REALIGN Toolkit: Reflexivity, Adaptability, Leadership, and Inclusion as Pillars of Responsible Research and Innovation

OPEN LETTER

REALIGN Toolkit: Reflexivity, Adaptability, Leadership, and Inclusion as Pillars of Responsible Research and Innovation

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Abstract

While public engagement and interdisciplinary collaborations are now requirements within Responsible Research and Innovation frameworks, a growing body of Science and Technology Studies literature has critiqued how these processes are insufficient on their own and how they often reduce social scientists and humanities scholars' engagement to tokenistic exercises aimed at legitimising and

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accelerating technological adoption. With this Open Letter, we address these limitations. Drawing on our collective experience and expertise as social scientists, humanities scholars, and technology developers, we propose a toolkit to reframe responsibility in research and innovation as a collective and sustained effort.

We argue that it is necessary to move beyond existing RRI approaches and to actively engage with critical, culturally informed, and interdisciplinary practices that acknowledge the layered complexities of innovation ecosystems, the social construction of technology, and the power asymmetries embedded in participatory processes. To achieve this, we offer a conceptual and reflexive toolkit with recommendations for fostering meaningful, continuous, and early-stage engagement with stakeholders that can advance ethically grounded, socially responsive, and culturally situated research and innovation systems. We call this toolkit REALIGN, as it is centred on four pillars: **Re**flexivity, **A**daptability, **L**eadership, and **I**nclusion.

We offer case studies from our projects, situated in East Asia and Western Europe, the regions with the most rapidly ageing populations. There, assistive robotics has emerged as a promising field for addressing socioeconomic challenges generated by this unprecedented demographic shift. Our critical analysis highlights persistent issues such as late-stage and selective public involvement and the marginalisation of vulnerable user groups. We also include examples of participatory design practices aimed at keeping innovation processes context-sensitive and responsive to real-world needs. We conclude that achieving responsible research and innovation approaches requires robust governance structures, interdisciplinary collaborations, and sustained dialogue among funders, scientists, policymakers, and diverse publics.

Plain Language Summary

This letter discusses how to make research and innovation more ethically responsible for societal needs. Several organisations, including major funders like Wellcome, now expect researchers to involve members of the public and to work together across different scientific fields. However, some scholars have raised concerns that these engagement activities are often superficial and used mainly to make and sell new technologies rather than to critically engage with technology development and adoption. In response to these concerns, we introduce a new toolkit, called **REALIGN**, which focuses on four main principles: **Reflexivity** (thinking carefully about the wider impacts of research and innovation, including through e.g., tackling unconscious biases); **Adaptability** (remaining flexible and open to change in response to evolving societal needs and technological advancements); **Leadership** (creating clear rules and shared responsibilities); and **Inclusion** (involving a wide range of people, especially those often marginalised and excluded in research

and innovation).

Drawing on our diverse research and experiences, we offer three real-life examples of technologies designed to help people with frailty, including individuals with disabilities, and other vulnerable populations. These are set in Western Europe and East Asia—regions facing major social and economic challenges related to rapidly ageing populations. These examples reveal common problems, such as involving the public too late in the innovation process and ignoring the needs of vulnerable groups. They also show positive examples of technologies codeveloped with the target group. Based on these findings, we offer recommendations to ensure key stakeholders are meaningfully involved from the very start of research and development, and that their input can shape the direction of innovation. As such, REALIGN offers a reflective toolkit for those involved in innovation to help ensure that new technologies are developed in ways that are fair, thoughtful, and truly useful to the people they are meant to serve.

Keywords
Responsible Research and Innovation; Risk Governance; Techno-politics of Innovation; Care Robotics; Social Science and Humanities; Human-Robot Interaction; Interdisciplinarity; Participatory Design

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This Open Letter contributes to ongoing debates on Responsible Research and Innovation (RRI), a discussion that originated in the early 2010s, with the term increasingly gaining traction in the EU's science policy landscape. Although it has been defined in many ways, a key definition of responsible research and innovation is "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe *et al.*, 2013: 1570). Von Schomberg (2012: 9) describes it as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability, and societal desirability of the innovation process and its marketable products (to allow a proper embedding of scientific and technological advances in our society)."

These debates have played a key role in shaping research and innovation priorities in the European region by supporting efforts aimed at promoting and institutionalising the framework of RRI as outlined by von Schomberg (2013) and Owen *et al.* (2013). Over the past decade, RRI has promoted a cultural shift in research and development by encouraging interventions not at the end of the innovation cycle, but during the 'mid-stream' phase of scientific work. At this early stage, researchers are urged to actively engage with ethical and societal concerns, evaluate the broader implications of their work, and critically examine their own positionality in the process of knowledge creation (Fisher *et al.*, 2006). In the UK, the Wellcome Trust has also taken this direction and refers to responsible research as an 'Engaged Research Approach'. In this context, funders' expectations of involving members of the public in research and innovation have led to several initiatives across the European region and to joint efforts with international collaborators across other regions.

While RRI has become the most influential and widely adopted framework in the European region, elsewhere other frameworks have remained in place. In East Asia, particularly in Japan and South Korea–the countries with the world's most rapidly ageing populations and which have been leading in assistive technologies development–what remains in place is the ELSI framework. The acronym refers to "Ethical, Legal, and Social Issues." ELSI as a concept originated from the Human Genome Project launched in the US in the 1990s. Notably, at that time, the "I" stood for *Implications*, not *Issues*–which has a negative connotation implying issues are problems that need fixes and solutions (Zwart *et al.*, 2014). Whereas in Europe, the concept of ELSI was known as ELSA (with the "A" standing for *Aspects*). The European Commission's Horizon 2020 program, launched in 2013, moved away from ELSI and promoted RRI by making it its central focus, attracting global attention to this new approach (European Commission, 2025). Reacting to this transition and urging Japan to also adopt RRI, in 2020, Atsuo Kishimoto–Director of the University of Osaka Research Center on Ethical, Legal, and Social Issues–stressed that there is growing concern in Japan that humanities and social science scholars, when incorporated into large science and technology programs under the ELSI framework umbrella, risk losing their critical stance. The term "ELSIfication," Kishimoto stresses, was coined by humanities and social science scholars in Japan to problematise this tendency (Kishimoto, 2020).

