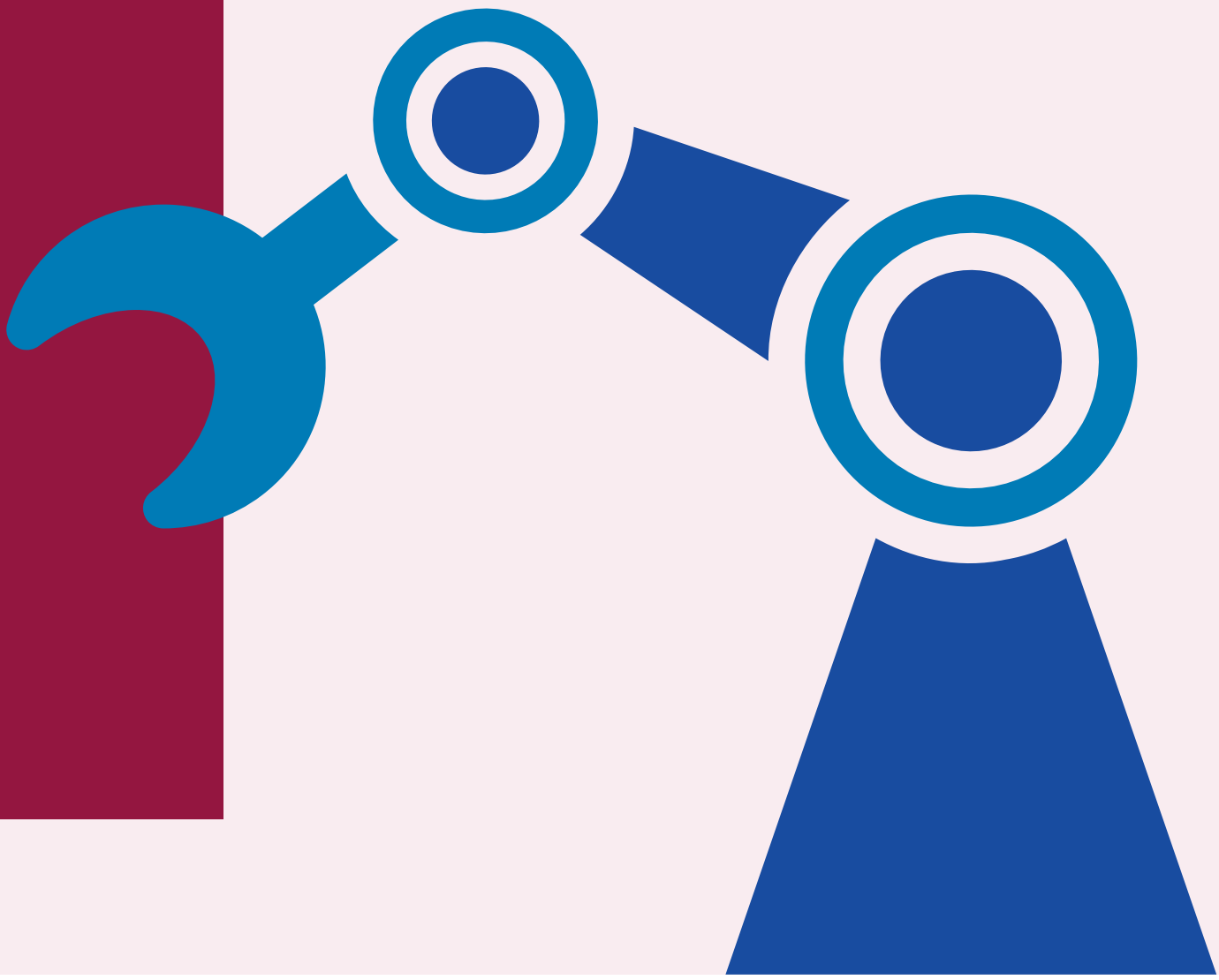
THE FUTURE OF CARE

2020 report

West of England Academic Health Science Network



The Future of Care

Robotics and autonomous systems

Contents

"The West of England is well placed to be thinking about and exploit the opportunities of robotics and autonomous systems. We have the Bristol Robotics Laboratory and an engaged group of health and social care providers and commissioners who are really excited at the potential to transform care."

