AGING, INDEPENDENT LIVING AND TECHNOLOGY

A White Paper by the Foundation for Internet and Society

FOUNDATION FOR INTERNET AND SOCIETY

DUCAH
DIGITAL URBAN CENTER FOR AGING & HEALTH

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EXECUTIVE SUMMARY

There is a significant demographic trend of aging, particularly in the wealthier Western nations. This trend is putting governments and caregivers under increased pressure to provide affordable support for a form of aging in place that enables the elderly to lead dignified, meaningful and engaged lives for as long as possible. Particularly in this time of COVID-19, when access, distancing, infection control and healthcare have become primary concerns, digital solutions may offer this vulnerable group ways to enhance their safety, autonomy and resilience. A flood of technological products and services have appeared to cater to this emerging market and meet government demands to keep the elderly in their own homes, which is the preferred location for many aging individuals.

THE SCOPE OF HEALTHY AGING AT HOME EXTENDS BEYOND THE HOME TO LOCAL STRUCTURES AND FACILITIES

These products include assistive technologies as well as technologies to monitor safety and health and provide company and social integration. The technologies can be individual and wearable but also embedded within the overall context of a smart home and a neighbourhood designed to enhance elderly well-being, as the scope of healthy aging at home extends beyond the immediate confines of the home to local structures and facilities. In general, these products have not considered the complexities of aging and the needs and expectations of the elderly, who are typically not included in design processes, nor have they been researched in depth to assess their acceptance or efficacy. The trend towards aging in place is also creating challenges for those engaged in the practice of caring: doctors, nurses, carers, workers in allied health areas and relatives.

Within the ecosystems of the elderly, there are several significant stakeholders to be considered, all of whom have an interest in digital solutions to support aging in place; these include the senior citizens themselves, their concerned relatives or the governments responsible for providing funding and structures. The methods for designing, testing and researching technological products and services are hence moving into sharp focus due to the importance and complexity of these challenges and the diversity of objectives among stakeholder constituencies.

While there is a growing body of research examining the effectiveness and success of adoption and use of technological products and the associated services, the absence of participatory design is a particular concern. Some research is experimental but most has involved surveys and interviews or product evaluations; on the whole, it has been highly product focused.

THE ABSENCE OF PARTICIPATORY DESIGN IS A PARTICULAR CONCERN

There has been little observation and assessment of in situ applications of these technologies, and we thus have little idea of how people actually use them and how much they contribute to the goal of independent living. The ways in which technologies interact with each other and with the complex realities and trajectories of elderly life remain opaque.

This has led the Digital Urban Center for Aging and Health (DUCAH) – an initiative of the Foundation for Internet and Society and the Alexander von Humboldt Institute for Internet and Society in partnership with the Einstein Center for Digital Future (ECDF) and several practice-focused organisations – to develop

DUCAH ENABLES COLLABORATION BETWEEN STAKEHOLDERS TO IMPLEMENT AND TEST NEW PROCESSES AND TECHNOLOGIES

the Learning Lab as its research platform. The Learning Lab can be understood as an open innovation ecosystem that operates at the interface between urbanisation, digitalisation and health; it is intended to be similar in concept to the Living Labs (European Network of Living Labs). The development of new solutions within this ecosystem is based on a user-centric design approach. Here, both research processes and innovation processes are integrated into real-life living and working settings. In this natural environment, the elderly, their relatives, carers and care organisations, governments and regulators and other stakeholders in the ecosystem can participate and collaborate to implement and test new processes and technologies for benefits, enhancement, acceptability, and usability.

CONTENTS

INTRODUCTION

Purpose and facts on current aging debates

This white paper discusses the rapid increase in aged cohorts in most countries of the world and the challenges and opportunities it presents for those involved – governments, service providers, technology companies, carers and relatives, and the elderly themselves. In it, we describe the demographic and social changes driving the need for action and policy efforts on digital health in Germany and Europe. Innovative solutions that ensure that older people can enjoy a dignified, meaningful and self-determined life are needed.

These solutions will be found in domains such as healthcare and nursing, monitoring and assistive technologies, architecture and town planning, government policy and regulation, psychology and caregiving. But the lives and concerns of the elderly themselves must be the primary consideration. Great care must be taken to ensure that they do not become passive recipients of supply-side, interventionist policies and disempowering design processes.

The purpose of this white paper is to provide information on the range of solutions and the current state of research into aging in place. Although our focus is on technologies that support the elderly in remaining in the home

WE MUST CONSIDER HOW AGED CARE HOMES CAN BE SHAPED AND EQUIPPED TO DELIVER STATE-OF-THE-ART SERVICES THAT SUPPORT HEALTH, WELL-BEING AND A RICH SOCIAL LIFE

and enjoying an active, healthy and socially connected life, we must also consider how aged care homes can be shaped and equipped to deliver state-of-the-art services that support health, well-being and a rich social life. We review the research into these technologies and consider their interaction with the needs and expectations of the elderly and identify issues in the research and gaps in knowledge.

THE CURRENT AND FUTURE SITUATION

Any definition of the elderly will necessarily be imprecise: older people or pensioners cannot be located in an exact age span, as individuals vary widely in their biological, psychological and culturally defined aging characteristics. Generally, the terms refer to a period when individuals reach the end of their working lives and when age-related conditions may begin to appear. In developed countries, this is generally seen to be between 60 and 65 years of age, though in Africa, this is considered to be around 55 (World Health Organization, n.d.). But aging is also a process and not just a stage. It might even begin at 50, and indeed the preparations for aging or the need for assistive technology or appropriate accommodation can begin earlier and be shared with other age cohorts.

Forecasts predict that the number of older people who will need care will increase considerably in most Western societies over the next 30 to 80 years. By 2050, the number of older people in Germany will have doubled to about 4.7 million. Within the EU-27, the share of the elderly "... is projected to increase from 20.3% (or 90.5 million elderly persons) at the start of 2019 to 31.3% (or 130.2 million elderly persons) by 2100 (eurostat Statistics Explained, 2020b). As such, the share of the elderly is projected to rise by 11 percentage points, reflecting an additional 39.7 million elderly persons by 2100" (eurostat Statistics Explained, 2020b). By 2034 in the United States there will be 77 million people aged 65 years and older and by 2030, 1 in every 5 residents will be of retirement age (United

States Census Bureau, 2018). The number of elderly people living alone in Korea tripled from 2000 to 2014, from 540,000 to 1.44 million. By 2026, this will reach 20.8% of the population, up from 15.6% in 2020 (Park et al., 2019). At the same time, the age dependency ratio, that is the number of working people who support one aged person will have risen:

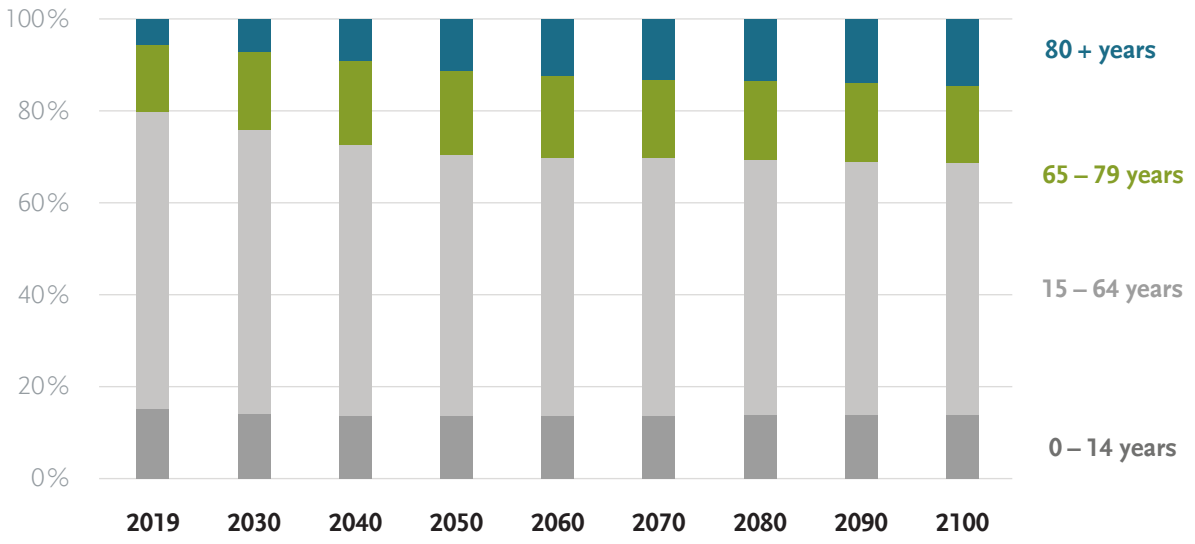
- In the United States, while in 2020 there were about 3.5 working age adults for every retirement-age person, by 2060 that ratio will be 2.5.
- The EU-27's old-age dependency ratio will almost double from 31.4% (or just over 3 persons of working age for every person aged 65 or over) in 2019 to 57.1% by 2100, as can be seen in the figure below.
- In Korea, in 2004 there were 8.2 working age people for each senior citizen, by 2030 this will be 2.8.

> "This will, in turn, lead to an increased burden on those of working age to provide the social expenditure required by the aging population for a range of related services" (eurostat Statistics Explained, 2020a).

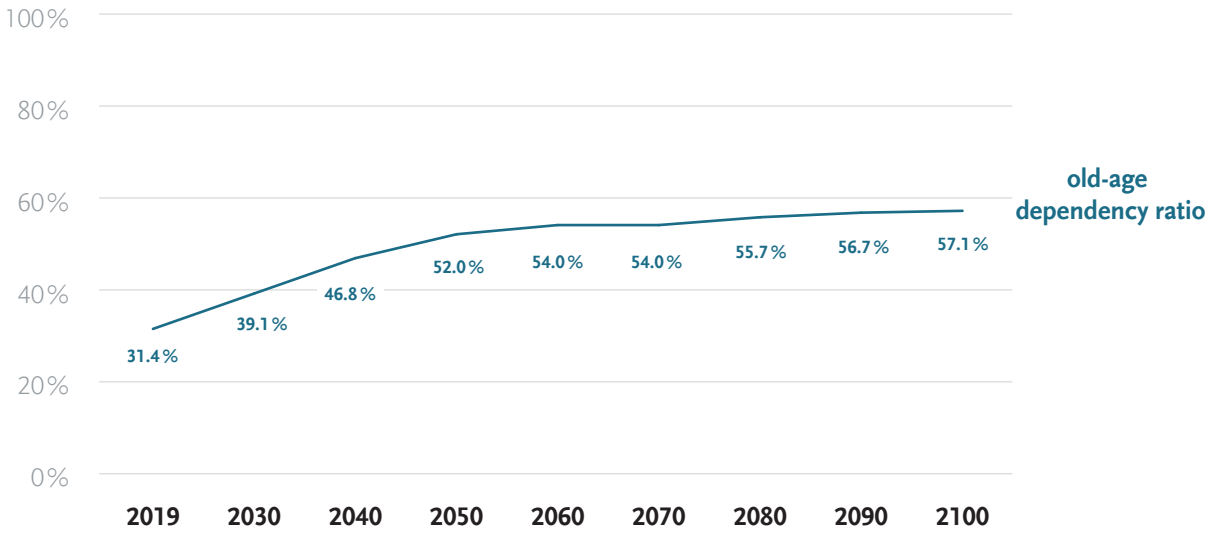
In Germany in 2017, there were 3.4 million people needing care. By 2050, this figure will grow to 4.7 million, an annual growth of 1.6%. It is estimated that about 1.7 million support staff and carers will be needed. According to some estimates, dementia, a general term for a range of conditions associated with loss of cognitive function, will affect a growing number of people in future, climbing from 50 million affected people globally now, to 82 million by 2030 and 150 million by 2050.

> "Before the pandemic, about a quarter of hospital beds in British hospitals were occupied by people with dementia. There was nowhere else for them to go" (The Economist, 2020).

The economic bottom line is relentless and unequivocal: there will be greatly increased demand, requiring significantly more resources in a highly human-centred industry. This demand will be funded by fewer and fewer taxpayers and there will be an expected shortfall in care professionals. It is essential that productivity is increased: "more of the same will not be enough" (World Health Organization, 2015). Indeed, the potential to apply digital technologies to optimise the business processes of care organisations, automate both care and support activities, reduce manual work and reduce travel and movement is particularly high. The quality of encounters in prevention and care can improve, and more individualised care and medical treatment can be provided (Roland Berger GmbH, 2017).



Population structure by major age groups, EU-27, 2019-2100(own presentation, based on eurostat Statistics Explained, 2020a)



Projected old-age dependency ratio, EU-27, 2019-2100 (own presentation, based on eurostat Data Browser, 2021)

PROJECTED AGE STRCTURE

AGING IN PLACE

The U.S. Center for Disease Control and Prevention (CDC) defines aging in place as:

> "The ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level." (Centers for Disease Control and Prevention, n.d.)

The overwhelming preference of aged people and those needing care is to remain in their own home, a familiar social and physical environment. This often concerns the family home but also applies to homes managed within a larger complex. Aging at home is also the most economically sustainable configuration of capital, accommodation and services. The maintenance of good health and independence for as long as possible is the primary goal. Other forms such as co-housing and retirement complexes have some specific advantages, such as greater social support, lower isolation and an increased sense of safety (Rusinovic et al., 2019). About half of the elderly population would be prepared to live in shared accommodation or with their family. Less than 40% would want to live in a nursing home.

