

Whitepaper Playbook

Longevity — Healthy Aging Assisted by Digital Technologies

German/US Opportunities for Innovation and Collaboration

Einstein-Circle
Berlin, Germany

31/03/2026

ISBN 978-3-945467-18-3

Felix Balzer MD PhD², Dawn I Bershtein³, Katarina Braune MD^{1,2}, Andrew Broderick MA MBA⁵, Pelin Celik PhD⁶, Tabea Flügge DDS⁷, Katherine K Kim PhD MPH MBA^{4,5}, Nils Lahmann PhD MSE^{8,9}, David Lindemann PhD MSW^{4,5}, Stefan Mainka PhD^{3,10}, Mike Martin PhD^{11,12}, Susan Mérillat PhD^{11,12}, Jörg Pohle PhD¹³, Thorsten Schaaf PhD², Thomas Schildhauer PhD^{3,13}

1. Hasso Plattner Institute for Digital Engineering, University of Potsdam, Potsdam, Germany
2. Institute of Medical Informatics, Charité – Universitätsmedizin Berlin, Berlin, Germany
3. Berlin University of the Arts, Berlin, Germany
4. University of California Davis, Davis, CA, United States
5. CITRIS Health, University of California, Berkeley, CA, United States
6. University of Applied Sciences (HTW Berlin), Berlin, Germany
7. Department of Oral and Maxillofacial Surgery, Charité – Universitätsmedizin Berlin, Berlin, Germany
8. Department of Geriatrics and Medical Gerontology, Charité – Universitätsmedizin Berlin, Berlin, Germany
9. Faculty of Natural Sciences, MSB Medical School Berlin, Berlin, Germany
10. Movement Disorder Clinic, Beelitz-Heilstätten, Germany
11. Department of Psychology, University of Zurich, Zurich, Switzerland
12. Healthy Longevity Center, University of Zurich, Zurich, Switzerland
13. Alexander von Humboldt Institute for Internet and Society (HIIG), Berlin, Germany

Table of Contents

Chapter 1: Introduction & Methodological Approach of the Einstein Circle.....	3
Chapter 2: Current Situation of digital health and digital care in Germany and Berlin.....	8
2.1 Demographic and care context.....	8
2.2 Digital health and technical landscape.....	10
2.3 Legal, ethical and regulatory framework.....	13
2.4 Why Berlin/Brandenburg is relevant.....	16
Chapter 3: Thematic Snapshots and Case Illustrations.....	18
3.1 Digital care models and clinical collaboration.....	18
3.2 Living Labs and Real World Environments.....	21
3.3 Participatory Design, therapy and user experience.....	25
3.4 International collaboration and research exchange.....	31
Chapter 4: Recommendations for Future Research.....	35
4.1 For designers, foundations and funders.....	35
4.2 For research groups / future circles.....	36
4.3 For practice partners, care workers, and networks.....	36
References.....	38
APPENDIX A: Process Reflection.....	41
APPENDIX B: The Position Paper's Publication Process.....	46
Attachment A: The Position Paper.....	48

Chapter 1: Introduction & Methodological Approach of the Einstein Circle

This Whitepaper Playbook has a dual purpose. It documents the work of the Einstein Circle “*Longevity – Healthy Ageing Assisted by Digital Technologies*” and, at the same time, it serves as an implementation guide for future initiatives. The focus is not only on our findings, but also on the way we organised ourselves, refined our goals, and linked conceptual work with concrete examples and collaborations. We hope that foundations and organisations (including, but not limited to, the Einstein Foundation) can use this as a reference when designing similar formats.

Background and link to the Position Paper

Rapid population ageing is one of the central health and societal challenges of the twenty-first century. Digital technologies are increasingly used to support older adults, but their development and deployment are often fragmented, unevenly accessible and not consistently guided by ethical and legal standards. In its Position Paper, the Einstein Circle therefore set out a coherent policy-oriented agenda for healthy longevity, based on the interdisciplinary work of the group.

Drawing on literature, expert deliberation and practical examples, the Circle developed a conceptual framework with seven interrelated domains: medical, technical, practical, interactive, psycho-social, ethical and legal. Taken together, these domains highlight the need to reframe health and ageing policy around functional ability and healthspan, rather than focusing only on individual diseases, and to embed equity and participation throughout the design and governance of digital health systems.

The Position Paper argues that digital technologies can extend preventive and personalised care, support independence and enable participation across the life course. At the same time, it shows that the benefits of such technologies are not distributed equally. Gaps in digital access, usability and representation in data and design mean that some older people are much better served than others. Policies and practice must therefore ensure that technologies respect human rights, protect autonomy and strengthen – rather than replace – social relationships and professional care.

To realise this potential, the Circle identified several key conditions: investment in interoperable infrastructures, participatory and user-centred design processes, and robust ethical and legal safeguards. Cross-sector collaboration and transparent governance are essential so that digital health contributes not only to longer lives, but also to maintaining the capabilities and social participation that make those added years meaningful.

This Whitepaper Playbook builds directly on that Position Paper. While the Position Paper formulates an overarching conceptual and policy agenda, the Playbook takes a more practical, report-style perspective. It documents how the Circle organised its work, which examples and case studies were used, which challenges were encountered and which recommendations can be derived for foundations and research groups that wish to support similar initiatives in the field of healthy longevity.

Our Methodological Approach

At the beginning of the reporting period, the Circle agreed on healthy longevity as its overarching theme. From the outset we decided to adopt a user-oriented and impact-based perspective. Rather than starting from technologies or institutions, we took the standpoint of older adults themselves and looked at how digital tools affect their everyday lives, their relationships with family and friends, and their possibilities for participation in community and society. This decision reflects our shared impression that the user is often a “blind spot” in research and innovation: technologies are frequently evaluated in terms of technical performance or system-level efficiency, while the lived experience and social context of older adults remain secondary.

To give this focus a more concrete shape, we formulated a small set of guiding aims. We wanted to harness knowledge and accumulated experience in a way that benefits society, to ensure that promising innovations are accessible and usable for different groups of older people, and to strengthen quality of life by supporting engagement with family, friends and the wider community. These aims were not treated as rigid objectives but as reference points that we returned to whenever we had to make strategic decisions about priorities or outputs. For future circles, we would recommend a similar exercise: defining a shared thematic focus, explicitly naming whose perspective is underrepresented, and translating this into a concise set of guiding aims.

Because the topic is broad and touches many disciplines, we structured our work into three thematic subgroups: (1) Technology Development and Usability, (2) Social Sciences, Ethics, and Policy, and (3) Longevity and Broader Impacts. A fourth subgroup on predictive analytics and monitoring was initially discussed, but we eventually decided to treat this as a cross-cutting theme embedded in all three groups. This reflects our view that data, prediction and monitoring are not niche topics but relevant across the entire spectrum of healthy longevity. The subgroup structure allowed members to focus more deeply on specific dimensions, while still contributing to a shared overall agenda. At the same time, we learned that subgroups must be kept manageable: when groups become too small or participation is irregular, meaningful work becomes difficult. We therefore recommend limiting the number of subgroups and

ensuring that each has a critical mass of active members, while cross-cutting issues are clearly assigned as shared responsibilities.

Our work proceeded in an iterative way. In the first phase, the subgroups explored their themes, collected case studies, examples and questions, and mapped out the relevant concepts. Over time it became clear that, to hold these different strands together, we needed a stronger conceptual backbone. This led to an important decision: to prioritise the development of a Position Paper as an intermediate product before concentrating on the more practice-oriented Whitepaper Playbook. The Position Paper allowed us to articulate a shared framework for digital health and healthy longevity, to define domains such as medical, technical, practical, psycho-social, ethical and legal aspects, and to formulate common recommendations. Methodologically, this step proved valuable because it gave us a stable reference for further work. For other groups, we consider it useful to plan at least one conceptual output – whether a position paper, framework document or consensus statement – that can anchor later implementation-oriented activities.

The Circle combined online and in-person meeting formats. Regular online meetings were used for coordination, presentation of ongoing work and editorial discussions. In addition, we held an in-person meeting in Berlin, which brought together partners from Berlin/Brandenburg and UC Berkeley. This meeting helped strengthen collaboration between Berlin institutions (such as UdK, Charité and the Weizenbaum Institute) and international partners. It also allowed us to discuss the structure and purpose of the Whitepaper Playbook in more depth and to share case studies face to face. Throughout the year, we invited members and guests to present their ongoing research and teaching projects, including student work in areas such as music therapy, design and occupational therapy. These presentations were not an add-on, but a core part of our method: they grounded our discussions in concrete examples and ensured that early-career researchers were visible and involved.

To support collaboration between meetings, we relied on simple, widely available tools: shared online documents for drafting texts, and a Miro board for collecting ideas, sketching structures and voting on options. This combination of synchronous and asynchronous work made it easier to continue progress even when not everyone could be present at the same time. For future circles, we would recommend a similarly mixed format: a small number of strategically placed in-person meetings, regular online sessions, and shared digital workspaces that are accessible to all members.

A distinctive feature of our approach was the systematic use of case studies and best practices. We did not restrict ourselves to abstract debates about “digital health” or “AI in ageing”. Instead, we collected and discussed concrete examples: Living Labs and real-world test environments, pilot projects on home-based

care, music- and design-based interventions for older people, and ongoing work on digital health equity. We also examined models from other contexts, especially the United States, and asked how elements of these experiences could be transferred or adapted to Berlin and the wider German setting. Across all these cases, we tried to pay attention to the perspective of individual users, the working realities of care professionals, and the organisational and structural conditions required for implementation. For us, case studies became a form of “data” that informed our conceptual work and our recommendations.

In parallel, we actively sought to strengthen Berlin as a research location through international collaboration. The involvement of partners from UC Berkeley was central to this, and the Circle served as a platform for discussing future exchanges and joint projects. One concrete result is a planned nine-month research stay of a Berlin-based PhD student in a lab at UC Berkeley, supported by a DAAD scholarship. Beyond this example, we considered research exchanges in both directions as an important component of a methodological approach that aims to compare systems, learn from different regulatory and cultural contexts, and create long-term cooperation. We would therefore recommend that foundations and future circles explicitly include mobility and exchange elements in their planning, even if only for a small number of participants.

The Whitepaper Playbook that this text introduces builds directly on the process described above. The Position Paper provided the conceptual framework and clarified our main arguments. On this basis, we began to formulate outcome-oriented recommendations and to identify where these recommendations are particularly relevant for specific groups – for example older users, family caregivers, professional care workers, practitioners, and decision-makers in funding and policy. Methodologically, we consider this continuous “re-centering” on concrete groups of people to be one of the most important elements of our approach and recommend that future initiatives working on longevity and digital health adopt a similar practice. The present section explains *how* we worked and which elements we consider transferable. The following sections, authored by the subject experts in the Circle, present the current situation in Germany and Berlin, followed by concise thematic snapshots and case illustrations from the Circle’s activities, and a final set of short, concrete recommendations and future perspectives. A more detailed reflection on where the Circle’s work was successful and where it faced challenges is provided in an appendix. This separation is intentional: the main text concentrates on transferable methods, context and examples, while the appendix documents lessons learned from our internal process.

In this way, the Playbook does more than present a set of conclusions. It offers a practical description of a process, with its strengths and limitations, that can be adapted by other foundations, research networks and professional communities interested in digital technologies and healthy longevity.



Figure 1: The seven domains of the Einstein Circle framework for digital technologies and healthy longevity. The framework integrates seven interrelated domains (Medical, Technical, Practical, Interactive, Psycho-Social, Ethical, and Legal) that together define the determinants of healthy ageing in the digital era. Each domain represents a distinct yet interconnected dimension of how technology, care, and society interact to promote functional ability, equity, and well-being across the life course. Credits: P.Celik, 2025.

Chapter 2: Current Situation of digital health and digital care in Germany and Berlin

2.1 Demographic and care context

Germany is undergoing a profound demographic transformation that fundamentally reshapes the conditions under which health and care systems operate. Rising life expectancy, declining birth rates and the ageing of the post-war cohorts are leading to a steadily increasing proportion of older adults in the population. This development is accompanied by a growing prevalence of chronic diseases, multimorbidity and cognitive impairment, as well as by rising numbers of people in need of long-term care. For initiatives concerned with healthy longevity, these demographic dynamics are not background variables; they define the structural challenge to which digital health solutions must respond.

From a medical and epidemiological perspective, the shift from acute to chronic disease patterns is particularly relevant. Cardiovascular diseases, diabetes, neurodegenerative disorders and frailty syndromes require long-term management rather than episodic intervention. At the same time, many older adults live with multiple interacting conditions that complicate treatment pathways and increase the risk of polypharmacy, adverse events and functional decline. In such constellations, the goal of care is not merely disease control but the preservation of functional ability, autonomy and participation. Digital technologies can support this aim, but only if they are embedded in coordinated, longitudinal care models rather than isolated point solutions.

The demographic shift also intersects with structural workforce challenges. Germany already faces shortages in nursing, geriatric medicine and general practice, particularly in rural areas. As the ratio of working-age individuals to older adults continues to decline, the sustainability of traditional care models becomes increasingly fragile. The burden on informal caregivers, often family members, many of whom are themselves ageing, adds another layer of complexity. Digital tools are frequently presented as a response to these shortages; however, their impact depends on whether they genuinely reduce workload, improve coordination and support decision-making, or whether they introduce additional documentation requirements and technical complexity.

Social determinants of health further shape the ageing landscape. Socioeconomic status, educational background, migration history and housing conditions influence both health trajectories and access to services. Digital literacy and access to digital infrastructure are unevenly distributed across age and income groups. Consequently, the introduction of digital health solutions risks widening existing inequalities if issues of accessibility, affordability and usability are not addressed systematically. For

healthy longevity to be more than a rhetorical ambition, digital strategies must therefore be aligned with equity-oriented health and social policy.

In addition, living arrangements are changing. Single-person households among older adults are increasing, and social isolation has become a significant public health concern. Loneliness is associated with adverse mental and physical health outcomes and increased care utilisation. Technologies that enable social connection, remote monitoring or community engagement may mitigate some of these risks, but they cannot replace human relationships. The demographic context thus requires a nuanced understanding of where digital interventions can strengthen existing social structures and where they risk displacing them.

Regionally, disparities between urban and rural areas are particularly salient. Urban centres often offer dense networks of specialised providers and shorter travel distances, while rural regions face declining physician density and longer response times in acute situations. Digital health solutions such as telemedicine, remote monitoring and decentralised care models (e.g. Hospital at Home¹) are frequently justified as means of bridging these gaps. However, their feasibility depends on reliable connectivity, interoperable systems and clear reimbursement pathways. Demographic pressure alone does not guarantee successful implementation.

In summary, the demographic and care context in Germany creates both urgency and opportunity. The ageing population, rising multimorbidity and workforce shortages necessitate structural innovation. At the same time, the heterogeneity of older adults in terms of health status, social resources and digital competence requires differentiated, context-sensitive approaches. Digital technologies can contribute to healthy longevity only if they are integrated into coherent care pathways, aligned with workforce realities and guided by principles of equity and participation. Demography defines the problem space; governance, infrastructure and design determine whether digital health becomes part of the solution.

¹ <https://hah-deutschland.de/>

2.2 Digital health and technical landscape

The digital transformation of the German health and care system is progressing, but unevenly and often more slowly than policy ambitions suggest. Over the past decade, substantial regulatory and infrastructural initiatives have been launched to promote electronic health records, telemedicine, digital health applications and data-driven innovation. Nevertheless, fragmentation of IT systems, limited interoperability and heterogeneous levels of digital maturity across institutions continue to constrain the practical impact of these efforts. For digital health to meaningfully support healthy longevity, the technical landscape must evolve from isolated pilot projects toward integrated, sustainable infrastructures.

A central element of the German digital health architecture is the telematics infrastructure (TI)², intended to enable secure data exchange across sectors. Electronic prescriptions, electronic patient records and digital communication channels between providers are gradually being implemented. However, integration into everyday clinical workflows remains incomplete. Many healthcare organisations operate legacy systems that are only partially compatible with national standards. Interfaces are often proprietary, and cross-sector data exchange particularly between ambulatory care, hospitals and long-term care facilities remains limited. As a result, information relevant for older patients with complex care needs is frequently fragmented across institutions.

The introduction of reimbursable digital health applications (DiGA) has created new opportunities for innovation. These applications, prescribed by physicians and reimbursed by statutory health insurance, aim to support self-management, monitoring and therapy in various conditions. While this model has stimulated market activity, uptake among older adults has been mixed. Barriers include limited awareness among providers, concerns about usability for older users and uncertainties regarding long-term effectiveness. Moreover, many applications focus on single conditions rather than multimorbidity, which limits their relevance for a substantial proportion of the ageing population.

Telemedicine has expanded significantly, particularly since the COVID-19 pandemic. Video consultations, remote monitoring and digital communication platforms have demonstrated their potential to maintain continuity of care under restrictive conditions. Yet the sustainability of these formats depends on reimbursement stability, technical reliability and integration into clinical documentation systems. For older adults, additional challenges arise: sensory impairments, cognitive limitations and limited digital literacy may complicate use. Technical feasibility does not automatically translate into accessibility.

² <https://gesund.bund.de/en/telematikinfrastruktur>

From a data perspective, Germany remains cautious. Strict data protection regulations, while essential for safeguarding fundamental rights, have contributed to a complex compliance environment. Research access to health data is often bureaucratically demanding, and secondary data use across sectors is limited. At the same time, large volumes of potentially valuable data routine care data, monitoring data, patient-reported outcomes are generated but insufficiently integrated. For predictive and preventive models in healthy longevity, high-quality, interoperable longitudinal data are indispensable. The current landscape provides building blocks but lacks both coherence and practicability..

Interoperability standards such as HL7 FHIR are increasingly adopted, and initiatives to harmonise data formats are underway. However, technical standardisation alone is insufficient. Organisational interoperability aligned processes, shared governance models and clearly defined responsibilities is equally critical. Particularly in the long-term care sector, digital maturity is often lower than in hospital settings, partly due to limited financial and human resources. If digital infrastructures are developed primarily around hospital-centric models, the needs of community-based and home-based care risk being marginalised.

Cybersecurity and system resilience are further essential dimensions. As health systems become more digitally interconnected, they also become more vulnerable to cyberattacks and technical failures. For older adults dependent on digital monitoring or assistive technologies, system downtime can have immediate consequences. Robust security architectures, redundancy mechanisms and clear incident response procedures are therefore not peripheral concerns but prerequisites for trustworthy digital care ecosystems.

