# Healthcare Technologies Grand Challenges Report
# August 2014

## Summary of contents

This report contains summary information from the following engagement undertaken by the EPSRC Healthcare Technologies Theme:

- User engagement workshop – January 2014
- User engagement workshop – April 2014
- Community web surveys – April to June 2014
- Key stakeholders' workshop – June 2014

The content is organised against the 10 initial Grand Challenges that EPSRC developed with the Healthcare Technologies Strategic Advisory Team (SAT). For each challenge the following is included:

- Original description of the challenge
- 2-page poster summarising the outputs of the 2 user engagement workshops and survey (these posters were presented at the key stakeholders' workshop)
- Summary of discussions from the key stakeholders' workshop

Following this there is some information on:

- A vote undertaken at the key stakeholders' workshop
- Areas that survey participants felt were missing from the 10 challenges

The annex gives details of who attended each of the workshops we held.

**Data Analytics and Digital Infrastructure for Healthcare**

This challenge would transform healthcare by developing novel digital methods of engaging patients, professionals and the public, new methods of data collection, the integration of data across scales and platforms, and its analysis and interpretation. This could enable more effective self-care by individuals, allow more personalised and targeted intervention, and provide insights into the determinants of disease and efficacy of treatments. Potential benefits include self-management of health, increased quality of care, enhanced health outcomes, reduction in errors and adverse events, improved cost-effectiveness and greater patient satisfaction.

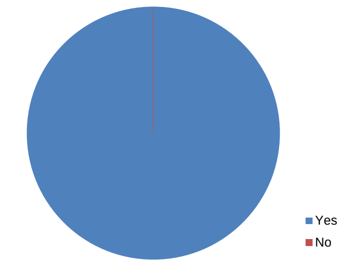
This potential will not be realised without significant advances in engineering and physical sciences to underpin the creation of scalable infrastructure and develop new ways of gathering knowledge from data. Researchers in the mathematical sciences and ICT are already making valuable contributions in fields such as data analytics, data mining, data security, image analysis, machine learning, modelling, natural language processing and statistics. Future research could lead to breakthroughs in topics such as:

- Distributed architectures for capturing and managing healthcare data;
- Integration and provenance of diverse sources of data (data interoperability);
- Capture and use of context;
- Decision support (for individuals and professionals);
- Spatial and temporal pattern discovery (at both individual and population levels).

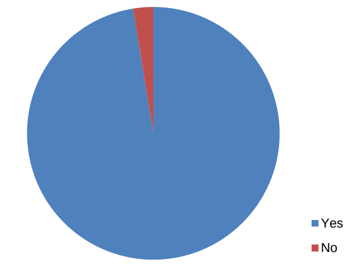
# Data analytics and digital infrastructure for healthcare

Group Responses: 8 Individual Responses: 24 Unknown: 7

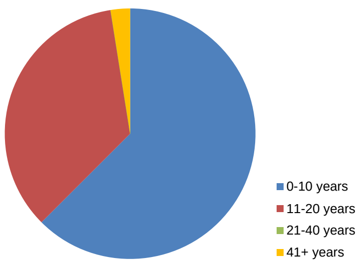
**Is this a Grand Challenge?**



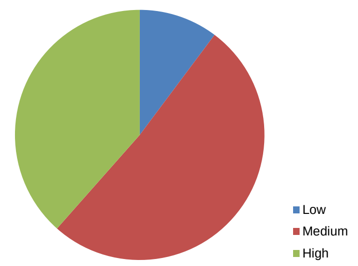

**Should EPSRC lead this Challenge?**




**Time frame for acheivement**




**Level of scientifc progress needed?**




**Potential for world leading EPS:**

Everyone agreed this was a grand challenge for EPS for a variety of reasons:

- Need an integrated approach across disciplines, including infrastructure, to enable a proper framework to be set up. Should enable secure, anonymised transfer of data for an effective business model to treat patients including a sound infrastructure which patients trust. The aim should be to use real-time data for real-time decision making to enable business to operate in a real-time environment;
- Increase in available data needs new approaches to maximise benefit and impact — i.e. need to know what we are looking for and then skim the data rather than just use algorithms and see what comes out. Need to represent it so it is useful to clinicians and patients;
- Healthcare is changing with the advance of cheap measurement technologies to monitor, diagnose and treat disease and infirmity;
- Will enable effective self-care by individuals, allow more personalised and targeted intervention and provide insights into the determinants of disease and efficacy of treatments resulting in significant potential to enhance quality of life and reduce healthcare costs.

Research challenges, identified relate to the need to:

- Create data analysis methods where knowledge discovery is central and goes beyond the typical black-box methods that most data mining methods use;
- Develop data aggregation against different criteria technologies;
- Develop remote intelligent, cost-effective and proactive health monitoring and sensing technologies using wireless data acquisition and transmission;
- Develop IT infrastructure to store information from different sources into a common framework with computational compatibility;
- Ensure data security;
- Develop statistical models of population health, as well as individuals health, to inform policy makers as well as the clinicians;
- Integrate not only the clinicians but also behavioural scientists and the public with the engineering and physical sciences community.

The engineering and physical sciences disciplines highlighted as important include:

- Data analytics including data mining and data interoperability;
- Statistics including modelling and pattern analysis;
- Machine learning;
- Cloud computing and HPC;
- Cryptography and data security;
- Sensor development;
- Image analysis and processing;
- HCI;
- Systems architecture;
- Mathematical modelling and complexity science;
- Decision support and knowledge management;
- Computer vision;
- Multiscale and multi-modal data integration;
- Fuzzy logic;
- Social networks analysis.

## Potential for delivering impact:

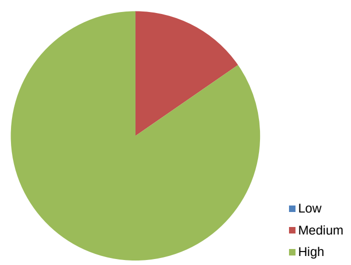
**Health Impact**

- Early identification of deterioration and adverse medical conditions;
- Enable patients to be more pro-active and take more control of their health;
- Keep people in their homes through effective long-distance monitoring;
- Step change in understanding the mechanism of disease for risk stratification and for planning intervention;
- Improved surveillance of the well and “diseased “ population to understand population needs and the impact of changes in commissioning or social care policy;
- Reduction in prescription errors and adverse drug effects;
- Allow a more stratified and personalised approach to patient treatments;
- Greater patient satisfaction.

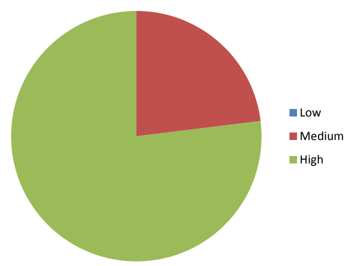
**Economic Impact**

- Improved cost-effectiveness;
- Reduction in the usage of medical services through treatment and care at home;
- Reduction in the size of clinical trials and therefore the cost of developing new therapies;
- Export of new technologies and healthcare methods;
- Creating a knowledge economy around health will deliver new sectors to the economy as the products and systems spin out will not necessarily relate to health;
- Healthier workforce will mean a reduction in absenteeism and an increase in productivity.

**Likely Health Impact:**

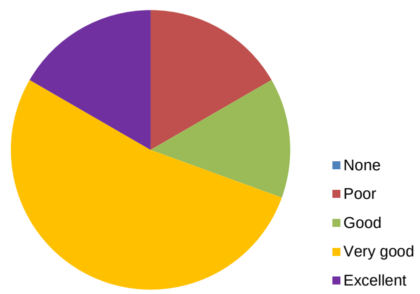



**Likely UK Economic Impact:**

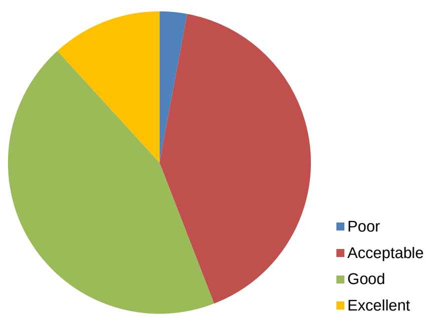


# Data analytics and digital infrastructure for healthcare

**UK Research Capacity**




**UK Research Infrastructure**



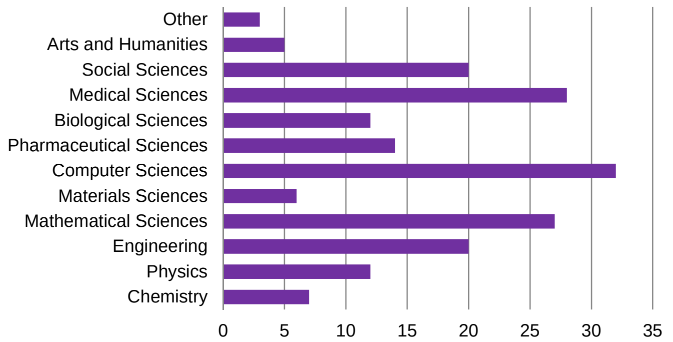

## Research Capability and infrastructure:

- Although mathematics, statistics, OR modelling and computer science is very strong in the UK, the application to healthcare is weak;
- There are a number of EPSRC funded critical mass centres in a number of key universities, many of whom have more than one. There is little evidence of synergy between them even within Institutions;
- There are a number of non-EPSRC funded initiatives which it may be useful to collaborate with:
  - ◊ NIHR funded D_CRIS system which has anonymised mental health records
  - ◊ Farr Institute of Health Informatics Research led by UCL
  - ◊ MRC Biostatistics Unit at Cambridge
  - ◊ Big Data Institute at Oxford
  - ◊ UK Biobank at Manchester
- There are no examples of academic discipline gaps; the main concerns were integration of disciplines and embedding them in the healthcare environment/ or focusing on the challenges;
- Needs strong leadership to bring the diverse capabilities together to focus on the healthcare research challenge;
- There are a lack of medics who really understand the engineering and physical sciences or the potential of its research so there is a real gap between those developing the potential innovations and the clinicians who could benefit from them;
- The research infrastructure is patchy and not on the scale of the UK's main rivals;
- There are no common software architectures.

## International collaborations:

- The USA was highlighted as a major potential collaborator. A number of specific institutes were highlighted:
  - ◊ Lab of Computational Physiology, MIT
  - ◊ Kaiser Permante Research Centres — data driven approach to healthcare
  - ◊ La King Shing Foundation, Stanford — a big data institute (linked to the one at Oxford)
  - ◊ NIH
- The EU was also highlighted as a major potential collaborator. A number of specific institutes were highlighted:
  - ◊ Body Sensor Networks
  - ◊ Lux Med is a private medical service in Poland which has strong electronic healthcare record skills.
- Australia, Canada and the Netherlands share the UK's socialised values in healthcare and are making some smart decisions on limited budgets.
- The Sao Paulo Research Foundation in Brazil (already has links with BBSRC, ESRC, Universities of Cambridge and Manchester, Intel and Microsoft Research)

**Research Capabilities needed:**




## Main linkages to other challenges:

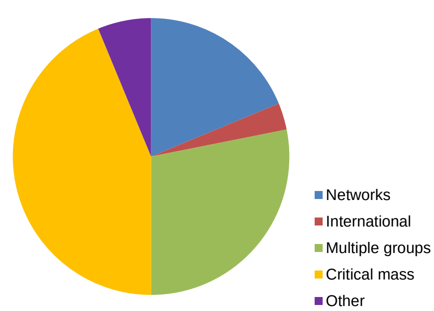
There were 4 other challenges identified which had strong linkages. They are listed in order of identified importance:

- Patient specific treatment;
- Prediction and early diagnosis;
- Systems to support and improve healthcare provision;
- Engineering healthy behaviours.

## Non-scientific barriers:

- Lack of publicly available data;
- The NHS/NIHR;
- Lack of integration between health and social care;
- Data governance, including public perception of how data would be used particularly by commercial companies (e.g. insurance companies);
- No legal framework within which cloud computing can operate;

**Recommended next Steps:**



**Data analytics and digital infrastructure for healthcare**

**Feedback from the key stakeholders' workshop**

- Discussions at the workshop primarily focussed on data analytics which was widely felt to underpin all the other challenges. Participants identified a risk that if we don't do this it would impact on our ability to realise the other challenges. Data analytics and digital infrastructure were considered to be very different.

- Participants had mixed views about this as a grand challenge for EPSRC with the majority agreeing it was a big challenge overall but then differing in their view of who should address it. Comments included:
    - This is squarely an EPS challenge and we have the breadth of expertise to tackle it e.g. excellent informatics, good HPC facilities etc.
    - The UK has momentum in this area and it would have high impact
    - This is more challenging as datasets become larger
    - There are challenges in the integration of data e.g. lifestyle and genetic data
    - What are the EPS challenges here?
    - How would EPSRC contribute when Google, IBM etc are investing heavily in the area? Although some participants questioned whether commercial operators were delivering on healthcare provider needs.
    - Is this a technology challenge or more about people / environmental issues in the healthcare system?

- A number of barriers to progress were identified, many of which were considered to be out of EPSRC control:
    - Logistic and political will isn't always there. This could be overcome if there was wider understanding of the value of data/information (this aligns with the interests of ESRC).
    - An open data policy is needed to enable sharing of data.
    - In order to link datasets they need to include a patient identifier.
    - Data ownership is not always clear – this is an issue for the NHS and can make sharing and using data difficult.
    - We have strength in research but this doesn't translate to clinical application
    - Business models can create barriers to progress.
    - There is a major social aspect around trust and willingness. Patients need to have confidence in the system. How can we manage consent / dynamic consent?

- Participants felt the UK had the infrastructure (NIHR/TSB) to tackle this challenge and the availability of NHS data provided a big opportunity.

- Some examples of where EPSRC could focus included:
    - Data integration – from different inputs/diagnostic approaches.
    - Intelligent interpretation of data
    - Working with clinicians to build expert knowledge into predictive algorithms.
    - Data mining from non-traditional sources (e.g. social media). Although what are the ethics of this?
    - Knowledge management and semantic technology
    - Interrogating low quality, cheap data using new high tech methods in a cost effective way.

- Other comments / observations on this potential Grand Challenge were:
    - Interoperability and data storage are important but are not EPS challenges.

- There are opportunities in stratification of big population health
- Big data (population, conditions) vs little data (individual, empowered)
- Can now integrate lifestyle analysis into healthcare – are there challenges in this?
- How do you determine what information healthcare providers need?  How do you give it to them?
- Acute vs chronic care (timing)
- How might integrated data be used to help clinically intervene?  Could inform treatment decisions e.g. identification of patients currently most at risk.
- If centralise data for rare conditions etc (e.g. in ICU) could really improve outcomes.
- Continuous monitoring approaches might be very disruptive – is data analytics therefore a big opportunity?
- Data – environment data not just clinical data.  Requires lots of creativity.
- How to get the right data from patients? Big data from non-tech people
- Linking genomic and phenotype information – for prediction / stratification
- Vast volumes of data exist for individual patients, let alone cohorts

**Enabling Technologies for Regenerative Medicine**

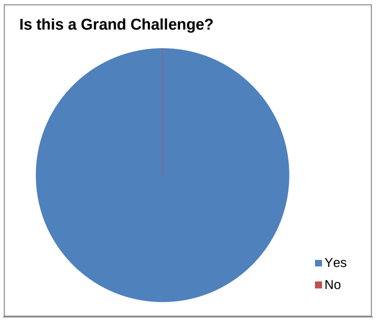
Regenerative medicine could lead to a revolution in healthcare for people with a wide range of conditions. These therapies involve repairing or replacing cells, tissues or organs that are not functioning normally, with living, functional tissues. They could improve the quality of life for patients with disorders including: neurodegenerative diseases, cardiovascular disease, organ failure, cancer, arthritis and wound healing. Ultimately, they may even remove the need for organ donation.

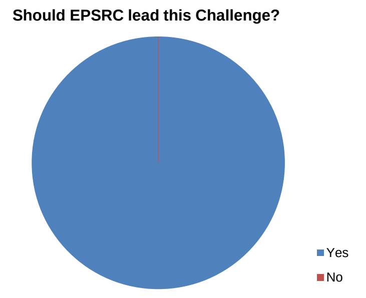
Engineers and physical scientists are already making valuable contributions to this vibrant, interdisciplinary field in areas such as biomaterials, tissue engineering, manufacturing, imaging and characterisation techniques. Future engineering and physical sciences research could lead to breakthroughs in topics such as:

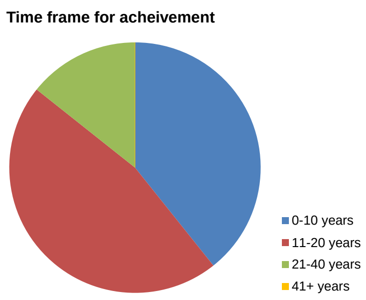
- The manufacture of large quantities of affordable, high quality cells and tissues;
- Sensing technologies to monitor and control bioactive implants and drug delivery;
- Implantable or injectable cells and tissues and tracking technologies;
- Engineering of materials that replicate biological structure and organisation for a wide variety of different tissues/organs.