Over the past five years, critics in Japan have criticised how the ELSI framework assumes that the humanities and social sciences should contribute to research and development primarily to foster adoption, rather than to inform research and innovation responsibly (Mikami *et al.*, 2021). Indeed, under the ELSI umbrella, social scientists and humanities scholars are engaged in the lab only at specific stages to assess risks (a box-ticking exercise) with little input into shaping the broader societal impact of innovations (De Togni, 2024; De Togni, 2025). This reflects a broader trend in governmental and scientific reports in Japan and South Korea of using the ELSI framework to support governmental techno-utopian narratives that promote innovation while overlooking the complex socio-economic and ethical issues that healthcare technologies raise (Wright, 2024).

In parallel, in the European region, a growing body of critique within Science and Technology Studies (STS) has emerged to highlight how, similarly to ELSI, also RRI approaches are still often instrumentalised for technology adoption by technology developers and other key stakeholders, including scientists, policy makers, the industry, and non-profit organisations (Ledingham *et al.*, 2024). This approach risks reducing engagement processes once again to box-ticking exercises and ways to ensure technology adoption rather than informing responsible innovation practices (Joly, 2015). In such a complex and problematic context, Irwin *et al.* (2013: 120) have highlighted the need to pay attention to navigating "the varieties of engagement that are very much less than perfect but still somehow 'good'." To help maximise what is 'good' in the imperfect landscape of innovation, where different actors have different drives and priorities, we argue that what is needed is continuous and engaged dialogue and combined efforts. Towards this goal, in what follows, we outline some of the key challenges we identified and our recommendations to tackle these.

We are a multidisciplinary group of social scientists, humanities scholars, and technology developers based in the UK, Norway, Germany, Japan and South Korea. We connected through a project fully funded by the **Wellcome Trust [223540/Z/21/Z]** and led by the corresponding author of this letter. Our first collective gathering was the *Caring Machines Symposium*, funded as part of this project and held in person in Edinburgh in December 2024. The two-day event brought together 70 attendees from the fields of robotics and STS. It combined presentations with interactive workshops and a final reflexive session to develop our ideas on what responsible innovation means and how to enable it. Drawing on our diverse expertise, experiences and past research projects, we discussed how to help ensure responsible research and innovation in assistive robotics. We focused on the contexts of Western

Europe and East Asia, where we are based for our work. These fruitful conversations led to conceptualising the REALIGN toolkit and writing this Open Letter. To achieve this, after the *Caring Machines Symposium*, between January and October 2025, we regularly met online (in total six one-hour-long sessions) while working in parallel on this letter. We hope our recommendations can guide scholars like us–both technology developers and humanities and social science scholars–to implement more inclusive, fairer and ethically acceptable approaches to research and innovation.

Drawing on our sustained conversations, we first want to acknowledge that there is an urgent need for research and innovation to prompt new discussions about research integrity, the potential (and limits) of interdisciplinary research, and the division of tasks and responsibilities throughout the innovation lifecycle. Our discussion re-ignites long-standing debates about the role and responsibilities of scientists in knowledge production and their broader moral responsibilities to society, including public expectations around scientists generating a positive impact through their work. As technology has the potential to produce both benefits and harms, these roles (knowledge production *and* positive impact) are often seen as conflicting. Over the past three decades, rapid technological advancements in AI and robotics have broadened discourses on scientists' moral responsibility (Beck, 1992; Groves, 2006). Scientists' ideas of research integrity have also evolved in response to societal concerns and pressing research agendas (Mitcham, 2003; Steneck, 2006).

Within these complex debates, STS literature has particularly highlighted how science and technology are always socially and politically constructed, and how they generate narratives of hope, hype, risk, and uncertainty that are often misleading (Jasanoff, 2015). Governance practices determine who decides which risks matter and how to address them, yet context-specific politics of innovation are also socially and politically constructed. Winner addressed this idea that innovation and technological design are inherently political across multiple works, including in his widely cited essay "Do Artifacts Have Politics?" (1980). In this essay, he pointed out that technological artefacts (machines, structures, and systems) can embody authority, power relations, and political designs. Several STS scholars have built on this idea over the past four decades and referred to the interrelated relationship of power and politics in science and innovation processes; including, for example, Lipp (2019), who uses the concept of the "technopolitics of innovation" to refer to the interconnection of robotics and care as the product of a wide range of political, technological, and social processes, specifically in the European context. In his work, Lipp (2022) has explored how roboticists navigate the striking discrepancy between the vision and the demonstration of care with robots. He introduced the concept of "robot dramas"—experimental, performative practices that both stage idealised visions of care robotics and expose the fragile realities of human–robot interaction, linking research on techno-scientific demonstrations with studies of expectations in science and technology. This is a powerful metaphor that problematises the role and responsibilities of scientists in innovation processes.