MAINTENANCE OF GOOD HEALTH AND INDEPENDENCE AT HOME FOR AS LONG AS POSSIBLE IS THE PRIMARY GOAL

Perhaps almost as important as the home is the community in which it is embedded: familiar streets, shopping and exercise facilities, access to transport, multi-generational networks and relationships, and the sense of belonging and mobility these generate. As neighbourhoods evolve or are developed, consideration of the needs of the growing cohort(s) of the aged will become more salient but these developments will require long-term, strategic attention and investment, in particular as regions undergo structural and economic changes that may limit the supply of services (Bundesministerium für Familie, Senioren, Frauen und Jugend, 2020).

ADAPTIVE AGING

Relevant domains and stakeholders

When designing technologies for adaptive aging, it is important to consider the key domains of elderly function and activity and not only focus on the capacity of technology to "fix issues" or "address productivity bottlenecks". There are a number of taxonomies for these functional areas, covering issues such as health and self-esteem, mobility and transport, housing and living, communication and governance, and work and leisure (Van Bronswijk et al., 2002). A report to the National Research Council of the National Academies in the United States divides these into communication, employment, health, learning living environment and transportation (Pew & Van Hemel, 2004). The DUCAH initiative focuses on three intricately connected domains of aging.

HEALTH

The elderly are the largest group of consumers of healthcare and appliances and health is the most prominent and promising domain of age-related technology. The safety benefits of condition monitoring, fall prevention, medication management and compliance, and telehealth are considerable (avoidance of acute incidents, suffering and trauma, faster response to incidents), as are the potential cost savings (reduction in hospital emergencies and stays, fewer medical staff required, and so on) (Kim et al., 2017).

HEALTH IS THE MOST PROMINENT AND PROMISING DOMAIN OF AGE-RELATED TECHNOLOGY

Furthermore, geriatric diseases are typically accompanied by other complex diseases, which have ambiguous symptoms that change unexpectedly and require comprehensive and constant care. Thus, it is necessary to develop technologies that can detect abnormal physical conditions at an early stage. Such information can then be communicated to medical experts for appropriate analysis and decision making (Park et al., 2019).

But with health and condition monitoring that is potentially so comprehensive, a significant challenge is to ensure that the elderly are shielded from the anxiety and stress of information overload and interventions. There are large quantities of data that must be refined for patients and caregivers, and there are ethical and liability issues emerging from possible malfunctions (Bächle & Wernick, 2019). Cost is also an issue.

With ever-smaller families to care for them and overstretched nursing homes, the difficulties of caring for sufferers of dementia is acute. As the Economist says:

> "The question most often asked is how to pay for it... And an even more fundamental question than who pays for care is: who will do it? Undertaken with humanity and dignity, it is extremely labour-intensive. Technology can help lighten the load – using remote monitoring ... and perhaps in future robots to perform some basic tasks. But looking after people with dementia requires people" (2020, p. 9).

Mental health care is an area that is revealing the promise of communications technologies. Relying as it does upon conversation, it is one of the few areas of standard telehealth already

in widespread use by consulting clinicians. For instance, positive results have been found in clinical trials of the online life review method, an effective, evidence-based treatment for depression in later life. Such trials have found improvements in depressive symptoms and engaged living (Westerhof et al., 2019).

LIVING ENVIRONMENTS

An appropriately furnished and well-equipped living environment is the basic prerequisite for independent aging. The most basic design features require attention – stairs and rugs should be avoided and physical supports installed, but aesthetic, mood enhancing design considerations, such as having a bright room and a nice view, are also relevant. Smart homes are the most salient technology in living environments for the elderly: fully networked, they can be equipped with devices that can provide comfort and mitigate disabilities, support daily activities, and allow caregivers to provide remote care and intervention. Technology in the home can compensate for motor and cognitive changes. There are several challenges and barriers to adoption here, such as high cost, complexity and ease of use, systems reliability and privacy (Pernice & Pohle, 2018).

MOBILITY AND THE NEIGHBOURHOOD

Movement is a cornerstone of healthy living, and this equally applies to aging. In its simplest form, mobility means that housing itself must be safely navigable, but the individual's wider surroundings should facilitate mobility, safety and access to services, companionship and leisure. The feature of the neighbourhood that are particularly challenging for older people need to be addressed – for example, authorities should provide dementia-friendly pathways, street layouts and designs and promote social programmes that educate others on how to deal with those suffering from dementia.

Chrysokou et al. call for the development of an integrated architecture for "enabling spaces", in which health, social and environmental factors can be co-designed to create spaces optimally oriented towards healthy and active aging (2018). As they state, "a crucial component of this ecosystem is the enabling of movement" as well as the integration of green areas and spaces for physical activity and social interaction.

THE SURROUNDINGS SHOULD FACILITATE MOBILITY, SAFETY AND ACCESS TO SERVICES, COMPANIONSHIP, AND LEISURE

This form of neighbourhood development requires long-term strategic thinking and innovation as it involves district redesign and the inclusion of inter-sectoral stakeholders with different innovation logics and aspirations. The intensification of work on smart cities, transportation and digital health serves to illustrate the need for forums in which exchange and mutual understanding of these objectives and logics can be facilitated and which then support sustained collaboration and co-design.

STAKEHOLDERS

The primary stakeholder in the context of this discussion is of course the aging person. People who need care, but also their relatives and caregivers, are the focus of interest, and their needs and specific problems form the basis for research and exchange with the other stakeholder groups.

But the goal of independent, healthy living for older people requires the involvement of further stakeholders, each with their own particular perspectives and objectives, and technological solutions must also deliver benefits for them. Research institutes and the scientific community have to focus on all participants in this ecosystem. They will need to be involved to some degree in researching and designing products, services, processes and environments for aging.

Relatives and children have a substantial influence on older people's decisions to acquire technologies. In general, this group focuses on older people's care, comfort, and safety. They may pay for commercial operators to monitor and provide care or take on a more substantive role themselves, such as the role of a primary carer or initial responder in a crisis. Alternatively, some members of this group may take little interest and simply wish to "outsource" the care.

Governments fund much aged care, providing financial, and sometimes means-tested, packages for home care depending upon levels of infirmity. While there may be public pressure on politicians to provide equitable care, government budgeting means that cost control is a primary motivator, often prompting a move to user-pays systems. This stakeholder group is interested in efficiencies and the ability to leverage the effectiveness of capital and human resources.

Other important adaptive aging stakeholders are non-profit organisations and associations representing the various providers in health, technology and mobility as well as patients' and older people's organisations and self-help groups. They have a deep understanding of the groups they represent and can in turn make this available to other stakeholders so that innovation is closely aligned with the needs of the target groups. All of these actors are multipliers and provide a network for testing solutions in suitable organisations and for bringing digital solutions to the wider public.