The economic sustainability of digital solutions remains an open question. Many innovations are funded through pilot grants or time-limited projects. Transitioning from pilot to routine care requires stable reimbursement models, clear evidence of benefit and alignment with existing regulatory frameworks. Without such pathways, promising technologies risk remaining confined to demonstration settings.

In summary, the German digital health and technical landscape is characterised by significant momentum combined with structural fragmentation. Key components secure infrastructure, digital applications, telemedicine formats and emerging interoperability standards are in place, but integration across sectors and care levels remains incomplete. For healthy longevity, this integration is decisive. Older adults with complex needs require coordinated, longitudinal and context-sensitive support. Achieving this requires not only technological advancement but systemic alignment: interoperable architectures, user-centred design, sustainable financing and governance models that balance innovation with rights protection. Only

under these conditions can digital health move from isolated innovation to structural contribution in an ageing society.

2.3 Legal, ethical and regulatory framework

Digital health for older adults operates within a dense legal, ethical and regulatory environment. Rules governing the handling of health data, the approval and monitoring of medical technologies and the protection of vulnerable populations shape what is possible in practice. At the same time, ethical considerations such as autonomy, equity, fairness and the protection of social relationships are particularly salient in the context of ageing. This subsection briefly sketches the key legal and ethical conditions relevant to digital technologies for healthy longevity in Germany, and highlights how they create both safeguards and practical challenges.

This section presents practical experiences from collaborative governance processes in health and care projects. It focuses on the rationale for using participatory governance to address legal and ethical issues, methods and formats, and recommendations for implementation. It illustrates how people – patients, people in need of care, but also careworkers – can be engaged to contribute meaningfully to negotiating the structures and rules that apply, the safeguards for their rights, the mechanisms for transparency and control, and how this ensures that the technology, the data and their use is legitimate and acceptable for all.

Law and ethics are often seen as requirements imposed on technology development and digitalization projects from the outside. They are therefore frequently delegated to experts, who are then expected to say what should be done – and how – and what should not. The involvement of the people who are supposed to use the digital tools later – patients, older adults, caregivers – or whose personal data are processed is often limited to the option of giving consent – or refusing it. This pushes these people into a passive role instead of recognizing them as actors with agency and a genuine interest in co-determination. This risks producing solutions that are formally ethically acceptable or legally compliant, but that miss people's actual interests (Jackson et al., 2021).

The fact that governance which is truly participatory and takes people's co-determination seriously, values it, and enables it to be effective is grounded in the specific role of law in a liberal, free society. In such a society, the adoption of laws must be justified, and this is fundamentally only possible when, without the law, the relevant conflicts of interest cannot be negotiated on eye level and therefore a law is needed as a substitute. If governance is genuinely implemented on equal terms with all stakeholders, then this governance can to a large extent take back the place of the law, and interests can be meaningfully negotiated. Lawyers are then left with two tasks: first, to translate the results of the negotiation of interests into the form required by law. To make this possible, the governance itself must be organized and

implemented in a legally informed way. This is the second task of lawyers: to ensure governance's legal grounding.

For such governance, it is necessary to distinguish between the aims that laws are intended to achieve and the individual provisions that are meant to operationalize the achievement of those aims. Otherwise, the aims of the laws are too easily overlooked in the thicket of detailed provisions. The key laws in the field of the digitalization of health and care – in Europe the General Data Protection Regulation (GDPR), the AI Act, and the Medical Device Regulation (MDR) – are consequentialist in nature and aim to protect people and all of their fundamental rights and freedoms in the design, implementation, and use of digital technologies and the processing of personal data (see Articles 1 of the GDPR, the AI Act and the MDR respectively).

Practical experience in projects shows that legally informed governance also enables older people, patients, relatives, and caregivers – who are usually not legal experts – to participate meaningfully in negotiations and to help shape the outcomes (Gubser & Pohle, 2026). Governance is legally informed when the following three aspects are prepared and provided with legal expertise: First, procedural requirements – especially regarding impact assessments, risk management, and documentation obligations – must be operationalized so that non-lawyers can implement them in practice. Second, the fundamental rights and freedoms that may be affected – in particular the rights to bodily integrity, dignity, and autonomy; private and family life; non-discrimination; and access to social and health services for older people, patients, and relatives, as well as the fundamental right to fair and just working conditions for caregivers, all enshrined in the Charter of Fundamental Rights of the European Union – must be described in generally understandable terms and ideally framed as questions, for example: Which feature of the digital technology or data processing produces which undesirable effects on fundamental right X? Third, the key individual legal provisions – for example on transparency, consent, or rights of intervention – must be explained just as clearly so that stakeholders can understand, reflect, and decide how implementation should take place in order to safeguard their interests.

A comparable approach can be used for governance to meaningfully address ethical aspects as well. Ethical requirements must not simply be turned into a checklist to be ticked off. Nor is it sufficient to arbitrarily select and apply something that is sold as an “ethical guideline.” Ethical requirements follow different logics – or belong to different types – and it is essential to recognize that different people adhere to different ethical approaches. The four main types of ethics are virtue ethics, which focuses on the characteristics and interests of actors; deontological ethics, which focuses on duties; teleological ethics, which focuses on benefits and consequences; and process ethics, which focuses on procedures, discourse,

and negotiation (cf. Birnbacher, 2013; Chakraborti, 2023). Analogous to the approach described for legally informed governance, ethically informed governance can also be implemented: the different types of ethics must be translated into question form and made the basis for stakeholder deliberation, so that participants can understand them, reflect on them, and meaningfully take part in decision-making. This governance approach thus enables substantive stakeholder participation in negotiation without the organizers determining which aspects are included or excluded, thereby ensuring that power over the deliberation and its outcomes is effectively shared (Gubser & Pohle, 2026).

The governance approach follows a step-by-step procedure. By proceeding in small steps, complexity is reduced and stakeholders are not overwhelmed by the process, while at the same time they are able to address and manage the substantive challenges in greater depth. This approach has been tested and refined in practice (Pohle et al., 2023; Gubser & Pohle, 2026). In a first step, a basic design of the system or data processing must be developed that is at least concrete enough for its features to be meaningfully criticized and its impacts to be identified. The design can already be developed together with stakeholders, but it does not have to be. In the second step, the design is evaluated by stakeholders in collaborative workshops; undesirable aspects are identified, and expectations, wishes, and also possible concerns are contributed. In the third step, stakeholders are involved in finding solutions. This works without illegitimately shifting responsibility onto stakeholders (cf. “responsibilization”), because in practice we repeatedly observe that laypersons may not necessarily know how something should be implemented, but they often do know which kind of approach should be used to address an issue – for example, whether it should be handled through legal, technical, or organizational measures. Stakeholders thus set the requirements, and in the fourth step experts from the relevant disciplines develop implementation proposals – from computer and data science to law and organizational design to human-computer interaction. In this way, experts are effectively bound to the interests and requirements formulated by the stakeholders. In the fifth step, stakeholders focus in collaborative workshops on whether the implementation proposals are practical and how they must be designed so that they can be used in real-world settings by the intended users – with the knowledge and skills they actually have, without requiring a degree in computer science. After that, the design of the system or data processing is revised and presented again to stakeholders for assessment and critique. If stakeholders find the design acceptable, it can be implemented accordingly. Otherwise, new – or previously unaddressed or unresolved – challenges and criticisms are identified, and the iterative governance process must be repeated.

2.4 Why Berlin/Brandenburg is relevant

Berlin/Brandenburg offers a distinctive and strategically important environment for advancing digital health and healthy longevity. The region combines dense academic expertise, a large and heterogeneous patient population, an active start-up ecosystem, and a comparatively open policy landscape. For the Einstein Circle, this constellation was not incidental but central: it provides both the structural preconditions and the real-world complexity necessary to develop, test and critically reflect on digital approaches to ageing.

From a research perspective, the Berlin/Brandenburg region hosts a unique concentration of institutions working across medicine, informatics, public health, social sciences, design and the humanities. Universities and research centres collaborate with large care providers, most prominently the Charité, one of Europe's largest university hospitals. At the same time, institutions such as the UdK and other design-oriented schools contribute expertise in user experience, participatory design and creative methods. This combination of clinical excellence and design competence is particularly relevant for digital health in older populations, where technical feasibility alone is insufficient without usability, contextual fit and psychosocial sensitivity.

In addition to academic institutions, the region has a vibrant ecosystem of start-ups and technology companies working on health IT, AI-based diagnostics, assistive technologies and platform solutions. Berlin has become one of the leading start-up hubs in Europe, including in the digital health sector. For projects focused on healthy longevity, this environment offers rapid prototyping capacities, agile development cultures and access to venture financing models. At the same time, it raises important questions about sustainability, regulatory compliance and equitable access questions that can be addressed locally through collaboration between developers, clinicians, regulators and patient representatives.

A further strength of the region lies in its demographic and social diversity. Berlin in particular combines affluent urban neighbourhoods with areas characterised by socioeconomic deprivation, migration histories and varying levels of digital literacy. Brandenburg, by contrast, includes rural and semi-rural areas facing structural challenges such as physician shortages and longer travel distances to specialist care. Together, these contrasting settings form a natural laboratory for studying digital health under heterogeneous conditions. Solutions that function across these contexts urban and rural, high and low resource, digitally experienced and digitally marginalised are more likely to be robust, scalable and socially acceptable.

This diversity also makes Berlin/Brandenburg a promising environment for Living Labs and real-world testbeds. The region contains a wide range of care settings: university hospitals, rehabilitation centres, outpatient clinics, home-care services, nursing homes and community-based initiatives. Such structural variety enables stepwise testing of digital solutions from controlled clinical pilots to community-based

implementation. For the Einstein Circle, this was particularly relevant in relation to concepts such as Hospital at Home and digitally supported transsectoral care. The presence of both tertiary care expertise and community-based providers within relatively short geographic distances facilitates iterative evaluation and rapid feedback loops.

From a governance perspective, Berlin as a federal state and capital city also plays a particular role. It is closely connected to national regulatory bodies, federal ministries and health policy debates. At the same time, it retains enough administrative autonomy to pilot innovative approaches within state-level structures. This positioning creates opportunities for policy-relevant experimentation: governance models, participatory formats and legally informed data practices can be tested locally while remaining aligned with national and European frameworks such as the GDPR, the AI Act and the Medical Device Regulation.

The region's international connectivity further enhances its relevance. Berlin/Brandenburg maintains numerous academic partnerships, including transatlantic collaborations. For the Einstein Circle, the link to UC Berkeley was not only symbolic but operational: it enabled comparison between different health systems, regulatory cultures and innovation pathways. Berlin thus functions as a node in a global network of digital health research, while still being grounded in the specific challenges of the German statutory health insurance system and long-term care framework.

Berlin/Brandenburg provides a favourable environment for interdisciplinary exchange. The relatively compact geography, combined with a culture of cross-institutional collaboration, lowers barriers between disciplines and sectors. Clinicians, engineers, designers, ethicists and social scientists can meet in shared formats, joint appointments and collaborative projects. In the context of healthy longevity, where medical, technical, social and ethical dimensions are inseparably intertwined, such proximity is a structural advantage.

To summarise, Berlin/Brandenburg is not merely a geographical backdrop but an enabling ecosystem. It combines academic excellence, clinical infrastructure, entrepreneurial dynamism, demographic diversity and policy relevance in a way that is particularly suited to developing, testing and governing digital technologies for healthy ageing. For the Einstein Circle, working within this regional context allowed us to link conceptual reflection with practical experimentation and to ground normative debates in real-world institutional settings. Future initiatives seeking to advance digital health for longevity can build on these existing structures, provided that collaboration across sectors is actively cultivated and that equity, participation and long-term sustainability remain guiding principles.

Chapter 3: Thematic Snapshots and Case Illustrations

3.1 Digital care models and clinical collaboration

Digital technologies are increasingly embedded in models of care that extend beyond the traditional hospital setting. For the Einstein Circle, digital and hybrid care approaches – including home-based care, telemedicine and new forms of clinical collaboration – were central reference points. They illustrate how prevention, monitoring and treatment can be organised closer to the everyday lives of older adults, while still drawing on specialised expertise. This subsection summarises the examples and ideas discussed in the Circle, such as digitally supported home-care models, hybrid consultations and cooperation with clinical partners, and reflects on their relevance for healthy longevity. One very popular concept is the “Hospital at Home” concept. Some of our ideas regarding this concept are outlined below:

The Concept of "Hospital at Home (HaH)"

The "Hospital at Home" model aims to provide acute, hospital-level care within a patient’s domestic environment, thereby reducing the burden on clinical facilities and improving patient well-being. This shift is made possible by two primary drivers: high-tech specialized interventions and seamless systemic networking. To outline this, two Charité based research projects of the geriatric research group will be introduced and it will be shown that – by combining the strengths and main focus of each project together – strong and powerful opportunities of the concept become very obvious.

The **6G-Path** project represents the "High-Tech Intervention" branch of HaH. It focuses on bringing advanced manufacturing and diagnostic capabilities (like 3D wound printing) to remote areas . By utilizing 5G/6G-enabled nomadic micro-networks, it ensures that even patients in connectivity "dead zones" can receive specialist-led treatment without leaving their homes (Ancuta et al., 2025).

Conversely, the **STH (Smart Transsectoral Healthcare or “Stay&Treat@Home”)** project focuses on the "Systemic Networking" branch. It creates a 24/7 safety net around the patient by integrating various care levels—from family members to university specialists at the Charité (Müller et al., 2024). Through a shared digital health record (DiG), it enables acute interventions, such as IV therapy or EKG monitoring, traditionally reserved for emergency rooms, to be safely performed at the bedside at home of the patients. Together, these projects demonstrate that the "Hospital at Home" is not just about a visit from a doctor, but about extending the entire clinical infrastructure—connectivity, diagnostics, and expert knowledge—into the private sphere.

The following table will provide the main differences between the two projects

Feature	6G-Path (Specialized Wound Care)	STH (Smart Transsectoral Healthcare)
Primary Goal	High-level care for complex wounds in remote areas via customized 3D printing.	Reduction of hospitalization rates through 24/7 transsectoral networking.
Target Group	Patients with customized patch requirements (often in rural/remote areas).	Outpatient care recipients of all care levels (SGB XI).
Core Technology	3D Stereo Modeling, Hydrogel Printing, 5G/6G Connectivity.	Digital Health Record (DiG), Telemedicine (TMA), 24/7 Mobile Service.
Connectivity Solution	Nomadic Micro-Networks: Vehicle-based 5G/6G extension with satellite backhaul.	Public Internet / VPN: Broad accessibility for relatives and providers outside the TI.
Key Actors	Field Nurse, Hospital-based Doctors (Remote), Tech Specialists.	GP, Relatives/Neighbors, KV 116117, HiOs, Charité TMA (Specialists).
Acute Intervention	Real-time diagnostic assessment and on-site manufacturing of patches.	Monitoring vital signs, EKG, IV fluids, and acute specialist tele-consultation.
Coordination Hub	The Nurse's Vehicle (Mobile Campus Network).	The Digital Health Record (DiG) and KV 116117 dispatch.

The integration of the 6G-Path and STH projects represents a sophisticated evolution of the "Hospital at Home" model, effectively merging high-tech infrastructure with high-touch clinical care. While these initiatives originate from distinct technical and medical disciplines, their combined application creates a "Gold Standard" for decentralized healthcare by addressing the critical gap between hospital-level

diagnostics and domestic recovery. At the foundational level, an infrastructure synergy exists where 6G-Path's nomadic micro-networks solve the "last-mile" connectivity challenges often faced by the STH network. In geographically isolated or rural areas where a stable connection to the Digital Health Record (DiG) might otherwise falter, the 6G-Path medical vehicle serves as a high-performance communication bridge. This ensures that the patient's vital data remains synchronized in real-time, allowing the STH framework to function with clinical-grade reliability regardless of the local terrestrial internet quality. The relationship between these projects also enables a more powerful form of preventative intervention. Within the STH ecosystem, daily documentation provided by relatives or general practitioners acts as an early warning system. When the DiG detects the first signs of wound deterioration or physiological instability, it can trigger the immediate deployment of a 6G-Path specialized nurse. By catching these complications early, the system moves from a reactive model to a proactive one, delivering advanced 3D-printed therapeutics directly to the doorstep before a patient's condition escalates into a clinical emergency requiring hospitalization. Finally, the collaboration facilitates advanced remote supervision by pairing the Charité TMA's specialist expertise with 6G-Path's massive bandwidth. In this scenario, a remote specialist in Berlin can do much more than provide a simple consultation; they can utilize the 6G-Path connection to supervise high-resolution 3D wound modeling and the intricate calibration of hydrogel printing in real-time. This ensures that even the most complex medical procedures—those typically confined to a sterile operating theater—can be performed safely in a living room under the watchful eye of the world's leading experts. Through this synthesis, the "Hospital at Home" transcends being a mere convenience and becomes a robust, technologically superior alternative to traditional inpatient care.

In summary, the fusion of 6G-Path and STH provides a comprehensive blueprint for the future of decentralized medicine. By combining 6G-Path's specialized mobile infrastructure—capable of high-tech diagnostics and on-site manufacturing—with the STH project's robust, 24/7 transsectoral network, the "Hospital at Home" concept evolves into a resilient healthcare ecosystem. This partnership ensures that geographical barriers are eliminated through nomadic connectivity, while clinical safety is maintained through continuous digital monitoring and specialist tele-supervision. Ultimately, this integrated approach not only reduces the burden on traditional hospital wards but significantly enhances patient autonomy and quality of life by delivering world-class medical expertise directly into the domestic sphere.

3.2 Living Labs and Real World Environments

Many questions about digital health and ageing cannot be answered in highly controlled settings alone. They require environments in which technologies can be tested and adapted under real-world conditions together with users, caregivers and practitioners. The concept of Living Labs and similar real-world test environments played an important role in the work of the Einstein Circle. It offered a way to think about co-creation, continuous feedback and context-sensitive implementation. This subsection outlines how Living-Lab ideas were discussed, which examples were considered and how such environments could be transferred or adapted to the Berlin/Brandenburg context.

3.2.1 Transfer and adaptation to the German context

While Living Labs and real-world environments have been widely implemented in Scandinavian countries, the Netherlands, the UK and the United States, their systematic transfer to the German health and care system requires careful contextual adaptation. The German system is characterised by strong sectoral boundaries, a complex reimbursement structure within the statutory health insurance framework (SGB), and comparatively strict data protection requirements. These structural conditions shape both the opportunities and the constraints for implementing Living-Lab-style approaches.

