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Robot telepresence as a practical tool for responsible and open research in trustworthy autonomous systems

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ABSTRACT

In developing Trustworthy Autonomous Systems (TAS), as in other domains of technology innovation and research, there is a need to make research processes and activities more accessible to external partners and to the wider public. In this article, we describe the rationale, background and potential for an Open Laboratories approach that complements current strategies in Responsible Research and Innovation and in Open Science, relating this to experience-based aspects of trust in new technologies. We also reflect on the value and benefits of robotic telepresence as an engagement tool that can provide direct access and first-person experience of research, in a manner that is scalable and safe while mitigating some environmental and health concerns.

1. Introduction

The adoption of autonomous systems, including robotics, in the UK and elsewhere, is affected by poor acceptance and low adoption rates (Waterstone, Charlton, Gibbs, & Prescott, 2021) and a correspondingly high-level of public concern, partly fuelled by poor communication concerning the current capabilities and likely future potential of these technologies (Johnson, 2017). Though there is evidence that labour displacement has been at least balanced by job creation in previous industrial revolutions (Bessen, 2016) (Dizikes, 2020) and that low adoption rates of automation are at the heart of the productivity challenges (Oxford Economics, 2019), there is still widespread and reasonable public concern about the benefits that such technology could bring, given the potential risks to individual livelihoods and ways of living (Vu & Lim, 2022). Research in autonomous systems must understand and address these concerns if it is to fulfil its promise to generate beneficial economic and societal impacts. In response to these issues, there is an emerging field of research in Trustworthy Autonomous Systems (TAS) that highlights issues such as safety, security, fault-tolerance, ease-of-use and adherence to ethical and legal frameworks (He et al., 2021) (Yazdanpanah et al., 2021). However, improving trust also depends on social and cultural factors. For example, technical literacy and prior experience have both been shown to be important determinants of anxiety and trust toward new technologies (Lemay, Basnet, & Doleck, 2020) (Johnson, 2017) (Sun, Lu, Sukui, & Finnie, 2007).

Nowotny and colleagues (Gibbons, Limoges, & Nowotny, 1994) have described a paradigm shift from historical "Mode 1" research, as a domain for scientific elites, to a more open "Mode 2" model, in which researchers are more responsive to public concern and mindful of the cultural, social and political context in which their research is carried out. A direct dialogue with a broader community of partners and end-users is central to this new approach which argues that research, as a source of reliable knowledge, needs to establish a broad consensus to be trusted and impactful (Prescott & Verschure, 2016). This wider effort to make R&D more transparent has resulted in the Open Science movement which has substantially improved access to the research outputs of publicly-funded organisations (Bartling & Friesike, 2014), and in Responsible Research and Innovation (RRI) approaches (Owen, Macnaghten, & Stilgoe, 2012) (Stilgoe, Owen, & Macnaghten, 2013) that are helping to redirect the targeting and motivation of research planning. In business and government laboratories, the Open Innovation approach stresses the value of purposive and early sharing of research outputs within networks of organisations (Huizingh, 2011) (Schillo & Kinder, 2017). However, R&D practices themselves, are still largely performed in cloistered laboratories—even in publicly-funded universities—with safety, health and efficiency practices often working at cross-purposes with the need to make research processes more accessible. Public trust in research is undermined by this lack of visibility,

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which also fosters concerns about RRI as an "ethics washing" (Wagner, 2018) and about the trustworthiness of results that are generated by research processes that are observed only by insiders. Moreover, this lack of visibility of R&D processes also means missed opportunities to improve technical awareness and literacy and to initiate experience-based development of trust.

In Section 2, we briefly review the emergence of RRI and Open Science over recent decades, identifying that there remains an important gap around the visibility of research processes. Section 3 examines how social unrest and public concern about animal testing accelerated the need for more inclusive and accessible research. This case study also serves to illustrate how new technologies, such as video and webcam tours of laboratories, have come to play an important role in public understanding of science practice. Finally, Section 4 examines robotic telepresence as a 21st century technology for enabling lab visits and for creating greater visibility of research processes. We will also argue that the engagement potential of telepresence offers researchers a new means to improve inclusion and diversity, while reducing the environmental impacts of inperson lab visits.