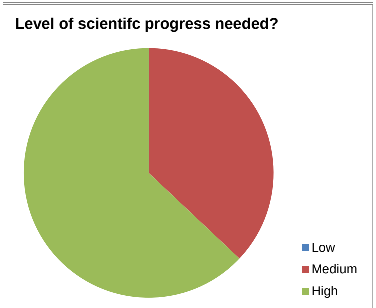
# Enabling technologies for regenerative medicine

Group Responses: 6 Individual Responses: 17 Unknown: 5




## Potential for world leading EPS:

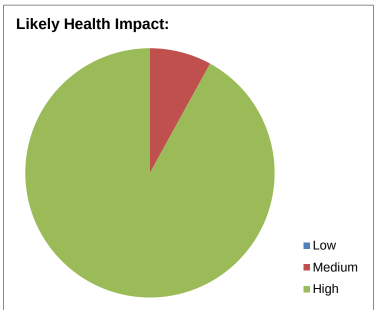
- Survey and workshop participants considered this to be a Grand Challenge
- A number of research challenges were highlighted:
  - ◊ Non-invasive, longitudinal monitoring of implanted cells / tissues (e.g. through novel imaging)
  - ◊ Optimising the manufacturing processes for regenerative therapies. Ensuring high quality, reproducible products are available when and where they are required.
  - ◊ Additive manufacturing for preparation of patient specific cells, materials or devices
  - ◊ Engineering of materials to replicate biological structure and function
  - ◊ Design of new, multi-functional biomaterials that are fit for purpose and can be manufactured at scale e.g. biodegradable scaffolds for cell delivery
  - ◊ Understanding the mechanical properties of engineered cells and tissues
  - ◊ Design of 3D environments and structures for tissue regeneration
  - ◊ Non– invasive characterisation techniques for engineered tissues / organs
  - ◊ Modelling of cellular behaviour and related biological systems
  - ◊ Realising the potential of active implantables and smart devices
  - ◊ Use of small molecules for cell transformation
  - ◊ Developing therapies that are operative from the time of implantation

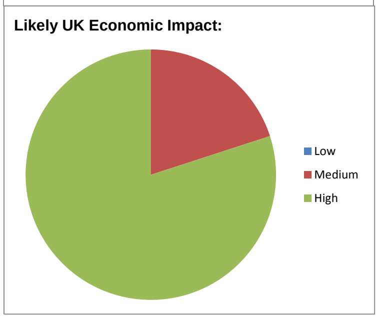
The types of EPSRC research needed includes:

- ◊ Biomaterials and tissue engineering
- ◊ Manufacturing technologies, including additive manufacturing
- ◊ Device engineering
- ◊ Computational science and mathematical modelling
- ◊ Chemical engineering
- ◊ Sensing and imaging
- ◊ Nanotechnology
- ◊ Analytical science
- ◊ Bioengineering
- ◊ Electronic engineering
- ◊ Chemistry, including polymer science

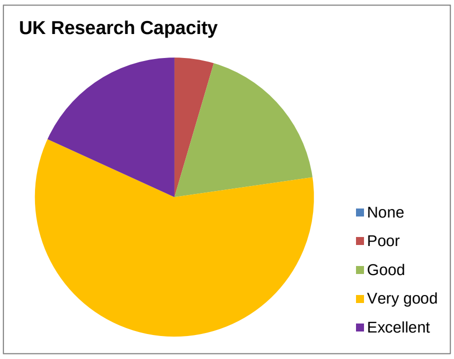
## Potential for delivering impact:

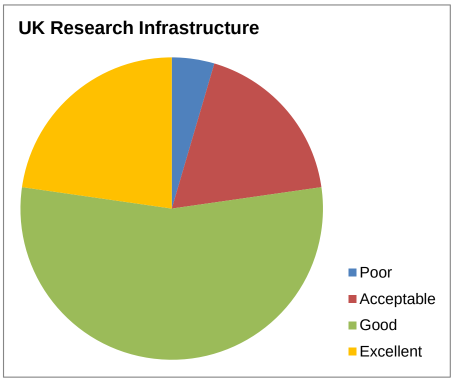
- Ability to cure otherwise incurable diseases — will no longer only treat symptoms
- Delivery of patient specific therapies
- Promoting healthy ageing, prolonging active lives, & increasing lifespans
- Reducing costs associated with disease management and social care
- Potential for long term economic impact through creation of new high-tech companies — big pharma is not yet fully engaged
- Some specific products/industries mentioned:
  - ◊ Design of functional biomaterials and their processing & manufacture at scale
  - ◊ Technology to support continuous and in-situ monitoring of therapeutic effectiveness
  - ◊ Better in-vitro assays to provide accurate screening of drug candidates



# Enabling technologies for regenerative medicine



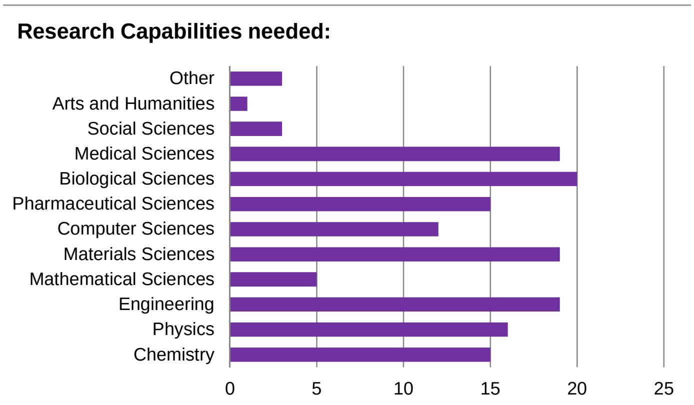




## Research Capability and infrastructure:

- A number of UK critical mass activities were highlighted (e.g. UKRMP, EPSRC CIMs, CDTs, MRC & BHF Centres).
- Other excellent groups across the UK spanning this & related areas were mentioned .
- Skills gaps were identified in computational modelling, cross-disciplinary training at all career stages (depth and breadth), expertise in GMP & scale up, and connectivity to the clinic.
- No major issues with UK infrastructure were listed. Some commenters stressed the need for mid-range facilities for imaging & characterisation. These should be co-located with equipment to support biology.
- More centres of excellence in healthcare manufacturing would encourage interdisciplinary and industrial collaborations.
- Greater sharing of translational expertise would be beneficial.

## Interdisciplinary & international collaborations:

- Respondents to the survey highlighted the need for well-rounded, multidisciplinary teams to tackle the challenge with a strong clinical pull.
- The value of cross-disciplinary training and joint appointments was highlighted (e,g, at chemistry—biology—engineering interface).
- A number of countries with strong research profiles were listed e.g. USA, China, Germany, India, Brazil, Switzerland, Sweden.
- International collaboration to enable synchrotron imaging was mentioned.

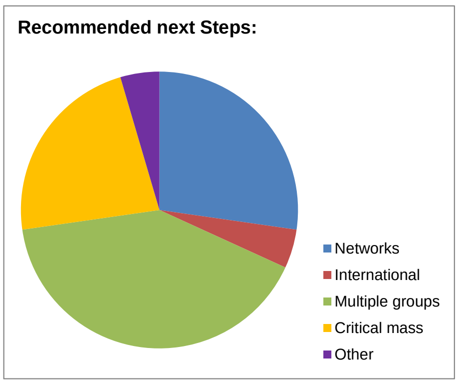



## Main linkages to other challenges:

- Smart surgeries and therapies
- Patient specific treatment
- Some linkages with data analytics & digital infrastructure for healthcare, prediction & early diagnosis, understanding and interventions in neurological function.

## Non-scientific barriers:

- Regulatory requirements — lack of understanding / expertise amongst academics
- Lack of investment from industry — both SMEs and large companies
- Slow progress in translating therapies to the clinic may risk alienating public / policy makers



**Enabling technologies for regenerative medicine**

**Feedback from the key stakeholders' workshop:**

- Most participants considered regenerative medicine to be a major challenge that could have a huge, transformative health impact in the long term. It was felt that there were still many unknowns in the field which are unlikely to be solved in the short term. The major science and technology challenges associated with the area mean there are strong opportunities for innovation and novelty.

- The group stated that there are pockets of excellence in this area; manufacturing, biomaterials, scaffolds, mechanobiology were mentioned as some of the EPS strengths in the UK. EPSRC's contribution would be in the field of developing enabling or platform technologies.

- Participants' opinions were split on whether this Grand Challenge should be led by EPSRC with a joined up, cross-council approach endorsed. The multidisciplinary teams and mind-set being created through the UK Regenerative Medicine Platform (UKRMP) which is funded by BBSRC, EPSRC and MRC was mentioned. Some participants supported an EPSRC lead for the particular focus on enabling technologies rather than the area as whole. A post UKRMP stock take could be useful.

- The group felt that this challenge was strongly linked to 'smart surgeries and therapies' as regenerative medicine is essentially a smart therapy. The link to 'early diagnosis' was also highlighted as regenerative medicine could be one of the therapies used following diagnosis. Participants emphasised that regenerative medicine research is currently focussed on end stage disease in order to get therapies into practice but that it may be more effective when used at early stages.

- Some discussion focussed on the fact that the area is not yet delivering and perhaps more focus would be good to drive it forward e.g. should there be more system or disease specific aspects? The need for focus was not universally held as some felt a natural focus has emerged e.g. there is much work in the UK on musculoskeletal, eye and liver. Other people commented that the need cuts across disease areas and so questioned any requirement to focus.

- Translational aspects of regenerative medicine require more focus (e.g. how to scale up biomaterial production) and links to the Cell Therapy Catapult will be important.

- The potential economic impact of the area was discussed; currently the area is too high risk for major investment. Once the science and technology is proven industry will invest e.g. by purchasing SMEs. It was felt that policy makers were supportive and recognised the area's potential. Resistance from existing industry due to disruption of current processes and practices was raised as a potential issue. Participants thought there was some low hanging fruit which could be commercialised in the short term (e.g. bone therapies, drug toxicology assays).

- Issues around regulation for regenerative therapies were highlighted. ESRC and TSB (through the catapult) have an interest in this.

- Some specific topics that EPSRC research could contribute to were identified as:
    - Manufacturing technologies
        - Continuous cell line manufacture.

    - Requirements for allogeneic vs autologous cells – central facilities vs personalised manufacture at point of care
    - Automation
    - Medical device manufacture
    - Characterisation of products – are cells usable / of sufficient quality?
  - New in vitro assays – not really regenerative medicine but very important to develop
  - Tools to switch on our own stem cells
  - Power extraction from biological materials
  - Biomaterials and scaffolds for cell delivery
  - Cell tracking technologies e.g. imaging

**Engineering healthy behaviours**

The development of wellbeing and prevention technologies that delay the onset of diseases or slow their progression could reduce costs to the healthcare system and improve quality of life. Such technologies would support and encourage healthy behaviours, without replacing an individual's responsibility for their own health, and could provide feedback to the individual and healthcare professionals. Research in this area would have to deliver practical outcomes demonstrated through quantitative testing, which are feasible at scale and financially viable.

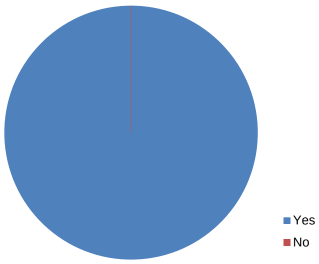
This challenge would draw upon UK strengths in urban design, civil engineering, sensing and monitoring, and ICT /digital economy. It would tackle topics such as:

- Design of the urban environment to encourage higher levels of physical activity;
- Understanding how to utilise the built environment to achieve personalised monitoring of health in everyday lives;
- Gamification of wellbeing and social inclusion using digital platforms;
- Novel non-intrusive sensing techniques, remote monitoring technologies and wearable monitoring technologies.

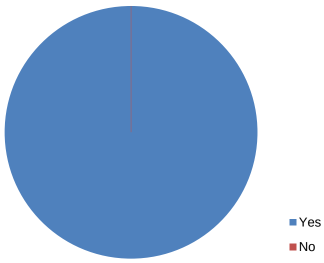
# Engineering healthy behaviours

Group Responses: 4 Individual Responses: 13 Unknown: 2

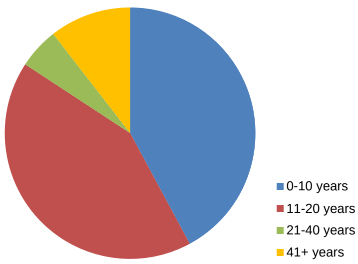
**Is this a Grand Challenge?**



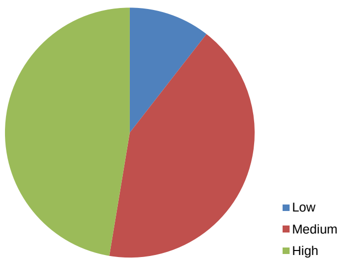

**Should EPSRC lead this Challenge?**




**Time frame for acheivement**




**Level of scientifc progress needed?**




**Potential for world leading EPS:**

Inputs received so far indicate that this ia a real and valid Grand Challenge. Whether EPSRC should lead is less clear:

- The world is getting older and medicine improving: instead of people dying of conditions, they are living with them. Helping people take on responsibility for their own health and preventing some of these conditions is important. This makes it a grand challenge.
- 5 health behaviours (diet, physical activity, smoking, excess alcohol consumption, sex) account for 40% of avoidable morbidity and premature mortality. Achieving even small changes in these behaviours across a population would have a huge impact on improving health and reducing health care costs.
- This is worthwhile, but is heavily cross-disciplinary — I don't think the EPSRC has the capacity to facilitate something as broad as this.
- This is not only looking at systems that CAN help people, but looking at HOW people use them.
- Many academic cultures tend to want to observe, rather than intervene in behaviours; to what extent is it appropriate and ethical to intervene in behaviours.
- The Health system needs to switch from treatment to prevention, with the individual taking responsibility, and Healthcare professionals need to manage patients to avoid health problems rather than provide cure.

Research challenges, identified broadly related to:

1) Monitoring, and interpretation of behaviour:

- How to provide sensing and modelling that can accurately represent behavioural risks?
- How to structure the built environment to shape peoples' patterns of activity, and understanding environment-behaviour interactions?
- How to build social computational systems that unobtrusively reinforce healthy patterns of behaviour and that educate the citizen to recognise unhealthy patterns? We can track and count everything physiologically but we are terrible at computational sense-making of that data in a way that makes it actionable. The role of models and their visualisation was identified as particularly important in developing information that counters unhealthy lifestyles. What algorithms can be used to mine the data to result in appropriate advice for users relating to goal setting to help them move towards healthier behaviour? Better dynamical models to understand and assess the individual.
- How to use big data from various sources such as environment, health, social care, climate, personal genome, and process it in a customised way for each individual, to develop a person centred care approach?

2) Lifestyle choices, behaviour change and the utilisation of technologies

- What behaviour change techniques can be combined with technology in effective ways? What new behaviour change techniques are made possible by technology? How different user groups will respond to different techniques e.g. is gamification suitable for older user groups?
- Experimental and modelling research into nutrition and engineering new food materials.

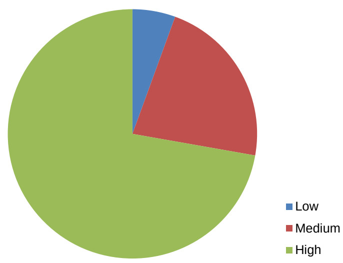
Key EPS research required to tackle this includes:

- Ubiquitous sensing and monitoring technologies. Novel diagnostic monitoring technologies that combine sensing, actuation, communication, as well as novel means of obtaining diagnostic information through, e.g. non-invasive technologies, new biomarkers for diagnosis or monitoring and novel algorithms to allow these new biomarkers to be effectively implemented.
- Big Data / data mining / algorithm development
- Built environment
- Food Engineering / food technology
- Internet of things
- HCI

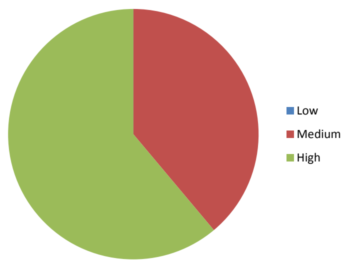
**Potential for delivering impact:**

- Moving healthcare out of the clinic and into people's everyday lives - would encourage personal responsibility for health outcomes and perhaps influence the rising prevalence of chronic conditions such as Type 2 diabetes.
- Small improvements across a large population have a big impact on population health. Small improvements in levels of physical activity, increased consumption of fruit and veg, reduced alcohol consumption and reduced levels of smoking would have substantial impact on population health, across all major long term conditions (cardiovascular disease, diabetes, arthritis, respiratory disease).
- Chronic disease management — technology to improve management would bring enormous benefits in terms of reduced morbidity, mortality and significant health economic benefits (reducing re-admittance & overall cost of condition).
- Improved healthy ageing, and independent living, reducing risks in the frail population, reducing health inequalities, improvement of health services use and efficiency, minimising unnecessary variation, improving the reliability of care, improving self-management and patient/citizen empowerment, improvement of the co-ordination and integration of care.
- This could influence the bottom line of the NHS. Chronic conditions such as Type 2 diabetes take up such as large proportion of healthcare costs, that it is necessary to attempt to address some of the underlying issues.
- A healthier population, will lead to increased productivity, and a reduced health care spend (or at least, a levelling off in the rate of increase). Exporting technology to other countries.