Natasha Swinscoe
Chief Executive
West of England AHSN

Executive summary

We find ourselves at a technological crossroads as the electronic and communication revolution opens up new opportunities to combine robotics and autonomous systems, with big data and artificial intelligence (AI), to redefine how we enable people to maintain their health and wellbeing.

Robotics is a wide field encompassing 'smart' technology already in our homes such as robotic vacuum cleaners and lawn mowers, to standalone autonomous systems that in future will have the potential to keep us safe, help us recover from an operation or stroke, support us to manage long-term conditions, and even assist us to dress ourselves.

Robots can be both strong and gentle. They can provide physical assistance through a partial exoskeleton, or act as a tool to enable physiotherapy. They can learn to mimic human interactions and encourage us to exercise, cook or simply cheer us up.

With an ageing population, robotics technology that can contribute to people's care at home will keep more of us active, independent and safe. If the potential applications in health care and for rehabilitation are fully realised, the impact on social care could be enormous.

The introduction of these technologies will have a significant impact on the workforce as we prepare for the different skills needed in future; it will also require professionals and carers to work differently with the individual, to act upon the data that robotics and autonomous systems collect and report. Approaches that prevent ill-health or hospital admissions by spotting changes early could also be transformative. Simply ensuring a person is well hydrated and has taken their medication can have a massive positive impact.

Introduction

The West of England Academic Health Science Network's 'The Future of Care' events are exploring the new frontiers of science and innovation which are set to transform health and care in the future.

Bringing together experts from across the world to discuss the implications for the NHS and local healthcare systems in the South West and West of England, these events are exploring the latest breakthroughs in technology and medical research. This report captures the cutting-edge thinking and discussions from an event on robotics and how it will influence the future of care.

What is robotics?

Bringing humans and tech together

A robot in the context of assistive support is defined as a system that is able to sense the environment, understand and recognise changes in that environment, and adapt its behaviour in relation to what is happening. Robots can give real-time support, but they also build up a pattern of understanding user behaviour over a period of time. It may notice that you've missed your daily medication, or are taking longer to move around your home, for example.

Smart technology now forms part of our everyday environment, from the washing machines in our homes to smart phones, speakers and TVs.

So it is no surprise that the introduction of robotics elements to make the technology physically responsive can take many forms. From Paro the seal which helps calm people with dementia, to a robot that can teach you the Rumba. Robots consist of some key components: internal and external sensors which can help them observe and move in their environment, a computer which processes that information and may use artificial intelligence (AI) to do so, input and output devices such as automated speech and touch screens, and a physical form which can vary significantly according to their intended functions.

Assistive robots

Socially Assistive

Physically Assistive

An illustration of some of the different types of robot already available. Adapted from work by Praminda Caleb-Solly, Bristol Robotics Laboratory.

The Bristol Robotics Laboratory

Bristol Robotics Laboratory (BRL) is the most comprehensive academic centre for multi-disciplinary robotics research in the UK. It is a collaborative partnership between the University of the West of England (UWE Bristol) and the University of Bristol, and home to over 300 academics, researchers and industry practitioners.

The BRL aims to understand the science, engineering and social role of robotics and embedded intelligence. In particular, the challenges surrounding adaptive robotics including dealing with people and their unpredictability, unstructured and uncertain environments, and equipping robots for flexible roles.

The laboratory's research projects address areas of robot capabilities and applications such as: smart automation, human-robot interaction, unmanned systems, assisted living technologies, and medical and rehabilitation robotics.

The Bristol Robotics Laboratory is home to over

300

academics, researchers and industry practitioners.

"Robots are the way that the digital world can engage with the real world."