2. Towards responsible and open research

RRI approaches are grounded in the view that research and innovation is not neutral, or even apolitical, but is embedded in social, economic, environmental and political contexts. On this basis, RRI proposes that research should be transparent, interactive and responsive to society in terms of its desirability, ethical acceptability and sustainability (Stilgoe et al., 2013) (Owen et al., 2012).

In its mission to mitigate the social risk for science, and to be proactive in engaging the public, contemporary RRI approaches, are, in part, a reaction to the scientific controversies that played out in the media of the late 1990s. For example, the birth of Dolly the cloned sheep in 1996 proved to be highly emotive in its public reception, with media reports focusing as much on dystopian future scenarios of human cloning and mass production as on the ground-breaking nature of the science (Alcibar, 2013). Significant social and political pressure to ban cloning followed close behind (Kutukdjian, 1999). Biotechnology further hit the UK headlines for nearly two weeks in February 1999, as news outlets debated the rights and wrongs of genetically modified (GM) food (Flipse & Osseweijer, 2013). The resulting controversies led many food manufacturers and suppliers to distance themselves from the use of GM methods.

Mindful to address such concerns, whilst still promoting the potential benefits of future technologies, national and international bodies have since focused on RRI initiatives as a way to preempt such controversies. For example, the EU has instituted a "Science with and for Society" approach to Horizon 2020-funded research and innovation projects in Europe (European Commission, 2013), while, in the United Kingdom, UK Research and Innovation (UKRI)—the body that sponsors most publicly-funded TAS research—has adopted the Anticipate, Reflect, Engage, and Act (AREA) framework and encourages scientists and engineers to integrate and cost RRI activities into their research funding proposals (Owen, 2014) (UKRI, 2022).

RRI approaches have generally stressed the importance of inclusively engaging citizens and being responsive to social concerns in research and innovation initiatives throughout the *whole* research process (Schuijff & Dijkstra, 2019). However, there is a need to close the gap between conceptual discussions of RRI and its practices (Stahl, Timmermans, & Flick, 2017) (Shelley-Egan, Bowman, & Robinson, 2018), the latter have generally focused on the goals and objectives of research, rather than on research methods and activities, which may be seen as less amenable to co-design with nonexperts. For example, the AREA framework promotes influencing the "direction and trajectory" of research, and engagement about the "motivations", "visions", "impact" and "implications" of research plans (UKRI, 2022), however, it is relatively silent on the question of how engagement might influence or help direct research processes and activities themselves.

As a related but distinct movement, Open Science seeks to increase the transparency of scientific research by making it easier to access (Bartling & Friesike, 2014) (Robson, Baum, Beaudry, & Beitner, 2021). The movement wants research outputs to be in the hands of as many people as possible by broadening access to scientific publications and data. The more people that can access data around a research issue, the better the forecasting and decision making generated by it. By generating more trust in science, the hope is that Open Science can also encourage more citizens to participate in experiments and data collection (OECD, 2022).

Open Science was catapulted to public attention with the success of the Human Genome Project in the early 1990s (International Human Genome Sequencing Consortium, 2001). A moratorium was established on publishing behind paywalls, with human genome data made freely available to the global research community. In 1996, scientists from the project promulgated the Bermuda Principles that genome data should be released in publicly-accessible databases within 24 hours of generation (Maxson Jones, Ankeny, & Cook-Deegan, 2018). Just five years later, the first fully assembled human genome sequence was announced to the world.