**Likely Health Impact:**

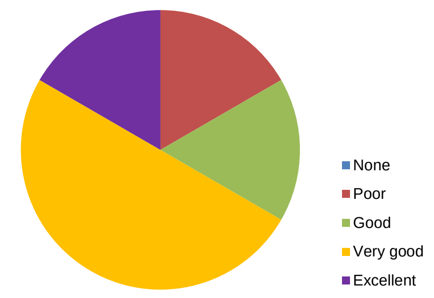



**Likely UK Economic Impact:**

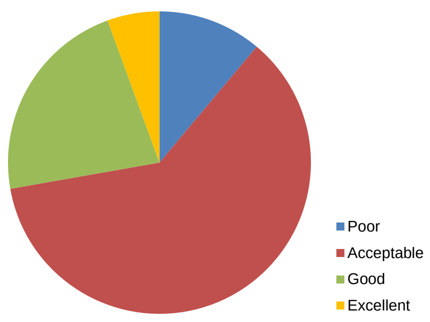


# Engineering healthy behaviours

**UK Research Capacity**




**UK Research Infrastructure**




**Research Capability and infrastructure:**

A range of existing groups of relevance across the UK were highlighted.  Some specific examples include:

Swansea FIT Lab; Newcastle Culture Lab; Open University Knowledge Media; City University Centre for HCI Design; UCL for UCLIC (UCL Human Computer Interaction),  Computer Science, e-Health group (part of the School of Life and Medical Sciences), and the Centre for Behaviour Change; LSE Health & Social Care (Behavioural Economics); Royal College of Art; Helen Hamlyn Centre for Design; Computer Science, University of Sheffield; World class NHS hospitals e.g. Wycombe Hospital, Imperial or Guys & St Thomas; eSMART project; SPHERE IRC; the pervasive sensing centre in Imperial College London; WT/EPSRC Medical Engineering Centres; SICSA alliance; Edinburgh University and the Scottish Collaboration for Public Health Research and Policy  (SCPHRP); Warwick, Manchester and UCL (CHIME); TSB Assisted Living and Innovation Programme.

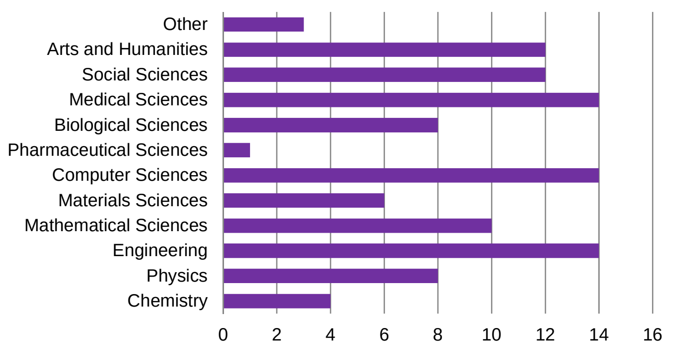
New capabilities required include:

A new discipline for "proactive health ICT design".  Very few researchers in relevant  parts of engineering know anything about the body. How we work physiologically, kinesiologically - how the brain and body interact. HCI is an interdisiplinary field already combining computer science and psychology - we need to get more of the 'brain' into this space to go even further. As long as we focus on behaviour change rather than systemic issues, we'll fail.  There is a need to adjust our emphasis from the individual, and "behaviour change" to addressing social norms and aspirations. We can deliver to the individual, but we need to think about systemic integration.

**Interdisciplinary & international collaborations:**

- Lots of work being done by research institutions in the far East - Hong Kong, China, Japan and Singapore - maybe as they are facing problems due to ageing populations at a more advanced level than the rest of the world.  The UK should collaborate with these countries to gain from their experience in this sector.
- Australia leads the way in innovative health and environment research relating to increasing physical activity and reducing sedentary behaviour. Links are therefore important, as well as with North American public health researchers.
- Links with Latin America may offer opportunities to understand environment-behaviour interactions in the context of healthy lifestyles in countries where new and radically different ways of approaching design and management of the built environment are being explored.
- Low cost sensors and networks development from EU
- Holland; organisations such as TI Food Nutrition
- USA e.g. Arizona State University
- Germany, because they have the biggest cluster of excellence in this area right now.
- Denmark and the Netherlands have considerable capacity in this field.
- European Innovation Partnership on Active and Healthy Ageing

**Research Capabilities needed:**




**Main linkages to other challenges:**

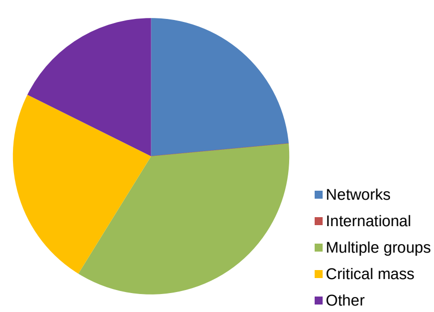
Strong connections to:

- Data analytics and digital infrastructure for healthcare
- Systems to support and improve healthcare provision (in particular due to strong relevance through sensors and monitoring)
- Functional enhancement for safe and independent living

**Non-scientific barriers:**

- Politics
- Socio-technical issues
- Demographics, young will adopt elderly will not
- Good vision and leadership, well planned with both short and long term impact and deliverables. A combination of emergent and applied research is required
- Social acceptance of these technologies by patients and privacy-related issues. An integration of social science experts in research teams and involving patients in the design process  may counter this.
- The relationship with the food industry and the need to develop clear healthy options in terms of food.  The obesity epidemic is a key starting point for anyone working in this area.

**Recommended next Steps:**



**Engineering healthy behaviour**

**Feedback from the key stakeholders' workshop:**

- Opinion amongst attendees was split between those who felt this was a challenge for EPSRC and those who felt others should lead. There was general agreement, however, that other challenges were more important for EPSRC to focus on.

- Strong linkages were identified to both 'systems to support and improve healthcare provision' and 'functional enhancement for safe and independent living'. It was suggested that aspects from these challenges could be merged e.g. to 'technology platforms for social wellbeing' (or similar).

- Some scientific / technological aspects of this challenge that would be most relevant for EPSRC were suggested as:
    - Built environment as a population level intervention – how the physical environment impacts behaviour
    - Sensors and sensor technologies – measuring, tracking, ubiquitous sensors, physiological sensors as ways to influence behaviour
    - Big data / data analytics – interpretation of personal data or population level data (e.g. from sensors), presentation of data in an accessible way.
    - Smart materials.
    - Gaming to influence behaviours.
    - Human-computer interaction

- There was widely considered to be a large non-EPSRC element to this challenge in terms of psychology, psychiatry, sociology etc. Much of the research would need to focus on how to change behaviours and lifestyles e.g. by changing individual's incentives, promoting healthy behaviours or educating people about diet. There are challenges in engaging people who don't take care of themselves. A consumer-led approach (rather than medic-led) tends to have greater success.

- Some other comments made on this challenge included:
    - A systems approach is essential
    - This challenge does not just focus on the ill but also on 'wellness' and maintaining that 'wellness'. There is a clear market for technology for the 'worried well'.
    - There can be a worry about 'big brother' e.g. it was difficult to engage patients with telehealth.
    - There is a strong link to MoD / Dstl activity.
    - Issues include sustained engagement and scalability.

**Functional enhancement for safe and independent living**

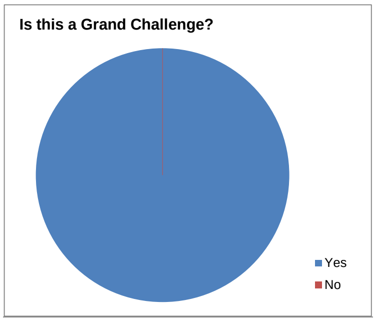
The focus of this challenge would be enabling people with impaired function to remain living as independently as possible within the home of their choice. Impaired function may be due to disability, cognitive impairment, natural ageing or other causes. Achieving this goal would help maximise people's quality of life.

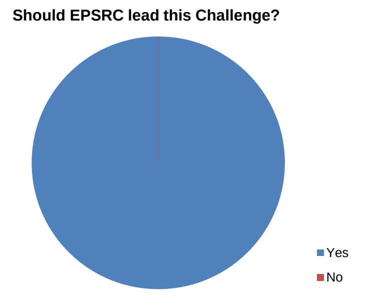
Valuable contributions are already being made to this challenge in disciplines such as materials science, additive manufacturing, sensors and instrumentation, human-computer interactions, robotics and biomechanics. Future engineering and physical sciences research could lead to breakthroughs such as:

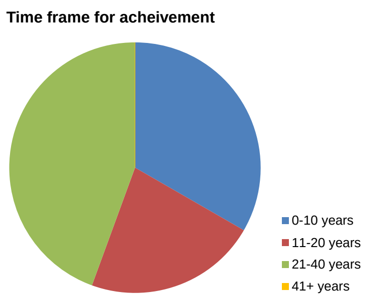
- Smart prostheses and wearable or companion robots that can respond to the user in an intelligent and cooperative manner;
- Affordable personalised assistive devices using novel manufacturing solutions;
- Technologies that provide an enhanced level of support and assistance without stigma, enabling independent living, through a user-centred approach;
- Integrated sensor systems such that individuals are closely monitored for falls, vital signs and location.

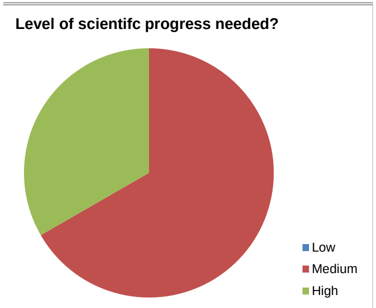
# Functional enhancement for safe and independent living

Group Responses: 2 Individual Responses: 6 Unknown: 1




## Potential for world leading EPS:

Survey participants and workshop attendees agreed this was a grand challenge for EPS for the following reasons:

- With an ageing population and increasing prevalence of chronic conditions e.g. stroke, there is a requirement for robust, reliable, safe and effective assistive technologies that allow patients to remain in their own home for as long as possible.
- There is a need for a variety of different types of assistive devices depending on the patient need including wearable technologies, implanted devices and rehabilitation robots.
- The challenge has the potential to enhance quality of life, improve independence and reduce burden on acute and social care but it will require a multidisciplinary approach to ensure technologies are developed with the user in mind.

A number of research challenges were identified:

- Continuous, self-generating and light weight power generation for assistive devices and improved control to mimic human locomotion.
- Autonomous control of rehabilitation/assistive robots and electrical stimulation that can react and adapt intelligently to the environment and the patient.
- Integration of prosthetics with the nervous system.
- Advances are needed in hardware and software engineering to enable to devices to be used independently without the need for a carer.
- Integration of sensor technologies, data transmission, energy harvesting, user centred design and additive manufacturing to enable low cost, usable, personalised devices.
- Algorithms to improve data quality from monitoring devices.
- Novel methodologies for designing/developing games at an affordable cost and their integration into rehabilitation technologies and robots

This was felt to be a challenge requiring a multidisciplinary approach including the following disciplines:

- Biomedical engineers
- Physical scientists, including Chemists and Materials scientists
- Robotics
- Power generation and storage
- Microelectronics
- Control engineering
- Biomechanics
- Manufacturing
- Neuroscientists
- Movement psychologists
- Biologists
- Health economists
- Healthcare professionals and clinicians

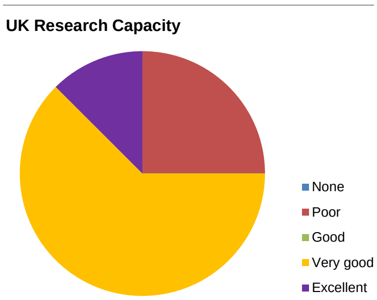
## Potential for delivering impact:

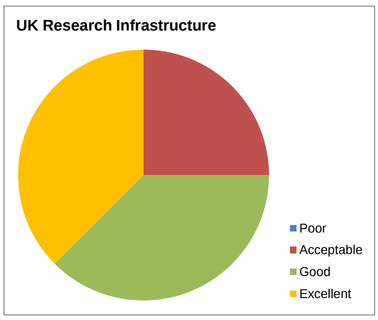
Health impact

- There was a strong consensus that achieving this challenge would increase the quality of life for older and disabled patients as it would enable them to remain independent.
- This challenge would allow clinicians to take a strategic overview of care and enable patients to spend more time on therapy in their own home and be less reliant on time spent with a clinician.

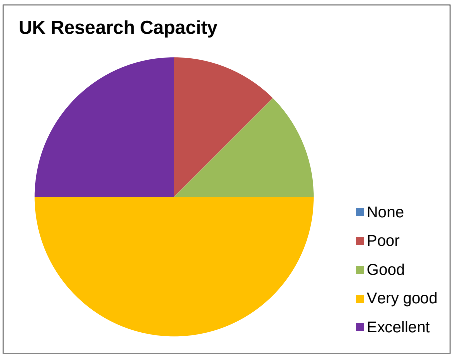
Economic impact

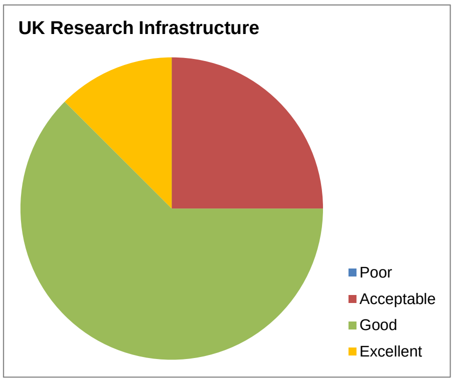
- The economic impacts would primarily be indirect through increasing efficiencies in the NHS and lowering the cost burden of social care.
- In addition this challenge would lead to increased working capacity as patients will have longer working lives and will be productive members of society for longer.
- There were mixed views on the benefits to the medical devices industry with some respondents viewing the UK as “weak in medical devices” with contrasting opinions that the “UK is an industry leader”.



# Functional enhancement for safe and independent living



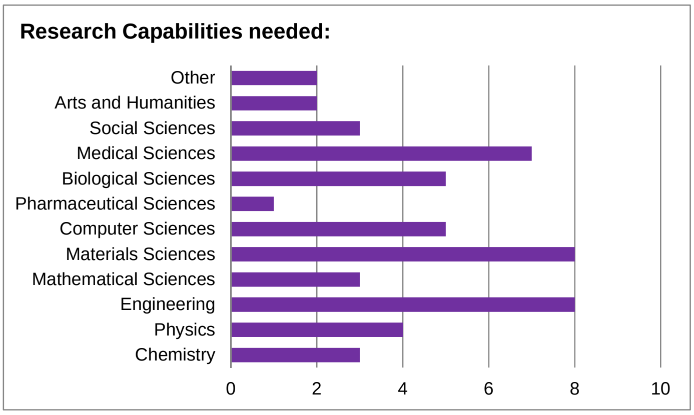




## Research Capability and infrastructure:

- There are groups working in this area but there are only a minority who have been able to work across disciplinary fields.
- More needs to be done to encourage the entire community to work together.
- It was felt that the UK research community would be able to respond to this challenge.
- There were mixed views about the research infrastructure in the UK with some comments that the infrastructure is sufficient but others suggesting that substantial infrastructure would be required.

## Interdisciplinary & international collaborations:

- The was a strong consensus across survey respondents and workshop participants that this challenge would require a highly multidisciplinary response. In addition to the areas highlighted neuroscience was felt to be specifically relevant.
- There was no particular steer given on international collaborations although the USA, Switzerland, Germany, Australia, Japan, Canada and Israel were identified in survey responses.

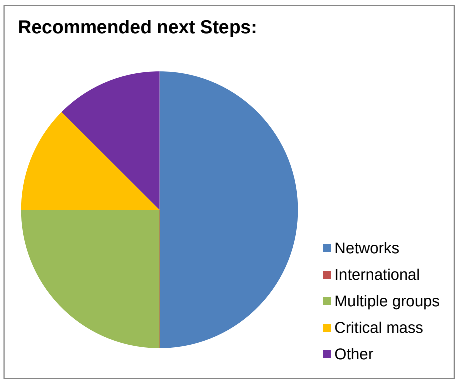



## Main linkages to other challenges:

- There wasn't a strong consensus on which other challenges this linked to. Although at least one person selected each of the challenges.

## Non-scientific barriers:

- Collaboration with Health Service professionals at the early stages of research and adoption into the health service.
- User acceptance and engagement with new technology
- Regulation for medical devices



**Functional enhancement for safe and independent living**

**Feedback from the key stakeholders' workshop:**

- Opinion amongst attendees was that this challenge was of relevance to EPSRC. However, they were not clear on the priority that should be given to the area in comparison to others. An NHS perspective was that mental health and neurological are more important.

- The title of this challenge does not appear to appropriately reflect the topics it covers e.g. workshop participants focussed on ageing populations due to the word 'safe'. The challenge was intended to include much of the assistive technologies portfolio. Are there really two challenges here:
    - Smart prosthetics (power generation, retina)
    - Safe and independent living for the ageing population

- Strong linkages were identified to both 'systems to support and improve healthcare provision' and 'engineering healthy behaviours'. It was suggested that aspects from these challenges could be merged e.g. to 'technology platforms for social wellbeing' (or similar). Other links were highlighted as 'data analytics' and 'patient specific treatments'. There are also overlaps with the assistive technology part of 'understanding and interventions in neurological function.