Chris Melhuish
Director
Bristol Robotics Laboratory

Find out more about their work at
www.bristolroboticslab.com

Robotics for rehabilitation

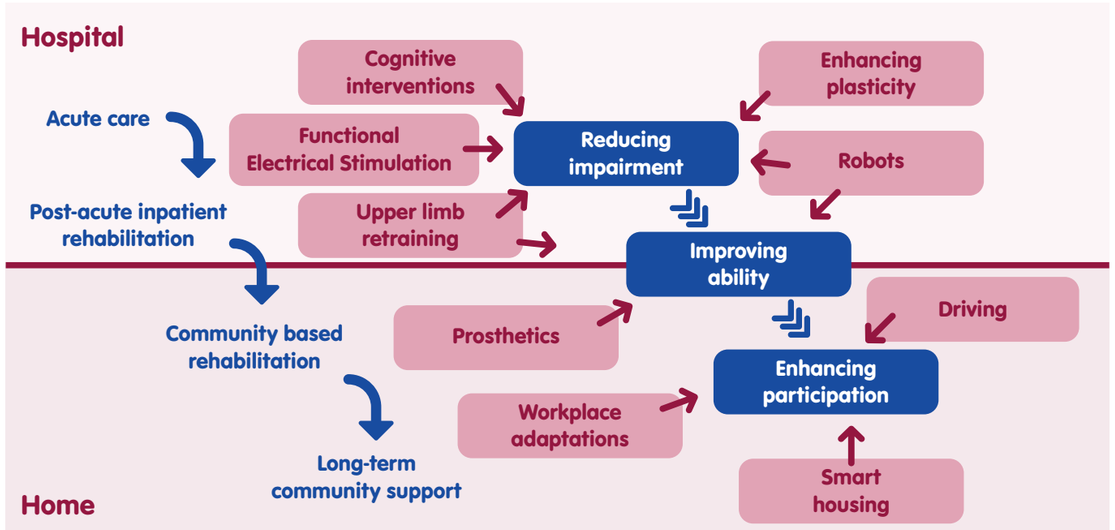
Helping patients get better faster

New research is showing how robotics might be used for people who have suffered a stroke. NICE guidelines say that patients benefit from 45 minutes a day of physiotherapy to help them regain some mobility after a stroke, but this is rarely possible to sustain for a long period with human therapists.

Robotics have been developed to aid recovery for upper and lower limbs, as well as assistive devices for the hand and even exoskeletons to support and aid people with very limited function through their rehabilitation.

The MIT-MANUS robot was invented around 30 years ago as an intervention to support stroke recovery. The device uses a joystick for people to practise movements with their arm by moving an object around on screen. The joystick uses sensors in the grip to measure how weak or strong the patient is, to track their rehabilitation progress. Once they are able to perform these tasks without assistance, they can move on to other therapies.

An illustration of some of the robotic interventions that could be used at different stages of a patient's care pathway



Adapted from a diagram created by Dr Manoj Sivan, Associate Clinical Professor, University of Leeds

More recent research at the University of Leeds has explored how such a robotic joystick device might be used at home. The system is best suited to patients who have limited, but at least some movement in their arm. The clinical trial was held with 17 chronic sufferers whose recovery had slowed down after six months. They had access to telephone support, but were otherwise self-directed in how they used the equipment. Data were collected after eight weeks and then a further month after they stopped using the device.

Everyone made improvements, but only three patients had clinically significant results. It was found that this was because they had engaged with the device very positively and were keen to continue using it after the trial ended. This may be because they enjoyed the games, found the task easy or had more free time to use the machine.

iPAM by contrast, is a more sophisticated robot that is attached to the shoulder and elbow, to support reach and grasp movements. A study of 39 participants compared one group which received 40 minutes of robotic therapy with another other group which were given an additional 15 minutes of normal physiotherapy. There was found to be no significant difference between the groups' improvement. In this example it was probably too soon after the stroke to discern the effect of robotic therapy from the patient's natural recovery.

Both studies demonstrate that comparing robotic therapy with standard physiotherapy is not helpful. A better approach is for robotics to supplement existing therapies and as additional resources to meet the growing need for physiotherapy.

In practice, robotic technology could provide additional rehabilitation opportunities after community therapy ends (usually after a year) or be deployed as part of a telehealth system where one physiotherapist could work remotely with a large number of patients. However, it's likely to be another five to 10 years before we see robotics featuring routinely as a part of NICE guidelines.