A first key difference concerns the fragmentation between inpatient, outpatient and long-term care sectors. In many international Living Lab models, experimentation across care levels is facilitated by integrated delivery systems or regionally coordinated care organisations. In Germany, by contrast, responsibilities, budgets and documentation systems are often separated. For Living Labs to function effectively in this environment, governance structures must explicitly bridge these divides. This may involve formal cooperation agreements between hospitals, ambulatory physicians, nursing services and municipalities, as well as clearly defined data-sharing arrangements compliant with national and European regulations.

Second, reimbursement logic plays a central role. International Living Labs often operate in systems where bundled payments, capitated models or value-based care frameworks provide incentives for prevention and cross-sector coordination. In Germany, reimbursement remains largely activity-based and sector-specific. As a result, innovations tested in Living Labs must demonstrate not only clinical or user benefit but also compatibility with existing remuneration pathways. Early involvement of statutory health insurers and regional physician associations (Kassenärztliche Vereinigungen) is therefore crucial to ensure that successful prototypes can transition into routine care.

Third, data governance in Germany requires particular attention. The regulatory environment shaped by the GDPR, national data protection law and professional confidentiality obligations demands legally informed design from the outset. In contrast to more permissive data ecosystems, Living Labs in Germany must integrate privacy-by-design principles, transparent consent processes and robust documentation mechanisms. However, this should not be understood as a barrier per se. Rather, it can become a strength: legally and ethically informed Living Labs may achieve higher levels of legitimacy and trust among older adults, caregivers and professionals. The governance approach outlined in Section 2.3 provides a methodological template for embedding participatory and rights-based principles into experimental environments.

Fourth, digital maturity varies considerably across German care settings, particularly in long-term care facilities and home-care services. In some regions, basic digital infrastructure reliable broadband access, interoperable documentation systems cannot be taken for granted. Consequently, Living Labs must be designed with scalable entry points. Pilot implementations may begin with low-threshold digital tools and gradually expand toward more complex, AI-supported systems. Technical ambition must be aligned with organisational capacity and staff training.

At the same time, the German context offers specific advantages for Living-Lab-style approaches. The federal structure enables regional experimentation within a shared legal framework. Municipalities and Länder can support local innovation ecosystems, especially when universities, university hospitals and applied sciences institutions are involved. Furthermore, Germany's strong tradition of social insurance and corporatist self-governance creates structured arenas for negotiation among stakeholders. If Living Labs are embedded within these existing negotiation platforms, they can move beyond isolated experimentation toward systemic learning.

A particularly promising pathway lies in linking Living Labs with community-based care networks and “Quartier” approaches. Germany has a growing number of neighbourhood-oriented ageing initiatives that aim to support ageing in place through local coordination, volunteer engagement and integrated services. Embedding digital experimentation into these existing community structures may increase acceptance and ensure contextual fit. In this sense, Living Labs should not be conceived primarily as high-tech demonstration spaces, but as socio-technical ecosystems rooted in everyday environments.

Evaluation strategies must reflect the German evidence culture. For innovations to be scaled nationally, robust evidence clinical, economic and organisational is often required. Living Labs in Germany should therefore combine iterative co-creation with structured evaluation frameworks, including health services

research methodologies, implementation science and cost-effectiveness analysis. This dual orientation flexible experimentation combined with rigorous assessment can help bridge the gap between innovation and regulation.

To sum up, the transfer of Living-Lab approaches to the German context is both feasible and promising, provided that structural characteristics of the health and care system are explicitly addressed. Sectoral fragmentation, reimbursement logic and data protection requirements necessitate legally and organisationally informed design. At the same time, federal flexibility, strong academic infrastructures and established stakeholder governance models create favourable conditions for regionally embedded, participatory innovation. If adapted thoughtfully, Living Labs can become a central instrument for developing and legitimising digital health solutions that are not only technically functional, but institutionally viable and socially acceptable within the German system.

Recommended actions for planning, designing, and implementing Living Labs include (Ballon et al., 2018; Følstad, 2008; Greve et al., 2021; Schuurman et al., 2015):

- **Bridge Sectoral Divides:** Establish formal cooperation agreements and compliant data-sharing arrangements to connect inpatient, outpatient, and long-term care sectors.
- **Align with Reimbursement Pathways:** Involve statutory health insurers and regional physician associations early to ensure prototypes are compatible with existing activity-based remuneration models.
- **Implement Legally Informed Design:** Embed privacy-by-design, transparent consent, and robust documentation from the outset to build legitimacy and trust under GDPR frameworks.
- **Design Scalable Entry Points:** Account for varying digital maturity levels by starting with low-threshold tools before expanding to complex, AI-supported systems.
- **Embed in Existing Governance Platforms:** Utilize federal flexibility and corporatist self-governance platforms to move beyond isolated experimentation toward systemic learning.
- **Integrate with Neighborhoods:** Anchor Living Labs in existing community-based care networks and "Quartier" initiatives to ensure solutions function as everyday socio-technical ecosystems.
- **Combine Innovation with Rigorous Evaluation:** Merge iterative co-creation and clinical, economic and organizational evaluation to build evidence for reimbursement and adoption.

3.2.2 Living Lab Case Study: US Model for Community-based Digital Aging Innovation and Research

The UC Davis Health *Community for Healthy Independence* and the broader *Healthy Aging in a Digital World* initiative serve as a reference model that embodies the Living Lab approach for participatory digital health innovation. This model moves technology evaluation out of highly controlled laboratory settings and embeds it directly into residential and community environments. As a result, this model operationalizes core Living Lab principles--ecological validity, continuous user engagement, and rapid-cycle iterative co-creation with older adults, caregivers, and clinicians--to function simultaneously as a robust research infrastructure and service innovation platform.

By successfully integrating geriatric medicine, engineering, and data science, the UC Davis framework facilitates continuous community-based participatory research. Moreover, it enables the longitudinal monitoring necessary to support aging-in-place through a convergence of interconnected technologies—ranging from AI-enabled passive environmental sensors and wearables to assistive robotics and smart home systems. Crucially, this model allows researchers to evaluate not just individual devices, but how these interact as a socio-technical ecosystem.

Using the UC Davis model as a foundational blueprint to guide the establishment Living Lab sites in the U.S. and Germany that would elevate Living Labs from local testbed to *transatlantic research agenda*, and thereby help to facilitate a transnational, human-centered, community-embedded approach to digital aging research and policy development.

3.3 Participatory Design, therapy and user experience

Digital health technologies have great potential to support aging in place. However, many solutions fail to address the psychological, social and emotional needs of older adults. This gap arises partly from a lack of authentic user involvement in the development process and partly from limited interdisciplinary collaboration. When designers, clinicians, engineers and caregivers do not share common methods and tools, solutions risk being fragmented, inaccessible or misaligned with lived realities, user contexts and their mental models.

This chapter documents practical experiences from participatory design and therapy projects that address these challenges. It focuses on methods, user experiences and recommendations from implementation. Selected case studies illustrate how older adults can be engaged as active contributors and how interventions were integrated into everyday contexts to enhance usability, relevance and well-being.

3.3.1 Participatory Design as a Principle, Not a Method

Design for aging populations often stops at user testing or feedback rounds, positioning older adults as passive evaluators rather than as experts in their own daily lives. This risks producing solutions that are technically functional but socially or psychologically misaligned with lived realities. Research shows that authentic co-creation with older people leads to greater acceptability, usability, and sustainability of digital health innovations (Lindsay et al., 2012).

My own work has demonstrated this through the Designpat:innen approach, which replaces abstract personas with real design mentors - older adults who are actively involved throughout the process (Celik & Kampe, 2017). This aligns with findings from long-term participatory design projects, where involving older adults and caregivers from the outset uncovered contextual challenges and improved real-world integration (Gasteiger et al., 2022). Situated participatory design methods further highlight that design in authentic environments, rather than in labs, generates deeper understanding of both barriers and opportunities for use (Stegner et al., 2023).

In the context of dementia care, systematic reviews show that people with dementia are rarely included early in the design process; their involvement is often limited to testing or evaluation phases. When they are actively engaged, however, their contributions improve usability, relevance, and acceptance of supportive digital applications, highlighting the importance of adapting methods to cognitive abilities and including caregivers as facilitators (Span et al., 2013).

Despite this evidence, participatory methods are still often treated as an add-on rather than a guiding principle (Kilfoy et al., 2024).

This underscores the need to embed co-creation with older adults and caregivers as a foundational principle of digital health development, ensuring that solutions are meaningfully aligned with lived experiences, psychological needs and everyday contexts.

3.3.2 Psychological and Social Needs in Digital Health

Digital health innovations often prioritize physical functionality, while psychological needs such as autonomy, competency and social connectedness are frequently overlooked. Authors such as Smits et al. (2022) indicate that, despite positive effects on well-being, there is no clear definition of well-being in digital health projects, leading to uncertainties in design.

Research demonstrates that interventions addressing these psychological dimensions can significantly enhance user experience and emotional well-being. Design project examples, such as music therapy (Fig. 1), digital clay (Fig. 2), AI assisted solutions (Fig. 3) and others, show that technology can support emotional engagement, agency and social connectedness among older adults. Beyond specific interventions, authors such as Peters (2022) provides a framework for “Wellbeing Supportive Design,” offering heuristics and strategies to explicitly support psychological well-being in UX design. His approach emphasizes autonomy, competence and relatedness as core principles, ensuring that digital products contribute positively to mental health and quality of life. Complementing this, Hassenzahl (2010) underscores the importance of fulfilling universal psychological needs, such as competence, relatedness and meaning, through interactive technologies to create positive and meaningful experiences.

JAZZ ORB A. KLODT-BUßMANN, U. KILINC

Three instruments,
Three devices,
Endless Social moments!

This innovative tool features three distinct orbs, each representing a different jazz instrument: the piano, saxophone, and cello. When used individually, users can enjoy a solo concert for each instrument. But when combined, they become part of a personalized orchestra, with each person playing the role of a different instrument, working together to create a harmonious atmosphere of joy and connection.

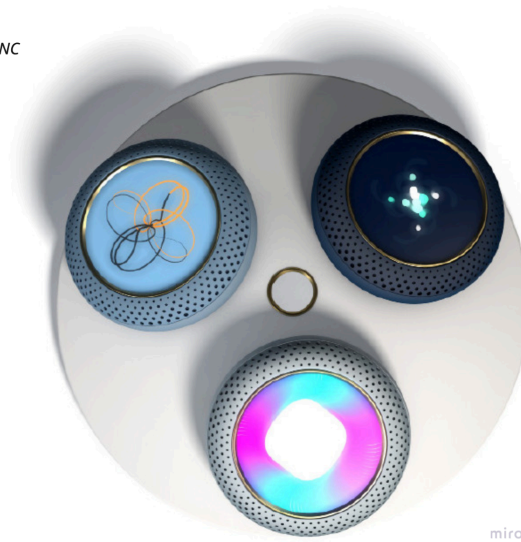


Figure 1: Interactive device for music therapy; co-creation process with elderly project participants (“design mentors”) and Industrial Design students in second year bachelor. Credits: A. Klodt-Bußmann & U. Kılınc.



miro

Figure 2: Digital Clay for occupational therap;, co-creation process with elderly project participants (“design mentors”) and Industrial Design students in second year bachelor. Credits: J. Rehse & Y. Hida.

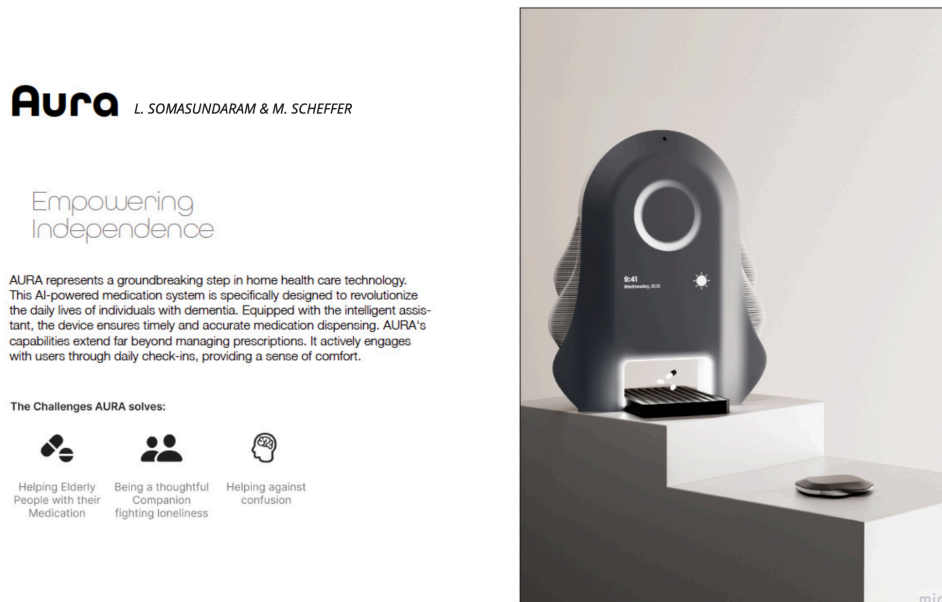


Figure 3: AI-powered medication system to support caregivers at home and in residential care settings; co-creation process with elderly project participants (“design mentors”) and Industrial Design students in second year bachelor. Credits: L. Somasundaram & M. Scheffer.

Understanding the mental models of older adults is critical in this context. Mental models - internal representations of how a system works - shape how users interpret, navigate and adopt digital technologies. When designers and developers fail to account for the mental models of elderly users, even well-intentioned innovations can be confusing or rejected (Garcia reyes et al., 2023). By mapping and validating mental models through participatory and observational methods, product developers can create interfaces and interactions that align with users’ expectations, increasing usability, adoption and satisfaction.

3.3.3 Aging in Place & Everyday Contexts

Many digital health solutions fail because they are not meaningfully integrated into the daily lives and home environments of older adults (Greenhalgh et al., 2013). Technology developments often overlook real-world routines, physical spaces and the social and emotional contexts in which they are used, leading to low adoption and limited impact (Peek et al., 2014). Research indicates that barriers such as limited

technology access, negative attitudes, low digital literacy and a lack of alignment with daily practices hinder effective use (Hauth et al., 2019). Interview studies show that older adults are more likely to engage with technologies that fit naturally into their routines, respect their preferences, and are socially and emotionally meaningful (Garcia Reyes et al., 2023).

Research from our group, including studies on household appliances, technology competence and Smart-Home integration, demonstrates that understanding everyday practices and living contexts is essential for designing effective solutions. Observations in real-life scenarios reveal how small mismatches between technology and routine can create barriers, highlighting the need for context-sensitive design. These findings are consistent with prior research of other authors, emphasizing the importance of situational and environmental factors in supporting aging in place (Garcia Reyes et al., 2023).

3.3.4 Interdisciplinary Collaboration and Shared Tools

Meaningful solutions for an aging population cannot be developed by any single discipline. Health, technology and design experts each bring essential perspectives, but interdisciplinary teams often face challenges due to differences in terminology, methods and priorities. This fragmentation can result in digital health solutions that fail to address the holistic needs of older adults (Krause-Jüttler et al., 2022; Sanders & Stappers, 2008).

Design disciplines provide structured tools and methods that serve two critical functions in interdisciplinary collaboration. First, design frameworks such as systemic design, user experience (UX) design, and participatory approaches can create a shared product development process, aligning stakeholders on goals, phases and evaluation criteria (Jones, 2014; Stickdorn et al., 2018; Sevaldson, 2021). Second, design methods can equip teams with practical tools—workshops, prototyping techniques, journey maps, (real)personas or design mentors and co-creation sessions—that enable effective communication and joint problem-solving across disciplines. Participatory frameworks further ensure that older adults and caregivers are actively engaged as co-designers, integrating lived experience into the development process and bridging the gap between technical feasibility and human-centered needs

3.3.5 Ethical & Empowerment Perspective in Design

Older adults are often framed as “vulnerable” or deficient, which can lead to paternalistic solutions that limit autonomy, agency and dignity. Such approaches risk reinforcing ageist stereotypes and reducing older adults to passive recipients of care or technology, rather than recognizing them as capable contributors with valuable lived experience (Finco et al., 2024; Del Barrio et al., 2018).

Participatory and co-creative design approaches offer a concrete way to counter these dynamics. By involving older adults as active co-designers, designers can enhance self-efficacy, promote agency and preserve dignity throughout the development process (Gasteiger et al., 2022). For example, frameworks like the Designpat:innen method (Celik, 2025) replace abstract personas with real older adult mentors, embedding their knowledge and preferences directly into product development. Studies have shown that such involvement not only improves usability and contextual fit but also strengthens participants' sense of empowerment and ownership over solutions (Span et al., 2013; Lindsay et al., 2012).

3.3.6 Prevention, therapy & music technologies

Research shows that music therapy helps many mental and physical health problems. It is useful for people with depression, anxiety, neurological diseases, and even during cancer treatment. Music activities such as moving to music, dancing, or playing an instrument activate many parts of the brain at the same time. This can help improve motor skills, speech and voice, memory, attention. The clinical evidence has led to a number of therapeutic techniques and interventions by which age-related diseases such as parkinson's disease, stroke and dementia can be treated.

A new German guideline on dementia (2025) recommends music therapy to support cognitive skills and to reduce symptoms like anxiety and restlessness. However, music therapy is still not widely available, mainly because there are too few trained therapists. At the same time, musical activities can also help healthy older adults maintain their abilities and overall well-being.

At this point digital tools can offer music-based exercises and self-training programs that target motor, cognitive, and physical functions. They can also collect real-time data and, with the help of AI, support personalized lifestyle adjustments. This may contribute maintain their health and quality of life in older adults even before clinical problems such as falls or cognitive decline appear. For example, the Curaswing app uses smartphone sensors to give musical feedback during movement. Music-based gait training has shown promising results for people with Parkinson's disease.

3.4 International collaboration and research exchange

Healthy longevity and digital health are global issues, and international collaboration is essential for comparing approaches, learning from different health systems and building long-term partnerships. From the beginning, the Einstein Circle included members and partners from outside Germany, particularly from UC Berkeley and related networks. These exchanges shaped both the conceptual and practical work of the Circle, from joint discussions and presentations to concrete plans for research stays and student projects and real-world environments where technologies were co-developed, deployed, and evaluated to show what works across diverse contexts. This subsection describes the main forms of international collaboration and research exchange that emerged in the Circle, and discusses how they contribute to strengthening Berlin as a location for research on healthy ageing.