Depending upon country-specific policies and funding, the (commercial) care sector has an interest in the efficiency and productivity of the care process. This sector's need for technology affects all stages of the business cycle: acquiring customers, securing funding, complying with regulation, establishing people at home with appropriate technologies and appliances, providing carers and cleaners, coordinating these resources optimally, conducting medical monitoring and intervention, and invoicing. In many cases, they look to provide excellent care products and services that differentiate them from other providers. Further, they require a workforce of clinicians, allied health professionals and care staff in an environment that is labour-intensive and often characterised by low wages and insecure employment.

Technology providers cover a wide spectrum of technologies and services and have a commercial focus. Some service providers offer the basic infrastructure and platforms for transmitting data and facilitating the installation of services by other providers, such as health monitoring, movement and fall recognition, medication

AGING PEOPLE
Primary stakeholder in the context

RELATIVES AND CHILDREN
These have a substantial influence on older people

CAREGIVERS
Providing remote care and intervention

RESEARCH INSTITUTES
Engaged in the research and design of services, processes and environments

GOVERNMENTS
Substantive funders of aged care, interested in effective use of capital and human resources

NON PROFIT ORGANISATIONS AND ASSOCIATIONS
Representing the various providers, patients' and older people's organisations and self-help groups

CARE SECTOR
Interested in efficiency and productivity of the care process

TECHNOLOGY PROVIDERS
Providing the basic infrastructure and platforms for transmitting and facilitating data

RESIDENTIAL CONSTRUCTION
Age-appropriate and inclusive living environments

HEALTH SYSTEM INSTITUTIONS
Medical insurance funds, hospitals and allied health professionals are critical participants

FINANCE
Provider of new financing instruments, e.g. social impact fonds, reinvestment for affordable healthcare solutions

STAKEHOLDERS OF ADAPTIVE AGING

monitoring and so on. Some provide end-user focused devices or platforms for the elderly: emergency buttons, care robots, computers, or phones for the elderly. Startups are of particular interest in this regard – they are often the source of service and product innovation and new business models (Puls & Matusiewicz, 2020).

Aligning the living environment with the needs of older people is a key challenge for housing companies and the residential construction sector. Demographic change is widening the gap between the available supply of housing and the demand for accommodation that is designed from the outset to enable older people to live self-determined lives in the long term. The positive consequences of age-appropriate construction and remodelling include an improved quality of life, including for families and people with disabilities, and an increased residential mix.

Institutions within the health system including health insurance providers, hospitals and allied health professionals are critical participants, as they seek to manage escalating demand. For example, the growth in chronic illness, particularly among older people, is driving a need for shared care models and care plans that use digital information technologies to coordinate referrals, diagnostics and therapies and move treatment and appointment attendance away from large tertiary hospitals to smaller, more local and even "virtual" clinics. When designing such models, it is important to consider other dimensions of being older – mobility, cognitive capacity, access to technology and so on.

As far as innovation processes in the field of digital healthcare solutions are concerned, the refinancing of healthcare services, reinvestment of profits in the health care sector and use of social return instruments often represents the starting points for discussions. Only through the participation of financial stakeholders can solutions that make good services financially feasible be developed.

TECHNOLOGY IN AGING AND HEALTH

Technology opportunities, design and context

Technologies can be divided into two types, those that seek to prevent, postpone, or detect conditions or events, and those that seek to promote and maintain outcomes. A report by the US Department of Health and Human Services (Aykan, 2012) into aging services technologies refined these into further categories:

PREVENTION, POSTPONEMENT AND EARLY DETECTION

- Fall prevention and recognition
- Cognitive impairment
- Sensory impairment
- Mobility impairment
- Functional decline

PROMOTION AND MAINTENANCE

- Chronic disease management
- Medication management
- Diet and nutrition
- Physical activity
- Activities of daily living
- Social contact and depression
- Wayfinding and mobility

Technology vendors have continued to develop an increasing array of healthcare products that offer great promise in the area of telehealth because they can delay the onset of acute care and allow the elderly to remain independent for longer. Products such as wearables, smart fabrics, alarms, bio-medical devices and sensors can help individuals to manage their physical health and well-being, but other products such as video conferencing, social robots and smart user interfaces for the elderly can also address mental health issues arising from loneliness, increasing cognitive impairment and isolation. The use of household appliances designed for the elderly can make life easier.

Caregivers can be more productive and efficient by using this technology to constantly monitor health, safety and well-being. Digital solutions can also be helpful in dealing with other stakeholders in the healthcare space, such as government agencies and insurance companies.

Most of these technologies involve monitoring, collecting, storing and integrating data, while others facilitate contact with other individuals, such as friends, relatives, and service providers. High-speed wide-area networks, such as 5G, powerful local processing, big data and social media allow convergent innovations to be developed in and across any of these categories to gather health information for future reference through biomedical devices. They can also provide highly personalised advice and information on individual mobile devices and allow ubiquitous, personalised guidance on walking, exercising or driving through sensors and GPS.

According to medical technology experts, examples of innovation and change enabled by technology include[1]:

– Artificial intelligence for the diagnosis, monitoring and prevention of medical conditions and incidents
– The use of AI and robots to substitute for human medical care
– Greater specificity in prescribing and measuring health outcomes

Increasing digitisation and better data availability will also have other consequences:

– A greater presence of big tech companies in the health market
– The development of care and health ecosystems by other players and startups
– The rise of data-driven platforms for health and elder care
– The ability to customise insurance charges, creating a portfolio of healthier clients

Given the cost and lack of public and health insurance funding for most products, the almost universal presence of the smartphone presents particular opportunities to provide services such as chronic disease management, social engagement and health promotion across the digital divide. More generally, simpler devices with less functionality ("frugal innovation") may not only be more affordable but also preferable in the context of aging.

THE ALMOST UNIVERSAL PRESENCE OF THE SMARTPHONE PRESENTS PARTICULAR OPPORTUNITIES TO PROVIDE SERVICES

The two illustrations below portray the difference between aged living with and without some of the features of technological assistance. The first shows a sequence of events for an elderly man who lives alone, experiences a fall and suffers as a result of the subsequent trauma.

The following illustration shows the same sequence of events but is a scenario in which technology and system integration are able to significantly reduce the trauma and cost and lead to better clinical and social outcomes. System interoperability, shared platforms and the development of clinical information repositories such as the electronic medical record (EMR) allow health services, care service providers and their staff, ambulance providers and even authorised acquaintances to provide optimal support and recovery.

1 See also https://www.ageinplacetech.com/ for a comprehensive, current list of technologies

Fred Müller is 80, lives at home alone, walks with a cane, receives home care and is being treated for a number of medical complaints.

Fred has a fall and lies immobile on the floor, unable to get up.

Maria Merkrath is Fred's carer who comes and provides assistance twice a week. John is a cleaner who comes once a week. Both work for a private care provider.