In 2016, an assembly of G7 Science and Technology ministers issued a joint communique (G7 Science & Technology Ministers Meeting, 2016) recognising that science, technology and innovation are vital to social and economic health and in addressing serious societal challenges. The communique further stressed that these benefits should be enjoyed by society as a whole and that Open Science could pave the way to an inclusive, prosperous society if it is held at the centre of future R&D. The ensuing formation of the Open Science Working Group, chaired by Japan and the European Commission, sought to share expertise and co-create Open Science paradigms. In 2018, the President and former Director General of Science Europe launched Plan S to ensure open access to scientific publications funded by EU public grants (Coalition, 2018), a move shortly followed by the Australian government with the formation of a publicly-accessible data cloud (ARDC, 2022). The European Open Science Data Cloud was launched shortly afterwards, as well as the FAIR (Findability, Accessibility, Interoperability and Reusability) Data expert group (European Commission, 2019). Open Science and FAIR data are key to the current Horizon Europe funding programme (European Commission, 2022).

The rapid spread of the Ebola epidemic from 2013 further accelerated calls for broadening access to research data and results (Knobloch, Albiez, & Schmitz, 1982). It was argued that Ebola could have been halted using existing public knowledge far more quickly than the three years it took to generate a vaccine, had the research data been made more readily available to the global medical research community (Burgelman, Pascu, Szkuta, & Von Schomberg, 2019). When the Zika epidemic broke out in south America, as the Ebola threat was receding in West Africa, the World Health Organization issued a global plea to open all research data around the virus and an experimental vaccine was quickly developed (World Health Organization, 2015). The outbreak of Covid-19 in Europe in 2020 saw scientists move rapidly to ensure open access to data for the development of a vaccine. The resultant Open Covid Pledge [22] stands as a testament to the effectiveness of Open Science in practice. Opening scientific data, information and IP to global access has undoubtedly saved lives in the rapid delivery of safe and effective vaccines (Beckman, 2021) (Covid-19 & Open Science, 2020) and this success has been seen as a model from which to develop future strategies for Open Science (Besancon, Peiffer-Smadja, Segalas, & Jiang, 2021).

Whilst Open Science has undoubted served to improve access to data and results, and has helped the scientific community serve the public with the very fast timescale of vaccine development, a lack of wider public inclusion and access to the processes of scientific research may have contributed to public distrust of vaccines, and of research more generally (Sridhar, 2022). The challenge here is that the Open Science movement has yet to significantly impact the transparency of research practices. As a consequence, public concern has not abated due to Open Science, but has shifted from the accessibility of scientific data to questions about the integrity of that information and the processes that generated it (Sutcliffe, 2020).

In sum, RRI and Open Science have made substantial progress in improving access to science and its outputs, and in encouraging researchers to think through the implications of their research and to develop their research ideas in collaboration with a wider pool of partners and knowledge users. However, these approaches bookend the core activities of research practice, which, while subject to substantive internal regulation and review (including of their ethical acceptability), are less amenable to public inspection and therefore provide an outstanding and significant source of potential public distrust.

3. Towards open laboratories

Even before the Covid pandemic, Europe saw the lowest levels of public trust in officialdom (Edelman Trust, 2011). Misinformation, and the belief in conspiracy theories that builds on it, threaten to derail the ability of science to solve some of the great challenges of the day (Sutcliffe, 2020) and could inhibit technologies such as autonomous systems from effecting positive social and economic change. Further effort at all stages of the research journey is needed to rebuild trust in science.

In a 2014 UK survey (Castell et al., 2014), 50% of respondents rated scientists as ‘secretive” while 31% said the same of engineers. Amongst the most concerning aspects of science is the laboratory which has come to stand as a metaphor for science in practice. Rather than the glamorous laboratories of eminent Victorian science philosophers producing “reliable knowledge” (de Jong, Kupper, & Roelofsen, 2015), the lab now is often thought of as a place where scientists covertly pursue agendas that place commercial or reputational gain before public good. Nowhere is this metaphoric shift (Kueffer & Larson, 2014) (Nerlich, Hamilton, & Rowe, 2002) more evident than in the use of animal testing in science laboratories. When three baboons escaped from an animal experimentation lab in Sydney in 2020, local outrage followed a cascade of negative stories about in vivo testing and the presence of the laboratory in the city (Speaking of Research, 2020). The negative hyperbole was only increased by a sense of scientific subterfuge in that very few local residents had known that the laboratory was there at all. It transpired that the baboons were in excellent health and had escaped from a veterinary unit attached to the lab, but the lack of local inclusion and public engagement meant that the story told was an antiscience one.