The following are examples of research exchange undertaken by participants of the Einstein Circle and potential opportunities for future topics of international collaboration that emerged.

3.4.1 Understanding Agetech Innovation Landscape

Members of the University of California Berkeley's CITRIS Health (Center for Information Technology in the Interest of Society) and the Digital Urban Center of Aging and Health (DUCAH) conducted a technology landscape assessment to understand how technology startups are addressing the needs of older adults and goals of healthy aging. Using an informal landscape assessment methodology, we searched for startup companies from multiple sources including a web search, listings of incubators and accelerators, participants of public innovation challenges, highlighted startups in health, aging, and accessibility categories at the CES conference (the largest industry technology exhibition in the world), and recommendations from the CITRIS Health network. We then collected information on the identified companies from their websites and the Crunchbase database. Third, we developed a structured data extraction format. We found there were many market reports on agetech that focus on market segments, but few frameworks that rigorously categorized the needs these agetech solutions attempted to address. Thus, we applied a human centered technology framework to create an initial categorization of needs which we called "pain points." We operationalized the term "human-centered" as involving the design, development and/or application of technology that a) focuses on humans' purposes, or b) is in alignment with human values, or c) that achieves the desired properties of humans, resulting in relevant, useful, usable, and trustworthy solutions. We analyzed a corpus of 558 companies. We uncovered four dimensions related to pain points: health condition addressed, role of user, care activity targeted, and process. Health conditions include defined conditions such as chronic diseases and health issues such as falls, fitness, and loneliness. Among the roles identified are patients, caregivers, home care providers,

senior living providers. Examples of care activities include complex care management, activities of daily living, and health education. Finally, processes include automation of service improvement, decision support, and digital or other skill development. Many startups offer multiple solutions and use different combinations of technology depending on the combination of dimensions they seek to address.

Results were shared both in-person at DUCAH forums in Berlin, and webinars hosted by CITRIS in the US. Several promising opportunities emerged from discussions at these events as well as at Einstein Circle meetings. These areas of interest are:

- Identification of promising, transferrable technologies and digital health practices across international lines.
- Interdisciplinary design approaches to overcome the multifaceted challenges facing older adults and their caregivers.
- Best practices for implementation and adoption of agotech that delivers outcomes.
- Solutions for reducing the burdens of chronic illness, preventing illness, and optimizing functional ability and well-being.

3.4.2 Sharing and Transferring the ACTIVATE Digital Care Model

The ACTIVATE project serves as CITRIS Health's primary case study for deploying digital care coordination and remote patient monitoring in rural, under-resourced communities. ACTIVATE is a digital health intervention implemented in three phases: community codesign, feasibility assessment, and a pilot phase. Pre- and postintervention outcomes included regularly collected hemoglobin A1c (A1c) for participants with diabetes and blood pressure for those with hypertension.

Codesign, coproduction, and related participatory methods are rooted in the principle that solutions are more relevant to the problem of interest and better able to produce the intended outcome if the users and others affected are engaged in the definition, design, and implementation. The research team worked closely with community co-designers including over 20 staff and providers of the health center as well as six adult patients and community members to design the intervention and implement the technology for optimal ease of use. The solution involved use of connected glucometers and blood pressure cuffs used by patients at home, monitoring of measures by the clinic staff via a real-time dashboard, medical assistant health coaches offering brief virtual check-ins with the patient, and telehealth visits as directed by the provider. This co-designed platform moved beyond theoretical modeling to demonstrate substantial real-world improvements in health outcomes: hemoglobin A1c and blood pressure over a six-month period.

Through multiple presentations on this research at DUCAH Forum, the Patient Monitoring Roundtable, and Einstein Circle meetings, we shared the ACTIVATE model and discussed how this model demonstrated in California might be adapted to a German setting. Key considerations for adaptation are also opportunities for comparative research.

Differences in payment models and consumer expectations:

- a) Patients in Germany expect to pay for healthcare devices and apps while those in the US expect healthcare insurance to cover the cost.
- b) The health data privacy and security regulations and patients' rights to control use of their health information for private and government purposes differ between the two countries with stronger consumer protections under GDPR.
- c) A low tolerance for risk by public and private healthcare stakeholders may impact the opportunities for initial pilots/demonstrations of innovative solutions.
- d) Partnering between US and German organizations may support adaptation.

3.4.3 Exploring Next-Generation Innovation: AI Digital Twins

Moving beyond standard analytics, Health Tequity LLC, founded by CITRIS Senior Scientist for Health Dr. Katherine Kim, is pioneering a digital twin and agentic AI for healthy aging, defined as a human-centered AI that virtually mimics a physical entity, dynamically updating with real-world data to predict structure, context, and behavior. The system combines wearables, patient-reported outcomes (PROs), electronic health records (EHR), and claims data and utilizes an ensemble of agentic AI, machine learning, and predictive analytics approaches. Early development of this digital twin system to simulate and predict trajectories of chronic disease under a large number of potential feature combinations is funded by the National Institutes of Health. Using this approach we hope to answer precision health questions, such as "Which patients with specific characteristics are most likely to achieve control of diabetes with remote patient monitoring using glucometers?" This allows providers to test scenarios before implementation. This research approach signals a pivot from static predictive models to dynamic, learning digital twins. These generative simulations allow clinicians to test what-if scenarios and run counterfactual analysis to prevent exacerbations, slow the progression of chronic disease, and optimize health and wellness for as long as possible.

Discussion between Health Tequity, CITRIS, and German colleagues has led to brainstorming of possible applications of digital twins to personalized AI-based health coaching and caregiving, models of population health improvement tailored to local regions, and efficiency in hospital services.

About CITRIS (Center for Information Technology Research in the Interest of Society)

CITRIS (Center for Information Technology Research in the Interest of Society) advances information technology research for social good across the University of California Berkeley, Davis, Merced, and Santa Cruz campuses. CITRIS Health advances AI- and data-enabled solutions at the intersection of precision health, chronic disease management, and ethical governance to support healthy aging, maintain independence, and facilitate equitable access to care.

Chapter 4: Recommendations for Future Research

4.1 For designers, foundations and funders

- Interdisciplinary collaboration should be actively supported by adopting shared methodologies, co-creative frameworks and practical design tools. By creating a common process and equipping teams with the right instruments for joint development, designers, clinicians, engineers, and caregivers can collaborate effectively to produce solutions that are contextually relevant, user-centered and responsive to both psychological and physical needs of older adults.
- Psychological and social needs, along with users' mental models, should be treated as core design drivers, equal in importance to physical and clinical considerations, ensuring that digital health solutions are holistic, user-centered, and supportive of well-being.
- Digital health and aging-focused design should prioritize empowerment over paternalism. Older adults must be treated as active collaborators and knowledge holders, shaping the solutions that affect their lives. Ethical design requires shifting from deficit-oriented assumptions toward co-creative, strengths-based frameworks that respect autonomy, promote agency and enhance well-being.
- Approaches to “implement” legal and ethical requirements into digital health and aging-focused design should prioritize governance and negotiations on eye level with stakeholders over expertocratic solutionism. Older adults, family members as well as care workers must be enabled effectively to meaningfully codetermine the digital and AI systems and data processing operations that affect their lives, interests and rights. Collaborative governance, both legally and ethically informed, must be implemented in a way that ensures that the negotiations and outcomes are acceptable to all stakeholders.
- Regarding digital care models and clinical collaboration and specifically the implementation of decentralized “hospital@home” concepts, the focus should be shifted from “point-solution” gadgets to systemic infrastructure and economic viability. For example, we need data on whether the initial high cost of modern nomadic 6G micro-networks is offset by reduced hospital readmissions and improved healthy longevity over 5–10 years.
- Implement an “equity-first” strategy to counter the digital divide by explicitly subsidizing digital infrastructure in under-connected communities, and prioritizing technologies designed specifically to be accessible for the digitally marginalized so that interventions do not exacerbate existing disparities.
- Prioritize funding for initiatives that move beyond isolated experimentation through embedding Living Labs within established governance platforms and aligning with reimbursement pathways

(eg, statutory health insurers) to ensure technical innovation is coupled with the rigorous clinical, economic, and organizational evaluation required to bridge the gap to national regulation.

4.2 For research groups / future circles

- Interdisciplinary collaboration benefits from the early presentation of concrete and visualized project examples.
- Project examples or best practices support the alignment of differing terminologies and implicit assumptions across disciplines more effectively than abstract descriptions alone.
- The early use of concrete project cases can accelerate the process of establishing a shared research focus.
- Future circles should investigate how the 24/7 data from the Digital Health Record (DiG) can be processed via AI to move from proactive to predictive care.
- Adopt a legally informed design strategy that integrates transparent consent and privacy-by-design under GDPR frameworks, while establishing formal data-sharing agreements to successfully evaluate technologies across inpatient, outpatient, and long-term care settings.
- Allow future Living Labs to systematically identify successful international practices (e.g., Digital Twins), and provide a structured methodology to adapt them to strict local privacy regulations (e.g., GDPR) and statutory health insurance (Se.g., SGB) requirements.

4.3 For practice partners, care workers, and networks

- Practice partners and care organizations should be encouraged to actively engage in collaborations with universities and research institutions.
- To ensure digital technologies for longevity are truly meaningful, participatory design with older adults and caregivers must be embedded as a foundational principle, not an optional method.
- Conducting field research in real-life contexts should be mandatory in the development of digital health interventions. By embedding solutions into the routines, spaces, and social networks of older adults, designers can ensure technologies are not only usable but genuinely supportive of independent, meaningful living.
- Jointly established Living Labs provide a structured but flexible framework to integrate everyday care contexts, lived experiences, and professional practice into research and development processes.

- Design scalable entry points to account for varying levels of digital maturity in care facilities by initiating Living Labs with low-threshold digital tools. Once established, gradually expand to include more complex, AI-supported technologies aligned with staff training capacity.
- Early and continuous involvement of care workers and older adults as “expert groups” in such settings supports the development of solutions that are context-sensitive, usable, and aligned with psychological and social needs.
- Develop and test training modules and Curricula for community health nurses. The role is evolving from traditional care to a "tech-clinical hybrid" role requiring new forms of expertise and digital literacy.
- Anchor digital health interventions directly within existing "Quartier" initiatives and community-based networks to ensure solutions function as everyday socio-technical ecosystems, utilizing formal cross-sector cooperation to effectively integrate tools that match the varying digital maturity levels of local workflows and communities.
- Music applications and digital music-based tools can support motor, cognitive, and emotional health in older adults and people with neurological or mental health conditions, helping maintain quality of life and potentially prevent age-related decline.

References

1. Ancuta Corici, Andreea, Hocquel-Hans, Martin, Chaudhary, Kalpana, Kuntz, Simone, Corici, Marius, Häusler, Benny, Zope, Hemant, Deter, Anne, Grohnert, Anne, Lahmann, Nils. Implementation Design and Validation Results of a Chronic Wound Management System Powered by Beyond 5G Private and Nomadic Networking. In: Springer, (Hrsg.) Springer VS Part of Springer Nature; 2025; S.181-93.
2. Ballon, P.; Van Hoed, M.; Schuurman, D. (2018) The effectiveness of involving users in digital innovation: Measuring the impact of living labs. *Telemat. Inform.*; 35, 1201–1214.
3. Birnbacher, D. (2013). *Analytische Einführung in die Ethik* (3rd ed.). De Gruyter. <https://doi.org/10.1515/9783110315707>
4. Celik, P. (2025). Holistic research with UX methods for social inclusion and sustainability. In *Innovation design for social inclusion and sustainability: Design cultures and creative practices for urban natural heritage beyond accessibility* (No. 5, pp. 47–59).
5. Chakraborti, C. (2023). *Introduction to Ethics: Concepts, Theories, and Contemporary Issues*. Springer. <https://doi.org/10.1007/978-981-99-0707-6>
6. Del Barrio, E., Marsillas, S., Buffel, T., Smetcoren, A.-S., & Sancho, M. (2018). From active aging to active citizenship: The role of (age) friendliness. *Social Sciences*, 7(8), 134. <https://doi.org/10.3390/socsci7080134>
7. Finco, M. G., Mir, N., Gresham, G., & Huisingh-Scheetz, M. (2024). Ethical considerations of digital health technology in older adult care. *The Lancet Healthy Longevity*, 5(1), e12–e13. [https://doi.org/10.1016/S2666-7568\(23\)00236-2](https://doi.org/10.1016/S2666-7568(23)00236-2)
8. Følstad, A. (2008). Living labs for innovation and development of information and communication technology: A literature review. *Electronic Journal of Organizational Virtualness*, 10, 99–131.
9. Garcia Reyes, E., Kelly, R., Buchanan, G., & Waycott, J. (2023). Understanding older adults' experiences with technologies for health self-management: Interview study. *JMIR Aging*, 6, e43197. <https://doi.org/10.2196/43197>
10. Gasteiger, N., Ahn, H. S., Lee, C., Lim, J., MacDonald, B. A., Kim, G. H., & Broadbent, E. (2022). Participatory design, development, and testing of assistive health robots with older adults: An

international four-year project. *Journal of Human-Robot Interaction*, 11(4), Article 45, 19 pages. <https://doi.org/10.1145/3533726>

11. Greve, K., Vita, R. D., Leminen, S., & Westerlund, M. (2021). Living Labs: From Niche to Mainstream Innovation Management. *Sustainability*, 13(2), 791.

12. Gubser, R., & Pohle, J. (2026). Towards Better Collaborative Governance of AI Systems Development and Use – the CoAIG Framework. *Digital Society* (under review).

13. Hassenzahl, M. (2010). Experience design: Technology for all the right reasons. *Synthesis Lectures on Human-Centered Informatics*, 3(1), 1–95. <https://doi.org/10.2200/S00261ED1V01Y201003HCI008>

14. Hauth, F., Bizu, V., App, R., Lautenbacher, H., Tenev, A., Bitzer, M., Malek, N., Zips, D., & Gani, C. (2019). Electronic patient-reported outcome measures in radiation oncology: Initial experience after workflow implementation. *JMIR mHealth and uHealth*, 7(7), e12345. <https://doi.org/10.2196/12345>

15. Jackson, P., Schildhauer, T., Ulich, A., Pohle, J., & Jansen, S. A. (2021). Aging, independent living and technology. *Stiftung für Internet und Gesellschaft*. <https://doi.org/10.5281/zenodo.5026032>

16. Jones, P. H. (2014). Systemic design principles for complex social systems.

17. Kilfoy, A., Hsu, T. C. C., Stockton-Powdrell, C., et al. (2024). An umbrella review on how digital health intervention co-design is conducted and described. *npj Digital Medicine*, 7, 374. <https://doi.org/10.1038/s41746-024-01385-1>

18. Krause-Jüttler, G., Weitz, J., & Bork, U. (2022). Interdisciplinary collaborations in digital health research: Mixed methods case study. *JMIR Human Factors*, 9(2), e36579. <https://doi.org/10.2196/36579>

19. Lindsay, S., Jackson, D., Schofield, G., & Olivier, P. (2012). Engaging older people using participatory design. In *CHI '12: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1199–1208). <https://doi.org/10.1145/2207676.2208570>

20. Müller, Doreen, Jachan, Deborah Elisabeth, Stahl, Maria, Rosenbusch, Marie-Luise, Liersch-Mazan, Daniela, Lippert, Peggi, Hinricher, Niels, Ivanova, Maria, STH Research Group, Schulz, Mandy, Lahmann, Nils. Establishing a telemedical supported trans-sectoral collaboration network from community support to emergency care for outpatient care recipients: study protocol of a prospective

non-randomized complex intervention study with a pragmatic approach, Stay@Home - Treat@Home. BMC Geriatr. 2024;24(1):987.

21. Peters, D. (2022). Wellbeing supportive design – Research-based guidelines for supporting psychological wellbeing in user experience. International Journal of Human–Computer Interaction, 39(14), 2965–2977. <https://doi.org/10.1080/10447318.2022.2089812>

22. Pohle, J., Grafenstein, M., & Ulich, A. (2023). Menschenzentrierte Data Governance im Gesundheits- und Pflegesektor. Digital Society Blog. <https://doi.org/10.5281/zenodo.7643098>

23. Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. CoDesign, 4(1), 5–18. <https://doi.org/10.1080/15710880701875068>

22. Schuurman, D., De Marez, L., & Ballon, P. (2015). Living Labs: a systematic literature review. *Open Living Lab Days 2015, Proceedings*. Presented at the Open Living Lab Days 2015, Istanbul, Turkey.

24. Sevaldson, B. (2021). Systemic design: Theory, methods, and practice. Oslo School of Architecture and Design. Smits, M., Kim, C. M., van Goor, H., & Ludden, G. D. S. (2022). From digital health to digital well-being: Systematic scoping review. Journal of Medical Internet Research, 24(4), e33787. <https://doi.org/10.2196/33787>

25. Span, M., Hettinga, M., Vernooij-Dassen, M., Eefsting, J., & Smits, C. (2013). Involving people with dementia in the development of supportive IT applications: A systematic review. Ageing Research Reviews, 12(2), 535–551. <https://doi.org/10.1016/j.arr.2013.01.002>

26. Stegner, L., Senft, E., & Mutlu, B. (2023). Situated participatory design: A method for in situ design of robotic interaction with older adults. arXiv. <https://doi.org/10.48550/arXiv.2302.00588> Stickdorn, M., Lawrence, A., Hormess, M. E., & Schneider, J. (2018). This is service design doing: Applying service design thinking in the real world. O'Reilly Media.

Appendix A: Process reflection

This appendix offers a brief reflection on how the Einstein Circle worked in practice – where our process was effective, and where we encountered difficulties. The aim is not to criticise individuals, but to provide honest feedback that can be useful for future circles and foundations when designing similar formats.

A.1 Subgroups:

At the beginning of the project, the Circle was divided into three thematic subgroups (Technology Development and Usability; Social Sciences, Ethics, and Policy; Longevity and Broader Impacts). In principle, this structure made sense: it reflected the interdisciplinary breadth of the topic and created smaller units in which members could, in theory, work more intensively and develop specific contributions.