Under the influence of the technopolitics of innovation, risk governance has often failed to manage the harms of new technologies, partly by overlooking precautionary warnings of potential long-term harms or by selectively dismissing certain risks as irrelevant (Hoffmann-Riem & Wynne, 2002). Referring to this problem, Callon *et al.* (2009) use the metaphor of science and technology 'overflowing' the boundaries of existing institutional frameworks for scientific regulation, destabilising the strict framing of what technology "should be." Emerging technologies frequently fall into what Hajer (2003) terms an "institutional void," where few agreed-upon structures and regulations exist to govern them. To address this regulatory gap, several initiatives from within STS have sought to embed ethical reflection into the scientific and innovation process, including through the creation of more democratic spaces for 'public dialogue' (Irwin, 2006). This trend has argued that scientists, research funders, the industry, and other key stakeholders share a "collective responsibility" (Grinbaum & Groves, 2013) to ensure that innovation generates positive societal impacts. However, as Beck observed twenty-five years ago—and as remains relevant today—the complex system of science and innovation creates a form of "organised irresponsibility" (Beck, 2000). This means that, although individual actors may not be irresponsible per se, the complexity of the innovation system itself makes it particularly challenging to organise responsibility throughout the innovation lifecycle. Recognising this major challenge, and drawing on our own experiences, we invite a reframing of responsibility that accounts for the layered complexities inherent in science and innovation processes. We argue that the involvement of funders is essential for this to happen.

In what follows, we identify key issues with dominant approaches to responsible research and innovation (RRI and ELSI) and offer our reflexive recommendations through the toolkit we created, REALIGN. We provide practical suggestions to develop context-specific, critical, interdisciplinary, and culturally informed frameworks that realign with these key pillars of responsible research and innovation. Drawing on our experiences of care innovation-in-the-making, we then offer three case studies from our research projects in 'robot hotspots' in Western Europe and East Asia to critically reflect on these context-specific processes of research and innovation. We conclude with reflections on how our proposed toolkit REALIGN might be taken forward to nurture novel, transformative and impactful interdisciplinary collaborations that help ensure that the 'responsible' in responsible innovation is meaningfully upheld throughout the lifecycle of a technology.

REALIGN: Identified issues and recommendations

Jakobsen *et al.* (2019) point out how RRI is often limited by its top-down, principle-based approach and insufficient attention to how responsibility is practised in real contexts. One of the limitations of RRI frameworks is, indeed, that they tend to be too abstract and vague with respect to the political, cultural and socio-economic contexts and practices of application. To avoid reproducing the same pitfalls, we focus specifically on assistive technologies within selected contexts for our analysis. In particular, we look at Socially Assistive Robots

(SARs) and our three case studies respectively focus on: 1) small and soft, child-looking robotic devices that provide companionship to older adults living alone while monitoring their vitals and feeding back information to care workers (*Hyodol* in South Korea); 2) telepresence robots remotely operated by people with physical and cognitive disabilities to enable them to work and reconnect with wider society (*OriHime* in Japan); and 3) the initiative eVITA, a collaboration between the EU and Japan focused on using assistive technologies for active ageing.

Through our analysis, we engage critically with innovation processes that are propelled by the current AI hype and so-called 'AI hallucinations' (Förster & Skop, 2025). We problematise the call for technologies to 'rescue' humanity in the face of ageing societies and shortages of care workers in a globally underfunded healthcare sector. In this context, there is an urgent need for what Fortun (2005) describes as 'an ethics of promising' — in other words, to disentangle present hype from future realities (Brown, 2003). One way to address this need has been to explore opportunities for public engagement in research and development, generating more realistic discussions about possible and desirable futures, and co-designing technologies with specific populations, including people with long-term care conditions. For example, Bennett *et al.* (2023) focus on the implications of designing data-driven technologies for the management of long-term conditions. These practices have the potential to open novel, creative and powerful ways to enrich and democratise thinking about the future. However, participatory practices may not be enough on their own; to address current limitations and ensure that research and innovation practices become more robust and responsible, we propose the REALIGN objectives.

Reflexivity, Adaptability, Leadership, and Inclusion are the four pillars that the author group, through sustained interdisciplinary discussions, has identified to conceptualise the REALIGN toolkit. We argue that a framework for responsible research and innovation should address these four objectives adequately. The path to achieving this, we argue, lies in adopting a critical, interdisciplinary, and culturally informed approach that acknowledges the aforementioned challenges while fostering and sustaining collaborative cultures among funders, technology developers, social science and humanities scholars, members of the public, and policy makers. We stress that funders have a vital role in enabling this transformation by supporting and incentivising such collaborative and inclusive practices—turning responsible research and innovation from a normative ideal into an operational practice. In what follows, we outline each of the pillars, followed by our key recommendations.

Reflexivity

In social theory, "reflexivity" refers to the process by which a researcher or a group of researchers critically examine their own beliefs, assumptions, social position, and experiences, and consider how these factors influence the research process—from design to the interpretation of findings (Lumsden, 2019). Through our sustained discussion, we identified a strong need for reflexivity throughout the entire innovation process. This, in our projects on SARs, applies to anticipating unintended consequences, understanding socio-cultural and political contexts, and ensuring that innovation processes remain both context-sensitive and responsive to real-world needs. While this is a common approach in qualitative research, this is not a new idea in quantitative research either; Schuurbiers (2011: 769), among others, highlighted the importance of "reflections of natural scientists on the socio-ethical contexts of their work." In the context of SARs, one way technology developers have started to reflect on the socio-ethical contexts of their work is through participatory practices, including public engagement and coproduction activities.

While public engagement is often top-down knowledge communication, with little emphasis on reflexivity, coproduction in RRI frameworks has been praised as a key approach to ensure inclusivity. However, research has shown how processes of coproduction have important limitations: scholars have highlighted how unconscious biases impact research practices and the need for critical engagement with these biases (Möller *et al.*, 2024); and how participatory models in healthcare coproduction can be influenced by power imbalances, affecting the inclusivity and outcomes of such initiatives (Lumsden, 2025). Questions to consider include: Who gets to decide who is worth listening to (and who is not)? Who determines which questions are worth asking (and which are not)? And who leads the conversation, steering discussions toward certain goals while neglecting others? As van Oudheusden (2011) stresses, to account for such imbalances, there must be space in participatory approaches for different stakeholders—especially marginalised groups—to question the framing assumptions of participatory processes themselves. This requires early and continuous engagement, including early involvement of target groups in study design, and a willingness to integrate ethical, social, and usability considerations alongside technical ones.