- Participants identified the need to move from 'engineering one-offs' to something more applicable for broader patient groups.

- The potential impact of the challenge was felt to be high if focussed on the ageing population; however, some participants questioned whether technology is the solution. Assisted living in an economically sustained way is needed e.g. using robots to support independent living. There are issues around technology integration and acceptability.

- Some issues raised around this challenge included:
    - Lack of understanding around the size of the problem
    - The commercial response in this area – what is industry doing?
    - The feeling it was already well resourced and much technology already available (e.g. telecare / telehealth)
    - It limits person to person contact
    - Translation into NHS is a barrier
    - Individual communities are well placed but we need to be better joined up

- There are strong links to social sciences, psychology, cognition research e.g. in acceptability of technological solutions.

- Other comments received at the workshop that the SAT may wish to note included:
    - Integration to the built environment e.g. 3D simulation of a person's home to enable consideration of how they can rehabilitate in their home.
    - Augmenting human performance in combat situations (Dstl)
    - Design important to be included in this challenge.
    - Keeping people at home but keeping them healthy through home monitoring
    - Functional feedback to improve independent living
    - Power generation miniaturised to aid usability
    - Medication adherence is missing – feedback to patients
    - Machine – machine communication. Internet of things.

- Missing the environment aspects – integration with design of environment, home, transport
- Rest of the world is good at exoskeletons but UK is good at biomechanics

## Infection prevention and control

The early detection, identification and control of infectious agents would improve the health of the global population. This could lead to fewer infections in clinical and non-clinical environments, prevention of the spread of infection and the development of more effective targeted antimicrobial therapies. This challenge has particular relevance to the global antimicrobial resistance challenge.

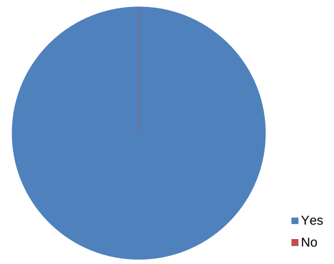
The engineering and physical sciences community are already making advances in areas such as self-cleaning surfaces, smart wound dressings, early diagnosis and surveillance of the spread of infection. Future research could lead to breakthroughs in areas such as:

- Prevention of the emergence of antimicrobial resistance e.g. by developing personal or point-of-care devices for rapid diagnosis which would ensure the most effective drugs are used;
- Development of new antimicrobial agents and interventions for specific resistant strains on a named microbe/patient basis;
- Predicting the emergence of pandemics through improved detection and surveillance systems to monitor the spread of infection;
- Prevention of initial infection and control of infection reservoirs through broader application of smart functional materials in clinical, surgical and other critical environments.

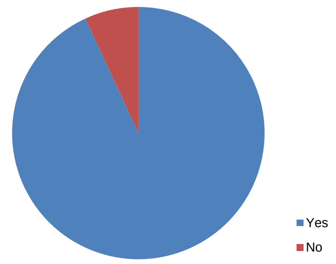
# Infection prevention and control

Group Responses: 7 Individual Responses: 17 Unknown: 5

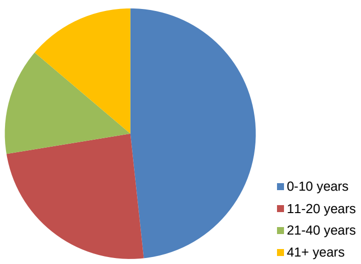
**Is this a Grand Challenge?**



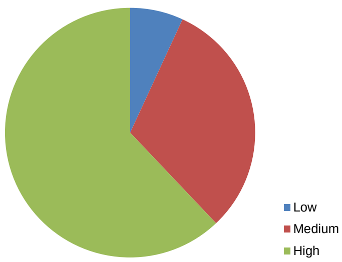

**Should EPSRC lead this Challenge?**




**Time frame for acheivement**




**Level of scientifc progress needed?**




## Potential for world leading EPS:

This area is considered to be a grand challenge for the following reasons:

- Antimicrobial resistance is seen as one of the greatest threats to global human health of the 21st century which is evidenced by it’s presence on the national risk register and it is recognised as a grand challenge by the WHO.
- Infection control underpins all aspects of healthcare and the spread of antimicrobial resistant infections has the potential to see a return to the pre-antibiotic era which would undermine all the other advances made in medical care.
- Several respondents argued that this was the most urgent of the grand challenges that would require an interdisciplinary approach.

The research challenges identified included:

- Low-cost, rapid, point of care diagnostics to identify the type of infection.
- New therapeutics to target infectious agents, this includes synthetic and medicinal chemistry approaches to current and new targets, novel anti-infectives and novel delivery mechanisms to target the infection.
- Development of instrumentation for in vivo imaging of infections to enable greater understanding of the biophysics of infection.
- Statistical and mathematical modelling to enable greater understanding of the spread of resistance within and between populations, within the environment and how pathogens interact with the host.
- Enhancement of surveillance capabilities of infection and development of predictive models.
- Smart materials to prevent bacterial colonisation on surfaces, wounds, surgical instruments or implants.
- There was a consensus that this challenge would require a multidisciplinary approach involving engineers, chemists, materials scientists, computer scientists, mathematicians and systems pharmacologists working closely with biologists and bacteriologists.

## Potential for delivering impact:

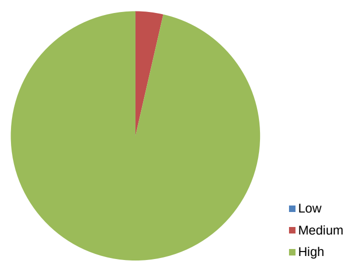
**Potential for health impact**

- If we do not address this challenge then we risk returning to a pre-antibiotic era where people will die from infections that are currently treatable.

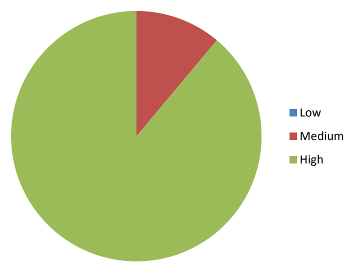
**Potential for economic impact**

- There are economic benefits to SMEs, the pharmaceutical industry and the diagnostics industry.
- A reduction in hospital acquired infections will reduce hospital stays and have an economic benefit for the NHS.
- There is also the potential for economic impact on the food and agriculture industry.

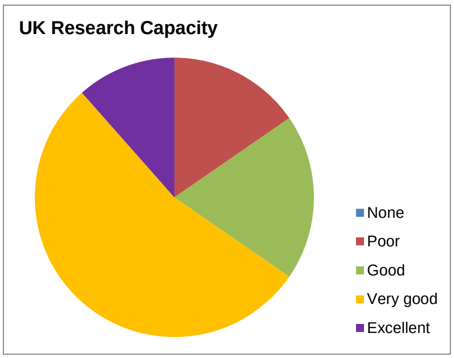
**Likely Health Impact:**

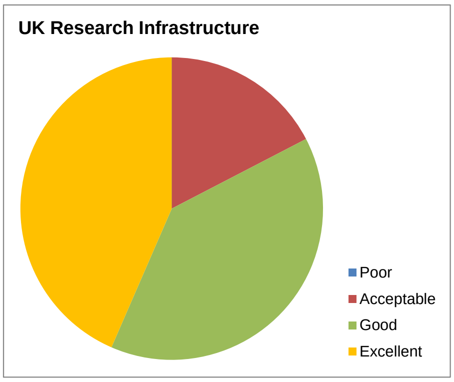



**Likely UK Economic Impact:**



# Infection prevention and control



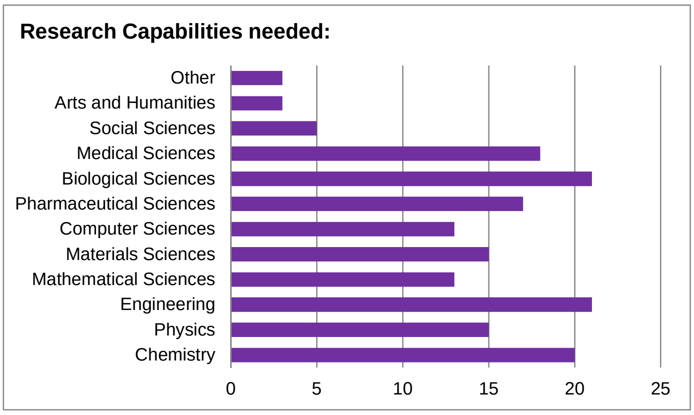




## Research Capability and infrastructure:

- There are a number of strong groups across the UK that could be united by a challenge in this area.
- There are a number of critical mass investments by the MRC and NIHR.
- It will be important that any work in this area is truly interdisciplinary. There were some concerns that the UK doesn't support enough multidisciplinary work in this area.
- Engagement of clinicians and industrialists would be beneficial.
- The research infrastructure in the UK was felt to be adequate.

## Interdisciplinary & international collaborations:

- Survey respondents felt that this spanned across a very broad range of disciplines.
- Specific disciplines highlighted include systems pharmacology, biological physics built environment, biomedical signal processing, applied molecular bacteriology and nanotechnology.
- As this is a global issue there was strong support for international collaboration.
- Countries that were mentioned include the USA, China, Europe in addition to developing countries.

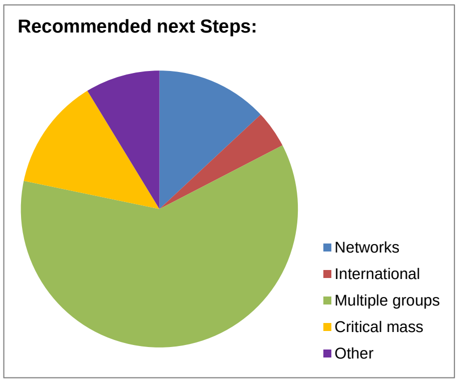



## Main linkages to other challenges:

- Prediction and early diagnosis
- Patient specific treatment

## Non-scientific barriers:

- The lack of economic incentives for the pharma industry to invest in this area.
- Lack of research funding support for interdisciplinary proposals.



**Infection prevention and control**

**Feedback from the key stakeholders' workshop:**

- Participants considered this to be a very important, global challenge and it is a high priority for the UK Chief Medical Officer. The political will is in place in the UK providing the right environment for success.

- It was felt that this is a challenge which can only be achieved in partnership with others. It could more appropriately be an RCUK challenge and others (e.g. Wellcome Trust) should also be engaged. A key target will be to create an interdisciplinary research community to tackle the problem. We will only succeed through coordination and growth.

- It was not clear that EPSRC should lead on this challenge but a significant role was endorsed. There are major challenges to address across the biological and medical sciences and perhaps a lead in this sector might be appropriate. As the challenge is so broad it is necessary to identify the key EPS contribution.

- Links to other challenges were identified as 'prediction and early diagnosis' (e.g. pre-symptomatic diagnosis or rapid diagnosis), 'systems to support and improve healthcare provision' and 'data analytics'.

- Some areas in which EPS researchers could contribute to this challenge included:
    - Wound engineering
    - Accurate, rapid diagnosis e.g. point of care devices
    - Computational modelling of epidemics, drug absorption and cell updake
    - Big data approaches - data analytics, anonymised and un-anonymised data to track infection.
    - Novel materials
    - Novel theranostics
    - Surface science
    - Infection control in built environment e.g. building design, modelling and air flow to prevent spread of infection.
    - Manufacturing challenges
    - Sensing and identification of biomarkers of infection.
    - Disposable technology for gas analysis
    - Multiscale modelling approaches

- Some additional comments / issues related to this challenge were identified as:
    - There is a lack of biological targets but EPSRC cannot address this
    - We're not good at translation in this area e.g. new treatments may not be developed by the pharmaceutical industry for economic reasons. New business models would help, along with changes to the regulation process and extended patent life.
    - Very little is said about viral infection in this challenge.
    - Should we include control of human pathogens in animal/food production environments?
    - We need to be able to respond quickly to the emergence of resistant strains.
    - There is a defence medical science programme.
    - The environmental component is important – reservoirs of resistance in water, land etc.

**Patient specific treatment**

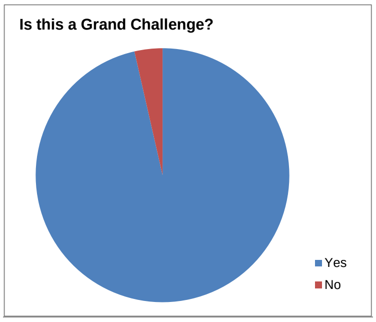
Current treatment programmes primarily target diseases or pathological conditions, with adjustments made in a reactive manner based on patient response. Individualised interventions, whether pharmacological, surgical and/or device-based, could increase effectiveness and improve overall patient outcomes by targeting the specific patient pathophysiology. Health interventions would be more precisely calibrated by combining imaging, sensing, computing, data analysis and targeted drugs based on a patient's genome, their local environment and any other pertinent factors. Areas likely to benefit include: oncology, cardiovascular disease, neurodegenerative diseases, psychiatric disorders, respiratory disease and metabolic diseases (obesity, diabetes).

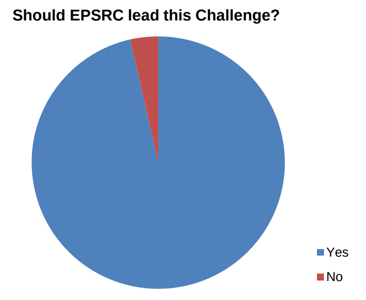
Engineers and physical scientists are currently pioneering advances in medical imaging, personalised implanted medical devices, bespoke additive manufacturing and the development of the Virtual Physiological Human initiative. Future contributions could include:

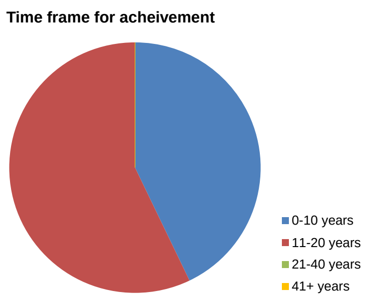
- Development of new analytical methods to improve the diagnostic process;
- Sensing systems to capture rich longitudinal health and lifestyle data;
- Development of new methodologies to predict the long-term prognosis following candidate interventions e.g. modelling and understanding of longer term interaction of physical and biological processes;
- Further developing affordable technologies for accurate genome sequencing, diagnosis, monitoring and response to treatment;
- Low cost facilities for bespoke drug manufacturing at the point of care, e.g. pharmacies, GP surgeries, an individual's home;
- Patient risk modelling/stratification based on an individual's genomic, lifestyle and environmental data.

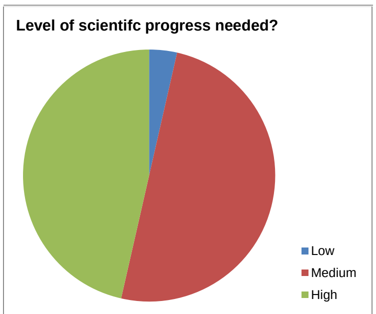
# Patient specific treatment

Group Responses: 12 Individual Responses: 15 Unknown: 1




## Potential for world leading EPS:

### *Why this is considered to be a Grand Challenge*

- This will be the next healthcare revolution and is what patients want
- Diseases, their symptoms and optimal treatment are complex issues dependent upon many factors
- The high degree of interdisciplinarity combined with the need to engage clinicians and industry (the whole supply chain) so breakthroughs are translated into the clinic
- Currently almost no 'Personalised Medicine' approaches exist, though a priority for the healthcare / pharma community. A priority in Horizon 2020.
- Data acquisition, security, evaluation, standardisation, integration, processing and validation are significant challenges
- A cross-cutting theme underpinning other grand challenges

### *The key EPS research that is needed to meet this challenge*

- Large, longitudinal cohort studies employing statistical modelling to aid data interpretation are needed. Much of the data has been collected but in many different ways - this data needs to be combined (standardised and integrated) for analysis.
- Human physiology is complex, integrative, and adaptive. Developing models that represent the structure and function of human cells, tissues and organs is difficult but tractable. The challenge is to is to develop techniques able to make use of personalized patient parameters in a spatial and temporal multiscale way to better predict the condition of the patient, by modelling the body's response to disease, treatment and the aging process.
- Multiplexed disease detection platforms for molecular level analyses and integration of the resultant data, to understand each disease's basic biology as well as the influence of a patient's genotype, phenotype, history and exposure to exogenous factors.
- Specification can occur at all stages; diagnosis, prognosis, intervention, management, rehabilitation, medical device manufacture.
- Develop portable instrumentation via method simplification and/or miniaturization of analyses provided by laboratory based platforms currently .
- Efficient, targeted drug delivery mechanisms.
- High quality, preferably non or minimally invasive sensing technologies.
- Image biological function quantitatively.
- 3D printing to regulatory standards.