In practice, however, the subgroups proved difficult to manage. Some of them had very few active members from the outset, and others lost members over time as people stepped back or became less available. Coordinating meeting times across time zones, professional commitments and personal schedules turned out to be challenging. As a result, many subgroup meetings either did not take place at all or had so few participants that sustained work was difficult. Over the course of the project, a considerable part of the subgroup activity shifted back into the full Circle meetings or into ad-hoc small constellations rather than formal subgroup sessions.

From this experience, we draw the conclusion that subgroups should be used with caution. They can be helpful, but only if there is a clear minimum number of active members, realistic expectations about their availability and a simple way to coordinate their work. Future circles may wish to keep the number of subgroups low, ensure that each has a critical mass of contributors and revisit the subgroup structure early on if participation patterns change.

A.2 Participation and tempo:

Throughout the project, one of the persistent challenges was limited active participation. Even though the Circle formally included a larger number of members, in most meetings only about half of them attended, and the same smaller core tended to carry the bulk of the ongoing work. This is understandable, given that members had many other professional and personal commitments; however, it meant that the pace of progress was slower than initially planned.

Deadlines had to be adjusted several times, and tasks such as drafting sections or revising documents often took longer because contributions were delayed or remained incomplete. This affected subgroup work as well as joint products like the position paper and the Whitepaper Playbook. An important lesson is that, in a voluntary or lightly funded setting, it is necessary to build in more time than one might expect and to accept that only a subset of members will actively contribute at any given moment.

Future circles may want to explore more flexible participation models, where smaller “task forces” or editorial teams are explicitly mandated to carry specific outputs forward, while the broader group is invited to review and comment rather than co-write every part.

A.3 Communication and tools:

The Circle mainly relied on email, scheduled online meetings and shared documents to coordinate its work. While these tools are standard and widely accessible, they have limitations. Email in particular is easy to overlook, and long threads can become confusing; shared documents were used, but not all members checked them regularly.

We also set up a Miro board as a shared brainstorming surface. It was useful at key moments (for example, to collect ideas, decide on main approaches, etc.), but in hindsight we did not integrate it consistently enough into our regular workflow. It remained more of an occasional tool than a central place where the project “lived”. A more deliberate integration – or the choice of another simple brainstorming / collaboration platform – might have helped to keep ideas, comments and decisions more visible and to invite contributions between meetings.

Looking back, it might have been helpful to use a more interactive platform or app as a central hub – for example, a dedicated online workspace where members can leave short “live” comments, react to others’ ideas and receive notifications when something new is added. Such a space could also make it easier to see everyone’s availability, propose meeting times and keep track of open questions and decisions in a structured way.

For future circles, we would therefore recommend choosing at the outset a simple but more dynamic collaboration environment (such as a shared workspace, project board or co-working platform), agreeing clearly on how it should be used, and revisiting this agreement once or twice during the project. The goal is not to add complexity, but to give members a central place where the project is present between meetings and where engagement is not dependent on email alone.

A.4 Interdisciplinarity and allocation of writing tasks

The Circle was deliberately interdisciplinary, bringing together different professional and disciplinary backgrounds. This breadth is one of its strengths, but it created challenges when it came to writing and structuring joint outputs, especially the position paper. Initially, many sections were drafted individually, with different authors working more or less independently on their own parts. Only later in the process did it become fully apparent how much thematic overlap existed between sections and how fragmented the overall structure had become.

As a consequence, substantial editorial work was needed to move from a collection of many partly overlapping, individually written sections to a more coherent, co-authored text that reflects contributions from across the Circle. A turning point was when one member of the Circle, Katarina Braune, took on a clear coordinating and editorial role and invested significant effort in reorganising the structure, merging overlapping sections and editing the language. Together with the rest of the editorial team, this work was crucial: the paper only really took shape once a specific person assumed responsibility for bringing the different contributions together.

The main lesson here is not that overlap is undesirable – in an interdisciplinary setting, it is inevitable and often productive – but that the process for managing it matters. Future circles might benefit from agreeing earlier on a shared structure, mapping out who plans to write about which topics, and revisiting this mapping once a first round of drafts exists. It may also help to designate a small editorial group with an explicit mandate and enough time to weave individual contributions together from the beginning, rather than only at the end, so that co-authorship is built into the process and not just the final stage.

A.5 Value of in-person meetings

The project included one in-person meeting in Berlin. This meeting was experienced as particularly productive and motivating. It allowed members to get to know each other better, to discuss topics in more depth and to share case studies in a more immediate way than is possible online. The personal atmosphere and informal conversations around the formal agenda helped build trust and make the Circle feel more like a cohesive group.

In retrospect, more than one in-person meeting would likely have been beneficial, even if kept short and combined with other events. Face-to-face interaction appears especially valuable in interdisciplinary constellations, where participants may not know each other beforehand and where trust and shared understanding are crucial.

For future circles, we would recommend planning at least two in-person meetings if resources allow: one early on to establish connections and one later to consolidate results and make decisions about outputs.

A.6 What worked well

Despite the challenges described above, several elements of the process worked very well and are worth preserving:

- Presentations of individual projects and research

Giving space for members and students to present their ongoing work – for example in music therapy, design, occupational therapy or digital health – was consistently useful. These presentations anchored discussions in concrete examples and reminded the group that the “smaller picture” of specific projects is just as important as the larger conceptual framework. We recommend that future circles continue to integrate such presentations regularly.

- Development of a position paper

The decision to write a position paper required considerable effort, but it proved to be one of the most valuable outcomes of the project. It allowed the Circle to collect and articulate its overall perspective, to formalise the seven-domain framework and to formulate a coherent agenda for healthy longevity. The position paper now serves as a reference point for the Whitepaper Playbook and for future work.

- International collaboration

The collaboration with international partners, particularly from outside Germany, was a clear positive element. It broadened perspectives, introduced additional case studies and programme examples, and led to concrete plans for research exchange. Such international links also strengthen the role of Berlin and Brandenburg in global discussions on digital health and ageing.

- Inviting external participants and public engagement opportunities

Inviting external people into the Circle’s activities, some of whom later became more closely involved, enriched discussions and extended the network. Opportunities to present the Circle’s work to the general public, such as the invitation to “Einstein in the Dome”, were also seen as very valuable. They provide a way to communicate complex topics beyond academic contexts and to test how messages resonate with broader audiences.

A.7 Summary of lessons learned

Overall, the work of the Einstein Circle shows that it is possible to generate meaningful conceptual and practical insights within a limited timeframe and with heterogeneous participation. At the same time, it also shows how demanding interdisciplinary collaboration can be when most participants are working under considerable time constraints.

Key lessons include:

- Subgroups need realistic staffing and may need to be adjusted if participation changes.
- A smaller core of active members will likely carry most of the work; structures should acknowledge this reality.
- More interactive and “live” communication tools could support engagement between meetings.
- In-person meetings, even if few, are highly valuable for building trust and advancing work.
- Regular presentations of concrete projects keep the work grounded.
- A substantial joint product, such as a position paper, can provide clarity and focus for subsequent activities.
- International collaboration and public-facing formats enrich the work and extend its impact.

These reflections are offered in the spirit of constructive feedback, with the hope that they will help future circles and foundations design processes that build on what worked well and address the challenges we encountered.

Appendix B: The Position Paper's Publication Process

One of the central outputs of the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies” is the position paper “Digital Technologies for Healthy Longevity: A Policy Agenda from the Einstein Circle on Inclusive, Data-Driven Ageing Societies”. The paper represents the Circle’s main external output, synthesising the interdisciplinary discussions within the group and formulating a policy-oriented agenda for advancing healthy longevity through digital technologies. As a peer-reviewed publication in an international scientific journal (indexed in academic databases such as PubMed), it is intended to reach the wider research and policy community and to contribute to the academic discourse on digital health and ageing.

The decision to develop a position paper emerged during the Circle’s work when it became clear that the wide range of examples, disciplinary perspectives, and thematic discussions required a stronger conceptual backbone. The paper therefore served to articulate a shared framework and common language that could integrate the contributions of the different subgroups and translate them into a coherent agenda.

The manuscript was developed iteratively. Initial ideas and case examples were explored within thematic subgroups, after which a smaller editorial team coordinated the integration and revision of the contributions. Through this process, the Circle formulated the conceptual framework that structures the paper. As described in Chapter 1 and illustrated in Figure 1 of this Playbook, the framework brings together seven interrelated domains (medical, technical, practical, interactive, psycho-social, ethical, and legal) to capture the different dimensions through which digital technologies influence health, care, and participation in ageing societies. [OBJ]

Drawing on the interdisciplinary expertise of the Circle, the position paper highlights best-practice examples and initiatives from the authors’ respective fields, including medicine, digital health, design, informatics, policy, and community-based care. These examples illustrate how digital approaches to prevention, monitoring, participation, and care can be implemented in practice and where structural barriers, such as fragmentation of care systems, limited interoperability, or insufficient user involvement, still need to be addressed. Based on these insights, the paper formulates recommendations for best practices and areas where further improvement is needed, addressing policymakers, researchers, healthcare organisations, and technology developers working on ageing and digital health.

The manuscript underwent several rounds of revision and was initially submitted to *The Lancet Healthy Longevity*. Following editorial review, the paper was transferred to Ageing Research Reviews, where it is currently under review.

While the position paper communicates the Circle's conceptual framework, examples, and policy recommendations to the wider community, the Whitepaper Playbook serves a complementary purpose. Rather than presenting the agenda externally, it documents how the Circle worked: how themes were developed, how interdisciplinary collaboration was organised, and what lessons can be drawn for future initiatives. In this sense, the Playbook builds on the conceptual work of the position paper while providing a practical reflection on the collaborative process that produced it.

Digital Technologies for Healthy Longevity: A Policy Agenda from the Einstein Circle on Inclusive, Data-Driven Ageing Societies

Katarina Braune MD^{1,2†}, Thorsten Schaaf PhD^{2†}, Felix Balzer MD PhD², Dawn I Bershtein³, Andrew Broderick MA MBA⁵, Pelin Celik PhD⁶, Tabea Flügge DDS⁷, Katherine K Kim PhD MPH MBA^{4,5}, Nils Lahmann PhD MSE^{8,9}, David Lindemann PhD MSW^{4,5}, Stefan Mainka PhD^{3,10}, Susan Mérillat PhD^{11,12}, Jörg Pohle PhD¹³, Thomas Schildhauer PhD^{3,13}, Mike Martin PhD^{11,12}

† These authors contributed equally.

1. Hasso Plattner Institute for Digital Engineering, University of Potsdam, Potsdam, Germany
2. Institute of Medical Informatics, Charité – Universitätsmedizin Berlin, Berlin, Germany
3. Berlin University of the Arts, Berlin, Germany
4. University of California Davis, Davis, CA, United States
5. CITRIS Health, University of California, Berkeley, CA, United States
6. University of Applied Sciences (HTW Berlin), Berlin, Germany
7. Department of Oral and Maxillofacial Surgery, Charité – Universitätsmedizin Berlin, Berlin, Germany
8. Department of Geriatrics and Medical Gerontology, Charité – Universitätsmedizin Berlin, Berlin, Germany
9. Faculty of Natural Sciences, MSB Medical School Berlin, Berlin, Germany
10. Movement Disorder Clinic, Beelitz-Heilstätten, Germany
11. Department of Psychology, University of Zurich, Zurich, Switzerland
12. Healthy Longevity Center, University of Zurich, Zurich, Switzerland
13. Alexander von Humboldt Institute for Internet and Society (HIIG), Berlin, Germany

Correspondence to: Prof Katarina Braune, Hasso Plattner Institute for Digital Engineering, University of Potsdam, Potsdam, Germany, Email: office-braune@hpi.de

Abstract

Background: Rapid population ageing presents one of the defining global health challenges of the twenty-first century. While digital technologies are increasingly used to support older adults, their deployment often remains fragmented, inequitable, and insufficiently guided by ethical and legal frameworks. This paper proposes an integrated policy agenda for healthy longevity, based on the interdisciplinary work of the Einstein Circle Longevity – Healthy Ageing Assisted by Digital Technologies. **Methods:** Drawing on literature, expert deliberation, and practical exemplars, we developed a conceptual framework encompassing seven interrelated domains—medical, technical, practical, interactive, psycho-social, ethical, and legal. The framework highlights the need to reframe health and ageing policy around functional ability and healthspan, not merely disease outcomes, and to embed equity and participation throughout the design and governance of digital health systems. **Interpretation:** Digital technologies can extend preventive and personalised care, foster independence, and enhance participation across the life course. Yet their benefits remain unevenly distributed because of disparities in digital access, usability, and representation in data and design. Policies must ensure that technologies respect human rights, protect autonomy, and strengthen – rather than replace – social relationships and professional care. **Policy implications:** Realising the potential of digital health for healthy longevity requires investment in interoperable infrastructure, participatory design, and ethical and legal safeguards. Cross-sector collaboration and transparent governance are essential to ensure that technology adds not only years to life, but life to years.

Introduction

Healthy longevity is increasingly recognised as a defining challenge of the twenty-first century. Population ageing is progressing across all world regions. By 2050, one in six people globally will be aged 65 years or older. Population ageing coincides with a surge in chronic multimorbidity and a digital revolution transforming the organisation of care. This transformation offers opportunities to reimagine how societies support wellbeing across the life course. Yet it also exposes weaknesses in health, social, and legal systems designed for a different era. Digital transformation has become a central driver of this shift, promising more personalised, preventive, and participatory care while also raising new ethical, technical, and governance challenges.

Building on the collaborative work of the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies”, this paper outlines a multidimensional framework to guide research, policy, and practice. It addresses seven interlinked domains, as illustrated in **Figure 1**: Medical, Technical, Practical, Interactive, Psycho-Social, Ethical, and Legal, each reflecting key determinants of healthy longevity in our digital world. Further, illustrative best-practice examples are summarised in **Table 1**, and overarching policy priorities are listed in **Panel 1** at the end of the article. To illustrate how the seven domains can be operationalised in practice, we compiled a set of diverse, cross-cutting examples from medicine, design, informatics, and community care. These examples highlight how real-world initiatives naturally draw on multiple domains at once and show how the principles of the framework can be translated into actionable strategies across different contexts and sectors.

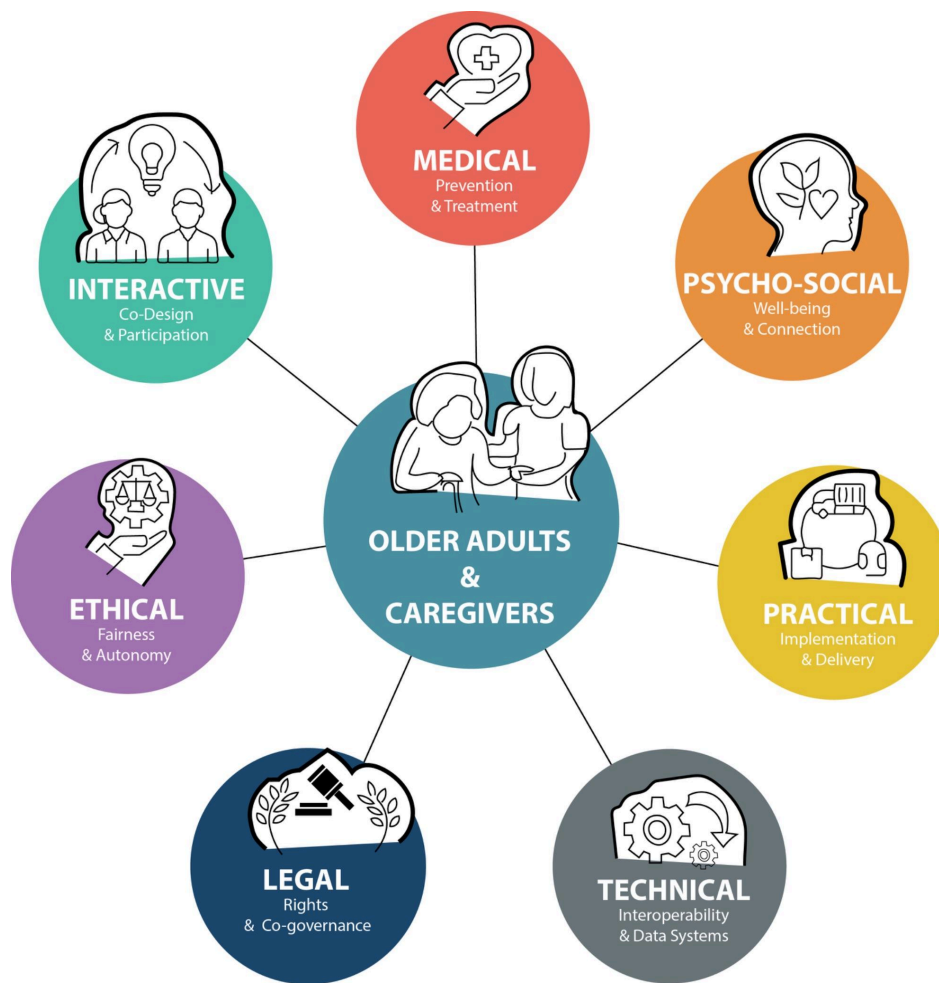


Figure 1: The seven domains of the Einstein Circle framework for digital technologies and healthy longevity. The framework integrates seven interrelated domains (Medical, Technical, Practical, Interactive, Psycho-Social, Ethical, and Legal) that together define the determinants of healthy ageing in the digital era. Each domain represents a distinct yet interconnected dimension of how technology, care, and society interact to promote functional ability, equity, and well-being across the life course.

Table 1: Best practice examples of digital technologies and participatory frameworks supporting healthy longevity. Illustrative best-practice examples demonstrating how the seven-domain framework can be applied across real-world settings. The examples are intentionally diverse: each reflects multiple interacting domains, highlighting that healthy longevity emerges from cross-sector, interdisciplinary, and context-specific approaches rather than from siloed interventions. Together, they offer practical insights into how innovation, governance, prevention, and participation can reinforce functional ability, equity, and dignity in later life.