Social scientists and humanities scholars can help make this happen. Working across disciplines, social scientists and humanities scholars can enable communication and meaningful exchange between different stakeholders, including technology developers and members of the public. Importantly, for social scientists and humanities scholars involved in research and innovation, reflexivity is also part of their practice. This is especially important when conducting ethics assessments. The recent 'institutional turn' to AI ethics—with social scientists embedded in labs—has given rise to the 'in-house AI ethicist,' who must navigate ambiguous objectives, conflicts of interest, and epistemological differences (Burema, 2025). Practising AI ethics within institutional contexts presents important challenges to professional identity and research integrity. As the number of technology ethics practitioners grows, scholars in the field of responsible innovation have called for a 'code of conduct' (Vermaas *et al.*, 2025). We strongly support this important call for action. In this environment, researchers and developers alike must reflect on their positionality, address not only safety and privacy but also usability and acceptability, and recognise that innovation is shaped by the techno-politics of its cultural, socio-economic, and political

contexts. Ultimately, this means embedding social science and humanities reflexive expertise throughout the innovation process, ensuring that diverse perspectives help to identify and challenge unconscious biases and keep responsibility at the centre of technological research and development.

However, how does one create space for reflexivity across different fields and stakeholders? Part of the response involves funding and the incentives that underpin innovation. As Wynne (2011) points out, responsibility does not rest with (social and natural) scientists alone. As Wynne (ibid.) highlights, this must be extended to research funders, regulators, and other key actors who shape science and innovation governance. These institutions and individuals share a collective responsibility to examine their research agendas, value systems, and practices. Central to these efforts is the role played by funders in ensuring the material conditions of possibility for meaningful engagement. As others have noted, limited financial and temporal resources–organised around the 'project' model of knowledge production (Smith *et al.*, 2024)–can hinder genuine and long-term stakeholder involvement. Similarly, an emphasis on short-term 'impact' and 'outputs' risks neutralising long-term objectives of responsibility and sustainability. Reflexivity, in this sense, is not only about researchers in a lab identifying concerns and risks, but also about funders and institutions ensuring the conditions of possibility for democratic, pluralistic, and accountable forms of decision-making in innovation processes. As such, reflexivity is a critical and foundational pillar for responsible approaches to research and innovation.

Adaptability

The second pillar we identified is adaptability, which entails the ability to respond to changing societal needs. In robotics innovation, Weiss and Spiel (2022) write about this challenge in their self-reflection as human-robot interaction (HRI) researchers. For research and innovation to be responsible, they must be capable of adjusting to specific socio-economic and cultural contexts, public values, and changing circumstances. This is an ongoing process that spans the entire lifecycle of a technology, from its initial conception and planning throughout development, implementation, adoption, and eventual end of life. We acknowledge that such flexibility is difficult to achieve through co-production alone, particularly if engagement occurs only in the early design phase or at the end of the innovation cycle during testing. We argue that what is needed instead is a longitudinal approach that actively fosters open communication and sustained collaborations among researchers, developers, users, policymakers, and other key stakeholders throughout the innovation lifecycle. As mentioned in the previous section, we recognise the importance of adequate funding in creating and maintaining long-term forms of collaboration and knowledge coproduction.

Adaptability is crucial because research and innovation environments are inherently dynamic and can be unpredictable. Adaptability allows actors to navigate uncertainty and respond to unexpected challenges, such as major disruptions like a pandemic (Rockström *et al.*, 2023). Adaptability also entails a continuous commitment to ensure that innovation creates societal value by remaining responsive to public expectations and by integrating diverse perspectives into the innovation process. For instance, sustainable development requires a systems approach that considers economic, environmental, and socio-ethical factors throughout a technology's lifecycle; however, traditional engineering focuses on stability while often failing to handle unexpected disruptions, whereas resilient design leverages diversity, adaptability, efficiency, and cohesion (Fiksel, 2003).

Overcoming these complex challenges requires deeper engagement with vulnerability contexts and involvement of marginalised groups to ensure responsible research and innovation (Eriksen *et al.*, 2021). Consequently, adaptability can build resilience, enabling innovation itself to sustain value-creating growth in the face of shifting markets and rapid technological change (Morais-Storz *et al.*, 2018). Without adaptability, there is a real risk that research and innovation goals will become misaligned with evolving stakeholder expectations or strategic priorities. Importantly, adaptability also requires commitment from funders. For example, it can be difficult to involve diverse stakeholders at the early stages of research design, conception and planning when no funding is available for such activities. Equally, it may be challenging to sustain stakeholder involvement once the funding period has ended. For example, Morrison *et al.* (2020) examine how the structure and governance of international biomedical research consortia often hinder the goals of RRI, particularly in areas like public engagement, data sharing, and long-term societal responsibility. They (ibid.) argue that standardised, contract-driven frameworks limit researchers' flexibility to respond to stakeholder input, and they call for the need for alternative governance models to better align with RRI principles. We tackle this call through our toolkit.

Fostering adaptability, we argue, depends on nurturing collaborations across disciplines and areas of expertise, supporting training and capacity-building initiatives, and developing skills for adaptive planning, critical reflection, and collaborative engagement. In practice, this means remaining flexible and responsive to feedback, conducting real-world pilot testing with iterative evaluation, and planning for sustained monitoring, maintenance, and repair, recognising that innovation continues well beyond the initial design phase (Wilson *et al.*, 2018). It also involves ensuring that research and practice inform effective policy and regulatory frameworks, while providing accessible training and capacity-building for end users and professionals. Ultimately, fostering adaptability requires embedding RRI principles into funding and governance frameworks that can adjust to changing contexts.