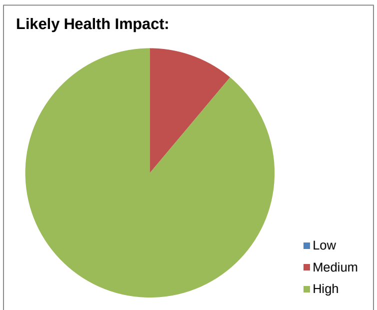
## Potential for delivering impact:

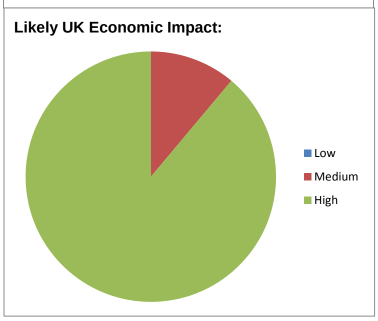
### *Health impact*

- A wide variety of applications, not just in cardiovascular, cancer etc
- Increased success in treating conditions, reduced side-effects
- A way of addressing the over-prescription of antibiotics and consequent increase in bacterial resistance

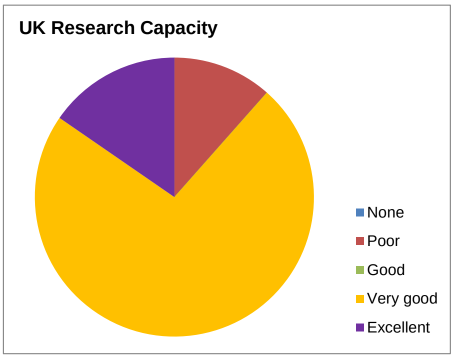
### *Economic impact*

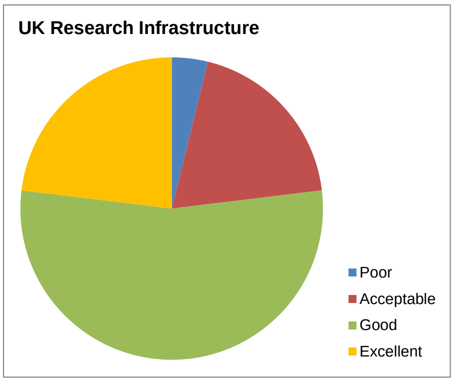
- Reducing illness/side effects associated with examination and/or treatment, better target expensive therapies (increasing cost effectiveness, offsetting the increased costs of diagnosis)
- Cost effectiveness (economically viable, efficient) requires advances in technologies (as well as clinical practice, awareness, education)
- Shorter rehabilitation times and a longer economically productive life-span
- Increased inward investment and job creation



# Patient specific treatment



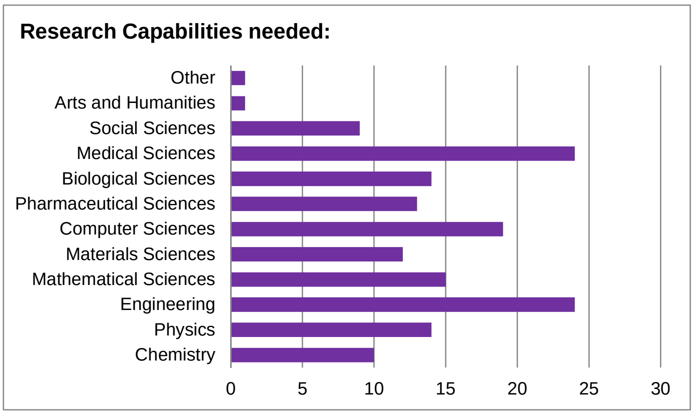




## Research Capability and infrastructure:

- A good spread across the UK of expertise relevant to this challenge was identified. A few specific centres listed were: INSIGNEO at University of Sheffield, CRUK/EPSRC Cancer Imaging Centres, NIHR BRCs, EPSRC CDTs, Crick Institute, and Farr Institute. Many other university departments were given.
- The most significant skills gap identified was in training EPS researchers in both the EPS and medical fields to enable truly interdisciplinary research.
- Other issues highlighted included the need for: investment in health economics analysis & a stronger focus on commercialisation and translation (e.g. not just publishing in EPS journals).
- There was no consensus in comments on research infrastructure but some examples of issues raised were:
  - ◊ Lack of microfabrication infrastructure constrains design of smaller, smarter analytical and imaging platforms.
  - ◊ Access to clinical data and sharing of data are essential.
  - ◊ HPC capacity should be maintained into the future.
  - ◊ Multiscale biomechanical laboratories are required .
  - ◊ Additional UK hubs in the field would be beneficial.

## Interdisciplinary & international collaborations:

- An integrative, cross-disciplinary approach to this challenge was endorsed.
- A greater level of involvement for social sciences was recommended than for other challenges.
- The USA was identified by most respondents as a key country for collaboration. Other specific examples included:
  - ◊ EU — Virtual Physiological Human.
  - ◊ Modelling / pathways — Germany and Italy.
  - ◊ Implantables — UCLA.
  - ◊ The Netherlands - e.g. Cancer Institute.
  - ◊ NIH Grand Challenges .
  - ◊ New Zealand e.g. Aukland Institute.
  - ◊ China, Brazil , Belgium, Japan, Spain, Poland, Austria, France were also mentioned.

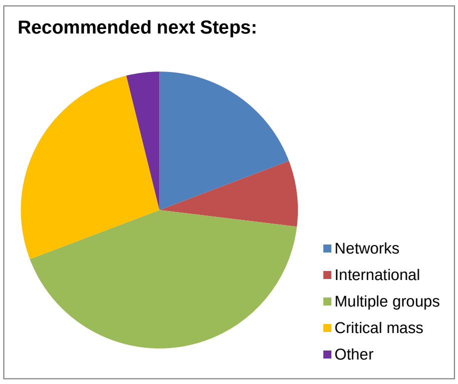



## Main linkages to other challenges:

- Data analytics and digital infrastructure for healthcare
- Prediction and early diagnosis
- Workshop participants also highlighted that this challenge was a cross-cutting theme underpinning all other challenges

## Non-scientific barriers:

- Lack of a functional research interface for engaging clincians, universities and industry. Insufficient presence of strong interdisciplinary networks.
- Funding streams are not integrated. EPSRC does not fund NHS researchers.
- Issue of handing patient identifiable data.
- Lack of connectivity between engineering and the basic sciences.
- Regulatory constraints.
- Tools are developed by EPS researchers without engaging healthcare professionals to identify needs and requirements.



**Patient specific treatment**

**Feedback from the key stakeholders' workshop:**

- Participants felt that personalisation is a major goal in healthcare today and has excellent user pull. It has the potential to be transformative due to the improved outcomes / success rates that would result. The challenges in getting there were considered to be very difficult.

- There were some questions about the title of this challenge with suggestions including: precision medicine (to reflect TSB Catapult), personalised, stratified, hyper local. The discussion was also broader than just 'treatment' so perhaps 'approaches' is more appropriate.

- The extent to which EPSRC should lead in this area was unclear despite general support for it. For example it was apparent from discussions that EPS research is required but that there are huge challenges outside EPSRC-space in behavioural/social sciences, genetics etc. In some fields, for example cancer, it was felt that the main challenges were not in EPS. EPSRC's role could be in developing platform technologies.

- A number of people questioned whether this area was a Grand Challenge in its own right or whether it could be subsumed into others. Suggestions included:
    - Data analytics for patient specific approaches
    - Functional enhancement for safe and independent living – this is patient centric
    - Early diagnosis – include patient specific approaches
    - Smart therapies – these are likely to be more patient specific
    - This is a first step to regenerative medicine

- Some examples of EPS research that relates to this challenge were given as:
    - Bespoke manufacturing
    - Responsive treatments e.g. pills that know how much to release
    - Technology for biomarker development
    - Diagnostic technology e.g. disposable advanced sensors integrating biology, electronics, big data.
    - Musculoskeletal research.
    - Data acquisition, data interpretation.
    - Knowledge management, individualised models, population models.

- Other comments and issues raised on this challenge included:
    - It is very dependent on the medical field, disease or intervention
    - Stratification has yet to deliver despite investments
    - More clinical pull is required
    - Scientific capacity needs to be built
    - Would increase choice for patients and encourage shared decision making.
    - Would allow individual to own their own data and manage their condition. Key interactions patient like me / patient power
    - There are a number of UK based datasets (100,000 genomes, UK biobank) meaning there is opportunity for UK to lead
    - There is funding from Horizon 2020 to do this
    - Would this have the most significant healthcare benefit?
    - Would allow integration of genotype and phenotype information
    - Needs to take account of affordability

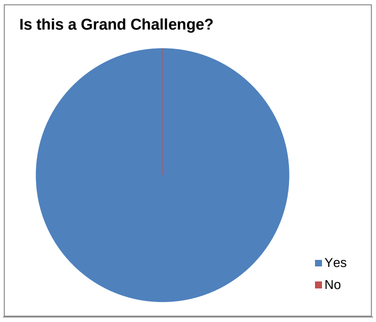
**Prediction and early diagnosis**
Early diagnosis of medical conditions can result in improved outcomes for patients by preventing or delaying the onset of disease, managing disease progression and allowing more effective treatments. This is an underpinning challenge that would be of relevance across the healthcare sector.

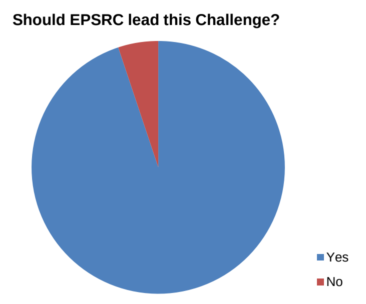
A range of sensing, imaging and analytical technologies are already in use, along with associated decision support and communication technologies. Future engineering and physical sciences research could be expected to lead to breakthroughs in areas such as:

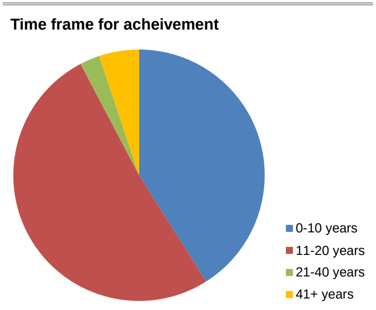
- Improved sensitivity, specificity and reliability for rapid detection of multiple analytes and biomarkers;
- Better screening techniques to identify silent or symptomless conditions;
- Improved integration of engineering analysis and image processing techniques to improve diagnosis;
- Robust computational and modelling tools for diagnosis;
- Integration of technologies, especially in portable devices that can be used by non-specialists;
- Better statistical methods for epidemiological studies;
- Early identification of disease types and patient responses to allow for effective, patient specific stratification.

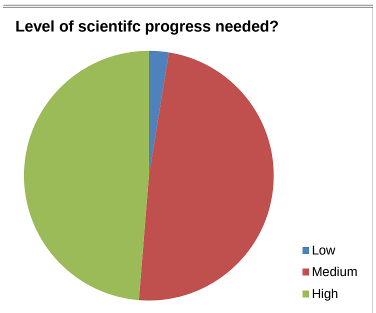
# Prediction and early diagnosis

Group Responses: 10 Individual Responses: 28 Unknown: 1



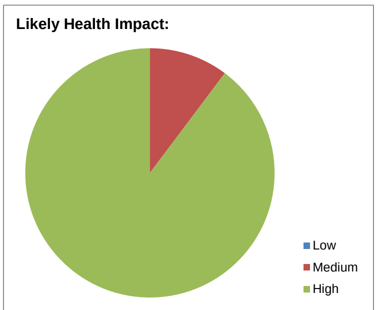



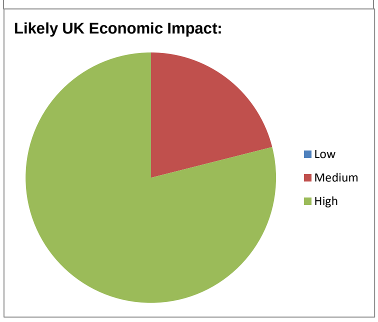

## Potential for world leading EPS:

- Survey and workshop participants considered this to be a Grand Challenge
- Some comments suggested focussing the challenge on specific goals or diseases — early diagnosis will only improve outcomes if treatments are available.
- The link between diagnosis and treatment was highlighted by many — rapid diagnosis can enable rapid treatment.
- Prediction could allow the optimum treatment to be identified. It is also crucial at the design stage to allow interventions to be assessed before clinical introduction.
- A number of research challenges were highlighted:
  - ◊ Novel instrumentation for rapid diagnostics at point of care with high sensitivity, ability to multiplex, robustness, affordability and ease of use.
  - ◊ Rapid integration of new biomarkers into diagnostic platforms.
  - ◊ Development of novel sensing platforms for non-invasive, continuous, real-time sensing.
  - ◊ Ability to extract accurate information from noisy signals e.g. in imaging.
  - ◊ Development of data sciences to effectively use clinical data for prediction and diagnosis, in particular to enable informed decision making.
  - ◊ Computational techniques for analysing large cross-sectional data sets to determine population level trends.
  - ◊ New predictive models that will provide diagnosis, prognosis and optimised personalised treatment for patients at an affordable cost.
  - ◊ Models with the ability to deal effectively with missing data.
  - ◊ Development of drugs / compounds that act as diagnostics and treatments.
  - ◊ High throughput analysis technologies for diagnostics.
  - ◊ Engineering to translate existing basic science instrumentation to the clinic.
  - ◊ Development of active implantables and smart devices.
- Research areas highlighted in the EPS space covered the breadth of areas supported by EPSRC from mathematical sciences, physics, chemistry, materials science, engineering and ICT.

## Potential for delivering impact:

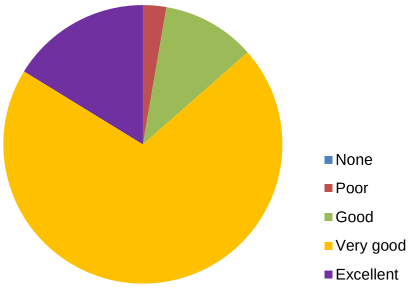
- Transformative change in diagnosis — rapid identification of disease at much earlier stages with greater diagnostic accuracy.
- Improved disease management and treatment at the point of need.
- Ability to identify which treatments patients will respond to.
- Improved understanding of risk factors for developing conditions.
- Could help bring diagnostic services to the developing world .
- Lower costs and burden on healthcare system.
- Potential for economic growth via innovative SMEs (e.g. for rare diseases) or UK strength in big pharma — all scales globally.
- Need to target efforts to specific diseases to achieve biggest impact.
- Risk that early interventions could result in treatments that do more harm than good (e.g. through false positives or conditions which may resolve themselves). Need to consider ethics and risks associated with screening programmes.



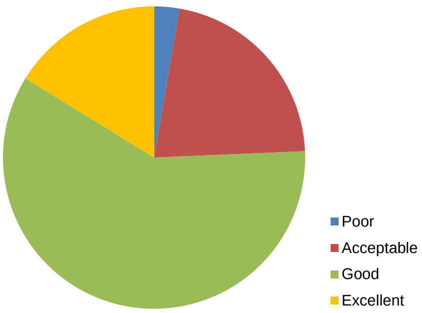



# Prediction and early diagnosis

**UK Research Capacity**




**UK Research Infrastructure**



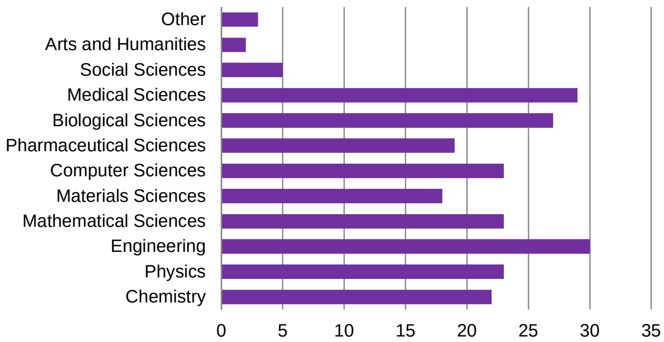

## Research Capability and infrastructure:

- The UK is considered to have a strong community of researchers relevant to this challenge.
- A number of EPSRC critical mass activities were felt to be of relevance e.g. IRCs, Programme Grants, CRUK/EPSRC Imaging Centres.
- The need for additional mechanisms for bringing together researchers from different backgrounds (e.g. clinicians and mathematicians) was highlighted, as well as cross-disciplinary trained researchers.
- A few specific skills gaps were mentioned including: engaging more researchers with mathematical, computational & manufacturing expertise in healthcare, and improving commercialisation skills.
- The UK was felt to have a good level of infrastructure to support this challenge and no real issues were raised.
- Comments were made on the need for teams of people and networks to work on the challenge.

## Interdisciplinary & international collaborations:

- This challenge is potentially so broad that it could span all research capabilities.
- A multidisciplinary approach was felt to be the key to success.
- Critical mass already exists across a wide range of domains in the UKs leading universities.
- No real consensus or steer was given on international collaboration although respondents felt it could be beneficial.
- The USA and EU were the main areas mentioned for collaboration. Japan and China were also identified by a few people.

**Research Capabilities needed:**



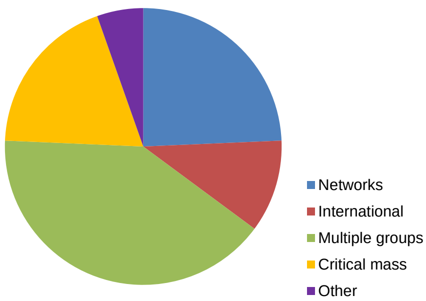

## Main linkages to other challenges:

- Patient specific treatment
- Data analytics and digital infrastructure for healthcare
- Majority of respondents identified these 2 challenges as relevant.
- All other challenges were felt to have some relevance.