Luckily, Fred's neighbour finds him and calls an ambulance.

Maria comes to care for Fred, but finds Fred is not at home, cannot reach him and has no-one to contact.

Fred is given painkillers and gets transported to a hospital, where he is treated for a fractured bone, bruising and dehydration. He is disoriented and unable to give his medical and medication history.

After being discharged from hospital, Fred is taken home. He gets an appointment with his primary care doctor, to take place six days later. He feels weak and vulnerable. He calls the care company to recommence services, but Maria has been allocated elsewhere and a new carer comes. The cleaner John could not access the house and the house is dirty.

Fred's primary care doctor does not receive a discharge summary in time. She applies for increased services for Fred, but it is difficult to access. He does not know how to organise this himself.

Fred is left stressed and anxious and unwell. The new services he requires have not arrived ...

TRAUMAS OF AGED LIVING

Fred Müller is 80, lives at home alone, walks with a cane, receives home care and is being treated for a number of medical complaints. Although 80, he uses social media.

Fred has a fall. His alarm is activated, notifying the care organisation. They view his status through video.

Maria Merkrath is his carer who comes and provides assistance twice a week. John is a cleaner who comes once a week. Both work for a private care provider.

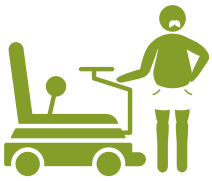
An ambulance is dispatched. His medical history, including allergies and alerts, is provided as well as his disability status.

Fred is given appropriate painkillers and gets transported to a hospital, where he is treated for a fractured bone, bruising and dehydration. He is given his standard medication and is therefore stable. The care organisation gets in contact with the hospital staff and Fred is reassured.

Maria comes to Fred as soon as he arrives home with a treatment and care plan based on hospital information. She lets the cleaner in prior to Fred's arrival, so the house is clean and welcoming.

Fred sees his primary care doctor, who reviews the care plan and adds some rehabilitation, which gets transmitted to the care plan. Resources are automatically booked and the budget is checked to ensure that everything is covered.

The primary care doctor organises the transport and appointments for Fred, who recovers quickly. He messages his friends on social media and, using his new wheelchair, he is able to meet them at the local park.



Fred and his friends continue to meet, interact and exercise within their limitations, but secure in the knowledge that they are cared for.

AGED LIVING WITH TECHNOLOGY

SMART HOMES AND SENSORS

Smart homes and intelligent housing, along with the management of the physical environment through digital technologies for ambient assisted living, offer many solutions that improve quality of life, facility management, and care provider productivity. Particularly when implemented through converged platforms, these can reduce the burden on the elderly by simplifying, automating or allowing single-point remote monitoring of a range of different technologies: bio-medical devices, security devices, device alarms, cleaning and kitchen devices (for example, when a person leaves the gas or water run too long), resident movement sensors, and lights and utility devices. This can help address the needs of people suffering from cognitive decline or Alzheimer's disease (Chan et al., 2009).

Sensors can be wearable or ambient. Wearable sensors can become uncomfortable and the elderly may reject them or forget to use them. Ambient sensors do not have this drawback, and if they provide adequate data and function, they can be readily accepted. Ambient sensors are embedded into daily living environments (Uddin et al., 2018). Ambient sensor systems currently focus on activity monitoring with a view to assessing immediate threats or events rather than long-term risks and care (Al-Shaqi et al., 2016). However, they may represent a greater investment while being less flexible and harder to upgrade as technology advances.

The events that sensors aim to address are the activities of daily living, falls, localisation, health status monitoring, sleeping patterns and gait. Ambient sensors such as passive infrared motion (PIR), video (the most common one), sound (for detecting the sounds of daily living), pressure (for detecting sit and standing transfers), floor vibration, doppler radar and contact sensors are used for such purposes. The data can be extracted and analysed using machine learning to recognise events and deviations and potentially predict events, such as falls or medical episodes.

However, until now, research has provided few satisfactory solutions in all areas of ambient assisted living for safety, health, and comfort. Most models are deterministic and based upon rigidly repeated patterns. As Uddin et al. say: "there is a lack of suitable outcomes to validate the installation, management and delivery of technological solutions to meet specific needs" (2018, p 21).

UNTIL NOW, RESEARCH HAS PROVIDED FEW SATISFACTORY SOLUTIONS IN ALL AREAS OF AMBIENT ASSISTED LIVING

One literature review of research on smart homes for health monitoring of the elderly found low technology readiness and a paucity of research. They also found little evidence that smart homes or health monitoring can predict disability or prevent falls. Few if any studies use a technology adoption model, and economic analyses are rare (Liu et al., 2016).

Furthermore, the factors inhibiting adoption by the elderly – such as privacy, cost and intrusion – are not well understood. The commercial and adoption case for smart home technology is therefore far from complete.

ROBOTS

Robots may play a significant role in assisting the elderly to age in place. Robots can be classified as service robots – for example, robots that accomplish tasks that are challenging for the frail – or companion robots that provide entertainment and communication and help overcome isolation (Zafrani & Nimrod, 2019). It is hoped that social robots can promote mental health and medication compliance and reduce anxiety and agitation, but research results are not yet clear on this point (Pu et al., 2019).

In a study to assess readiness to use robots, Park et al. (2019) found that the elderly responded positively to robots as far as detecting and responding to emergencies was concerned. Indeed, the elderly were positive about any useful capability that gave them the ability to determine their own lives, irrespective of their decline in cognitive and physical function. But in a small multi-perspective evaluation of service robots, Bedaf et al. found that while older people seemed keener to use them than their caregivers or relatives, robot functionality was too limited (2017). The levels of flexibility, personalisation and responsiveness demanded were similar to those demanded of a human carer, suggesting further progress in robot technology is required (Bedaf et al., 2017).

TECHNOLOGY PUSH

There are several pitfalls regarding the application of technology to aging. The first pitfall concerns the general consequences of a push approach: these arise when technology providers develop "solutions" for a perceived market with little depth analysis for demand, suitability, concerns and barriers for users, stakeholders, and institutional frameworks, such as insurance or government policy. For example, online grocery shopping could easily be seen as a functional solution for the elderly, particularly in the time of COVID-19, but the reality is that for many, a walk to the shops to buy one item can be an important part of their daily exercise routine as well as offering a change of scene and social interaction with others, such as a grocer, their neighbours or others in the shop.

The second is that, in many cases, technology may not even be the right solution: in fact, technology may be a tool that enables an undesirable state to continue. Much research into healthy, independent longevity shows that lifelong local friends and social engagement, family support, continuous incidental movement and a healthy diet are key elements of resilient, healthy and independent aging. Interventions to encourage this require stronger, often low-tech solutions and more general social policy around societal infrastructure, community engagement, and architecture, urban planning, clinical care and healthcare facility management. All these stakeholders should be educated to familiarise them with a synergistic and holistic approach to understanding and supporting aging at the operational level (Illario et al., 2016).