Leadership

Fostering a productive and open dialogue with different stakeholders throughout the innovation lifecycle is a core principle of responsible research and innovation (RRI). Yet,

as Callon *et al.* (2009) point out, the effectiveness of such engagement depends on when and how it occurs: whether publics are consulted early enough in the process to meaningfully shape outcomes, whether diverse groups are truly engaged and represented, rather than tokenistically included, and whether discussions are sustained over time, rather than confined to one-off events. User requirements, in particular, are inherently diverse and can be difficult to capture. Akrich (1992: 207–208) observes that, as a result, designers often end up projecting their own assumptions about competence, motives, and aspirations onto end-users, embedding these visions into artefacts. Even participatory design methods, Akrich notes (1995), while valuable for understanding users and contexts, still raise questions about how competing user perspectives can be reconciled, as well as, as aforementioned, how to take into account imbalanced power dynamics.

To tackle these complex challenges, we argue that in addition to reflexivity and adaptability, strong leadership is essential. Leadership in RRI requires anticipation: the ability to look ahead, identify potential risks and unintended consequences, and critically evaluate the values and goals underpinning innovation (Owen & Pansera, 2019). It demands openness and transparency, making processes, data, and publications accessible to all stakeholders and ensuring that decisions are made openly (Cole *et al.*, 2023). It also requires creating equal opportunities for diverse publics to shape research agendas, as well as upholding research integrity, so that practices align with the highest professional standards. Leadership also entails promoting race and gender equality by striving for balanced representation in research teams and by integrating diverse perspectives into all phases of innovation. This is particularly key in STEM, which is characterised by strong gender and ethnic imbalance. Moreover, in the context of innovation, leadership entails a commitment to strengthening science literacy so that publics are able to engage in informed debate and decision-making (Willis *et al.*, 2014).

Contexts for applying such leadership vary. Within academic and research institutions, strong leadership means cultivating positive cultures of integrity and managing the complexities of research and innovation environments. At a territorial level, it involves applying the RRI paradigm to regional systems to design anticipatory, inclusive, and responsive policies that are culturally sensitive and context-specific. To ensure responsible innovation in practice, leadership must establish clear governance structures and regulatory frameworks that foster ethical, inclusive, and adaptive research systems (Pacifico Silva *et al.*, 2018). This includes a commitment from funders to supporting interdisciplinary collaborations and nurturing long-term partnerships between technology developers, social scientists, policymakers, and local communities.

Inclusion

Inclusion, the fourth pillar, entails the active involvement of diverse stakeholders, especially groups traditionally underrepresented in research and innovation. Inclusion means engaging a wide range of actors throughout the entire research lifecycle, from the earliest stages of conception to the dissemination of findings and deployment of a technology. Inclusion can help ensure societal desirability by aligning research and innovation with public priorities, making outcomes more relevant, and socially and ethically acceptable (Li *et al.*, 2023). It also reduces risk, as the involvement of diverse voices helps to identify and address potential harms more effectively (Novek & Wilkinson, 2017). Applying a critical inclusion lens allows researchers to uncover systemic injustices, incorporate marginalised perspectives, and recognise vulnerabilities that might otherwise be overlooked. By giving all the key actors a seat at the table, inclusion also fosters legitimacy and builds public trust in science and innovation governance. Ultimately, inclusive processes lead to ethically and socially acceptable outcomes: they produce research that is more robust, relevant, and impactful by drawing on varied forms of knowledge and lived experiences (Walmsley *et al.*, 2018).

Implementing inclusion requires a deliberate and critical approach. Researchers can apply an inclusion lens at every stage of the research and innovation lifecycle, from formulating questions to disseminating results, ensuring that all steps are examined for their openness and accessibility. Stakeholder engagement can move beyond consultation and involve meaningful participation, e.g., by using participatory and codesign methods that can enable stakeholders to shape research and innovation directions. Targeted involvement of individuals and communities is vital, as their insights provide grounded knowledge that can transform both research design and outcomes. Throughout, maintaining open and transparent communication is key to sustaining public trust. The flexible toolkit we propose can guide this integration of inclusion across disciplines and contexts.

Examples of successful inclusive practices we adopted in our research included organising public dialogues and participatory workshops to open up innovation processes; involving civil society organisations, user groups, and lay citizens in shaping research agendas; making research outputs accessible by translating materials into multiple languages and accessible formats; and listening attentively to those most affected by innovation to ensure their needs are prioritised. For inclusion to be meaningful, research must actively involve diverse stakeholders at every stage, with particular attention to accessibility, affordability, inclusivity, and sustainability. This involves engaging publics early and continuously through interactive and creative methods, while fostering open, ongoing collaboration between researchers, technology developers, users, policymakers, and other key actors. Once again, funders have a responsibility in requesting and enabling such approaches.

REALIGN toolkit

In Table 1, we summarise the key recommendations emerging from the conceptual toolkit we propose.

Table 1.

REALIGN objectives	Recommended Actions
Reflexivity	• Critically reflect on assumptions, values, and decisions throughout the research and innovation processes. • Integrate practical, ethical and social considerations at every stage of technology development (innovation *lifecycle*). • Anticipate potential risks, unintended consequences, and societal impacts (culturally sensitive and context-informed innovation practices). • Address not just technical and ethical challenges (e.g., safety and privacy) but also usability, acceptability, and effectiveness. • Understand the cultural, socio-economic, and political contexts where the technology will be implemented (*technopolitics of innovation*). • Include social scientists and humanities scholars throughout the innovation process to help identify and challenge unconscious bias of developers.
Adaptability	• Remain flexible and responsive to feedback and adapt to changing needs and contexts. • Conduct real-world pilot testing and iterative evaluations, gathering feedback for refinement. • Acknowledge that innovation continues beyond initial design and plan for sustained monitoring and improvement, including maintenance and repair. • Actively influence and inform through our work the development of effective policy and regulatory frameworks. • Provide adequate and accessible training and capacity-building for end-users and professionals.
Leadership	• Establish clear governance structures and regulatory frameworks to create an organised and responsible innovation system. • Effective and collaborative leadership to support ethical, reflexive, inclusive, and adaptable practices at all stages of the innovation process. • Champion interdisciplinary collaborations and sustain cultures of cooperation between technology developers, social scientists, and local communities. • Advocate for policy development that upholds principles of responsible research and innovation including research integrity and EDI (equality, diversity and inclusion).
Inclusion	• Actively involve diverse stakeholders—especially groups underrepresented in research—in all phases of design, development, and deployment. • Prioritise user needs, accessibility, affordability, inclusivity, and sustainability. • Engage users and other stakeholders early and continuously through participatory methods. To ensure these are accessible and engaging, consider using interactive hands-on activities and creative methods (e.g. storytelling). • Foster open, ongoing communication and collaboration between researchers, technology developers, users, policymakers, and other key stakeholders.

