely to increase even more. This was a view expressed equally by those who are already using NIs, such as cochlear implant users and people with Parkinson's, and those playing (online) video games who recognised that the immersive experience of NI enabled gaming might be a route to greater addiction. As described in 3.3 there was also a view that a reliance on NIs might lead to humanity becoming complacent about their lifestyle choices. The implications for society in this over-reliance on NIs was felt to be particularly concerning when the technology fails.

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[2] Small-scale devices that treat ailments with electrical impulses

4.   What does it mean for humanity?

NIs were seen as fundamentally different from other technologies as working with the brain and nervous system touches on what participants saw as the very essence of what gives us our individual personalities and characteristics. Discussions about a future with NIs therefore led to philosophical deliberations about the implications for humanity. For example, participants reflected on the transformations that might occur as a result of living in a world without disability. Questions raised included, 'Will society attach a greater stigma to untreatable disability?' and 'Who decides which disabilities will be prioritised in NI research and why?'. They also reflected on the potential of a warped power balance between humans and NIs and expressed concern about an imaginary future reality in which humans relinquish control to NIs to such an extent that our ability to think independently and make our own decisions based on a set of moral codes becomes eroded.

The themes discussed most widely included concerns about a potential loss of a sense of self; the erosion of skills and human faculties; and the impact of NIs on human relationships.

4.1 Loss of a sense of self

There was widespread concern that the use of NIs might lead to personality change. From the view that our personality is shaped by learning and life experiences, positive as well as negative, participants considered what the impact would be on our sense of self if NIs are used to enhance the ability to process information and to treat mental health conditions. For many, a sense of self implies taking responsibility for one's actions. There was a view that allowing NI technology to impact on our behaviour, for example in enhancing reactions when driving, or through expecting NIs to provide preventive treatment of conditions resulting from a poor lifestyle, reduces this part of what makes us human.

4.2 Erosion of skills and human faculties

Whilst recognising the positive outcomes of using NIs for the treatment of debilitating physical and mental health conditions, participants expressed concern that NIs can make lives so much easier that it might lead to a more sedentary existence and a deterioration of our intellectual capacity. The impact of NIs on communication and social skills was seen as an almost inevitable consequence of living in a digital society. However, the potential loss of motor skills as well as our ability to think critically based on an individual's unique set of moral codes was felt to be unique to NIs and have the potential to profoundly affect what it means to be human.

4.3 Diminished social interaction

Across the locations participants shared the view that NI-enhanced realities might be so enticing that people become increasingly addicted, which they feared may lead to a greater disconnect from the real world, diminished social interaction and a neglect of physical needs. For the vast majority of participants, humanity is defined by social interaction. Whilst welcoming the fact that some NIs offer life-changing opportunities to restore some patients' ability to communicate, dialogue participants and gamers talked about their worry that the risk of reduced social interaction and a

separation from real life, including a potential dependency on an NI-enhanced reality, may result in a negative impact on mental health.

5. Conclusions and recommendations

Dialogue participants and members of special interest groups were all extremely interested in NIs. There was near universal approval, and strong admiration, for NI technology for medical purposes and though they tended to be received with greater caution, some applications of non-medical NIs were seen as a positive development for society as well.

Some participants believed that NIs are an inevitable progression. They saw the developments in the internet, social media, artificial intelligence and neurological science as coming together and driving an unstoppable race to develop ourselves and society. What was identified as being distinctly different from other emerging technologies is the fact that NIs link directly to the brain and peripheral nervous system, which most research participants perceived as the very essence of what gives human beings individual personalities and characteristics.

5.1 Questions to inform the debate about future uses of NIs

HVM concludes that there are four factors which need to be taken forward into the debate around future uses of NI technology:

- No imposed behavioural manipulation: Safeguards must be in place to protect users from being manipulated by those who monitor and use data generated from NIs. Research participants did not object to medical closed-loop systems which first record activity and then stimulate some form of action based upon the data received, for example, deep brain stimulation (DBS) systems used to treat Parkinson's disease. However, they did express concern about a potential future in which their minds could be read or behaviour controlled without prior consent. This was true for both medical and non-medical devices including EEG[3] sets for gaming.
- Personal choice always: Although there is no indication that NIs will be used without active personal consent, participants said that the use of NIs is a matter of personal preference and for that reason they want to have the final say as individuals. This includes having the opportunity to pro-actively opt into the use of NIs based on a consideration of balanced information rather than passively accepting NIs as part of their medical treatment plan or daily life.
- Balancing innovation and public trust: Participants emphasised the importance of getting the balance right between allowing innovation to flourish whilst ensuring research and development is robust and the implications for individuals and society are fully understood. The research showed that publics appreciate agency and human autonomy and therefore require evidence-based, factual information to enable informed decision-making.
- Creating societal awareness: As the field develops and the use of NIs becomes more widespread, the big societal and ethical questions participants discussed in this study will come into focus.