"Robotic technology has a huge role to play in stroke rehabilitation. These technologies can provide a continuum of care and supplement conventional physiotherapy treatments."

Dr Manoj Sivan
Associate Clinical Professor
University of Leeds

Connected care for independent living

How robots and tech can help at home

The Bristol Robotics Laboratory (BRL) has an Assisted Living Studio where they have been researching new technologies and how they interact with people in real-life situations. The first step is to understand the specific gap or need that robotics might fill. Working with a domiciliary care provider, researchers looked in detail at 20 people who were receiving care services to determine what issues care staff were dealing with and what was really needed on the ground.

There are three challenges the Assistive Robotics group at the BRL is considering for robotics to provide care at home:

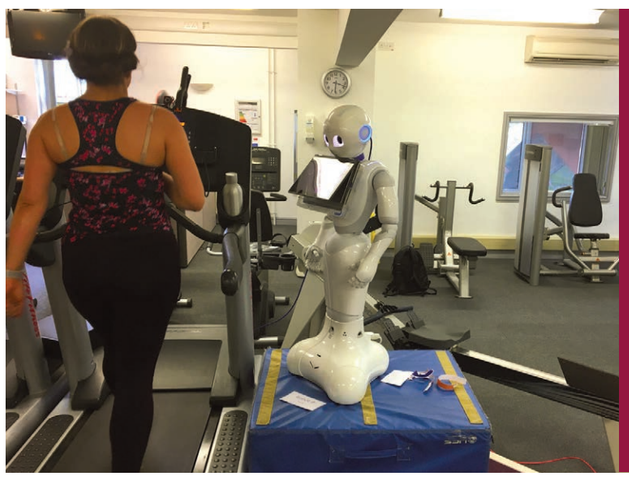
- Supporting wellbeing and self-management of conditions
- Facilitating access to staff and services for patients who are in their own home
- Identifying changes in patterns of behaviour to intervene at an earlier stage

While simple assistive technology products, such as walking aids and medication reminders, are already freely available, they often get left on the shelf. This can be for many reasons: perhaps the person is unable to use the technology or if it takes too long to deploy, the tech may no longer be appropriate or needed.

The reality is if someone is feeling unwell, they simply may not be encouraged to self-manage their condition. So any smart technology that is deployed also needs to become a champion, knowing what drives you and encouraging you to take action.

By definition, robots and autonomous systems sense their environment and take information from a range of sources, adapting and acting in response. Could they also spot when your mood changes? And learn how to motivate people?

Researchers at the BRL tried an approach using the Pepper robot to observe and learn how a personal trainer encouraged people attempting the NHS Couch to 5K running programme. The robot then used artificial intelligence to replicate saying the right things at the right time, in order to coach someone itself.



Pepper the robot takes on the role of personal trainer

Using these techniques, socially assistive robots could also address issues of memory and cognitive decline, as well as sensory and physical impairments. This is much more sophisticated than a simple smart phone app, which can only give you reminders: robots have the potential to connect and physically interact with you.

Robots can also offer physical help. Linking robotics with a hoist could have applications in rehabilitation, and tele-robotic assistance is already being trialled in Japan where a remote operator checks in with a person at home and helps with some physical tasks.

Through all of these trials, it is important to remember that people also need to have some social interaction, whether that is engaging with the robot or a remote carer or using robotics to complement home visits. The more personal the solution, the more likely it is to be successful.

A connected care ecosystem

The Assisted Living Studio at the Bristol Robotics Lab, UWE.