Example	Description and Key Insights	Domains
Hospital@Home Models	Originating in the 1970s and revitalised through telemedicine and remote monitoring, these programmes provide hospital-level care at home for selected conditions such as heart failure, COPD exacerbations, and post-operative recovery. Mobile teams, point-of-care diagnostics, and wearable sensors enable acute and rehabilitative care while preserving autonomy and reducing institutionalisation. Evidence shows comparable or improved outcomes and satisfaction relative to inpatient care. Implementation requires aligned reimbursement, governance, workforce training, and interoperable digital infrastructure.	Medical, Practical, Technical
#WeAreNotWaiting (Open-Source Diabetes Technology Movement)	A global, community-driven initiative in which people with diabetes, caregivers, and technologists co-develop interoperable software for automated insulin delivery (AID). It illustrates user-led innovation and the role of lived experience in advancing responsible, transparent, and person-centred technology development. Open-source AID solutions address diverse needs, including voice-enabled control, accessibility for visual or motor impairments, and caregiver monitoring. This model shows how user-driven ecosystems can complement regulation and inspire inclusive policy frameworks for chronic-disease management. ¹	Medical, Technical, Interactive
Digital Twin Models for Personalised Ageing	Simulation and prediction engines applying artificial intelligence to multimodal data – clinical, behavioural, and environmental – model an individual’s ageing trajectory and response to interventions. Although still in early development, digital twin models demonstrate how real-world data can support personalised prevention, scenario testing, and adaptive care planning. ^{2,3} When validated and applied equitably, they hold potential to guide proactive, context-sensitive approaches to healthy longevity across diverse populations.	Medical, Technical
Open-Standards Health Data Infrastructure	International interoperability standards facilitate secure exchange of clinical and self-generated data across hospitals, outpatient settings, and home monitoring. By promoting consistency in content representation, semantics (e.g. SNOMED), data exchange (e.g., FHIR), and privacy and security (e.g., HIPAA, GDPR), such standards underpin longitudinal data ecosystems essential for continuity of care and healthy longevity. Sustained governance and workforce capacity are key for equitable implementation.	Technical, Legal
Federated Learning and Privacy-Preserving Data Analytics	Federated and privacy-preserving analytical methods enable the collaborative use of distributed health data without transferring or centralising sensitive information. ⁴ In ageing and longevity research, these approaches allow institutions to generate cross-cohort insights while maintaining data sovereignty and local control. Techniques such as differential privacy, federated learning, and blockchain-based audit trails strengthen compliance with data protection regulations and enhance public trust. When paired with equitable access to computing infrastructure and transparent governance, these methods can expand participation in global research networks, including institutions in low- and middle-income countries.	Technical, Ethical, Legal

Dynamic Consent Models in Health Data Ecosystems	Adaptive consent frameworks enable individuals to exercise ongoing control over how their personal health data are accessed and used. ^{5,6} Through user-friendly digital interfaces, individuals can modify permissions, monitor secondary data use, and withdraw consent at any time. Such models enhance transparency, autonomy, and accountability in data governance, aligning with participatory ethics and international data protection standards such as the EU General Data Protection Regulation. When adapted for low-literacy or low-connectivity environments, dynamic consent can also strengthen trust and engagement in global and cross-border health research.	Legal, Ethical, Technical
Algorithmic Auditing and Fairness Frameworks in AI for Ageing	Systematic auditing of artificial intelligence models – through transparent documentation of training datasets, age-stratified performance evaluation, and regular recalibration using diverse real-world data – helps prevent discrimination and bias against older adults. Such frameworks translate ethical and legal principles of justice, beneficence, and accountability into practice, ensuring that AI systems support equitable and context-sensitive care across populations. Incorporating data from varied geographic, socioeconomic, and health system contexts is essential to avoid exporting bias from high-income to low-resource settings.	Ethical, Technical, Legal
Living Lab Approaches for Digital Health Innovation	Living labs are real-world settings in which older adults, caregivers, clinicians, and developers collaboratively design and test technologies within authentic everyday environments. These participatory ecosystems enable iterative improvement, ethical foresight, and evaluation of usability and impact under practical conditions. By linking research directly to community needs, living labs bridge the gap between innovation and implementation. When adapted for diverse cultural and infrastructural contexts, they can support equitable digital health development across income settings.	Interactive, Practical, Ethical
Participatory Design of Assistive Robots	International multi-year research programmes have integrated older adults, caregivers, clinicians, and engineers in the co-design of assistive robots for daily living and care environments. ⁷ Through iterative workshops, prototyping, and real-world field testing, participants directly informed the refinement of usability, aesthetics, emotional interaction, and ethical acceptability. Findings demonstrated that early and sustained involvement of users enhances trust, emotional connection, and long-term adoption, while mitigating perceptions of paternalism and dependence.	Technical, Interactive, Psycho-Social
Systemic and Experience Design Frameworks	Design methodologies that integrate system-level complexity with user experience (UX) principles align digital health solutions with the psychological needs of older adults—particularly autonomy, competence, and relatedness. Frameworks such as those developed by Hassenzahl offer heuristics for creating emotionally positive, inclusive, and accessible technologies that promote well-being and engagement across diverse populations.	Interactive, Psycho-Social
Interdisciplinary Collaboration Models	Transdisciplinary initiatives bring together clinicians, engineers, designers, and social scientists to build a shared understanding of ageing, care, and technology. Structured collaboration methods—such as co-creation workshops, journey mapping, and rapid prototyping—enhance communication and integration across disciplines, ensuring that innovations align with real-world workflows, ethical principles, and user values. Such models strengthen translation from research to implementation and foster innovation ecosystems that are both context-sensitive and sustainable.	Interactive, Practical
Community-Based Digital Health and Ageing-in-Place	Digital care programs that integrate remote monitoring, mobile health applications, and community health workers enable older adults to remain safely at home while maintaining continuity of care. Effective programs	Medical, Practical

Programs	enhance the technical infrastructure embedded with workflows in care provider organizations and support adoption among older adults to improve self-management and collaboration with the clinicians. ⁸ In low- and middle-income countries, such programmes illustrate how low-cost, decentralised digital solutions can extend access to essential services, enhance equity, and reduce pressure on hospitals. When embedded within existing primary care and community structures, they also strengthen trust and ensure culturally appropriate delivery.	
Age-Friendly Cities and Active Citizenship Initiatives	Municipal and community programmes that promote digital literacy, intergenerational learning, and social participation help older adults engage meaningfully in civic and community life. These initiatives bridge the gap between digital inclusion and active citizenship, reinforcing autonomy, purpose, and belonging—key social determinants of healthy ageing. When embedded in local governance and supported by accessible digital infrastructure, they foster inclusion, intergenerational solidarity, and lifelong participation.	Interactive, Practical, Psycho-Social
Music- and Art-Based Digital Therapies	Digital platforms delivering music-based activities, movement-to-music training (for example, Curaswing), and virtual-reality art programmes have shown measurable benefits for cognitive function, mood, motor coordination, and social connectedness among older adults, including those living with Parkinson’s disease or dementia. These creative, evidence-informed interventions illustrate how technology can nurture emotional well-being and neuroplasticity, particularly where access to qualified therapists or rehabilitation services is limited.	Medical, Psycho-Social, Interactive
AI-Powered Medication Management	AI-powered medication management systems, combining intelligent pill dispensing with conversational AI interactions, support older adults and individuals with cognitive impairment in medication adherence, daily routines, and overall well-being. Companion devices and mobile interfaces enable seamless communication with caregivers and healthcare professionals, providing real-time insights into health, activity, and adherence. These evidence-informed, user-centred technologies illustrate how AI can enhance autonomy, safety, and connectedness, particularly for individuals living independently or in assisted care settings, while complementing traditional healthcare support.	Medical, Psycho-Social, Interactive
Design-Based Digital Occupational Therapy	Digital tools that support art- and design-based occupational therapy, combining interactive clay modelling with 3D printing to foster creative self-expression, fine motor skills, and emotional well-being. Tangible artistic outputs serve as meaningful reminders of accomplishment and shared experiences, extending access to therapeutic activities in home or care settings.	Technical, Interactive, Psycho-Social
Age-Friendly Health Systems	The Age-Friendly Health Systems (AFHS) initiative provides a framework for hospitals, primary care practices, pharmacies, nursing homes, and home-care organisations to deliver care that is safe, evidence-based, and tailored to the needs of older adults. Centred on the “4Ms” model – What Matters, Medication, Mentation, and Mobility – AFHS promotes consistent, person-centred care across the continuum. Implementation requires coordination across health and public-health sectors to embed healthy ageing and equity as core functions of service delivery. Collaboration across organisations and communities enables shared measurement and improvement strategies that reduce avoidable hospitalisations, support recovery at home, and enhance quality of life for older adults.	Medical, Practical, Ethical
Quality Health	Under the U.S. Trusted Exchange Framework and Common Agreement	Technical,

Information Networks	(TEFCA), QHINs provide a national infrastructure for secure, standardised exchange of clinical data between health systems, public health agencies, and digital health providers. The “connect once, access many” architecture enables interoperable data flow across settings, reducing fragmentation and improving care coordination. For ageing populations, longitudinal data exchange through QHINs can support continuity of care, especially for older adults managing multiple conditions across providers. While currently specific to the U.S. context, the model illustrates how large-scale, standards-based data networks could strengthen equitable, person-centred, and preventive care for older adults in other regions.	Medical, Legal
California Data Exchange Framework	The California Data Exchange Framework (DxF) establishes a statewide legal and technical foundation for secure, real-time sharing of health and social data across hospitals, physician groups, nursing facilities, health plans, laboratories, and community organisations. By leveraging existing health information networks and modern interoperability standards (e.g., FHIR, HL7), the DxF enables coordinated, “whole-person” care that integrates clinical and social determinants of health. For older adults, event-based alerts and linked social-care data support timely follow-up after hospital discharge, prevent care gaps, and help maintain functional ability and independence. The DxF demonstrates how regional, standards-based data ecosystems can enhance continuity, safety, and equity in ageing populations.	Technical, Practical, Legal
Real-World Evidence Collaborative	Real-world data—derived from electronic health records, laboratory systems, claims databases, and patient-generated sources—capture how medical interventions perform in routine practice. When analysed systematically, such data generate real-world evidence (RWE) that can complement clinical trials, inform regulatory and reimbursement decisions, and guide person-centred care. For ageing populations, RWE helps identify treatment effects in multimorbid and frail individuals often excluded from traditional studies. Integration of patient-generated health data further enriches understanding of functional ability and lived experience. Globally, collaborative initiatives are developing methodological and ethical standards to ensure that RWE strengthens safety, precision, and equity in digital and population health research.	Legal, Practical, Medical
Participatory AI Frameworks	Participatory AI builds on co-design principles that develop technologies with rather than for affected populations. By involving older adults and other underrepresented groups in model design, data selection, and evaluation, these frameworks aim to create fairer, more accurate, and trustworthy AI systems. Moving beyond deficit-based assumptions, participatory AI recognises older adults as experts in their lived experience and supports technologies that enhance independence, accessibility, and dignity. Applied in ageing contexts, this approach ensures that AI-driven health tools—such as adaptive medication reminders, remote monitoring, or cognitive support applications—reflect real user priorities, cultural contexts, and functional needs.	Legal, Practical, Interactive, Psycho-social
AgeTech Collaborative	The AgeTech Collaborative from AARP is a mission-driven, business-to-business ecosystem advancing technology innovation for healthy ageing. The Collaborative convenes startups, researchers, caregivers, investors, and older adults to co-create solutions that enhance physical independence, support chronic-disease management, and reduce social isolation. Through its accelerator and virtual community, it provides mentorship, pilot-testing opportunities, and partnerships that help scale inclusive, evidence-based, and sustainable technologies. By focusing on prevention, health promotion, and cognitive and social well-being, the	Interactive, Practical, Ethical. Psycho-social

	Collaborative exemplifies a whole-of-society approach to ageing innovation rooted in participatory design and real-world validation.	
--	--	--

Medical Domain

The prevalence of chronic and complex health conditions increases with age. Cardiovascular disease, diabetes, cancer, chronic respiratory illness, dementia, depression, musculoskeletal disorders, and sensory decline frequently coexist, producing multimorbidity that challenges traditional, single-disease models of care.⁹ Globally, at least two-thirds of older adults live with multiple health challenges, underscoring the need for personalised and coordinated approaches that extend beyond episodic treatment to continuous, person-centred support.¹⁰ The COVID-19 pandemic further exposed vulnerabilities in long-term care facilities and underscored the importance of resilient systems that ensure safety, social connection, and adequate staffing.¹¹

Oral health is an important component of healthy ageing, supporting essential functions such as eating, speaking, breathing, and social interaction, and contributing to dignity and societal participation.¹² Oral conditions, including dental caries, periodontal disease, tooth loss, and oral cancer, are among the most prevalent non-communicable diseases worldwide and disproportionately affect older adults.¹³ Oral health and systemic health care are closely linked: for instance, diabetes and periodontitis have a bidirectional relationship, and further associations have been shown with cardiovascular disease, chronic respiratory illness, and cognitive decline.¹⁴

The World Health Organisation defines functional ability – the capacity to do what one values – as the central outcome of healthy ageing.¹⁵ Addressing geriatric syndromes such as frailty, falls, delirium, incontinence, and pressure injuries requires strategies that integrate physical, psychological, and environmental factors. This reframing shifts the focus from single conditions to overall capacity, aligning with person-centred perspectives, and from extending lifespan to enhancing healthspan, which refers to the years lived in good health and with functional ability. This concept of compression of morbidity emphasises delaying the onset of functional decline so that added years are quality years.¹⁶

Prevention and health promotion are critical to achieving this goal. Evidence shows that modifiable factors – nutrition, physical activity, reduced smoking and alcohol use, and social engagement – substantially influence well-being in later life.^{17–22} Yet preventive measures remain underused because of fragmented systems and the misconception that prevention yields limited benefit in older age. Digital health technologies can bridge this gap by extending the reach of preventive interventions and strengthening continuity of care.^{23–25} In many low- and middle-income countries, mobile-first health interventions, text-based counselling, and task-shared community programs already demonstrate how digital approaches can enhance prevention and follow-up care, even where specialist resources are limited.²⁶

Wearables, sensors, and mobile applications provide continuous feedback on activity, sleep, and vital signs, allowing early detection of deviation from baseline. Predictive analytics can identify risk for frailty or functional decline and guide timely interventions. Digital platforms also enable remote rehabilitation and support self-management.²⁷ These tools promote agency and shared responsibility for health, reinforcing the active role of older adults in maintaining independence.

However, benefits remain unevenly distributed. The digital divide—driven by disparities in connectivity, literacy, and usability—continues to exclude many who might benefit most. Beyond usability, disparities in infrastructure, affordability, and internet access—particularly in rural and low-resource settings—further constrain participation and adoption.^{28–31} Bridging this divide requires not only investment in accessible infrastructure and inclusive design but also in lifelong digital literacy and locally adapted implementation strategies.³²

Effective management of multimorbidity demands collaboration across medicine, nursing, rehabilitation, social work, and informal care. In many resource-limited settings, community health workers and family caregivers play a pivotal role in ensuring continuity of care and monitoring functional ability.^{33,34} Digital systems can facilitate such collaboration by creating shared information environments, enabling multidisciplinary care planning, and connecting families and professionals across settings. When adapted to local health system structures and capacities, digital tools can extend the reach of care, strengthen autonomy, and enhance quality of life in later years.

Technical Domain

The digital transformation of healthcare offers unprecedented opportunities to promote healthy ageing, but the fragmentation of health data continues to limit its potential. Older adults interact with multiple providers, sectors, and technologies throughout their lives. Data generated across hospitals, general practice, rehabilitation, and home-care settings, together with information from wearables, apps, and sensors, is stored in isolated systems. This fragmentation prevents continuous monitoring, delays timely interventions, and undermines coordination across care pathways.

Even when individuals use digital devices for activity tracking or arrhythmia detection, clinicians often lack the means to access or interpret the resulting data within clinical systems.³⁵ Semantic and technical incompatibilities between consumer technologies and hospital infrastructures result in valuable information being left unused. Healthy ageing, therefore, requires data systems that connect health information seamlessly across the life course and enable both individual and collective learning.

An interoperable and standards-based infrastructure is essential to address this challenge. Frameworks such as FHIR (Fast Healthcare Interoperability Resources) and SNOMED CT enable semantic consistency and secure exchange of health information across sectors.³⁶ Yet technical standards alone are insufficient. Interoperability also depends on governance, long-term investment, and policy incentives that promote shared maintenance and accountability. Sustainable governance frameworks should ensure quality assurance, equitable access, and continuity of care across institutional and national boundaries.

Interoperability must also be human-centred. Systems should be designed for usability and workflow integration, thereby reducing the documentation burden and facilitating effective communication among professionals, patients, and caregivers. Aligning data architecture with the practical realities of daily care can transform interoperability from a technical goal into a catalyst for person-centred service delivery.

Healthy ageing is an individual and dynamic process shaped by the interaction between an individual's intrinsic capacity and their environment. Capturing this complexity requires longitudinal and context-rich data that extend beyond episodic medical encounters.

Real-world data (RWD) from wearables, lifestyle apps, and home sensors complement traditional medical records by revealing patterns of behaviour, function, and context in everyday life.³⁷ Integration of multimodal RWD with clinical data can detect subtle changes in health trajectories, guide personalised prevention, and support adaptive intervention.³⁸ These data also enable care teams to understand the lived experiences of individuals and tailor support to their unique priorities. Examples of interoperable data infrastructures and federated governance models that operationalise such integration are summarised in **Table 1**.

Existing health-data infrastructures largely focus on clinical and research data, with limited capacity for high-density, longitudinal, or patient-generated information. Complementary architectures centred on individuals are therefore needed.^{39,40} Personal data accounts or citizen-controlled data hubs allow individuals to consolidate their own data across silos and exercise dynamic consent over their use. These systems can enhance health literacy and agency while enabling ethically governed secondary use for science and innovation.^{41,42}

Trust is fundamental. Strong privacy, security, and consent mechanisms must safeguard autonomy while permitting responsible data sharing.^{43,44} Federated and privacy-preserving approaches, such as distributed learning models, allow cross-institutional collaboration without centralising sensitive data.⁴ Transparent governance and ethical oversight are prerequisites for public confidence.⁴⁵

Key challenges include data quality, standardisation, and analytical reliability. Data from consumer devices vary in precision, and longitudinal drift undermines comparability over time.^{46,47} Continuous validation and calibration are essential. Balancing privacy with utility remains difficult: excessive protection can restrict learning, while lax governance risks eroding trust.⁴⁵ Analytical complexity also increases as data become more heterogeneous, demanding models that remain interpretable and fair.⁴⁸

Sustainability is equally critical. Interoperable infrastructures should be recognised as public goods requiring long-term investment, evaluation, and stewardship. Fragmented pilot projects or temporary funding cannot provide the continuity necessary for lifelong data integration. Coordinated action across healthcare, research, technology, and policy domains is necessary to establish enduring, equitable systems that support the goal of healthy longevity.