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[3] Headsets using Electroencephalogram (EEG): recording of brain activity made by placing small sensors on the scalp.

To prepare society for the NI-enabled future ahead of us, public voices should not only be heard in the current early stages of the debate, but as part of an ongoing process as the technologies continue to be developed. Further deliberation about these concepts is necessary to reassure diverse publics that the technology is a valuable addition to their lives, rather than an undesirable intrusion.
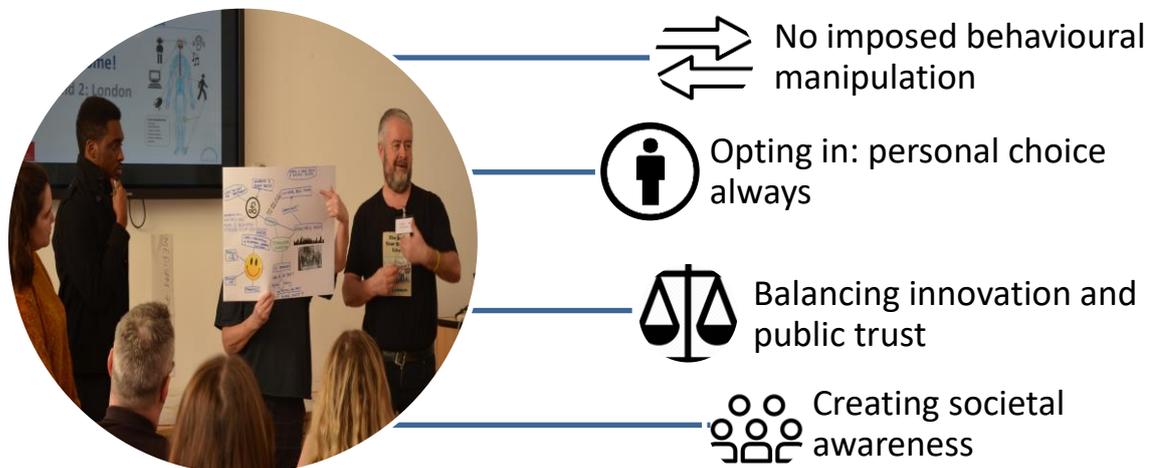
Figure 4: Key factors to inform the neural interface technology debate

5.2 HVM recommendations

To help inform the debate on the future of NIs HVM has developed three recommendations:

- Use jargon-free communication: The study demonstrated that NIs as a term is not the most useful way to describe the technology. Only a small number of dialogue participants, patients and gamers had heard of NIs as a collective noun for these diverse technologies and hardly anyone knew what the technology is without further explanation. The use of 'a technology that links the brain to an external device' was more widely understood by participants. Although the use of 'peripheral nervous system' is scientifically more accurate, the study showed that this isn't what helps people's understanding of the technology.

- Ensure ongoing public engagement: Research participants expressed a strong desire for society to be involved in shaping the criteria for the acceptability of NIs for society on an ongoing, application-by-application basis as the technology evolves. HVM therefore recommends that key players in the funding of public engagement with emerging science are involved in finding ways to develop a comprehensive programme of ongoing public engagement to build on the trust established through this dialogue and further elicit the views of UK publics.

- Explore outstanding questions: Our recommendation on the questions which need to be explored further in ongoing public engagement activities is based on an analysis of the most frequently discussed themes in the study that will become increasingly relevant over the next few years. They include:
  - How does society create an environment in which everyone who has a debilitating medical condition or injury has access to NIs to restore or improve their quality of life?

- How can we make sure NIs develop in such a way that people have the opportunity to opt-in pro-actively to the use of the technology based on balanced information about the pros and cons of the devices, who has access to the data generated and how it will be used?
- How do we arrive at a regulatory framework that is sufficiently flexible to enable scientific research to progress whilst making sure it covers the elements participants in this study identified as essential (the parameters of use; open standards and transparency of information; data protection assurances; safety of the devices) and allows for its relevance to be monitored over time?
- If the widespread use of NIs leads to a growing number of increasingly independent older people, how is society going to redefine the current health and social care system to meet their needs?
- What needs to be in place if a more widespread use of NIs leads to a society that might have to balance a growing workforce (more people healthier / independent for longer) with a lower demand for labour due to an increased efficiency of NI-equipped workers and automation?

Having been given opportunities to interact with specialists working at the cutting-edge of this field and space to reflect on the issues drawing on robust evidence and creative stimulus, participants demonstrated that public engagement on NIs is worthwhile. HVM hopes it will continue to be used to inform the work of those making and shaping policies on these emerging technologies.