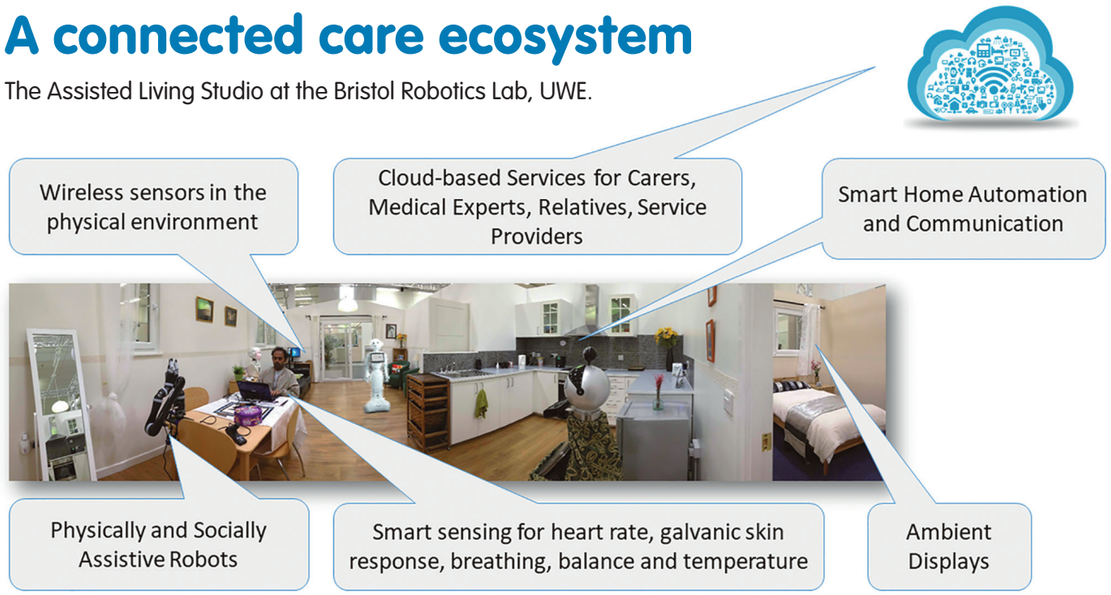


Diagram provided by the Bristol Robotics Laboratory, UWE

"The best system is no use if it's rejected by the user."

Praminda Caleb-Solly
Professor Assistive Robotics
Bristol Robotics Lab

Case study
Smart monitoring for dementia patients

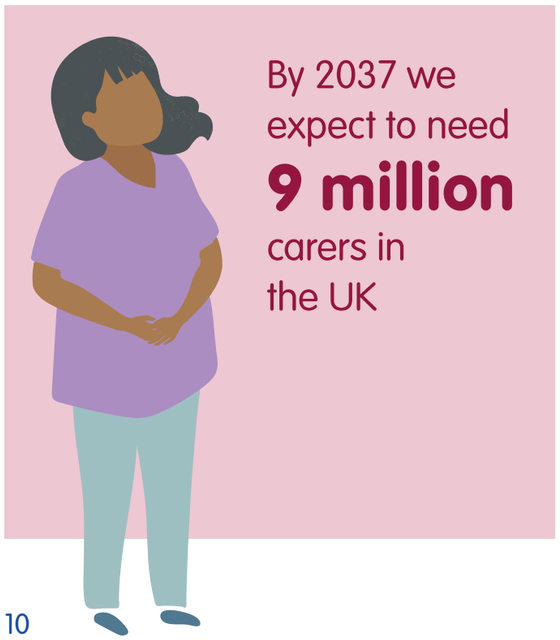
Using two weeks of data from sensors placed around the home of a dementia patient, researchers at the BRL were able to distinguish between two groups of people: one group had early-stage dementia and the other group were residents in specialist housing for older people who did not have dementia.

They created a 'busyness footprint' for each individual and this in turn helped create a model of the support they needed. Using artificial intelligence and input from the person to help confirm and correct the robot's actions, researchers are now able to start predicting what the subject's next steps would be and what they were doing.

The AI helps to cluster logs of activity and spot questions to ask – perhaps the person went shopping every week or had a regular visitor on a Monday. The more data they collected, the more accurate the predictions became. This helped to filter out noise and spot developing patterns that could indicate an emerging problem or change, which the carer can then be prompted to investigate.

AI, robotics and the workforce

Robotics and AI may transform how we deliver social care



The economic impact over the last 10-15 years of AI on how we work has been significant, and is already having the effect of 'hollowing out' routine, semi-skilled jobs. So what does this mean for the estimated 6.5 million people working in social care in the UK?