Integrated, secure, and human-centred data ecosystems can thus form the technical foundation for ageing well. They enable individuals to remain active participants in their own care, support professionals with shared insights, and generate the evidence base for informed policy.^{41,42}

Practical Domain

Rapid population ageing will intensify demand for acute and long-term care worldwide, exposing structural weaknesses in health and social care systems. Without redesign, current models of service delivery will struggle to remain sustainable. Expanding institutional capacity through conventional means would require substantial investment to meet a temporary demand peak. Sustainable strategies must instead focus on redesigning care delivery; integrating digital technologies, community-based services, and user-led innovation to maintain independence and quality of life.

Digitally supported home-based and community care models provide promising alternatives to traditional institutional care. These models deliver acute or rehabilitative services in domestic settings, supported by telemedicine, mobile care teams, and remote patient monitoring. Evidence suggests that when implemented within well-coordinated systems, such approaches can reduce hospital stays, improve quality of life, and lower costs. Illustrative initiatives, including hospital-at-home programmes, are summarised in **Table 1**.

Implementation remains constrained by persistent structural and regulatory barriers. Health systems are commonly divided into distinct sectors – hospital, outpatient, rehabilitation, and long-term care – each with its own financing and accountability mechanisms. These divisions inhibit coordination and continuity, while reimbursement systems seldom reward cross-sector collaboration. Reforming payment models and governance frameworks will be essential to scale digitally enabled care beyond pilot projects.

Educational barriers also hinder progress. New models of care require health professionals who are trained in both clinical and digital competencies, capable of delivering effective home-based care. Many older adults face challenges in using digital tools due to limited literacy or accessibility. Addressing these disparities demands sustained investment in training, digital inclusion, and universal design that accommodates sensory and cognitive diversity.

Technical limitations further restrict the implementation of integrated care. Reliable broadband connectivity, telemedicine infrastructure, and interoperable electronic health records are essential prerequisites for safe and effective care coordination; however, they remain unevenly developed across regions. Secure data exchange and real-time communication between sectors are vital for accountability and continuity.

Achieving digitally supported, person-centred care for ageing populations requires coordinated action across industry, regulation, workforce, and infrastructure.⁴⁹ Policy frameworks should align reimbursement and governance structures to facilitate integrated care, while investment in digital infrastructure and workforce training must ensure that innovation reaches all populations equitably. Policy must also take into account private sector companies and market forces which affect the supply of application digital solutions. Strengthening digital inclusion through accessible design and lifelong literacy initiatives will be essential to ensure that no group is left behind.

When structural, educational, and technical conditions are aligned, digitally enabled community care can become a foundation of healthy longevity – reducing unnecessary hospitalisation, maintaining autonomy, and enhancing wellbeing. These imperatives are echoed in the broader policy priorities outlined in **Panel 1**.

Interactive Domain

Despite growing recognition of their potential, many digital health technologies fail to address the psychological, social, and emotional dimensions of ageing. This gap often arises from the limited involvement of older adults in the design process and insufficient collaboration between disciplines. When designers, clinicians, engineers, and caregivers do not share common frameworks or tools, resulting technologies risk being fragmented, inaccessible, or misaligned with lived realities and user contexts.

Design for ageing populations frequently positions older adults as evaluators rather than as experts in their own lives. As a result, solutions may be technically effective yet socially or psychologically disconnected. Research consistently shows that authentic co-creation with older adults leads to greater acceptance, usability, and long-term engagement.⁵⁰ Participatory approaches that involve users and caregivers throughout the design process – rather than only at testing stages – reveal contextual barriers and enable the development of solutions that are embedded in real life.^{51,52} Situated co-design methods, conducted in everyday environments rather than laboratories, generate deeper insight into habits, routines, and social contexts that shape technology adoption.⁵³ In dementia care, for example, projects that engaged people living with dementia early in the design process achieved greater usability and emotional resonance than those that involved them only in the evaluation phase.⁵⁴ Yet participatory design is still too often treated as an optional add-on rather than as a foundational principle.⁵⁵ Embedding genuine co-creation as a standard of practice is essential to ensure that digital health solutions align with the psychological, cognitive, and social realities of older adults.

Digital health interventions tend to prioritise physical or clinical outcomes, overlooking psychological needs such as autonomy, competence, and relatedness. Evidence suggests that designs explicitly addressing these dimensions can enhance engagement, satisfaction, and overall well-being.⁵⁶ Frameworks for wellbeing-supportive design emphasise these universal needs and offer heuristics for creating technology that supports agency and connectedness, rather than merely functioning.^{57,58}

Understanding older adults' mental models – their internal representations of how systems work – is also critical. When design assumptions diverge from users' expectations, even well-intentioned technologies can provoke frustration or rejection.⁵⁹ Mapping and validating mental models through participatory and observational research improves usability, fosters trust, and increases adoption.⁵⁹

By grounding development in the lived contexts of ageing, designers can ensure that digital health tools are not only technically usable but also socially acceptable and emotionally supportive. But no single discipline can address the complex realities of ageing. Effective innovation requires collaboration among health, design, engineering, and social sciences.⁶⁰ Yet interdisciplinary teams often struggle to bridge methodological and linguistic divides. Design

disciplines can provide unifying frameworks such as systemic design and user experience design, which establish shared development processes and evaluation criteria.^{61,62} Participatory design tools—workshops, prototyping, journey mapping, and co-creation sessions—help align stakeholders around common goals and foster communication between clinicians, technologists, and end-users.⁶³ Embedding structured co-creation frameworks within interdisciplinary teams ensures that solutions are not only technically sound but also contextually relevant and responsive to the psychological and physical needs of older adults.

Design practices for ageing frequently adopt a deficit-based lens, framing older adults as vulnerable rather than as knowledgeable agents. This perspective risks paternalistic solutions that limit autonomy and reinforce ageist assumptions. Participatory and co-creative design methods offer a corrective, positioning older adults as contributors and mentors who bring experiential expertise to innovation. Such engagement strengthens self-efficacy, ownership, and dignity, ensuring that digital health solutions promote empowerment rather than dependency.^{41,42}

Ethical design for ageing must therefore move from protectionist frameworks toward partnership models that recognise capability, respect autonomy, and enhance wellbeing. When older adults are treated as collaborators and knowledge holders, technologies become vehicles for inclusion and agency rather than control.

Psycho-social Domain

Emotional health is a cornerstone of healthy ageing. It shapes motivation, resilience, social participation, and the ability to lead a meaningful life. As people age, changes in social roles, physical capacity, and social networks make emotional stability and connectedness increasingly important. According to the World Health Organisation, healthy ageing is “the process of developing and maintaining the functional ability that enables well-being in older age.” Well-being, therefore, is not merely the absence of disease but the capacity to do what one values. Emotional health is thus both a determinant and an indicator of functional ability and overall quality of life.

Digital technologies can promote emotional and psychosocial well-being in later life when designed with empathy, participation, and sensitivity to individual lived experiences. Digital innovation supports emotional health across multiple dimensions, including creativity, social connectedness, and self-regulation.

Creative and cultural engagement plays a critical role in emotional, cognitive and physical vitality. Music- and art-based interventions, digital musical instruments, and interactive dance or movement platforms stimulate neural networks involved in cognitive processes like auditory perception, attention, working memory and episodic memory, in motor functions, and in reward and emotion. Studies have shown that music interventions can reduce stress hormones, enhance mood, and strengthen cognitive, motor and social engagement in older adults, including those with mild cognitive impairment.⁶⁴ Technology can extend access to such interventions through adaptive sensors, AI-supported feedback, and online group participation.

Social connectedness is equally vital to emotional well-being. Digital communication, telecare systems, and online communities can help reduce isolation and foster a sense of belonging, particularly for individuals with limited mobility or caregiving responsibilities. Yet, evidence

underscores that emotional benefits arise from the *quality* rather than the frequency of digital interaction. Technologies that enable meaningful social exchange, rather than transactional communication, contribute most to overall well-being.

Self-regulation and mindfulness technologies, including digital diaries, emotion-tracking apps, biofeedback tools, and mindfulness platforms, can enhance awareness of emotional states and support stress reduction. These interventions show potential for strengthening coping mechanisms and maintaining emotional balance in daily life. However, their effectiveness depends on tailoring to cognitive and sensory capacities, as well as ensuring privacy and data security.

Emotional outcomes are rarely prioritised in the design and evaluation of digital health technologies. Most systems emphasise clinical or physical metrics, overlooking indicators such as joy, belonging, or a sense of purpose. Embedding emotion as a design parameter can ensure that digital tools support holistic well-being, rather than merely functional performance. Co-creation with older adults, caregivers, and therapists enables the inclusion of emotional priorities such as dignity, autonomy, and meaning from the outset.

As technologies become more responsive to emotional cues, ethical safeguards are essential. Emotion-sensitive systems must preserve transparency, respect, and psychological safety. Guidelines for empathetic and responsible AI should prevent manipulation and uphold dignity and consent in all human-technology interactions.

Digital technologies will contribute most to healthy longevity when they engage the full emotional and social spectrum of ageing. Integrating creativity, connection, and emotional awareness into the design and evaluation of digital health innovations can help ensure that technological progress enhances not only function but also fulfilment in later life.

Ethical Domain

Ethical considerations are central to the responsible development of digital health technologies for ageing populations.⁴⁵ Older adults are frequently portrayed as vulnerable or technologically passive, yet they represent a highly diverse group with distinct values, capacities, and life contexts.⁶⁵ Ethical reflection must therefore strike a balance between protection and empowerment, ensuring that digital innovation promotes agency, dignity, and inclusion rather than dependency or paternalism.

Equity is one of the most pressing ethical concerns in digital health and longevity. Unequal access to devices, connectivity, and digital literacy can exacerbate existing health disparities. The UN Decade of Healthy Ageing identifies combating ageism—changing how we think, feel, and act about ageing—as a cornerstone of global action.⁶⁶ To uphold justice, digital health initiatives must embed inclusivity as a design and policy imperative, addressing affordability, accessibility, and representation. Inclusive and participatory design processes that involve older adults and their communities can help ensure that digital tools are relevant, acceptable, and equitable across socioeconomic and cultural contexts.⁶⁷ In low- and middle-income countries, where resource constraints are more significant, ethical digital innovation must also consider the distribution of limited connectivity, the affordability of mobile data, and competing priorities for essential

health services. Collaborations with community organisations, non-governmental partners, and local innovators can ensure that technologies respond to contextual realities rather than replicate inequities.

In later life, decision-making about health and technology is often shared within families, communities, and care networks. Digital health tools should strengthen, not replace, these relationships. Ethical frameworks for digital ageing must therefore adopt a relational understanding of autonomy, recognising that agency is interdependent and often exercised collectively. At the same time, new forms of digital monitoring and automation challenge traditional notions of informed consent. Many systems collect or process personal information continuously and unobtrusively, sometimes beyond the user's awareness. Transparent communication, ongoing consent processes, and mechanisms for review or withdrawal are essential, particularly for individuals with cognitive impairment or fluctuating capacity. Ethical design must ensure that autonomy is supported rather than undermined by digital mediation. In settings with limited literacy or access to legal safeguards, consent procedures must be simplified, culturally adapted, and reinforced by trusted intermediaries such as community health workers or family caregivers.

Trust is foundational for sustained engagement with digital health technologies. Concerns about surveillance, data misuse, or loss of control are especially salient for older adults who may be less familiar with digital infrastructures.⁶⁸ Transparent governance, data minimisation, and participatory oversight mechanisms are necessary to protect privacy and reinforce confidence. Ethical digital ecosystems should ensure that users know how their data are collected, stored, and shared, and that they can meaningfully influence these processes. Building trust also requires institutional accountability – ethical review boards, certification standards, and public reporting can provide transparency and guard against misuse. In contexts where such formal mechanisms are not yet established, community advisory boards and local participatory governance structures can play a similar role in ensuring transparency and legitimacy.

AI-based decision-making offers opportunities for precision and efficiency but also introduces risks of bias and exclusion. Many predictive models used in digital health are trained on datasets that underrepresent older adults, particularly those with multiple conditions or limited digital literacy. As a result, algorithmic outputs can misclassify, misdiagnose, or deprioritise older individuals, perpetuating inequities in access and quality of care.^{69,70} To address this, algorithmic auditing should become a standard practice in the development and deployment of AI tools for ageing populations. Transparent documentation of training datasets, performance monitoring stratified by age, and recalibration using diverse real-world data are necessary safeguards. In global health contexts, it is equally important to ensure that AI models incorporate data from diverse populations and health systems, avoiding the export of biases from high- into low-resource settings. Ethical AI must adapt to the physiological, cognitive, and social heterogeneity of ageing, ensuring fair and context-sensitive outcomes.

The ethical agenda for digital longevity extends beyond harm prevention. It must also promote empowerment, co-creation, and solidarity across generations. Older adults should be recognised not merely as recipients of technology but as contributors to its governance, development, and evaluation. Embedding participatory ethics, where design, data use, and oversight are shared with affected communities, can ensure that digital innovation advances human dignity and social

justice. Integrating global and intergenerational perspectives also reinforces that longevity and digital health equity are collective goals, not privileges of affluent societies. Fair, inclusive, and trustworthy technologies will not only protect but also enable older adults to shape their digital futures. Ethical digital health for longevity thus requires a dual commitment: to safeguard rights and to expand opportunities for agency and participation in later life.

Legal Domain

Law, like ethics and social norms, is always situated in a particular context. It reflects not only written statutes but also the local interpretations, practices, and objectives that give legal systems their texture and meaning. In the digital domain, however, there is a persistent tendency to overlook or flatten out these differences. This simplification extends beyond geographical boundaries to encompass variations in interpretation, legal purpose, and the relationships between individual rights and regulatory objectives.

Digital health policies frequently assume a degree of global convergence that does not exist. Standards developed in one jurisdiction, such as the U.S. Health Insurance Portability and Accountability Act (HIPAA) ⁷¹ are often treated as broadly equivalent to European frameworks like the General Data Protection Regulation (GDPR). ⁷² This assumption obscures crucial differences in legal purpose and protection. Whereas HIPAA focuses primarily on data privacy in a medical context, the GDPR seeks to safeguard all fundamental rights implicated in data processing, including those related to physical integrity, autonomy, non-discrimination, and fair working conditions. In the health and care sectors, these rights extend beyond patients to caregivers and families, underlining the deeply relational nature of legal protection. A narrow understanding of law as a checklist of procedural requirements risks overlooking these broader human rights dimensions. When compliance is reduced to documentation and consent forms, the law's fundamental purpose – protecting individuals and their fundamental rights – can be obscured by bureaucracy.

Recent European legislation, including the GDPR and the AI Act ⁷³, adopts a consequentialist logic, seeking to prevent harm from digital systems by translating broad principles into enforceable requirements. Yet as the corpus of regulatory provisions grows denser, their underlying aims often fade from view. The resulting compliance burden reinforces perceptions of regulation as a bureaucratic obstacle rather than as a human rights safeguard. This dynamic is especially evident in the overemphasis on informed consent as the principal basis for lawful data processing. Consent is only one of several legitimate grounds under the GDPR, but its dominance in public discourse has diverted attention from the law's broader intent: to uphold all fundamental rights in the digital age.

Effective rights protection requires practical, rights-based guidance that bridges the gap between legal abstraction and technological implementation. Legislators, regulators, and standardisation bodies have yet to provide such actionable frameworks for developers and operators of digital health technologies. In their absence, professional and research communities must take the lead in interpreting and operationalising legal principles in ways that preserve the law's emancipatory intent.

A growing number of legal instruments now explicitly require stakeholder participation in the governance and design of digital systems. Examples include data protection impact assessments under the GDPR and fundamental rights assessments proposed in the EU AI Act.^{73,74} Participation in this context extends beyond the giving or withholding of consent—it grants affected individuals and communities real power to shape outcomes. Stakeholder involvement is therefore not merely an ethical aspiration but a legal necessity. True participation demands governance processes that meet stakeholders as equals, valuing their lived experiences and perspectives. This requires facilitators who can translate between technical, legal, and social domains, ensuring that participation empowers rather than burdens those involved.

For stakeholder participation to be genuine, three principles are essential. First, digital systems should remain understandable in scale and complexity, following the idea that “small is beautiful.” Second, governance should proceed iteratively and transparently, allowing participants to engage meaningfully at each stage of the design and implementation process. Third, facilitators must assume responsibility for accessibility, bridging gaps in digital literacy, language, and knowledge.

Finally, digital governance must move from a paradigm of acceptance to one of acceptability. Rather than expecting individuals to adapt to technological systems, technologies themselves should be designed to align with human values, lived realities, and normative expectations. Legal frameworks should therefore prioritise the development of digital systems that are not merely compliant, but acceptable, usable, trustworthy, and consistent with the rights and dignity of the people they serve.

Policy Pathways

Panel 1: Key policy priorities for advancing healthy longevity in the digital age. Summary of cross-domain recommendations from the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies”. These priorities outline how digital transformation can support equitable, person-centred, and resilient systems for ageing populations.

1. Reorient ageing and health policy around functional ability and healthspan, embedding prevention, early intervention, and continuity of care across the life course.
2. Develop interoperable national and regional digital health infrastructures grounded in open global standards to enable secure data exchange and longitudinal care.
3. Implement transparent governance frameworks to ensure data quality, accountability, and coordination across health, social, and community sectors.
4. Adopt hybrid models of care that integrate digital, home-, and community-based services to strengthen accessibility, autonomy, and system resilience.
5. Promote lifelong digital literacy and inclusion for professionals, patients, and caregivers, addressing barriers related to affordability, accessibility, and usability.
6. Institutionalise participatory and co-creative design by involving older adults, caregivers, and frontline workers as co-developers of digital health solutions.
7. Integrate emotional and social well-being metrics into digital health evaluation and quality frameworks alongside clinical and economic indicators.
8. Ensure fairness, transparency, and independent oversight in the design, validation, and deployment of AI and data-driven technologies.
9. Translate human-rights principles into practical, adaptive regulation that safeguards autonomy, privacy, and equity in digital health systems.
10. Establish ethical and legal co-governance structures linking policymakers, clinicians, technologists, and communities to ensure inclusive and accountable innovation.