THE PRESENCE OF HEALTH AND SAFETY MONITORING CAN BRING GREAT COMFORT

This is not to say that technology is unimportant, quite the contrary. The presence of health and

A report by the US National Research Council into adaptive aging argued that several conditions must be met for technology to be adopted (Pew & Van Hemel, 2004):

- ☐ **Interest** in efficiency and productivity of the care process
- ☐ The **safety** of devices and their functions must be obvious, and things that reduce safety – such as proliferation of distracting information – must be avoided.
- ☐ **Culture** and language variations affect demand and uptake.
- ☐ The elderly are sensitive to **stigmas** associated with aging, so care must be taken to avoid self-stereotyping and pejorative images of products that make the recipient or user seem infirm or deficient.
- ☐ **Usability** barriers are higher than among the general population, so extreme design for usability is required. Customisation to a specific, personal set of needs must be easily achievable.
- ☐ **Privacy** must be assured, as much of the information is highly personal, and people fear misuse or access by unauthorised people.
- ☐ One size does not fit all, so **design criteria** must be rigorously researched. There are significant differences between seniors that must be catered for and products must be easily configurable.
- ☐ **Trust** must be built in technology through reliability, ease of use, simplicity and so on.

PRE-CONDITIONS FOR ADOPTION

safety monitoring can bring great comfort and assurance to the elderly and their families while providing economies of scale that make it possible for care providers to deliver it at affordable prices (Chrysikou et al., 2016). And as younger generations age, computer-mediated socialising or personal robots may become a natural part of the household landscape. But individual technological products should always be viewed with the primary objective in mind: how can the elderly be supported in leading independent, healthy lives for as long as possible. And this, by necessity, must include frameworks and policies that address people, regulation, physical spaces, relationships and participants' beliefs and attitudes.

ATTITUDES TO TECHNOLOGY USE

Pre-adoption, the most important benefit of technology for aging perceived by the elderly is an increase in safety and usefulness, followed by increased independence and a reduction in their sense of being a burden on family caregivers. Other factors include the desire to age in place, cultural background, existing familiarity with technology and the type of housing (Peek et al., 2014). After actual use of the technologies, users may feel increased communication and companionship, safety and security, personal capability to perform the activities of daily living (ADL), trust in the reliability of the systems, awareness of their own health condition and independence (Tsertsidis et al., 2019). Concerns persist about information accuracy, lack of control over data and the recipient, anxiety about becoming dependent, lack of adaptability, easily forgetting functions, stigmatisation and insufficient training. But older people are a very heterogeneous group: just because people are old does not mean that they share any particular beliefs about technology. Attitudes, which are at the heart of their willingness to use technologies, are embedded in their personal, cultural, economic, social and physical context (Peek et al., 2016).

PARTICIPATORY DESIGN

Technology producers build values and assumptions about the elderly into their products that can disrupt and impinge upon the autonomy of elderly individuals. In particular, it can problematise older adults and construct them as being homogeneous and passive recipients of care, as well as introducing changes to power relations that alter behaviour.

For the individuals being monitored, their typical behaviours become norms, and changes to these behaviours become deviations that trigger alarms, interventions and a feeling of intrusion and external control. For example, the fear of creating unnecessary and invasive callouts will cause older people to limit their own behaviours for fear of triggering an alarm or placing too much pressure on family as the initial responder. This can cause recipients of passive monitoring to abandon such systems (Berridge, 2017).

Furthermore, the elderly are not passive recipients of such monitoring: they adapt their behaviour to refuse it, to work around it and

avoid alarms, or indeed to cause alarms in order to obtain some human contact (Berridge, 2017). The marginalisation of older adults in the design, development and especially in the determination of the purpose of passive monitoring is not neutral and leads inevitably to poor outcomes.

THE TECHNOLOGICAL CONTEXT

As with many technology and medical products and services, there are a number of less subjective considerations influencing adoption. For example, is the technology interoperable with other devices, manufacturers, or systems, is it approved by regulators, what is the level of support or warranty and how invasive is maintenance? As new products and protocols are introduced or upgraded, will the elderly find themselves in an endless cycle of technology glitches, feature changes, software upgrades and obsolescence? The physical instantiation of buildings and technologies and their different life cycles are important: a smartphone will be upgraded perhaps regularly and easily, whereas a home with built-in features is a long-term investment and difficult to change. For many, approval or underwriting by a health insurance provider will be critical in accepting a technology. The technological, institutional and economic reality into which assistive technologies are to be implemented must be understood and navigated in order to achieve movement into the market, uptake and productive use.

CONCLUSION

Gaps in knowledge and proposal
for research approaches

In summary, the health and care sectors are increasingly going digital as new technologies emerge. Unfortunately, these digital solutions are not proven to be ready to use – often they do not meet either the natural expectations of the elderly or the wider living environment in which they find themselves. The elderly must adapt to complex and inflexible technical systems, which are often not unified, consistent, or seamless. This causes various problems – people may be unable to adapt their living conditions to utilise these digital solutions and consequently have to move to a nursing home or they may misuse the technology or seek to work around it so as not to be disruptive or be a burden. Second, most research settings in this field are similarly dysfunctional – they are highly artificial and built around the technologies to be researched rather than the desired outcome. They thus resemble technology showrooms rather than the living environment in which they will be used.

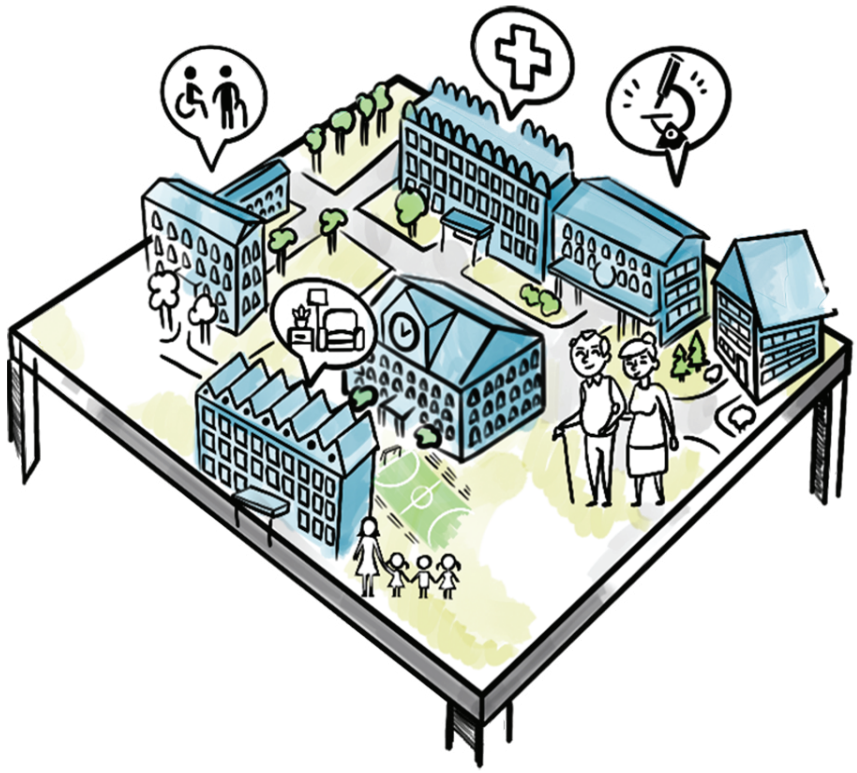
Both issues need to be addressed. HIIG and ECDF's Digital Urban Center for Aging and Health (DUCAH) and its Learning Labs in Berlin and all over Germany, is a research environment that explores a fundamentally different kind of solution, namely systems that adapt to people and their lives. It involves older people with a range of characteristics in participatory design and research across the full product and service process. It engages researchers, care providers, entrepreneurs and other stakeholders in developing and testing digital health and care solutions that help preserve the existing social environment for all generations, thus offering an example for how to implement multi-sided platforms and research in human-centred digital field studies.