There are around 650,000 home care support workers in the UK on minimum wage. While they might have a smart phone, they are unlikely to have a computer or tablet, so training is essential to give them the confidence to use new technology. Most care workers love their job because they want to work with people, they don't do it to fill in care records on a computer or become a data analyst. So we need to focus on the benefits for them as well as the person they care for.

For instance if care staff have difficulty reading and writing, capturing videos on their phone is a better record than writing something down. For the person being cared for, robotics could help them to have more choice and certainly more dignity, if it enables them to carry out tasks without needing a carer to be present or help with personal care in privacy. As many people either pay for or arrange their own care, these solutions won't become mainstream until they are socially desirable and affordable for people to buy themselves.

The current commissioning model for social care is generally to meet physical needs. If we use a robot to provide these in future, people could be denied interaction with a care worker, which could be detrimental to their emotional and mental health needs. Commissioners themselves also don't have the knowledge to commission technology effectively yet and are often reliant on the supplier to tell them what it is they ought to buy. The social care industry is worth £42 billion to the UK economy, so making the right procurement decisions is vital.

Our knowledge, confidence and ability to use data is another gap. We are gathering much more data but aren't sure how to use it to make better decisions. If care workers were able to understand and use data more effectively, we could improve quality and safety for people. Examples include monitoring how much people drink each day using smart cups or using heat sensors to know if someone has gone into the kitchen to cook food for themselves.

What does this mean for the workforce? We are still going to need care workers on the front line to engage directly with people, but this is also an opportunity to think differently about creating more highly skilled technical jobs that attract a different type of worker, to programme systems and analyse data.

However, we must never forget that the main reason people work in care and support roles is because they care about people and want to support, enable and empower them. We need to hang on to this passion.

"Technology needs to empower and enable individuals to retain their dignity, independence and make choices about their own lives. If it restricts, controls or prevents them from living their life the way they want to, it's not doing the right thing."

Jim Thomas
Programme Head – Workforce Innovation
Skills for Health

The safety and ethics of robotics

Where are the boundaries for emerging technologies?

As the progress of new technology and robotics gathers pace, there is increasing pressure from civil society, the public, government and the media about the unintended consequences of technology on society.

Every new technology raises questions as it becomes embedded. What are the benefits and risks? Who is in control and how do we deal with undesirable and hard-to-foresee consequences and errors? Regulation and the law are often on the back foot and struggle to keep up. Take social media for example, which was deeply rooted in society before we fully understood the unintended consequences.

While we can't predict the future impacts of research with any certainly, trying to control and prevent them would leave us stuck with the status quo. One way forward is to take an anticipatory approach, where we try to develop a capacity to respond to what the future might hold.

'Responsible innovation' asks science and society to work together and understand what society needs and how innovation can help. This anticipatory governance works with society and for society, looking at both the positive and negative consequences.

There are some practical frameworks in place (such as the AREA framework) to encourage stakeholders to participate and reflect on the consequences of innovation, even where there is a high degree of uncertainty and ambiguity about the future direction of that research.

"Responsible innovation is trying to align the values and expectations of society with new science and technological innovation."

Marina Jirotka
Professor of Human Centred Computing
University of Oxford

The AREA framework

The Engineering and Physical Research Sciences Council (EPSRC) has created the AREA framework, a set of processes to think through what it is we're trying to do with an innovation.

Anticipatory: describing the impact of our innovation, both good and bad, intended and unintended. This is not trying to predict what will happen, but to be imaginative about the possibilities and opening them up for discussion.

Reflect: thinking carefully about the purpose and motivations, recognising the limits of our own knowledge. Understanding what is known or not known, the assumptions and risks.

Engage: opening up the debate in an inclusive way through an ongoing process. Thinking who the users will be and being responsive to what is shared.

Act: using these processes to influence the direction and trajectory of the research and innovation process itself.

Ethics in robotics

You can't have regulations without standards, and in turn standards must be built on a foundation of ethics. Around the world, organisations including the UN, IEEE and the UK's Engineering and Physical Sciences Research Council (EPSRC) have been publishing ethical principles for the field of robotics and autonomous systems. More than 80 principles have been published to date, most since 2017, and a study of them all discovered that transparency is one of the most universal themes.