## Non-scientific barriers:

- Lack of co-ordination and active leadership.
- Need for more interdisciplinary networks.
- Requirement for greater sharing of data.
- Need better communication between different groups: scientists, engineers, clinicians, patients and health service managers.
- Lack of sustained investment at all stages of R&D e.g. for proof of concept projects and commercialisation.

**Recommended next Steps:**



## Prediction and early diagnosis

### Feedback from the key stakeholders' workshop

- Workshop participants were supportive of this Grand Challenge as it was considered to have potentially high impact. They felt there were unique opportunities for EPSRC researchers, whilst also endorsing working with others (e.g. biologists and clinicians).

- The impact of prediction and early diagnosis was considered to be very disease specific but had potential to influence the outcomes of a huge range of conditions, including rare diseases. As a result the challenge would be long term (e.g. to tackle something like dementia) but with short term success stories (e.g. in diabetes). There is an opportunity to identify application areas for the EPS community to stimulate interest (e.g. early diagnosis in cystic fibrosis could make a real difference). However, some participants felt that EPSRC should focus on the development of tools for diagnosis.

- Impact would be felt by improving the accuracy of diagnosis and reducing subjectivity. However, the importance of linking prediction and early diagnosis to early intervention (e.g. through 'smart therapies') was highlighted.

- Participants stated that EPSRC had an opportunity to be at the forefront in this area as it is well placed to provide coordination and focus. A lot is being done but it needs coherence. EPSRC is uniquely placed to develop and promote mulit-application techniques e.g. imaging. Integrating different diagnostic approaches was also suggested as an approach.

- Links to other challenges were identified, in particular, 'data analytics' and 'patient specific treatment' e.g. in terms of prediction of the effectiveness of treatment options following diagnosis.

- The challenge strongly aligns to excellent research in the UK in areas such as imaging and modelling. Specific topics which EPSRC research could address were identified as:
    - Integration of technology with biological understanding and clinical insight to produce more effective diagnostic tools
    - Imaging for early diagnosis
    - Manufacturing of medical diagnostic devices
    - Modelling optimisation
    - Population level prediction

- Participants felt that there were some ethical issues associated with this area e.g. around screening programmes. We also lack cohorts of pre-symptomatic patients. However, the ability to identify sub-sets of the population who are susceptible to certain conditions would be very useful in delivering healthcare.

- Other organisations (both Research Council and Charities) have interests in this challenge e.g. CRUK identified early diagnosis in their research strategy.

- Other specific comments / issues raised on this challenge included:
    - Is there commercial pull for this challenge?
    - We have the EPS capability, not the pre-EPS e.g. discovery of new biomarkers

- Innovative Medicines Initiative (IMI2) ‘RADAR’ - The following topic is under consideration for inclusion in future calls for proposals to be launched under IMI 2: RADAR: Remote assessment of disease and relapse
- Solutions need to be low cost in order to aid translation

**Smart surgeries and therapies**

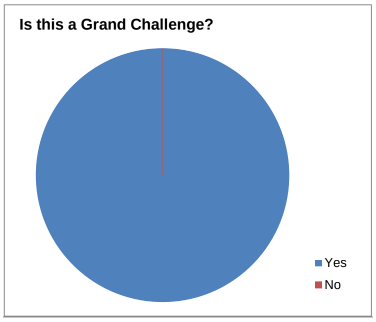
Smart surgeries and therapies that promote and enhance recovery could result in patients experiencing less pain, spending less time in hospital and having fewer side-effects. Furthermore, these smart approaches may match or even exceed outcomes of traditional therapies. The future trend is towards high precision and minimally or non-invasive approaches.

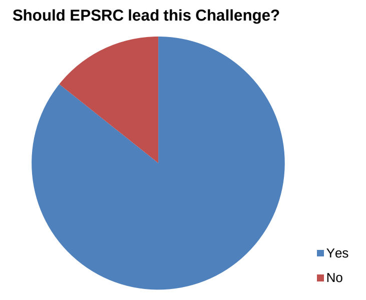
Techniques such as robot-assisted surgery, image-guided interventions, smart instrumentation, augmented reality and laser surgery are already in clinical practice. Future research could be expected to lead to breakthroughs in areas such as:

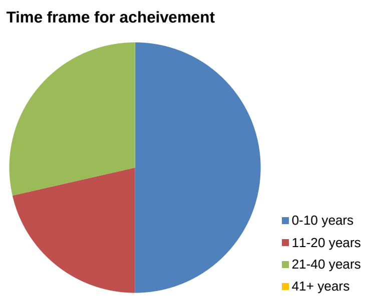
- Robotic surgery; including innovative and affordable design, improved human robot interface and autonomous robots;
- Better integration of technologies for cost-effective use during surgery;
- Surgery performed outside the operating theatre or even remotely;
- Augmented reality and image-guided interventions to reduce radiation exposure to physicians;
- Novel methods for locoregional treatments;
- Smart, targeted therapies; for example utilising biomaterials, nanomaterials or synthetic antibodies as delivery systems;
- Further development of theranostic technologies.

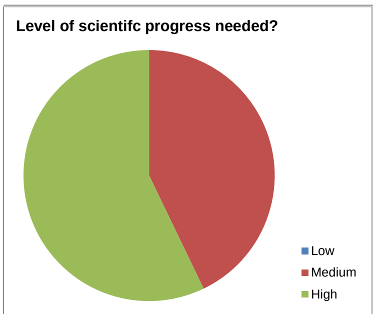
# Smart surgeries and therapies

Group Responses: 5 Individual Responses: 8 Unknown: 1



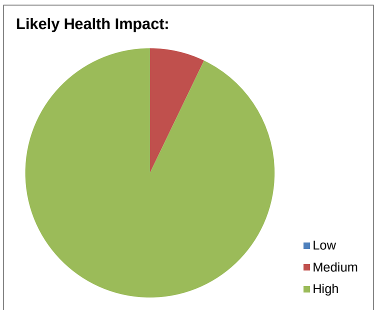



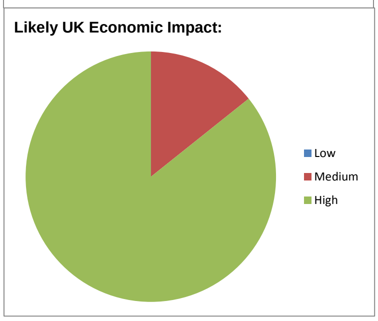

## Potential for world leading EPS:

- This was felt to be a Grand Challenge with 2 distinct aspects:
  - ◊ Smart surgery — particularly emphasised by workshop participants
  - ◊ Other therapies — brought out more by the survey
- Both aspects were described as providing tools and technologies for future therapeutic interventions.
- Research challenges identified related to:
  - ◊ Real-time imaging for interventional surgery or drug delivery
  - ◊ Surgery for repair & regeneration of functional, physiological system(s)
  - ◊ Development of theranostic technologies — integrating rapid diagnosis with therapeutic delivery
  - ◊ Novel therapies and delivery systems
- Key EPS research topics required to tackle this include:
  - ◊ Medical imaging — data analysis, image processing, algorithm development, machine learning
  - ◊ Chemistry — sensors, analytical science, therapeutic discovery
  - ◊ Robotics
  - ◊ Augmented reality
  - ◊ Fluid dynamics
  - ◊ Chemical engineering
  - ◊ Sensors
  - ◊ Computational modelling
  - ◊ Material science for drug delivery
  - ◊ Software engineering
  - ◊ Physics (radiation and optical)

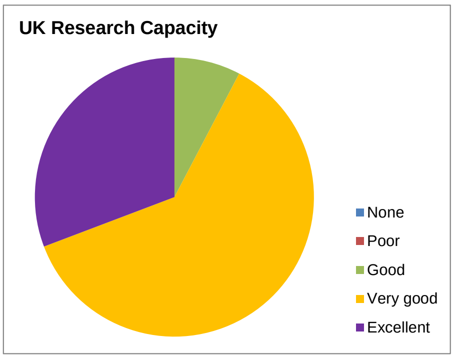
## Potential for delivering impact:

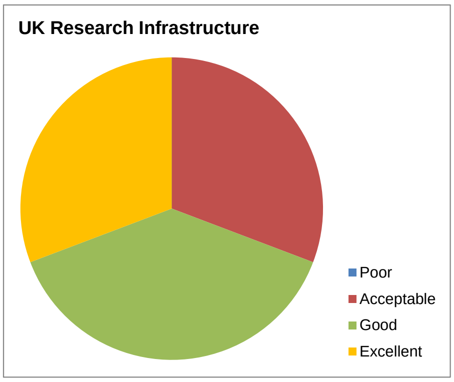
- Improved efficacy and safety of treatments;
- Fewer patients undergoing major invasive surgery;
- Significant cost savings to the NHS (e.g. fewer days in hospital);
- Point of care diagnosis and site-specific therapy;
- Enhanced quality of life of patients due to faster recovery and fewer side effects;
- Move beyond small molecule drugs to smart therapeutics — could open up new industry;
- Manufacturing opportunities for the UK, especially SMEs.



# Smart surgeries and therapies



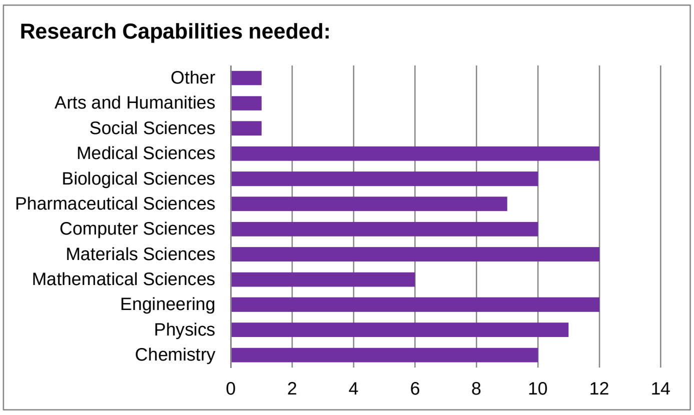




## Research Capability and infrastructure:

- A number of strong UK research groups and centres were mentioned with a particular focus on London & Oxford. Other groups in Scotland, North of England & Midlands were listed.
- There was no consensus on skills gaps.  The new CDTs in medical imaging were supported. More could be done to enable interdisciplinary research.
- A few people stated the need for UK mid-range facilities to support:
  - ◊ State of the art imaging;
  - ◊ EPS researchers to work with animal models.
- There were some comments on the need for technical support and a career structure for skilled engineers.

## Interdisciplinary & international collaborations:

- A broad selection of research capabilities were identified across all engineering, physical, biological and medical sciences.
- The need for greater involvement of chemists was highlighted — this may reflect the % of respondents to the survey with chemistry backgrounds.
- Respondents highlighted the potential to collaborate with US, EU, Japan, Canada and China.  However, few specific research areas or groups were mentioned.

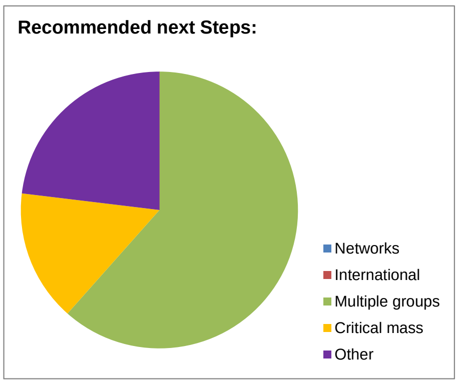



## Main linkages to other challenges:

- Enabling technologies for regenerative medicine
- Patient specific treatment
- Prediction and early diagnosis
- Some links to other challenges were mentioned

## Non-scientific barriers:

- Main barrier identified was funding — in particular continuity of funding.  This is for research, translation / commercialisation, & bringing together different disciplines.
- Other issues mentioned include: slow take up of technology by NHS & surgeons, regulatory requirements, and scale up manufacturing.



**Smart surgeries and therapies**

**Feedback from the key stakeholders' workshop:**

- Workshop discussions on this Grand Challenge did not result in particularly coherent feedback as participants struggled to fully understand the novel EPS challenges. Many ended up treating 'surgery' and 'other therapies' as 2 separate topics, although the area was still reasonably well supported.

- In terms of smart surgery it was felt that the underpinning technology in robotics, optics and imaging was excellent in the UK. However, the 'pull' for new surgical innovation was questioned as the healthcare system can't sustain the cost of new surgical technologies, especially when they may only have incremental benefits. Other interventions could add more value. It was also felt that international competition in this area is high e.g. in robotic surgery. There were felt to be some opportunities in surgical innovations as these would not usually require clinical trials, so enabling faster adoption.

- Other comments around surgery included:
    - Autonomous robots would have low consent.
    - What is the new high tech surgery c.f. remote surgery?
    - Would need to work with others (e.g. MRC) as you move from EPS research to translation. How do you get surgeons involved?
    - MoD's future battlefield medic combines human first responders with augmented reality and remote expertise.
    - Surgery could be considered a sign of failure – isn't it better not to get to this stage? Some participants gave the example of earlier diagnosis in cancer leading to more surgery. Surgery, combined with radiotherapy, tends to be the intervention used when cancer is found at early stages.
    - Minimally invasive techniques aid recovery and are cost effective.
    - Wellcome Trust / Department of Health have a joint call on smart surgeries.
    - Does EPSRC need to be involved? Can't industry just do this and take it on?
    - Need interaction with EPS imaging expertise.

- We would need to be clear on what EPSRC can do in the area of smart therapies as there are clear overlaps with the work of MRC and the pharmaceutical industry (e.g. in terms of drug development). What are the real unmet clinical needs and would EPSRC lead on these? Some examples of focus for EPSRC were given as:
    - Nanotechnology enabled drug delivery.
    - Theranostic approaches.
    - Smart targeting for drugs or regenerative therapies.
    - Additive manufacturing for non-cell based regenerative therapies.
    - Novel non-drug based therapies (e.g. what is new radiotherapy?)
    - Repair from the inside e.g. nanorobots.
    - Robotic physiotherapy.

- Smart 'surgery' and 'other therapies' did come together in some aspects of the discussion:
    - Smart surgery may be surgery plus simultaneous application of other therapies.
    - Smart surgery and smart therapies link closely to regenerative medicine e.g. surgery as the delivery vehicle for new therapies.
    - There is a clear link to 'patient specific therapies'.

**Systems to support and improve healthcare provision**

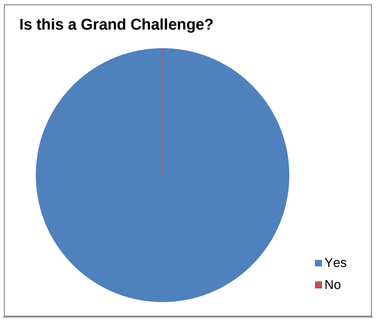
While we can do more to encourage health and wellbeing, it is likely that at some point people will become unwell and require medical treatment. This challenge would explore the role of engineering and physical sciences in designing the healthcare system of the future, providing the technologies to support our healthcare needs within this context, and enabling the delivery of high quality, cost effective healthcare solutions.

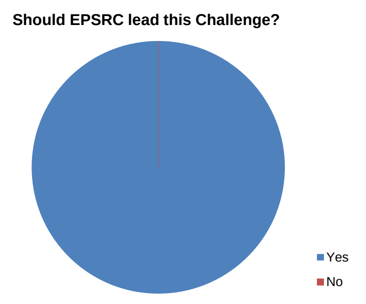
This challenge would draw upon a diverse range of UK strengths including building design, sensing and monitoring technologies, digital economy, computer science, and robotics. Topics which could be tackled through this challenge include:

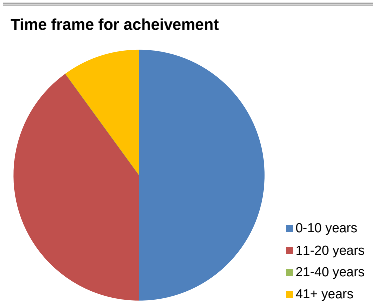
- Systems integration within the healthcare system;
- The physical infrastructure required for the healthcare system of the future e.g. hospital design;
- Engineering design of equipment and the environment, including user centred design approaches;
- Support systems which allow patients to be monitored and receive more care in the home or at the GP surgery rather than a hospital;
- Systems which enable reduced contact times with healthcare professionals, but maintain high quality of care.

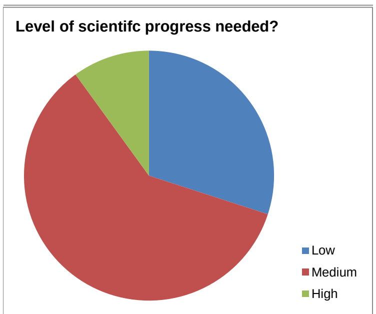
# Systems to support and improve healthcare provision

Group Responses: 5 Individual Responses: 3 Unknown: 2




**Potential for world leading EPS:**

Contrasting views expressed through survey and workshops regarding the question "is this a grand challenge?" E.g.