DUCAH OFFERS A RESEARCH ENVIRONMENT TO EXPLORE SYSTEMS THAT ADAPT TO PEOPLE AND THEIR LIVES

A key finding of this white paper is the need for a strategic multi-disciplinary approach to research and design of solutions for aging. In the fields of aged care, healthcare, digital technology, district planning, neighbourhood development and housing construction, there are different problems to solve, decoupled lifecycles and varying institutional and regulatory contexts, but what these fields share is the objective of creating environments that support the elderly in living healthy, socially integrated and independent lives for as long as possible. The DUCAH Learning Lab initiative provides an environment in which such collaborative forums can be facilitated and inform the research and solution design needs of all stakeholders.

The DUCAH approach addresses three different levels at which the research and practice actors work together in idea teams: 1. specification and matching, 2. (data) integration and 3. regulation and policy. First, there is the level of matching, in which existing solutions from technology providers are brought together with the care facilities or housing companies. Here, a human-centred, participation-oriented testing of existing digitally supported innovations takes place in the neighbourhood, care home and hospital. Second, there is the data integration level. Here, the diverse stakeholders of the ideas team dedicate themselves to the prototyping of an interoperable digital platform for neighbourhoods, taking into account the integration of different applications and user groups. Third, there is the regulation and policy level. On this level, urgently needed financing concepts are considered. Reinvestment of profits in the health sector, models for social return instruments, and new ideas for refinancing innovations and start-ups are the focus of research here.

Most research until now into technology for aging has employed product evaluation, surveys and interviews, and observation of product use



The Learning Lab explores and innovates systems that adapt to people and their lives. The people who live and work here are involved in participatory design and research across the full product and service process. Researchers, care providers, entrepreneurs and other stakeholders are engaged in developing and testing digital health and care solutions that help preserve the existing social environment for all generations. The findings are transferred to the health sector and policy.

DUCAH LEARNING LAB

under laboratory conditions. Some use has been made of technology acceptance models, but such models fail to account for the bio-physical changes of aging as well as psychological and contextual factors. Further, technology acceptance studies focus on specific technologies and not on the general class of technologies required to support aging in place. While individual studies of system usability, efficacy and adoption are important, it is essential to observe and evaluate such systems in lived environments:

- To understand what resources are needed in a location to meet the requirements of a healthy life as older people decline in health and functional capacity
- To ensure that products and services consider ethical boundaries and are not pushed onto vulnerable subjects (Flick et al., 2020)
- To observe and understand how people actually use (or don't use) products and how they feel about them and to grasp what their concerns are in reality about privacy, stigma or being a burden
- To understand the interplay between different technologies and affordances
- To understand the ability of the elderly, in different stages of their lives, to cope with technologies
- To understand the relative role of the technology within the whole context of the lived environment, including the neighbourhood, and technology interoperability, evolution and support
- To provide an ecological context for trialling and observing how technology affects different stakeholders in the same context (the elderly, the spouse, relatives, caregivers, other service providers)
- To assess actual efficiency and productivity gains from the use of technology

The Learning Lab project will build upon HIIG's and ECDF´s considerable experience in interdisciplinary research and a variety of research projects that focus on creating socially acceptable solutions for the digital society. HIIG and ECDF will transfer and build upon results from previous projects such as: The Futures of Telemedicine: Knowledge, Policy, Regulation and Privacy by Design in Smart Cities. HIIG is examining Humanoid and Social Robots and the ethical considerations, regulatory requirements and legal repercussions that their use in care raises; it is also developing models for Data Governance that encourage data sharing and re-use to foster innovation and increase economic and social welfare and facilitate Digital Innovation in German SMEs.

PROPOSALS FOR RESEARCH

The scope of aging research is enormous and covers a wide range of disciplines. First, as a foundational principle, HIIG and ECDF will research the lived experience of the elderly and their interactions with technologies of all kinds. The means for doing this is the Learning Lab concept. Second, HIIG and ECDF will be able to introduce and research any areas that are amenable to this approach. The first projects will build upon previous knowledge accumulated in research projects in the health and technology sectors. Some initial project concepts and research questions within the DUCAH idea teams are as follows:

- Which data models in home care and aging at home are needed to ensure that life in old age is dignified and self-determined for as long as possible? What are fair and reasonable approaches to sharing the benefits of captured data between the elderly person being monitored and the companies gathering and analysing that data?

- What are the best practice smart home designs specifically for the elderly?

- How should multi-sided platforms be designed so that they offer sufficiently economically attractive incentives for participating companies and also beneficial, simple, and intuitive use for the elderly, with fair treatment of the data provided?

- How and in what form is work changing in the context of digitally supported care and age-appropriate furnishing of residential units?

- What innovative business models can be created in the interplay of care facilities, real estate and neighbourhood developers, technology companies, financial and insurance service providers, business advisors and other industrial companies with the focus on digital urban health and aging?

Others include:

- Social investing: how can community resources, perhaps a social impact bond or community hackathons with local startups for example, be mobilised to invest in applications that may eventually generate a return?

- Electronic health records: what are the benefits, costs, challenges, and risks of incorporating data from aging services technologies into master electronic health records?

- Data privacy and ownership: as large amounts of sensitive, personal data are captured through monitors and sensors, information management, data lineage and governance over the data will become especially important (von Grafenstein et al., 2019). Further, the voluminous, continuous data is a perfect subject for big data analytics and machine learning, which can use it to predict events such as falls or seizures or even incipient chronic disease. But who owns this data, and who has the rights to use it to gain commercial advantage (Zuboff, 2019)?