To counter a wave of negative publicity in 2018, a group of over 600 American scientists, veterinarians and animal care workers, four Nobel Laureates in their number, publicly pleaded for more openness and engagement around animal research and for scientific institutions to do more to propagate its critical role in developing new treatments and cures. The hope was that this call for openness would drive such institutions to find new and innovative ways to explain their research to the wider public (Speaking of Research, 2018).

As pointed out more recently in reference to Covid misinformation, it is important to ‘prebunk’ the myths that fuel antiscience sentiment (van der Linden, 2021). Speaking of Research (SOR) is such an approach to public engagement and a telling example of the need to do more to engage the public in scientific research and innovation. Born from the “Pro-Test” movement that emerged from the Oxford Student Union in the early 2000s, SOR was founded in 2009 to take science’s message out into the open, in the belief that a more informed public would rally against animal rights extremism and support scientists in their use of animals to facilitate “lifesaving biomedical research” (Speaking of Research, 2022). Regular, proactive press releases help to counter the public’s mistrust of animal research laboratories, by attempting to preframe narratives around in vivo testing, while the use of video invites sceptics to see the labs for themselves and hear what the researchers have to say, unmediated by news channels. Videos made by animal testing units at some leading UK universities strove to directly put the animal research case to the public and show how, far from being sites of animal torture, the labs strove for the best possible practice in animal welfare, since “good animal welfare brings good science”. The UK-based not-for-profit Understanding Animal Research (UAR) released a further set of videos putting the case for animal research in 2020, while several universities, as well as the Pirbright and MRC Harwell Institutes, set up cameras in the main areas of their laboratories so that members of the public could navigate around the labs in ‘virtual tours’ by directing the camera’s gaze.

Such efforts to reframe the narrative around animal research and science reflect the call made by de Jong et al. (2015) for research to view hype rhetoric as a strategic resource rather than as simply an unpleasant by-product of reporting. Whereas animal research scientists sought to engage the public to address public opposition to research in their field, de Jong was concerned with helping Dutch neuroimaging researchers mitigate the often unrealistic public expectations around brain imaging. It was found that such ‘(neuro)hype’ could lead to reputational damage and misallocation of resources when innovations fail to live up to media-inspired imaginings. Hype narrows the public gaze to the exaggerated promise of an innovation while the surrounding science becomes largely ignored. De Jong et al. suggest that other new technologies similarly prone to hype could follow their proposal for scientists to seed more helpful narratives and metaphors around their work. Science itself should work to develop the rich and deep storylines that help construct imagined technological futures.

Social media is the lens through which many view robotics and science; it is also the home of much of the misinformation and negative narrative around such new technologies. As mode 2 science moves to include new benchmarks of impact, researchers are increasingly taking to social media to promote their work (Huber, Barnidge, Gil de Zúñiga, & Liu, 2019) and publishers have begun accumulating social media citations as measures of impact.

It is not just hype that makes stories more viral on social media platforms, but how “interesting-if-true” a story might be. Fake news and misinformation are clearly shared in large numbers, as are unrhetorical straight news pieces, but the most shared stories in social media are those that are interesting if-true (Altay, de Araujo, & Mercier, 2022). As well as how plausible it might be, the relevance and interestingness of a message rests on the extent to which it generates rich inferences (Clark, 2013). As Phillipe Galiay of the European Commission said, when asked what would be his favoured outcome from the commission’s New Horizon RRI initiative: “Stories. Because everything we do is based on stories about the future and how we want the world to be” (European Commission, 2022).