Conclusion

Healthy longevity in the digital age requires more than technological innovation. It demands interoperable infrastructures that connect data across the life course, as well as ethical and legal safeguards that uphold individual rights, and participatory processes that empower individuals and communities. The Einstein Circle’s framework emphasises that ageing is a collective responsibility – encompassing medical, technical, social, and moral aspects. By aligning digital transformation with inclusion, dignity, and justice, societies can ensure that innovation adds not only years to life, but life to years.

References

- 1 Braune K, Lal RA, Petruželková L, *et al.* Open-source automated insulin delivery: international consensus statement and practical guidance for health-care professionals. *Lancet Diabetes Endocrinol* 2022; **10**: 58–74.
- 2 Lehmann J, Granrath L, Browne R, *et al.* Digital twins for supporting Ageing well: Approaches in current research and innovation in Europe and Japan. *Sustainability* 2024; **16**: 3064.
- 3 Kamel Boulos MN, Zhang P. Digital twins: From personalised medicine to precision public health. *J Pers Med* 2021; **11**: 745.
- 4 Khan SR, Khan MW. A comprehensive review of privacy-preserving techniques in health data analysis. In: 2025 International Conference on Cognitive Computing in Engineering, Communications, Sciences and Biomedical Health Informatics (IC3ECSBHI). IEEE, 2025: 104–9.
- 5 Kaye J, Whitley EA, Lund D, Morrison M, Teare H, Melham K. Dynamic consent: a patient interface for twenty-first century research networks. *Eur J Hum Genet* 2015; **23**: 141–6.
- 6 Lee AR, Koo D, Kim IK, *et al.* Identifying facilitators of and barriers to the adoption of dynamic consent in digital health ecosystems: a scoping review. *BMC Med Ethics* 2023; **24**: 107.
- 7 Gasteiger N, Loveys K, Law M, Broadbent E. Friends from the future: A scoping review of research into robots and computer agents to combat loneliness in older people. *Clin Interv Aging* 2021; **16**: 941–71.
- 8 Kim KK, McGrath SP, Solorza JL, Lindeman D. The ACTIVATE digital health pilot program for diabetes and hypertension in an underserved and rural community. *Appl Clin Inform* 2023; **14**: 644–53.
- 9 Haapanen MJ, Vetrano DL, Mikkola TM, *et al.* Early growth, stress, and socioeconomic factors as predictors of the rate of multimorbidity accumulation across the life course: a longitudinal birth cohort study. *Lancet Healthy Longev* 2024; **5**: e56–65.
- 10 Decade of healthy ageing: baseline report. 2021; published online Jan 14. <https://www.who.int/publications/i/item/9789240017900> (accessed Oct 23, 2025).
- 11 Jacobsen FF, Glasdam S, Haukelien H, van den Muijsenbergh METC, Ågotnes G. Healthy ageing in long-term care? Lessons learned from the COVID-19 pandemic: a position paper. *Prim Health Care Res Dev* 2024; **25**: e66.
- 12 Oral health data portal. <https://www.who.int/data/gho/data/themes/oral-health-data-portal> (accessed Oct 27, 2025).
- 13 GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017; **390**: 1211–59.
- 14 Asher S, Stephen R, Mäntylä P, Suominen AL, Solomon A. Periodontal health, cognitive decline, and dementia: A systematic review and meta-analysis of longitudinal studies. *J Am Geriatr Soc* 2022; **70**: 2695–709.

- 15 Healthy ageing and functional ability.
<https://www.who.int/news-room/questions-and-answers/item/healthy-ageing-and-functional-ability> (accessed Oct 23, 2025).
- 16 Garmany A, Terzic A. Global healthspan-lifespan gaps among 183 World Health Organization member states. *JAMA Netw Open* 2024; **7**: e2450241.
- 17 Fadnes LT, Økland J-M, Haaland ØA, Johansson KA. Estimating impact of food choices on life expectancy: A modeling study. *PLoS Med* 2022; **19**: e1003889.
- 18 Hu FB. Diet strategies for promoting healthy aging and longevity: An epidemiological perspective. *J Intern Med* 2024; **295**: 508–31.
- 19 Zaninotto P, Head J, Steptoe A. Behavioural risk factors and healthy life expectancy: evidence from two longitudinal studies of ageing in England and the US. *Sci Rep* 2020; **10**: 6955.
- 20 Li Y, Pan A, Wang DD, *et al.* Impact of healthy lifestyle factors on life expectancies in the US population. *Circulation* 2018; **138**: 345–55.
- 21 Jiesisibieke ZL, Schooling CM. Impact of Alcohol Consumption on Lifespan: a Mendelian randomization study in Europeans. *Sci Rep* 2024; **14**: 25321.
- 22 Rueda-Salazar S, Spijker J, Devolder D, Albala C. The contribution of social participation to differences in life expectancy and healthy years among the older population: A comparison between Chile, Costa Rica and Spain. *PLoS One* 2021; **16**: e0248179.
- 23 Lassell RKF, Pritchard K, Baehr LA, *et al.* New horizons in advancing lifestyle medicine for older adults utilizing a transdisciplinary approach: gaps and opportunities. *Age Ageing* 2025; **54**. DOI:10.1093/ageing/afaf159.
- 24 Besdine RW, Wetle TF. Improving health for elderly people: an international health promotion and disease prevention agenda. *Aging Clin Exp Res* 2010; **22**: 219–30.
- 25 Moghadasi AM, Sum S, Matlabi H. Why do older people not use the public health services of the integrated aging program? A multidimensional approach in a qualitative study. *BMC Health Serv Res* 2022; **22**: 1288.
- 26 Geldsetzer P, Manne-Goehler J, Marcus M-E, *et al.* The state of hypertension care in 44 low-income and middle-income countries: a cross-sectional study of nationally representative individual-level data from 1·1 million adults. *Lancet* 2019; **394**: 652–62.
- 27 Mohan D, Chong PHJ, Gutierrez J. A novel cooperative AI-based fall risk prediction model for older adults. *Sensors (Basel)* 2025; **25**: 3991.
- 28 Yang R, Gao S, Jiang Y. Digital divide as a determinant of health in the U.S. older adults: prevalence, trends, and risk factors. *BMC Geriatr* 2024; **24**: 1027.
- 29 Wang K, Chen XS, Gu D, Smith BD, Dong Y, Peet JZ. Examining first- and second-level digital divide at the intersection of race/ethnicity, gender, and socioeconomic status: An analysis of the National Health and Aging Trends Study. *Gerontologist* 2024; **64**. DOI:10.1093/geront/gnae079.
- 30 Sachdeva M, Dugerdil A, Flahault A, Carrara V. Are wearables effective in LMICs? *Public Health Rev* 2025; **46**: 1607940.

- 31 Pillars. Policies, And Plausible Pathways Linking Digital Inclusion And Health Equity. *Health Affairs Health Policy Brief* 2024. DOI:10.1377/hpb20240327.505.
- 32 Schirmer M, Dalko K, Stoevesandt D, Paulicke D, Jahn P. Educational concepts of digital competence development for older adults-A scoping review. *Int J Environ Res Public Health* 2023; **20**: 6269.
- 33 George T, Manski-Nankervis J-A, Klaic M, Kang G, Sudarsanam TD. Interventions in adult patients with multimorbidity in low-income and middle-income countries: protocol for a mixed-methods systematic review. *BMJ Open* 2024; **14**: e074038.
- 34 Endalamaw A, Zewdie A, Wolka E, Assefa Y. Care models for individuals with chronic multimorbidity: lessons for low- and middle-income countries. *BMC Health Serv Res* 2024; **24**: 895.
- 35 Ginsburg GS, Picard RW, Friend SH. Key issues as wearable digital health technologies enter clinical care. *N Engl J Med* 2024; **390**: 1118–27.
- 36 Torab-Miandoab A, Samad-Soltani T, Jodati A, Rezaei-Hachesu P. Interoperability of heterogeneous health information systems: a systematic literature review. *BMC Med Inform Decis Mak* 2023; **23**: 18.
- 37 Khatiwada P, Yang B, Lin J-C, Blobel B. Patient-Generated Health Data (PGHD): Understanding, requirements, challenges, and existing techniques for data security and privacy. *J Pers Med* 2024; **14**: 282.
- 38 Randhawa IS, Sigalov G. Mass medicine vs. personalized medicine: from mathematical methods to regulatory implications. *Front Physiol* 2025; **16**: 1649114.
- 39 Cummins N, Schuller BW. Five crucial challenges in digital health. *Front Digit Health* 2020; **2**: 536203.
- 40 Landers C, Blasimme A, Vayena E. Sync fast and solve things-best practices for responsible digital health. *NPJ Digit Med* 2024; **7**: 113.
- 41 Cruickshank V, Otten C, Evans J, Jarvis M, Nash R. The importance of health literacy for sustainable development. In: Education and the UN Sustainable Development Goals. Singapore: Springer Nature Singapore, 2023: 491–505.
- 42 Mesko B, deBronkart D, Dhunnoo P, Arvai N, Katonai G, Riggare S. The evolution of patient empowerment and its impact on health care's future. *J Med Internet Res* 2025; **27**: e60562.
- 43 Daniore P, Hurndall K-H, Zavattaro F, Leis M, Gille F. Fostering public trust in national health data platforms: key considerations for public involvement activities for England and Switzerland. *Data Policy* 2025; **7**. DOI:10.1017/dap.2024.95.
- 44 Gille F, Jobin A, Ienca M. What we talk about when we talk about trust: Theory of trust for AI in healthcare. *Intell Based Med* 2020; **1-2**: 100001.
- 45 Maeckelberghe E, Zdunek K, Marceglia S, Farsides B, Rigby M. The ethical challenges of personalized digital health. *Front Med (Lausanne)* 2023; **10**: 1123863.
- 46 Cho S, Ensari I, Weng C, Kahn MG, Natarajan K. Factors affecting the quality of person-generated wearable device data and associated challenges: Rapid systematic review. *JMIR MHealth UHealth*

2021; **9**: e20738.

- 47 Canali S, Schiaffonati V, Aliverti A. Challenges and recommendations for wearable devices in digital health: Data quality, interoperability, health equity, fairness. *PLOS Digit Health* 2022; **1**: e0000104.
- 48 Wang L, Alexander CA. Big data analytics in medical engineering and healthcare: methods, advances and challenges. *J Med Eng Technol* 2020; **44**: 267–83.
- 49 Kim KK, Backonja U. Digital health equity frameworks and key concepts: a scoping review. *J Am Med Inform Assoc* 2025; **32**: 932–44.
- 50 Lindsay S, Jackson D, Schofield G, Olivier P. Engaging older people using participatory design. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. New York, NY, USA: ACM, 2012. DOI:10.1145/2207676.2208570.
- 51 Gasteiger N, Ahn HS, Lee C, *et al.* Participatory design, development, and testing of assistive health robots with older adults: An international four-year project. *ACM Trans Hum Robot Interact* 2022; **11**: 1–19.
- 52 Holistic research with UX methods for social inclusion and sustainability. In Innovation design for social inclusion and sustainability: Design cultures and creative practices for urban natural heritage beyond accessibility. .
- 53 Stegner L, Senft E, Mutlu B. Situated Participatory Design: A method for in situ design of robotic interaction with older adults. arXiv [cs.RO]. 2023. DOI:10.48550/ARXIV.2302.00588.
- 54 Span M, Hettinga M, Vernooij-Dassen M, Eefsting J, Smits C. Involving people with dementia in the development of supportive IT applications: a systematic review. *Ageing Res Rev* 2013; **12**: 535–51.
- 55 Martin CL, Bakker CJ, Sarkar S, *et al.* Consumer involvement in the co-design of diabetes self-management smartphone apps: A scoping review. *Appl Clin Inform* 2025; **16**: 698–707.
- 56 Hassenzahl M. Experience design: Technology for all the right reasons. *Synth Lect Hum-centered Inform* 2010; **3**: 1–95.
- 57 Smits M, Kim CM, van Goor H, Ludden GDS. From digital health to digital well-being: Systematic scoping review. *J Med Internet Res* 2022; **24**: e33787.
- 58 Peters D. Wellbeing supportive design – research-based guidelines for supporting psychological wellbeing in user experience. *Int J Hum Comput Interact* 2023; **39**: 2965–77.
- 59 Garcia Reyes EP, Kelly R, Buchanan G, Waycott J. Understanding older adults’ experiences with technologies for health self-management: Interview study. *JMIR Aging* 2023; **6**: e43197.
- 60 Krause-Jüttler G, Weitz J, Bork U. Interdisciplinary collaborations in digital health research: Mixed methods case study. *JMIR Hum Factors* 2022; **9**: e36579.
- 61 Sevaldson B. Systemic design: Theory, methods, and practice. Oslo School of Architecture and Design. 2021.
- 62 Stickdorn M, Lawrence A, Hormess ME, Schneider J. This is service design doing: Applying service design thinking in the real world. O’Reilly Media, 2018.

- 63 Sanders EB-N, Stappers PJ. Co-creation and the new landscapes of design. *CoDesign* 2008; **4**: 5–18.
- 64 Särkämö T, Sihvonen AJ. Golden oldies and silver brains: Deficits, preservation, learning, and rehabilitation effects of music in ageing-related neurological disorders. *Cortex* 2018; **109**: 104–23.
- 65 Rothermund K, de Paula Couto MCP. Age stereotypes: Dimensions, origins, and consequences. *Curr Opin Psychol* 2024; **55**: 101747.
- 66 Amuthavalli Thiyagarajan J, Mikton C, Harwood RH, *et al.* The UN Decade of healthy ageing: strengthening measurement for monitoring health and wellbeing of older people. *Age Ageing* 2022; **51**. DOI:10.1093/ageing/afac147.
- 67 Mannheim I, Schwartz E, Xi W, *et al.* Inclusion of older adults in the research and design of digital technology. *Int J Environ Res Public Health* 2019; **16**: 3718.
- 68 Györfy Z, Boros J, Döbrösy B, Girasek E. Older adults in the digital health era: insights on the digital health related knowledge, habits and attitudes of the 65 year and older population. *BMC Geriatr* 2023; **23**: 779.
- 69 Stypinska J. AI ageism: a critical roadmap for studying age discrimination and exclusion in digitalized societies. *AI Soc* 2023; **38**: 665–77.
- 70 Shiwani T, Relton S, Evans R, *et al.* New Horizons in artificial intelligence in the healthcare of older people. *Age Ageing* 2023; **52**. DOI:10.1093/ageing/afad219.
- 71 Summary of the HIPAA Privacy Rule. 2008; published online May 7. <https://www.hhs.gov/hipaa/for-professionals/privacy/laws-regulations/index.html> (accessed Nov 12, 2025).
- 72 Regulation - 2016/679 - EN - gdpr - EUR-Lex. <https://eur-lex.europa.eu/eli/reg/2016/679/oj> (accessed Nov 12, 2025).
- 73 Regulation - EU - 2024/1689 - EN - EUR-Lex. <https://eur-lex.europa.eu/eli/reg/2024/1689/oj> (accessed Nov 12, 2025).
- 74 Data Protection Impact Assessment (DPIA). https://www.edpb.europa.eu/our-work-tools/our-documents/topic/data-protection-impact-assessment-dpia_en (accessed Nov 12, 2025).

Contributors

TSch and DIB led the Einstein Circle “Longevity – Healthy Ageing Assisted by Digital Technologies” and coordinated the collaborative process. KB and TSc developed the overall outline, integrated co-author input, and prepared the final manuscript. All authors contributed to the conceptualisation, drafting, and revision of their respective domain sections, critically reviewed the manuscript for intellectual content, and approved the final version. KB and TSc contributed equally. KB and MM are guarantors.

Declaration of interests

FB reports grants from the Hans Boeckler Foundation, Charité Foundation, German Research Foundation, Joint Federal Committee, the Federal Ministry of Education and Research, the Federal Ministry of Health, Honda Research Institute, the Federal Ministry of Research, Technology and Space, Berlin University Alliance, the German Portal for Medical Research Data, the European Commission, and the Fresenius Foundation; royalties from Elsevier; honoraria for lectures from Pfizer; and travel support from the Bavarian Academy of Sciences and Humanities and the Association of German Anaesthetists.

KB declares support from the University of Potsdam for the publication of this manuscript. is supported by the German Research Foundation (DFG, SFB 1340/2), the GBA Innovationsausschuss (01VSF24052), the ISPAD-T1D Breakthrough Fellowship and by the Honda Research Institute Europe. KB has previously served on advisory boards and provided paid consultancy services for Abbott Diabetes Care, Dexcom, Diabeter, Diabetes Center Berne, Novo Nordisk, and Sanofi Diabetes, as well as an unpaid advisory role for Tidepool, a non-profit organisation. None of these entities was involved in the conception, data provision, analysis, or funding of the present work.

StM serves as an unpaid consultant for Curaswing and the German Music Therapy Association, a non-profit organisation, both were not involved in compiling this work.

TF reports receiving individual payments for lectures from the Philipp-Pfaff-Institut; the International Team for Implantology, Basel; and the Verbond van Vlaamse Tandartsen. TF serves as Speaker of the Board of Directors at the Einstein Center Digital Future (ECDF), Berlin, Germany, an unpaid position.

KKK reports grants from the National Institute of Minority Health and Health Disparities/NIH/DHHS and the National Institute on Aging/NIH/DHHS (payments made to Health Tequity LLC); consulting fees from LeadingAge California (payment made to Health Tequity LLC); travel support from the Einstein Foundation; serves as a board member of the Archstone Foundation; and is the founder and owner of Health Tequity LLC.

DL reports travel support from DUCAH (payment made to UC Berkeley).

TScha reports serving on the Research Committee of Charité and the Degree Program Commission of Charité (both unpaid positions).

TSchi reports support for the present manuscript from the Einstein Foundation (funding for Einstein Circle Project), Digital Urban Center for Aging and Health, and University of the Arts; consulting fees from Digital Urban Center for Aging and Health; travel support for a research visit at UC Berkeley/CITRIS; and serves as an Ethics Committee Member at the Weizenbaum Institute.

SM and MM report receiving grant support from the Velux Stiftung for the Healthy Longevity Center.

Authors AB, DIB, PC, and NL have no conflicts of interests to declare.

Acknowledgments

Funding: This work was supported by the Einstein Foundation Berlin. No funder had any role in writing or the decision to publish.

The authors used OpenAI's GPT-5 model to support improvements in grammar, punctuation, and style harmonisation throughout the manuscript. The tool was used under human supervision, and all substantive content, analysis, and interpretation were produced, verified, and approved by the authors.

Data sharing: No new data were generated or analysed in this Health Policy paper.