To highlight the practical role of funders, we summarise their contributions using the acronym FUND:

***F**acilitate reflection*: Encourage reflexivity by supporting reflection on societal impacts, assumptions, and potential consequences.

***U**plift adaptability*: Enable flexible project designs, iterative testing, and ongoing improvements to respond to changing contexts.

***N**urture leadership*: Model transparent, accountable, and collaborative governance and encourage the same in research teams.

***D**rive inclusion*: Ensure diverse voices are involved through participatory methods, engagement of underrepresented groups, and continuous stakeholder collaboration.

How to foster and sustain continuous engagement?

We recognise that even when applying reflexivity, adaptability, leadership and inclusion in research and innovation, some challenges still exist. A main point for consideration is how to foster and sustain continuous engagement, in the form of both interdisciplinary collaborations and engagement with target communities. In relation to participatory approaches, involving certain populations in research and innovation processes and, most importantly, keeping them motivated to continue engaging throughout the research and innovation lifecycle is an important first challenge that needs to be considered. As highlighted by Skeie *et al.* (2025), user inclusion in innovation is vital, yet often poorly executed, especially in the case of vulnerable groups. In addition to compensating participants adequately, which requires support from funders, Skeie *et al.* (ibid.) recommend prioritising motivation as an essential component for effectively including vulnerable groups

in innovation. A question that needs to be tackled is, then, what research and innovation can offer to these populations to engage them more effectively.

Research has emphasised the challenges of sustaining long-term participant engagement and the importance of careful participant selection (Akasaka *et al.*, 2022; Bridi *et al.*, 2022; Ogonowski *et al.*, 2013). A key issue that has been identified in the literature is that users are often engaged only in the later stages of innovation, responding to nearly completed products that offer little opportunity for substantial change (Knight-Davidson *et al.*, 2020; Silva *et al.*, 2019). Instead, key stakeholders should be involved early in the process and given the power to influence the research direction over the course of innovation (White & Langenheim, 2021). Towards the goal of achieving continuous and meaningful engagement, several studies have identified practical factors related to participation that influence users' motivation when a technology is involved (e.g., Antikainen *et al.*, 2010; Füller *et al.*, 2009; Georges *et al.*, 2015). Users appear to be driven by personal interests, a desire to contribute and feel useful, curiosity about emerging technologies, and learning opportunities (Lievens *et al.*, 2014; Nov *et al.*, 2011; Ståhlbröst & Bergvall-Kåreborn, 2011). In health- and care-related contexts, particularly, additional motivations include the aspiration to improve treatment, care, and overall quality of life (Engström & Elg, 2015; Jørgensen *et al.*, 2018; Oliveira *et al.*, 2015; Span *et al.*, 2018). Trust and trustworthiness are also essential to sustaining participant engagement in clinical and technological research and innovation (Blom *et al.*, 2025; Goisauf *et al.*, 2025; Stamm *et al.*, 2025). Ensuring meaningful participation therefore requires a human-centred, relational approach to building trust by engaging users and keeping them informed while avoiding extractivist research practices (Chagnon *et al.*, 2022; Kellmeyer, 2024).

In the next section, we move to our three case studies to show how a critical, interdisciplinary, and culturally informed framework can help sustain meaningful and continuous engagement. For responsible research and innovation to take place, these must be situated within the specific political economy of science and governance that considers both products and purposes (Stilgoe *et al.*, 2013: 1572). In Western Europe and East Asia, where our projects are based, there is a rapidly growing policy interest in addressing so-called 'societal grand challenges' (Lund Declaration, 2009). In our case studies of assistive technologies, the primary grand challenge is tackling a global healthcare crisis. Discourses around technologies 'rescuing' ageing societies are particularly prominent in Japan and South Korea, which have some of the world's most rapidly ageing populations and are also global leaders in the development of assistive technologies (De Togni & Wright, 2024). In this context, one proposed solution is the development of intelligent and semi- or autonomous robotic systems to support ageing populations and people with long-term conditions in living independently. The following three case studies critically examine assistive technologies developed and deployed in these contexts, specifically SARs.

Case studies: assistive technologies

While developing the REALIGN toolkit described above, we had the opportunity to critically reflect on our ongoing and past projects, all of which focus on SARs or robotics technologies for the care sector. This reflective process allowed us to deepen our thinking about the approaches adopted in these projects and to consider what worked well and what could be improved to better uphold the principles of responsible research and innovation that we have identified. In this section, we provide a reflexive overview of three case studies selected from our projects, situating them within their broader socio-political contexts and the governance arrangements in place. To inform the discussion, we share the key takeaways from these experiences.

Case study 1: East Asia - Japan (Robot Avatar café)

Context: The telepresence robot *OriHime* was developed in 2012 to connect socially isolated people with society. This includes people with chronic illnesses, physical disabilities, and neurodivergent individuals with difficulties leaving their homes. The small stationary *OriHime* robot features a camera on its forehead, a microphone and speaker, and wing-like arms to gesture and express emotions. Initially, *OriHime* was marketed as a device for personal use; for example, for homebound individuals to accompany their family and friends to events, or for hospitalised students to participate in the classroom through the robot and stay socially connected with their peers. Since 2018, the usage has been extended to remote work. In cooperation with disabled individuals, a 120 cm mobile OriHime-D was also developed and is utilised in a café in Tokyo (Figure 1) to serve guests remotely.