4. Improving access to research through robot telepresence

The lab visit has been a traditional means of engaging the public about University research, however, it has always faced limitations of scale and practical issues around health, safety and travel. Ipsos MORI found that only 7% of participants in their 2014 survey had visited a laboratory in the last 12 months, compared to around 40% for a zoo, aquarium or nature reserve (Castell et al., 2014). Access to laboratories is often limited to a few times a year and to specific audiences such as other scientists, funders, and prospective students and their families. Access for the general public to university research laboratories also ended abruptly in early 2020 with the start of the Covid-19 epidemic and is only gradually being restored more than two years on.

Robotic telepresence (Kristoffersson, Coradeschi, & Loutfi, 2013)—direct control of a moveable robot equipped with cameras, microphones, and speaker—gives us the opportunity to utilise a new technology that in itself adds interestingness to the practice of responsible innovation. Through the robot’s sensors and actuators, a visitor is able to see and hear what is happening in the laboratory, engage with the environment around them and converse with host researchers. Immersive telepresence via virtual reality technologies, including headsets and hand controls (Martinez-Hernandez, Szollosy, Boorman, Kerdegari, & Prescott, 2017), can give a feeling of "being there" that promotes engagement and involvement in the remote activity. By avoiding bringing people directly to labs, many concerns about public access to laboratories are mitigated including the potential for theft, sabotage, and infection. Travel costs are also reduced to a minimum allowing visits to distant facilities.

Telepresence also builds on the "RRI in practice" initiatives using video and webcams pursued by UK and US universities including in the SOR and UAR movements. Moreover, in an age of distrust of scientific practice, and of what goes on behind laboratory closed doors, to experience the research environment in real time, with remote bodily control of robot, can bring a degree of authenticity and immediacy to the experience that goes beyond that achieved with edited video or views from webcams.

Whereas the videos generated in the SOR and UAR projects are scripted and edited, telepresence gives participants a more tangible and authentic connection to technology. Telepresence also offers a more active lab visit, where a surrogate robot body can be moved around and used to communicate directly with researchers in situ. This ability to 'do' in a remote location further heightens the participant's sense of immersion and their degree of engagement with a remote scenario (Sanchez-Vives & Slater, 2005). The extra agency that telepresence gives to participants allows them to own the experience and place themselves in positive narratives about the technology that they are engaging with.

In terms of robotics and autonomous systems, the use of robotic technology itself provides visitors with 'touchpoints' with the technology and provides better direct insight into the how these technologies operate, as well as some of their uses and limits. Direct contact, of this kind, is known to be a strong facilitator of attitude change (Sarda Gou, Webb, & Prescott, 2021).

Telepresence's ability to allow participants to act in a remote world through an alternative presence also helps to make it an inclusive experience—allowing participants to experience situations that they otherwise might not be able to access. Differently-abled people can visit labs through other bodies (i.e. those of robots) and explore new experiences. Visitors are also less vulnerable to prejudice as physical signs of ability, gender and ethnic origin are not apparent in the robot body in which the participant is immersed.

As part of the Open Laboratories Programme for Trustworthy Autonomous Systems (OPEN-TAS) pump-priming project, funded by the UKRI Trustworthy Autonomous Systems programme, four Universities and a spin-out company came together to develop and trial technologies for remote visits to University facilities by robot telepresence. Successful trials were conducted with groups of both national and inter-continental visitors. As illustrated in Fig. 1, visitors were able to observe ongoing research activities in the Sheffield Robotics laboratory, interact with researchers and play games, including navigating a maze and stacking cups.

5. Ethical and privacy issues

Telepresence robotics, like all emerging technologies, has important ethical implications that must be proactively addressed to maximize the benefits of initiatives like telepresence laboratory visits. For a broader review of these challenges see (Robillard et al., 2020).