The world's first explicit ethical standard for robotics was published in 2016. BS8611 describes a method for undertaking an ethical risk assessment. So what does happen when robotics go wrong?

In the US, the government tracks industrial accidents caused by robots but elsewhere around the world this is not standard practice. Currently, it is only down to the manufacturer's goodwill and ability to investigate. For instance, we only hear about issues with driverless vehicles when they make the news.

A solution to this issue is the idea of a data recorder or 'ethical black box' such as you find in aeroplanes. A black box would help to build robots with explainability – you could potentially ask the robot, 'Why did you do that?' And what-if questions such as, 'What would you do if I fell down?' or 'What would you do if I forgot to take my medicine?' This would help users build a mental model of what a robot does, when and why.

Case study
The Robotips project

Robotips (www.robotips.co.uk) is a collaboration between Oxford University and the BRL. It is looking at social robots that interact with humans on a daily basis, staging different types of potential accidents to consider issues of trust, identity, privacy and security. This approach assumes a culture of collective responsibility, where we move beyond individual accountability and liability to be more responsive to what might go wrong.

In this five-year project, three types of accidents are being staged:

- Assisted living robots
- Educational/toy robots
- Driverless cars

For each of these accidents, they are using human volunteers to act in three roles: people who have the accident, witnesses to the accident and members of the accident investigation team.

The project will test the boundaries of the assistive robot's actions, and look at digital rights, privacy and autonomy from a human perspective, to understand what level of autonomy people need to have over the control of their robot.

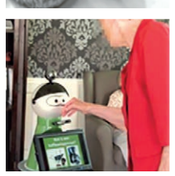
Physical safety

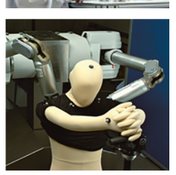
A more tangible risk from robotics is people's physical safety when using them. How can we ensure a safe physical human-robot interaction?

Robots need to be able to be both gentle and strong, and there is huge variation in what we call a robot. There is a big difference in the requirements for a robot which has the power to help a person stand up, compared with a robot that takes an object from your hand and needs to be both gentle and able to deal with considerable variation in how the object is given.

Human-robot interaction complexity

No interaction	**Cooperation**
Co-existence	**Physical interaction**





Adapted from a chart by Sanja Dogramadzi, Medical Robotics, Bristol Robotics Laboratory

One idea being explored is to embed safety within the design of the robot itself, so they are intrinsically safe. This is happening in the development of soft robotics, which use soft, elastic materials which are more flexible in their applications than hard robots. Sensors inside the robots maintain their safety by avoiding direct physical contact with the user.

Softer rehabilitation devices being developed include exoskeletons for the hand and a project called 'The Right Trousers' which helps vulnerable people with walking, climbing stairs and standing up. These types of physical assistance robots are already a big industry in Japan, where they are used to help with transferring patients, dressing, bathing, and walking. However, they remain very expensive.

I-DRESS is another project looking at how a robot might help a person to dress. This is a significant personal care need which usually requires assistance from a carer. The project is considering whether robotics can provide proactive assistance for people with limited mobility, or cognitive ability, to dress.

Once again, researchers are learning from mapping human-to-human interaction first, with a person playing the robot dressing another person. Using sensors and AI, they are looking at different types of clothing and various starting points, including what the person is already wearing. The next step will be to test the system with a potential user to understand the role they could play in validating and directing the robot system.

The Right Trousers is an Engineering and Physical Sciences Research Council (EPSRC) funded research project which aims to develop new soft robotic technologies that will help older people and people with disabilities to live more independently and with greater quality of life. Find out more at www.therighttrousers.com.

"In order for us to get on top of the safety issues, we have to perform more trials and not just with healthy people. We need to take a leap of faith and ask the people who have health conditions or disabilities to test some of this technology."

Sanja Dogramadzi
Medical Robotics
Bristol Robotics Laboratory

Opportunities and challenges

Delegates at the event fed back their impressions on robotics and the implications for the healthcare system in the South West. Here are the opportunities and barriers they noted.