- "Perhaps underpins other challenges rather than being 'grand' in itself?"
- "Why is this a grand challenge? It's culture, care models and in NIHR's remit?"
- Strong need for monitoring systems, novel sensors and the integration of sensors and infrastructure
- This is certainly a grand challenge because it confronts a major societal challenge and poses many open technical challenges that require a multidisciplinary approach to solve."

Research challenges, identified relate to:
1) Novel sensors and monitoring (and their integration into infrastructure)

- New sensors and novel applications of existing sensors will add value to existing devices. How might devices and sensing deliver a Technology-enabled service?
- How do you deliver integrated, dynamic, personalised health monitoring?
- How can you deliver effective health management, through (clinical and personal) decision support?
- The development of wearable sensors that are robust and reliable. This includes Civil, Mechanical, Electrical and Electronic engineering as key areas to meet this challenge

Key EPS research required to tackle this includes:*

- Improved signal processing
- Improved sensing
- The provision of reliable mobile networks for health
- Built environment; integration of sensing and monitoring technologies and design of the new generation of hospitals.
- Chemistry — in new sensor technologies to ensure safety in a wider variety of contexts e.g. the detection of wound infection or other condition in a virtualised hospital ward.

2) Whole Systems approaches:

- How might we deliver integrated healthcare provision? i.e. Not only technical system integration, but also pathway, process and service integration (e.g. health ***and*** social care). "This challenge needs to be extended to "Systems to support and improve health and care provision".
- How might we use technology to ensure that existing treatments are delivered more effectively and efficiently? ["The amount of error and inefficiency and waste in the existing healthcare systems is extraordinary and the appropriate use of technology could have a massive impact by enabling small improvements on a massive scale."]

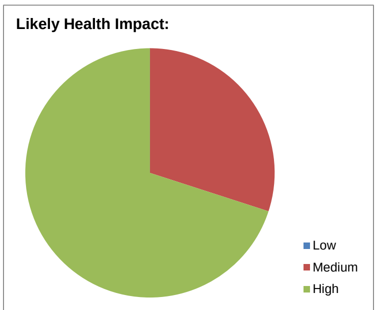
Key EPS research required to tackle this includes:*

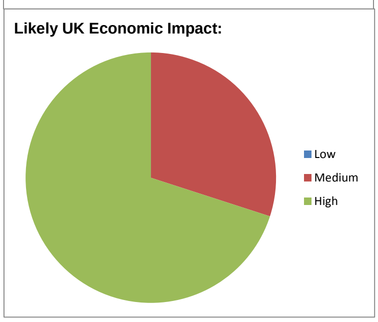
- ICT driven healthcare / Software engineering + Human computer interaction — understanding the processes of 'work' in complex organisations, and design of systems that are effective in complex organisations
- Designing and development of modern information systems is to meet the complex demands of multiple stakeholders of a system.
- Mathematics - OR and techniques of mathematical modelling and data analysis. Mathematical modelling, scientific computation, mathematical reasoning, and statistical analysis. This could be applied for example in the area of planning and modelling of patient discharge
- Planning / modelling of patient discharge
- In Computational and Mathematical Sciences the need for development in social computation, social machines, robust analytics, coordination technologies, provenance, stratification and modelling, are all necessary to enable more dynamic, responsive and mobile data driven health and care delivery models.

(*This list highlights the EPS required, but It is noted socio-technical approaches will be required in some instances)

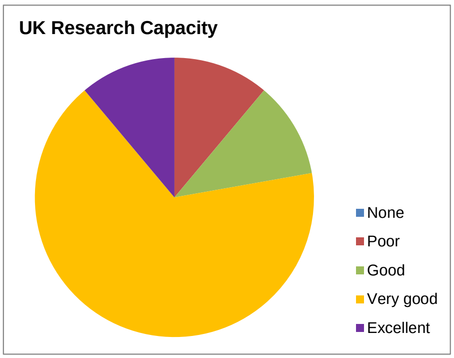
## Potential for delivering impact:

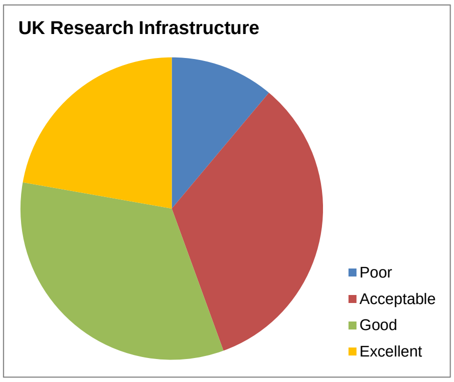
- Indirect benefit of managing resources more effectively will lead to better usage of resource in clinical areas, increase clinical / social care
- Reduced waiting times for diagnosis and treatment due to efficient use of face-to-face time with healthcare professionals as a result of technology
- Improved patient health outcomes
- New design and functionality for hospitals and care home
- Being aware of properties that reflect the whole and not the parts, will deliver components of a system which interact with each other efficiently
- Significant impact in terms of potential cost effectiveness gains to NHS and a better understanding of health dynamics
- Benefits in translating to other countries with similar demographics, export of new system / designs
- Efficiency savings (longer term) for NHS in relation to staffing costs



# Systems to support and improve healthcare provision




## Research Capability and infrastructure:

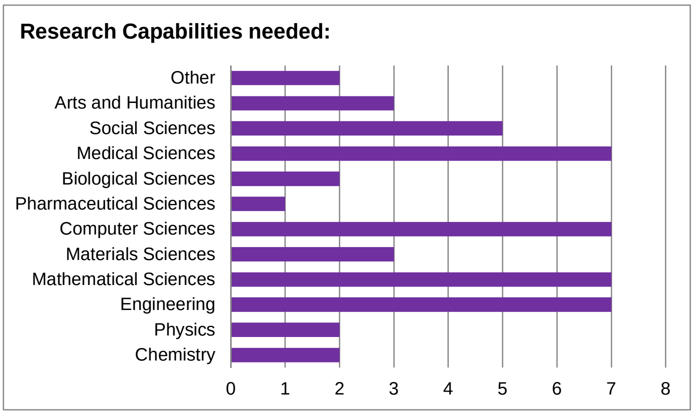
The UK has strong capability in this area and is well positioned to tackle challenges in this area:

- Expertise in Pervasive Health care and sensing exists in various locations throughout the UK including: Imperial College, Lancaster University, University of Southampton, Loughborough University, Connected health research centre, University of Ulster.
- In Scotland the Digital Health Institute (supported by the Scottish Funding Council), Stratified Medicine innovation Centre (Glasgow) , Sensors Innovation Centre (Glasgow) and DataLab Innovation Centre (supported by the Scottish Funding Council) , EPCC ( Edinburgh Parallel Computing Centre).
- The Farr Institute of Health Infomatics, and the ESRC's 4 Administrative Data Research Centres and their associated groups all have strong relevance to health and care delivery.
- Centre for Health Informatics & Multiprofessional Education at UCL. There is potential for cooperating with the CDEC (Connected Digital Economy Catapult) Open Health Data Platform and with the EPSRC Digital Economy Hubs. The New Economic Models for the Digital Economy Network is also a strong interdisciplinary network that has high relevance for the health sector.
- The Cumberland initiative (Brunel University) are also well place d to contribute to modelling and systems thinking.
- The Academic Health Science Networks and Partnerships are active in IT innovation.

The following research capabilities have been highlighted as important for work in this area: Design Innovation, Social computation and Social Machines, Data Science, Building design, Sensor design and integration, Robotics for Independent Living, Governance and regulation, Organisational science on the design of delivery organisations.

## Interdisciplinary & international collaborations:

- This area is of international interest with successful research groups operating in the USA and Switzerland.
- This problem prevails in the economically advanced countries with a high level of social care, national health coverage and an aging population. Those currently with an interest include: major EU countries Canada and Japan are the most relevant at this moment.
- Developing broader collaborations with the leading reference sites in the EU European Partnership on Active and Health Ageing would be beneficial. The reference sites are led by delivery organisations and the leading centres in UK, Denmark, Netherlands, Spain, and France.

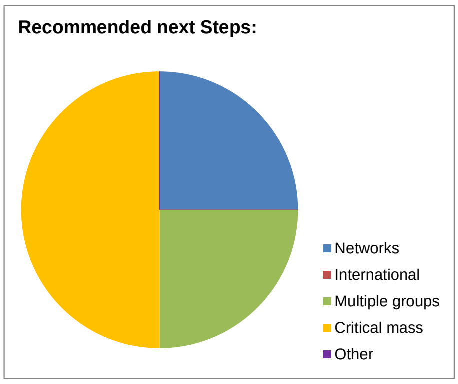



## Main linkages to other challenges:

- Workshop outputs draw a link between this theme and "Prediction and Early diagnosis" theme (due to monitoring / sensing aspects)
- Survey outputs draw a link between this challenge and:
  - ◊ Data analytics and digital infrastructure for healthcare
  - ◊ Functional enhancement for safe and independent living
  - ◊ Engineering healthy behaviours

## Non-scientific barriers:

- Barriers to deploying commercial technologies - regulation, ethical considerations (of ubiquitous monitoring), and cost of developing technology is significant
- Barriers to making integrated data accessible to researchers and all potential healthcare provider organisations
- Complexity of IP arising and agreements on sensible exploitation approaches
- Research governance procedures



**Systems to support and improve healthcare provision**

**Feedback from the key stakeholders' workshop:**

- Participants had mixed views on this Grand Challenge with some questioning how EPSRC could add value to what healthcare providers were doing. Other comments were that EPSRC should support and not lead. It was acknowledged that EPS research could contribute to the overall aims, especially with the right focus.

- Strong linkages were identified to both 'engineering healthy behaviours' and 'functional enhancement for safe and independent living'. It was suggested that aspects from these challenges could be merged e.g. to 'technology platforms for social wellbeing' (or similar). The challenge also links to 'data analytics' and 'patient specific treatment'.

- EPS could contribute to this challenge in the following ways:
    - Low cost, reliable devices which give the clinician more data
    - Intelligent systems for data visualisation
    - Modelling the patient through the system e.g. avoiding re-admission
    - Ambulance modelling – matching resource to need
    - Links to software engineering and engineering
    - Data and data analysis e.g. to inform decision making.
    - Modelling for patient stratification
    - Integrated systems for point of care.
    - Platforms to support community well-being
    - Design of hospitals to maximise patient flow
    - Sensors e.g. for hospital settings

- Opportunities were identified as:
    - Integration between health and social care, including a range of care settings e.g. home, hospital etc.
    - Looking at the healthcare system as a whole.
    - Providing affordable healthcare
    - Improving life for patients with chronic conditions

- Other comments / issues raised were:
    - Would allow us to achieve more with the same resource
    - We need to consider different support systems
    - How does this relate to DALLAS (delivering assisted living lifestyles at scale)? (TSB)
    - Would need longitudinal studies
    - Adoption is likely to be difficult / challenging
    - MoD wound mapping, complex battle trauma - early sets of data to inform the system
    - Can we provide care through familiar platforms that look like facebook?

**Understanding and Interventions in Neurological Function**

This challenge concerns new techniques, tools and approaches capable of furthering our understanding of neurology and neurological function. It focuses on the engineering, physical science and mathematical challenges in imaging and modelling of the brain, spinal cord and nerves. Research here would make a contribution towards understanding the healthy brain and brain function, early diagnosis of neurodegenerative diseases, pain management and imaging of nerves in the body, as well as treatments for neurological and psychiatric conditions.

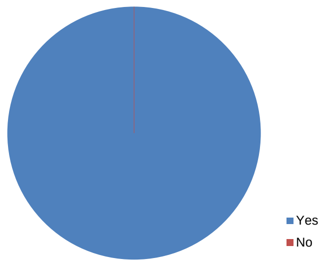
Engineers and physical scientists are already making valuable contributions in areas such as neuroimaging and computational modelling. Future research directions relevant to this challenge may include:

- Computational modelling of neurological processes, brain connectivity, disease progression and disease prediction;
- Tools for early diagnosis and screening of neurodegenerative diseases;
- Pain and pain relief e.g. quantification of pain, and improving our understanding of the blood brain barrier and its limits in therapy;
- Monitoring therapeutic responses e.g. non-invasive monitoring of novel chemical tracers as a prognostic predictor of response to treatment.

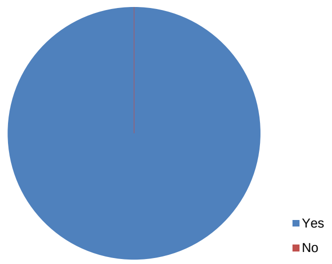
# Understanding and interventions in neurological function

Group Responses: 1 Individual Responses: 12 Unknown: 0

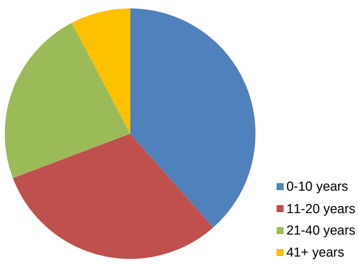
**Is this a Grand Challenge?**



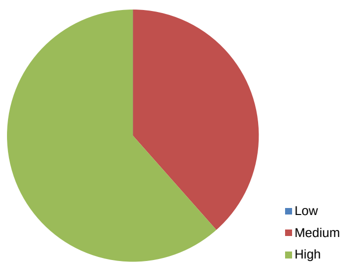

**Should EPSRC lead this Challenge?**




**Time frame for acheivement**




**Level of scientifc progress needed?**




## Potential for world leading EPS:

### *Why this is considered to be a Grand Challenge:*

- The normal healthy physical and chemical dynamics of the brain are not understood
- Central nervous system diseases and brain disorders are top of the World Health Organisation's agenda, effective interventions is a priority
- Political interest at a national and international level
- Increases in life expectancy will result in significant costs associated with neurological conditions
- The pharmaceutical industry is developing drugs for brain disease assuming that the cause is an abnormal chemistry. Many brain diseases may be due to physical conditions, very little investment is being made into this important aspect of brain health
- Quantification of pain an unresolved challenge

### *The key EPS research that is needed to meet this challenge:*

- Techniques for in vivo brain imaging and/or sensing
- Identification of biomarkers for disease prevention
- Development of robust in vitro models and systems for drug testing
- Understanding the interplay with cardiovascular function
- Robust and efficient numerical models of neurological function and injury
- Brain-machine (hybrid) interfaces and human-machine (hybrid) interaction systems
- A better understanding of the structural and functional properties of biological membranes and membrane transport processes
- Technologies that facilitate the discovery of alternatives to the current small molecule therapies or direct interventions
- Better tools for non-invasive monitoring of intracranial flow and pressure and understanding the normal mechanisms of cerebrovascular and intracranial pressure control and the impact of disease
- Molecular engineering to develop targeted pain medicines
- Assistive technologies development (e.g. augmented reality, personal robotics, artificial intelligence)

Some workshop participants questioned why this was the only disease specific challenge.

## Potential for delivering impact:

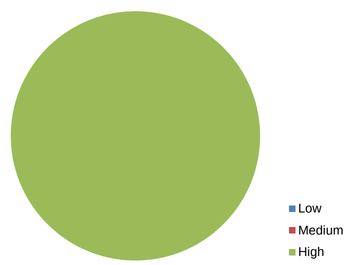
### *Health impact*

- Reduction in impacts of debilitating diseases such as dementia, epilepsy, spinal cord injury etc.
- Pain reduction using physical interventions
- Improvements in the treatment of paralysis
- Improvements in accuracy of diagnosis

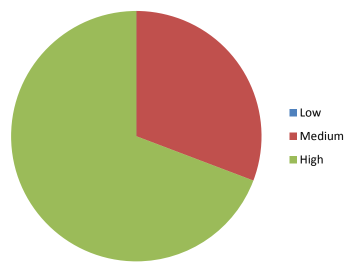
### *Economic impact*

- Current costs estimated at £0.65-1.29 trillion globally, any effective treatments likely to have a very significant impact
- Longer economically productive lives
- New technologies will facilitate drug development by (UK based) pharma companies
- Decreased costs of identifying suitable (patient specific) therapies
- Reduced mental health disease burden, including but not restricted to dementia

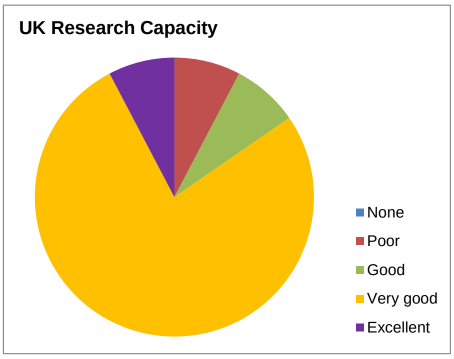
**Likely Health Impact:**

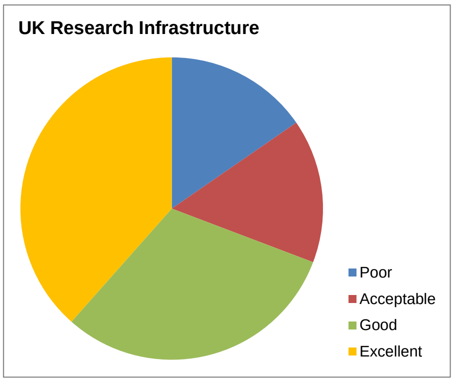



**Likely UK Economic Impact:**



# Understanding and interventions in neurological function



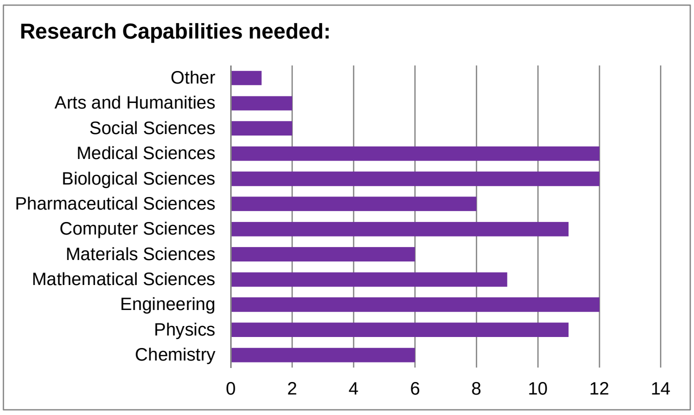




## Research Capability and infrastructure:

- A number of universities across the UK were felt to have expertise in this area. Some specific examples of critical mass activities are:
    - ◊ UCL: Institute of Neurology, Institute of Biomedical Engineering
    - ◊ Imperial College: Centre for Neurotechnology — hosting EPSRC CDT in Neurotechnology for Life and Health
    - ◊ London Pain Consortium
    - ◊ University of Cambridge: Pharmacology
    - ◊ University of Leeds: Biomedical Sciences
    - ◊ University of Oxford: Neurology and OXION consortium, IBME
    - ◊ University of Surrey: CVSSP, Centre for Biomedical Engineering
- The following specific skills gaps were identified:
    - ◊ EPS researchers with a deep understanding of neurosciences
    - ◊ Complex network analysis
    - ◊ Sensing, modelling understanding and aiding human physiology at the level of the complete system
- Very few comments were received on infrastructure. The lack of major centres in the UK and lack of funding compared to competitors were highlighted.