Privacy is a key consideration for the visitor, whose voice, gestures, and perhaps other forms of data, must be transmitted to the telepresence platform, and could potentially be stored or shared by the communications provider for reasons not directly related to the visit. For the host, privacy issues can arise as laboratory environments may inadvertently display confidential information (e.g., research participant health information) or intellectual property (e.g., proprietary protocols or algorithms), either through visible means, such as on a white board, or audible means, such as in conversations between researchers. Threats to visitor privacy can be mitigated by treating the user's data as one would a real visit, and not store or utilize data for purposes beyond the visit. The host organization should ensure it has adequate control of such data and commitments on data privacy from any technology partners. This measure, combined with a meaningful informed consent process that allows the visitor to clearly understand the implications of data management in telepresence, would limit privacy threats considerably. Similar mitigating strategies can be used for the host, treating the virtual visit as they would a real visit and following relevant preparation steps to preserve any confidential or sensitive information from being accessible during the visit. Research organisations generally have clear guidelines about the treatment of sensitive information and these should be respected when conducting lab visits either in person or via telepresence. Visiting via telepresence can reduce some risks compared to inperson visits as the research organisation can control where the telepresence robot is able to go and what sensory modalities it is able to use.

Fig. 1. Example of pilot "Open Lab" activities supported by the UKRI Trustworthy Autonomous Systems programme. Visitors were able to telepresence into various humanoid and animaloid social robot telepresence platforms including Softbank's Pepper (Pandey & Gelin, 2018) as shown here. Visitors interacted through the robot either using either a screen and keyboard or via a virtual reality head set (Oculus Quest). Communications were supported by Cyberselves' Teleport (Camilleri et al., 2020; Dizikes, 2020) which allows users to select between available robot platforms through a browser-based interface and access the sensor and motor systems of the robot including any arms and grippers. In the figure, the bottom-left insert shows a user wearing the headset and controlling the Pepper robot, the top-left insert shows their view of the robotics laboratory via the robot's camera, the right-hand image shows the robot in the laboratory.

Another common concern around telepresence applications is that it may lead to a reduction in human contact or an increase in social isolation. This is an area of debate, as there is no strong evidence to date that supports this concern, and there is emerging evidence in support of telepresence as a way to address, not increase, social isolation (Prescott & Robillard, 2021). The Covid-19 pandemic in particular has served to highlight the potential of telepresence applications to broaden reach and access to various services and experiences.

A further issue concerns the experience of research staff that they may feel anxious or intimidated by being observed. There is clearly a balance to be achieved between improving the visibility of research practice and avoiding introducing stress into the work environment. This risk can be mitigated by providing telepresence access in a planned way, following consultation, and with researcher consent. A change in the culture may happen gradually, beginning in a limited area, and with researchers who are enthusiastic about open laboratories, then extended to other areas and activities as relevant challenges are overcome and risks mitigated. The trend toward "open kitchens" in the restaurant industry shows that interest in improving transparency goes across multiple sectors, and that innovation in this direction is possible, including the possibility of working in public sight.

Addressing these ethical concerns and others can be carried out proactively by close engagement with end-users in the design and implementation of the virtual visit and ensuring both the technology and the experience is aligned with end-user values and priorities (Robillard et al., 2020) while respecting the role and rights of researchers.

6. Conclusion

This article has advocated for a change in research culture whereby research practices are made more open and accessible to the wider public. This Open Laboratories initiative can operate alongside Open Science, RRI, and Open Innovation approaches to improve public trust in research. A change in the culture may happen gradually, beginning with areas of the laboratory that are easier to access, and with researchers who are enthusiastic about science communication, then extended to other areas and activities as relevant practical challenges are overcome and ethical risks mitigated.

Telepresence offers a new way of making research practice accessible; in the case of autonomous systems utilising the same kind of technology that is also being witnessed in action. Beside environmental and safety benefits, telepresence also gives researchers an opportunity to improve inclusion through its relative ease-of-use for people with mobility issues. As these technologies mature we hope they can provide new ways of promoting transparency in research practice and make an experience-based impact on public trust in science and autonomous systems research.

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CRediT authorship contribution statement

RW and TJP contributed equally to this manuscript, JMR contributed the section on ethics in telepresence.

Declaration of Competing Interest

RW and TJP are directors and shareholders in the UK company Cyberselves Ltd that develop robotic middleware solutions, including for robot telepresence. TJP is also a director and shareholder of the UK company Consequential Robotics Ltd that develops social and assistive robots. JMR has no competing interests.

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