Reflexivity: Since *OriHime* was developed for bedridden or hospitalised people, it does not display the operator to protect their privacy. To enable easy usage, the interface is intuitive and available as a tablet or smartphone application. Although *OriHime-D* is not offered for purchase or rental, rental plans are available for the small *OriHime* version. Since 2023, it has also been available for purchase, along with various repair and support plans provided by the technology developer, the Ory Laboratory. However, structures still need to be established to grant equal access, for example, through educational board regulations and affordable budgets for funding avatar technologies in the nationwide school context across Japan (Spoden & Ema, 2024).

Adaptability: The technology is continuously adapted to accommodate users' needs; for instance, gaze control has been integrated into the interface to enhance accessibility. Additionally, experienced operators serve as mentors for novices and contribute their ideas for improvements. The Ory Laboratory is open to new collaborations and experiments with fields of application, such as *OriHime* receptionists at local administrations or internship programs for students with disabilities in the café in Tokyo.

Leadership: Whether *OriHime* fosters community and inclusion depends on how it is and will be integrated into broader sociotechnical systems. Engaging policymakers and establishing appropriate regulations–to adequately protect the interests of

Figure 1. Photo of OriHime avatar robots, taken by Celia Spoden at the Avatar Robot Café DAWN ver.β. located in Tokyo, Nihonbashi. The café allows people with disabilities or mobility issues to remotely control OriHime avatar robots to serve customers, offering a unique and inclusive experience with coffee, food, and real-time interaction with the remote operators.

users and ensure that technologies remain an additional option and do not replace efforts to build barrier-free environments–is crucial.

Inclusion: From the outset, the Ory Laboratory has collaborated with individuals living with chronic illnesses or disabilities who may benefit from *OriHime* and are interested in further developing or adapting the technology for new use cases. In addition, the café in Tokyo serves as an experimental space for engaging with the public, as well as interested companies, scientists, and politicians on both a national and international scale.

Case study 2: East Asia - South Korea (Hyodol)

Context: *Hyodol* is a stuffed doll-shaped robot that has the appearance of a young boy or girl (Figure 2). As of November 2025, more than 12,000 units of *Hyodol* have been deployed in the homes of older adults who live alone in South Korea. It provides reminders for routine activities such as wake-up, meals, and medications, and offers entertainment programs including home fitness, religious chants, and dementia-prevention quizzes. The robot comes with a smartphone application and a web-based monitoring system, which enable caregivers to configure the robot's settings and track human-robot interactions. Most elderly users receive *Hyodol* robots via public eldercare programs

Figure 2. Photo of Hyodol, taken by Chihyung Jeon. As of November 2025, over 12,000 Hyodol robots have been deployed to elderly people living alone across South Korea, primarily distributed through government and public welfare programs. Around 1,000 more have been purchased directly by families.

run by local municipalities, regional welfare and healthcare centres. These eldercare institutions purchase the robots and allocate them to older adults. Care practitioners affiliated with the institutions become responsible for implementing the *Hyodol* program, ensuring that older adults make the most of the robots (Shin & Jeon, 2024).

Reflexivity: *Hyodol* is framed as a "robot grandchild," which reflects the Korean emic value of *Hyo* (filial piety) that has long shaped the cultural meaning of caregiving in South Korea and other East Asian countries. While this framing helps the robot gain traction among the users, one could criticise it for relying on a familialist logic within the state-led care system and raise a question of whether technical objects should be made to embody kinship. Developers and welfare institutions often focus on immediate policy goals (e.g., addressing loneliness or expanding care capacity) without fully reflecting on long-term ethical and societal implications.

Adaptability: Integrating robots into eldercare programs is never straightforward. Communication failures, technical glitches, and older users' inexperience and/or disinterest hinder sustained use of the robot. It takes more than a sophisticated design for the robot to remain appealing and useful in the real world. It is noteworthy that care practitioners from welfare centres often repurpose *Hyodol* beyond its intended use by organising educational sessions, fashion shows, or drawing contests with the robot as a centrepiece. These improvisations show that adaptability is critical not only for developers who must design systems open to continual revision, but also for practitioners who must reinvent ways to keep the technology relevant in caregiving contexts.

Leadership: The nationwide *Hyodol* program illustrates the risks of fragmented governance. Welfare centres distribute robots while caregivers manage daily use, yet no clear

structure defines who is responsible for long-term maintenance, retrieval, or data management. When the two-year contract between welfare centres and the company ends, older adults may lose access suddenly if the robot is recalled or stops functioning. More responsible leadership and governance are necessary to embed assistive technologies into sustainable innovation and welfare systems.

Inclusion: Hyodol's distribution relies heavily on government subsidy. Municipalities and welfare centres select older adults whom they believe would benefit from interacting with Hyodol. The user group thus selected tends to include those who are living alone or are socially withdrawn, often with mild depression and low income. If implemented with care and caution, the Hyodol program can be an experiment for social inclusion with a care technology.

Case study 3: EU–Japan case (the e-VITA Virtual Coach)

Context: The e-VITA project (www.e-vita.coach/homepage), funded as part of Horizon 2020, was a collaboration between the EU (France, Germany and Italy) and Japan focused on Active and Healthy Ageing (AHA). Its overarching goals were to enhance older adults' well-being across cognition, mobility, social interaction, and spirituality, and to enable them to manage health and daily activities through novel robot and sensor technology.