Opportunities

- Robotic solutions at home can increase wellbeing and independence. Their ability to use AI together with monitoring mean they can raise the alarm more quickly if something unusual happens or there is an emergency.
- There is growing evidence that robotics can be a powerful tool to tackle social isolation. With more naturalistic speech patterns and responses, machines can interact with people in a 'friendly' more human way.
- Robots can give reassurance to patients by providing a reliable and trusted solution to help them with specific tasks. People may be less embarrassed or worried when receiving assistance from a robot.
- The gamification used in some robotic applications, such as rehabilitation helps encourage people to stick to the medical goals that have been set for them – for instance completing physiotherapy or taking medication.
- Robots can reduce manual handling costs and reduce the physical workload for carers. This is best suited at the moment to repeatable tasks in specific situations, such as getting a patient up into a standing position.
- Robotics may increasingly allow us to respond in a timely way to people's health needs and is already showing promise in stroke rehabilitation and supporting dementia patients. By working with partners and health psychologists, we can explore the art of the possible.

Challenges

- We have a complex healthcare system where change can be difficult and slow. Using robotics effectively will require much closer multi-disciplinary working.
- We will need new models of funding to allow for investment in robotics and we need to fully understand the implications for workforce planning. There will be a long-term impact on system infrastructure.
- People are still resistant and suspicious of some robotics, while already embracing similar tech in their home such as smart speakers or TVs. We still need to shift user acceptance and expectations to 'trust' robotics as a safe and effective solution to their health or care needs.
- There is a need for controlled trials in the field alongside the carers, therapists and other professionals who will increasingly use these autonomous systems as part of their daily routine.
- As this is a growing area, regulation and ethical concerns will need to keep up. We will require a policy framework across the NHS to ensure equality of access in different areas which may have different budget priorities.
- There may be unintended consequences. Not everyone will fit the algorithms. Using robotics in the home may increase social isolation rather than reduce it. We may never be able to make robots 100 per cent safe. These are all concerns that require proper research and monitoring to understand before we roll out the technology widely.

"There are clearly many opportunities to deploy this technology. The feedback from delegates and the panel was that we have to do this in partnership with patients and the staff involved in delivering care."

Nigel Harris
Director of Innovation and Growth
West of England AHSN

Conclusion

While there is huge potential for robotics and autonomous systems, we are still at a relatively early stage in their development, with widespread home use still some years away. Meanwhile, the rapid progress in thinking about the intended and unintended consequences of combining robotics and AI mean we need to quickly tackle questions of safety and ethics in their use and how this emerging sector should be regulated.

With the Bristol Robotics Laboratory in the area and an engaged health and care sector, the West of England is a great place to pioneer new applications for robotics and autonomous systems. With support from the West of England AHSN, promising technologies can be developed and tested in real-world settings, and potentially spread across the country.

The involvement of patients in testing and improving these new technologies is vital. We are fast moving beyond the usefulness of trials in the laboratory with healthy people standing in for the intended user and need to hold more, controlled trials jointly with the technology's potential users and the professionals who will be expected to use these autonomous systems in their work.

The impact on the workforce is potentially huge. It will certainly mean that different skills are needed in the future, but rather than the 'robots taking over', we may move towards a vision of robots filling in the gaps: providing 24/7 monitoring and assistance, helping a person maintain their independence and dignity by assisting with personal care tasks, or providing a continuity of care after conventional therapies stop.

All of these are exciting interventions and used appropriately as part of new care pathways, will allow health and care professionals to focus more of their time on what matters – supporting people to live their lives as they wish.

Challenges for real-world deployment

- **Achieving safety and reliability - standards and regulations**
- **Ensuring user acceptance - appropriate embodiments and usability**
- **Staying relevant - personalisation and adaptation to changing needs**
- **Sustainability of solutions - cost and maintainability**
- **Integration with healthcare infrastructures - realising new care pathways**
- **Identifying models for ownership, liability and ethical deployment use**

Adapted from work by Praminda Caleb-Solly, Bristol Robotics Laboratory

Acknowledgements

Many thanks to our speakers at the Future of Care event.

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