## Interdisciplinary & international collaborations:

- A broad range of research capabilities were identified as relevant to this challenge. Some specific areas mentioned were: mathematical modelling, sensing systems, and electronic packaging.
- A limited number of responses were received about the potential for international collaborations but some specific suggestions were:
    - ◊ Major brain projects in US / EU
    - ◊ US pharmaceutical organisations (Pfizer, Eli Lilly)
    - ◊ Key drivers are space travel and sports injury — NASA and NFL
    - ◊ Neurotechnology with Canada (especially McGill University), MIT, University of Washington, National University of Singapore and University of Melbourne.
    - ◊ Pain biomedicines with Ireland, Finland, USA, Italy, Turkey and Slovenia.
    - ◊ Mapping of the brain with USA and The Netherlands.




## Main linkages to other challenges:

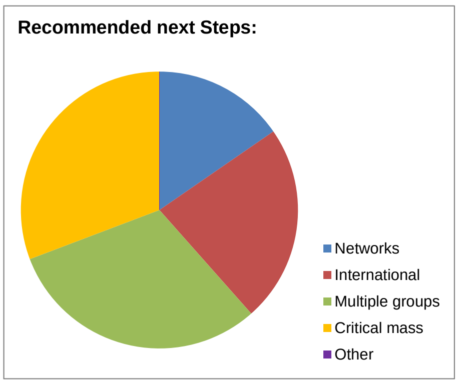
The main linkages highlighted were:

- Patient specific treatment
- Prediction and early diagnosis

A number of other challenges were also mentioned as linked in the survey but due to low response rates no firm conclusions could be drawn.

## Non-scientific barriers:

- Difficulties in collaborations between different disciplines which are served by different Research Councils.
- Disconnect between clinicians treating patients with chronic, non-specific symptoms, physiology researchers and those developing tools for modelling and measurement.



**Understanding and interventions in neurological function**

**Feedback from the key stakeholders' workshop:**

- Workshop participants considered that EPSRC could take a prominent role in this cross-disciplinary challenge. However, other funders including Wellcome Trust, BBSRC, and MRC were also mentioned in the context of leadership. Possible collaboration with the EU Human Brain project was also mentioned.

- There were mixed views on why EPSRC would choose to focus on neurological function with comments including:
    - Neurological is a good focus as the system is particularly complex and poorly understood. Understanding even a proportion of the neurological system would permit significant insights and interventions.
    - The focus should be on dementia as this is major problem and a huge cost to the NHS
    - The focus should be broadened to cover mental health which is not well supported by EPSRC. Stroke and brain injury were also mentioned.
    - This is the only disease / physiological system focussed challenge and the others are much broader in scope – it's not clear why this was selected and not cardiovascular, cancer or trauma for example. Could be amended to 'understanding and interventions in function' (or similar).
    - This reads more like a research project – the other challenges are end user driven.
    - Are there 2 goals here:
        - Systems / signalling and sensor / effector interface sciences for repair.
        - Discovery tools for neurobiology and computational science.

- Linkages to the other Grand Challenges were highlighted as:
    - 'Enabling technologies for regenerative medicine' - in terms of therapies for neurological disorders
    - 'Early diagnosis' – e.g. for dementia this may help prepare people for their future life and enable dementia friendly communities
    - 'Patient specific treatment' and 'functional enhancement for safe and independent living' – due to the overlap in assistive technologies

- It was felt that EPSRC lends itself to looking at the brain in the context of a system. The UK has world class neuroscience and imaging to enable this (although the US was felt to be stronger in neurology). Some specific challenges that EPS could contribute to were highlighted as:
    - Monitoring brain activity of healthy brain vs diseased brain
    - Integration of biochemistry and imaging
    - Brain-computer connectivity and neural control of complex systems – although some felt the skills for this were outside the UK.
        - MoD is funding brain-machine interface work with US/Australia/EU countries. MoD strategic paper highlights control of complex systems through brain-computer interface by 2035. MoD interest is broader than healthcare e.g. unmanned aircraft.
    - Deep brain simulation implants
    - Neuroelectronics expected to be a growth area
    - Hearing and visual implants
    - Assistive technologies for managing care e.g. robots, detection/monitoring of disease progression
    - High resolution imaging

    - The brain as a processor / sensor.

- Other comments highlighted:
    - Good access to data and well managed patient populations
    - The importance of getting the right partners e.g. NHS centres of excellence, MRC.
    - There are risks to achieving clinical impact e.g. would the NHS pay?
    - BBSRC funds a lot of basic neurology and are interested in multidisciplinary approaches to develop impact, especially in less clinically driven areas e.g. role of brain in nutrition and food behaviour.
    - This is part of a broader issue – social aspects should not be forgotten.

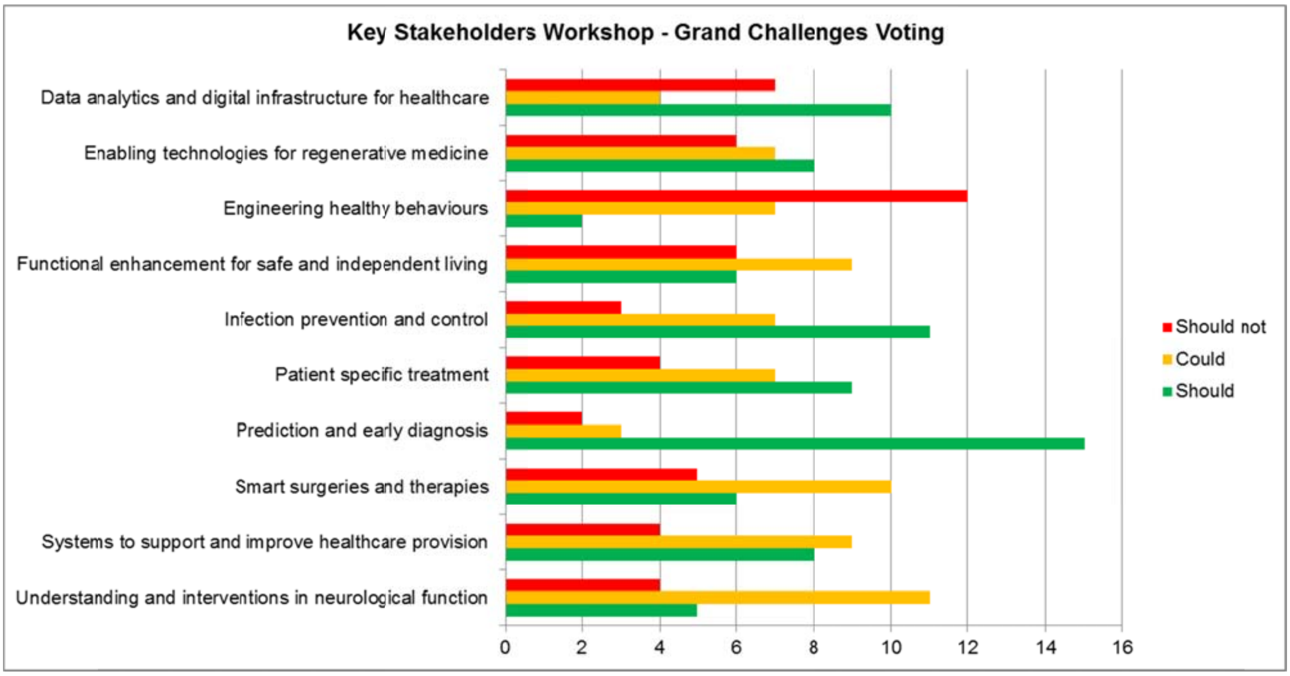
## Key Stakeholders' Workshop – Output of Vote on Challenges

Participants at the key stakeholders' workshop on 30th June were asked to vote on which challenges they viewed as both a major challenge and most appropriate for an EPSRC lead.

For each of the 10 challenges they'd spent the day discussing they had to select one of the following options:

| Category | Voting rule |
|---|---|
| EPSRC **should proceed** with this challenge | Between 3-5 challenges could be selected in this category |
| EPSRC **could proceed** with this challenge | No specific rule |
| EPSRC **should not proceed** with this challenge | A minimum of 2 challenges must be selected in this category |

The results of this vote are given below. However, it should be noted that the outputs of the workshop and hence the vote were dictated by the people who were present and should be viewed as such.



| Challenge | Should | Could | Should not |
|---|---|---|---|
| Understanding and interventions in neurological function | 5 | 11 | 4 |
| Systems to support and improve healthcare provision | 8 | 9 | 4 |
| Smart surgeries and therapies | 6 | 10 | 5 |
| Prediction and early diagnosis | 15 | 3 | 2 |
| Patient specific treatment | 9 | 7 | 4 |
| Infection prevention and control | 11 | 7 | 3 |
| Functional enhancement for safe and independent living | 6 | 9 | 6 |
| Engineering healthy behaviours | 2 | 7 | 12 |
| Enabling technologies for regenerative medicine | 8 | 7 | 6 |
| Data analytics and digital infrastructure for healthcare | 10 | 4 | 7 |

**What's missing from the Healthcare Technologies Grand Challenges?**

The following areas were identified by survey participants as currently missing from the Grand Challenges:

| Missing Challenge | Detail | No. of groups or individuals to identify |
|---|---|---|
| **Physical Science challenges in drug discovery science** | Physical sciences challenges surrounding drug discovery are underestimated. EPS community could contribute e.g. to the discovery of new antibiotics | Individuals: 2<br>Groups: 1 |
| **Supporting self-management of chronic conditions** | e.g. Through interactive technologies such as the artificial pancreas project | Individuals:1<br>Groups: 0 |
| **Engineering for patient safety** | N/A | Individuals: 1<br>Groups: 0 |
| **Cancer diagnosis and treatment** | N/A | Individuals: 1<br>Groups: 0 |
| **Nanomedicines for chronic disease** | The transition of nanomedicines away from injected cancer therapies through to oral dosed non-cancer therapies is hugely overlooked. To produce a nanoparticle therapy that can be dosed orally but deliver nanoparticles to the systemic circulation is a huge challenge. The move to addressing chronic illness where dosing of nanomedicines may be needed for decades (e.g. long term chronic pain, psychiatric illness, heart-attack prevention) is a huge area that is not being adequately supported or highlighted as many scientists are focussed purely on acute disease and IV administration - the most unfavourable dosing route. | Individuals: 0<br>Groups: 1 |
| **Tools technologies and techniques for measuring, monitoring and manipulating molecular mechanisms of disease** | Greater understanding of mechanisms is required as current published mechanisms are largely spurious. | Individuals: 0<br>Groups: 1 |
| **Membrane technology for separation: analytical, therapeutic, environmental** | N/A | Individuals: 1<br>Groups: 0 |

| | | |
|---|---|---|
| **Early intervention procedures, enabling small, quick and cheap corrections to the patient earlier in their life** | This is currently missing from all themes. | Individuals: 1<br>Groups: 0 |
| **Alternative therapeutics** | Alternative therapeutics could include radiotherapy, photothermal or similar non-drug based therapies. | Individuals: 1<br>Groups: 0 |
| **Micro-manipulators and nano-instruments** | N/A | Individuals: 1<br>Groups: 0 |
| **Design and development of crystallisation methodology** | Understanding the 3D structure of proteins sheds light on their function, which in turn can lead to understanding of disease mechanism and pathways. X-ray crystallography, used to determine protein structures, relies on the availability of high-quality crystals. EPSRC has always funded unique innovative ways of designing and developing crystallisation methodology which underpins the success of crystallography. This is because EPSRC has funded crucial interdisciplinary research in this field involving physical chemistry, material sciences, nanotechnology, physics and chemistry. It is very important that this aspect of funding continues. | Individuals: 0<br>Groups: 1 |
| **Traditional manufacturing improvements for the medium term** | The grand challenges do not reflect the need for traditional manufacturing improvements in the medium term to keep the UK at the competitive forefront. While a number of companies have invested significant resources to advance their processing capabilities, the changes have been largely driven by incremental advances rather than radical step changes which no company would risk developing in-house. While this area does not sound intuitively attractive the economic return that could be achieved by developing innovative engineering solutions in this sector is immense. | Individuals: 1<br>Groups: 0 |
| **Understanding and interventions in cardiovascular function** | Cardiovascular research is greatly under-researched with respect to neurology yet the health of the cardiovascular system is very important. The neurological community is quite mature and has a reasonable critical mass. It is time that cardiovascular medicine started to catch up and make stronger links with the healthcare technology community. There is interest from the clinical side to do this. Relates to better understanding of cardiovascular system development, conditions such as pre-eclampsia, hypertension, | Individuals: 1<br>Groups: 0 |

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| | stroke, cardiovascular diseases of ageing, obesity (and for the developing world) malnutrition. | |

**Annex – Workshop Attendees**

**EPSRC / Health KTN User Engagement Workshop – 28th January 2014**

Zabeda Ali-Fogarty, ESP IT Consultancy Ltd
Steve Battersby, Philips
Sue Dunkerton, Health KTN
David Farrar, Smith & Nephew
Patrick Finlay, Medimaton
Janak Gunatilleke, Dictate IT
Rodney Gush, Moor Instruments
John Lees, Gamma Technologies Limited (Leicester Uni)
Peter Levison, Pall Life Sciences
Andy Lewis, Biocompatibles
Hedley Rees, Pharma Flow
Andy Taylor, ABHI
Paul Varley, MedImmune
Amanda Weiss, Fujifilm Diosynth Biotechnologies
Fred Wilson, Medical Imaging and Physiological Measurements Consultant

**EPSRC / ABHI Stakeholders Engagement Workshop – 8th April 2014**

Chris Blatchford, 3M
Craig Buckley, Siemens
Patrick Courtney, TAP Biosystems
Sue Dunkerton, Healthcare KTN
Chris Herbert, Cell Therapy Catapult
Sarah Jones, ABPI
Georgios Kalogridis, Toshiba (TREL)
Andrew McCaskie, University of Cambridge
John McLean, IBM Europe
Matt Morrison, GE
Jon Siddall, SW England AHSN
Stephen Simpson, Arthritis Research UK
Andy Taylor, ABHI
Paul Unwin, Stanmore Implants Worldwide Ltd
Paula Varndell, SW England AHSN
David Williams, Loughborough University
Saeed Zahedi, Blatchford
David Pan, MRC

**Key Stakeholders' Workshop – 30th June 2014**

Janet Allen, Cystic Fibrosis Trust
Barbara Camanzi, STFC
David Calder, Health KTN
Andy Taylor, ABHI
Joy Todd, ESRC
Valerie Shanks-Pepper, AHSN's
Jef Grainger, BBSRC
Bo Kara, Fuji Film Diosynth
Karen Livingstone, SBRI Healthcare
Declan Mulkeen, MRC
Steve Emmett, DSTL
John Robertson, DSTL

Mark Bradley, University of Edinburgh
John Ainsworth, University of Manchester
Anthony Bull, Imperial College London
Nick Grant, CRUK
John Hattersley, University Hospitals Coventry and Warwickshire
Shaun Lawson, Lincoln University
Sebastian Ourselin, UCL
Richard Seabrook, Wellcome Trust
Lionel Tarassenko, University of Oxford
Ruth Wilcox, University of Leeds
Sybo Dijkstra, Philips
Carl Saxby, Smith and Nephew
Danny Alexander, UCL