RESEARCH APPROACHES AND THE LEARNING LAB

Despite a wide range of emerging and current technologies, there are significant challenges for those wishing to implement technologies for aging, including an uneven evidence base, economic barriers, and educational and ergonomic issues that adversely affect many older adults. For example, great care must be taken to ensure that telecare systems avoid becoming totalising, imposed and coercive (Bächle, 2020). Understanding needs and individual creativity in customising systems is essential to the ethical use of telecare, and this customisation process should be respected (Bächle, 2020). Indeed, as the final report into ethical frameworks for healthcare technologies for older people at home found:

> "... telecare does not offer a technological fix' to replace either traditional healthcare services or informal care networks: it is not an easy solution to demographic ageing, 'care crises', personnel crises, or budget crises in ageing societies. Telecare does not perform care on its own. Respondents expressed grave concerns that telecare technologies might be used to replace face-to-face or hands-on care in order to cut costs." (Mort, 2011).

Peine and Neven (2019) contend that an interventionist logic in which aging is a target for technological interventions has exacerbated the digital divide. They support an innovation approach that utilises collaborative design, considers the socio-material practices of older people and other stakeholders, and includes policy discourse as an element of design. Older people must not be seen as a homogeneous group of actors simply because they are the same age: they will (not) use, modify, and produce technologies in varied ways for many different, possibly contradictory reasons. This is supported by Merkel and Kucharski (2019), who argue that it is important to include older users in all stages of the innovation and development process.

How the elderly perceive and use technology to enable living at home is driven by their personal, social, cognitive, and physical contexts – and these vary widely and change over time. Careful consideration is needed to determine how to design, implement and adapt technologies to support living in place. Evaluation must capture the interplay of these elements over time in real-life environments in order to provide meaningful results. These results will in turn shape the technologies and the environments to achieve the ultimate goal – aging in place for the elderly.

Above all, research must focus on the ultimate goal: aging in place. Research into individual devices from technology companies is limited in its usefulness. A better approach is to identify packages of technologies that enhance a functional area, such as health or mobility, so that a set of effective and affordable technologies can be introduced to improve aging in place for the diverse elderly population. This will also require multidisciplinary teams of technologists, gerontologists, clinicians, and public health researchers and collaborations with policy makers, community administrators, technology developers and the other participating stakeholders.

RESEARCH MUST FOCUS ON THE ULTIMATE GOAL: AGING IN PLACE

The concept of Living Labs has gained currency as a way of testing applications within an existing social environment (Keyson et al.,

2017) and has been applied to areas as diverse as traffic management and cultural heritage. Furthermore, Living Labs are "user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings" (European Network of Living Labs, n.d.). Based on that idea, the Foundation for Internet and Society's vision is to create a European showcase for testing innovative concepts for digital aging & health within a Learning Lab for Aging and Health in the Digital Society, in which the adaptation of technologies and systems to people can be observed and evaluated within a live environment. This evaluation should include interoperability and collaboration in digital ecosystems as well as best practices in digital supported care organisation and provision.

The creation of a comprehensive, inter-disciplinary research environment is a necessary condition for designing and researching digital care and health technologies that adapt to people and their social environments and focus on the supporting and hindering factors for the usage of technology in caring for the aging population. The planned Digital Urban Center for Aging and Health will bring together technologies for older people and the perspectives of the elderly, their relatives, caregivers and the care sector along with those of other health system institutions, technology providers and digital services start-ups, finance providers and the government.

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ABOUT

ABOUT THE ALEXANDER VON HUMBOLDT INSTITUTE FOR INTERNET AND SOCIETY

The Alexander von Humboldt Institute for Internet and Society (HIIG) researches the development of the internet from a societal perspective. The aim is to better understand the digitalisation of all spheres of life. As the first institute in Germany with a focus on internet and society, HIIG has established an understanding that emphasises the embeddedness of digital innovations in societal processes.

Drawing on the scientific competencies brought together at the institute, HIIG makes substantive contributions to our understanding of the relationship between innovation and governance in the digital society. It is about the realisation and change of social values and norms, but also about the question of how this can be done in an innovation-friendly way.

The institute fulfils this function in a distinctive way: we use institutional support to develop open and flexible projects. Programmatic research questions give structure to this work and enable a strategic research orientation. HIIG offers the pioneering thinkers of the digital society the opportunity to set the agenda early on and to create networks. We promote unconventional approaches and are open to ideas from all parts of society. HIIG builds interdisciplinary bridges instead of faculty boundaries.

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ABOUT THE FOUNDATION FOR INTERNET AND SOCIETY

The Foundation for Internet and Society understands reflection on the tension between internet and society as a prerequisite for bringing about developments, unleashing potential, but also recognising risks and proposing solutions for a digital transformation aimed at the common good. These considerations form the basis for its work in helping research organisations to generate the necessary knowledge to do so.

As a non-profit foundation, we want to find innovative solutions to future global problems and events that will challenge our global community. Excellent research is a prerequisite for empowering society and individuals to make informed and responsible decisions.

The purpose of the foundation is to promote a European-focused international debate on the social changes with and through the internet, not only from a technological but also from a legal, social-scientific and economic perspective.

The primary task of the foundation is to support the non-profit Alexander von Humboldt Institute for Internet and Society (HIIG), headquartered in Berlin, with ideas and funding. Additionally, the foundation is able to directly conduct its own projects, like the Digital Urban Center for Aging & Health (DUCAH).

www.stiftung-internet-und-gesellschaft.de

ABOUT THE DIGITAL URBAN CENTER FOR AGING AND HEALTH (DUCAH)

Why are so many digital systems being developed without taking the realities of life into account? What can we learn from the many research projects on assisted living applications that could increase future acceptance? Why are people often asked to adapt to technical systems and not vice versa? Is empathic robotics possible and desirable? How can intelligent neighbourhood development influence individual health? Why have previous smart city concepts not been successful? How can we develop a European standard for data sovereignty and information processing and at the same time create an alternative to Chinese or US models?

The Internet and Society Foundation has developed a new type of interface between digitisation, urbanisation and health: the Digital Urban Center for Aging & Health (DUCAH) is an inter-university cooperation platform, implemented through the Alexander von Humboldt Institute for Internet and Society (HIIG) in cooperation with the Einstein Center Digital Future (ECDF). DUCAH's mission is to research digital and social innovation within urban health and care systems from multiple perspectives. It will explore how the use of expanding volumes of digital data could be improved for social, economic and personal benefits and what changes can be expected in the economics of platforms, value creation and business models, particularly in Europe. Furthermore, it examines the questions of how to establish creative synergies between the medical domain and startups, how to effectively and ethically employ robots and artificial intelligence to support the needs of the aged, and how to ensure that efforts to design and develop care technologies centre on people.. It also asks how care work can be humanised through technology and how healthy living and neighbourhoods that support well-being and self-determination can be developed.

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