Reflexivity: At the centre of the project is the e-VITA Coaching System, built around a dialogue system that combines Generative AI, RASA dialogue architecture, and the RAG framework. This hybrid approach aims to connect technological innovation with practical coaching applications. The RAG framework emphasises trustworthy and reliable coaching—delivering accurate information on exercise, sleep, nutrition, and spirituality, while supporting older adults in daily activities. As Generative AI and social robots have now gained prominence, the project raises broader questions about multimodal interaction, trust, and the future of human–AI collaboration. Key concerns included cross-border data security, reliability of information, and stability of interaction strategies.

Adaptability: The system was deployed in pilot sites and living labs across countries, offering personalised services through robots, holograms, androids, and digital notepads. Environmental and wearable sensors supported context-aware, adaptive coaching within smart homes. Acknowledging individual differences, the project stressed the need for multidisciplinary approaches to personalisation. The Dialogue Manager that was created as part of this project drew on Motivational Coaching, encouraging users to reflect on behaviour and adopt positive lifestyle changes. Coaching covered physical activity, sleep, and nutrition, tailoring adaptability responses to user profiles that included cultural background, individual interests and hobbies, and readiness for change. By carefully aligning topics with interests and routines, the coach fostered tailored engagement. The system also supported multilingual conversations, addressing challenges of language, politeness norms, and intercultural coaching strategies to build public trust.

Leadership: Designed for smart living environments, the coach integrated diverse devices and sensors. However, ensuring interoperability of components and protecting privacy, especially for sensitive topics related to health or public interactions, were major challenges. Careful standardisation was highlighted as key for system evaluation and further development. While energy-related sustainability of Generative AI models was rarely discussed, the project drew attention to *social sustainability*: ensuring access to AI through leasing options for affordability. It also called for educational initiatives to support older adults and their families, towards boosting confidence in the potential of new technologies that are developed responsibly.

Inclusion: Stakeholder collaboration involved technical experts, gerontologists, nurses, community actors, and older adults themselves. Reflecting the scale and ambition of this international, multidisciplinary, multi-sited and multiparty project, the findings underscored the need for more attention to user-centred design to ensure responsible innovation and accessibility of care technologies.

Conclusive remarks

We hold that moving beyond existing RRI approaches is necessary to actively engage with critical, culturally informed, and interdisciplinary practices that acknowledge the layered complexities of innovation ecosystems, the social construction of a technology, and power asymmetries embedded in participatory processes. To support this endeavour, we offer a conceptual and reflexive toolkit—REALIGN—which is centred on four pillars: Reflexivity, Adaptability, Leadership, and Inclusion. This toolkit provides practical recommendations for fostering meaningful, continuous, and early-stage engagement with stakeholders, advancing ethically grounded, socially responsive, and culturally situated research and innovation systems.

We argue that creating a framework for responsible research and innovation requires thoughtfully and actively integrating ethical, social, and practical considerations throughout every stage of technology research and development. Such a framework should prioritise user needs, ensure accessibility and affordability, and foster inclusivity. Key elements include anticipating potential risks and societal consequences, critically reflecting on assumptions and decisions, and actively involving diverse stakeholders—particularly underrepresented groups—throughout the innovation process. Flexibility and responsiveness to feedback and evolving contexts are also essential. Practical measures to ensure this include early and continuous stakeholder engagement, real-world pilot testing that is context-aware and culturally sensitive, capacity building, and the development of supportive policies and regulations. By adopting this comprehensive approach, care technologies can deliver meaningful, equitable, and responsible solutions that enhance the quality of care for those who rely on them.

Our experience, supported by extensive and diverse prior research, shows that addressing these key challenges requires more than user-centred design alone. Participatory design and coproduction can help prioritise the needs, preferences, and

lived experiences of individuals who will use—and hopefully benefit from—assistive technologies. However, outcomes, both positive and negative, also depend on how a device is used across different contexts, by different actors, and for varied purposes. These factors can be unpredictable if the context in which technologies are created is not properly understood. This underscores the importance of recognising the cultural, socio-economic, and political environments in which a technology is developed and deployed. Moreover, coproduction is not infallible; research has shown that it can embed biases. Designers often unintentionally impose assumptions about users, their activities, and priorities into a technology—assumptions that often misrepresent actual needs.

Social scientists and humanities scholars can play a vital role by working closely with technology developers and end users to identify and challenge such biases. Importantly, innovation does not end with design; it continues as artefacts are implemented, used, and further developed—a process known as *innofusion* (Greenhalgh *et al.*, 2017; Stewart & Williams, 2005). Strategic collaboration with social scientists and humanities scholars working on responsible innovation should therefore be sustained throughout a technology's lifecycle, with continuous engagement with the evolving community of users. How can different actors build a sustainable and feasible framework to support this longitudinal endeavour? By adopting the REALIGN objectives—a toolkit that integrates key principles and practices—researchers and developers can help ensure this endeavour, so that new technologies are designed and used in ways that maximise benefits to end users, minimise risks, and promote inclusive, equitable innovation.

We illustrated our approach with case studies from projects in East Asia and Western Europe, regions with rapidly ageing populations. In these regions, robotics for the care sector has emerged as a promising means to address socioeconomic challenges linked to demographic shifts. Our analysis highlights persistent issues such as the need for stronger governance, data management and privacy, explainability, sustainability, and accessibility. Our case studies problematised these issues in relation to each of the pillars we identified, offering suggestions to tackle these. We concluded that achieving responsible research and innovation requires actively tackling these issues through robust governance structures—including commitment from funding bodies to enable this transformation—interdisciplinary collaboration, and sustained dialogue among funders, scientists, policymakers, and diverse publics. This is outlined in each of the pillars of the REALIGN toolkit we proposed in this letter. Finally, to summarise the role of funders in enabling this, we introduced the acronym *FUND*, which stands for *Facilitate reflection, Uplift adaptability, Nurture leadership, and Drive inclusion*. By actively adopting these roles, funders can help transform research and innovation ecosystems, ensuring that technologies are developed responsibly, inclusively, and in ways that genuinely serve society.

Data (and software) availability

"No data are associated with this article."

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