The Assisted Living Project

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Executive summary

The Assisted Living Project (2015–2020) was a research and development project led by OsloMet – Oslo Metropolitan University and funded under the Research Council of Norway's SAMANSVAR and IKT PLUSS strands. The project applied insights from Responsible Research and Innovation (RRI) to the research and development of assistive technologies.

The project combined mutual and independent research and innovation efforts from nursing, occupational therapy, engineering, machine learning, ethics, and social sciences in order to approach assistive technologies in an integrated manner. Through extensive engagement activities with several stakeholders, particularly older adults, the project has increased the understanding of inclusion of groups that are under-represented in technology research and innovation. Further, the project discovered how machine learning could contribute to developing future self-learning systems that may enable older adults to live at home longer. In addition, it documented how the insights from RRI might guide reflection on value realizations in assistive technologies. Towards the end of this report, we make several recommendations for future projects.

Contents

Introduction

A lamp shines in the corner of Edna's flat on the fourth floor in an assisted living facility in a central part of Oslo, Norway. Edna is very content with the lamp as it is operated by a remote switch which helps her control it from her favourite chair. Earlier, she had to struggle around the table and into the narrow corner to turn it on or off. Edna's lamp is one type of goods produced by the Assisted Living Project (2015–2020), a research and development project led by the Oslo Metropolitan University (OsloMet). The project aspired to use insights from Responsible Research and Innovation (RRI) in order to produce responsible innovations for dignified lives at home for persons with mild cognitive impairment or dementia (MCI/D). In this report, the project participants present other goods and additional insights from the project.

The Assisted Living Project represented a novelty for research and innovation, as it took seriously the ambitions inherent in RRI and utilized the procedural dimensions in applied research. Accordingly, it was an experiment in reconfiguring the research and innovation process; the case involved assistive technologies to be researched and developed from scratch through field studies and participatory processes, through to an advanced system based on machine learning.

The project followed an ambitious and integrated approach with four different stages or work packages, aimed at first understanding the field and the state-of-the-art of RRI, user participation, assistive technologies as well as machine learning, before entering into a development phase where these elements were to be incorporated into a proposed solution that would make it possible for older adults to live at home for longer periods. In the third stage of the project, the insights from the first phase were used to assess the solution with respect to its technical qualities, its effects on quality of life and health, as well as its overall societal and ethical impacts. Towards the end of the project, the approach developed through the Assisted Living Project was discussed in international contexts and with practitioners and researchers in Norway.

This report follows the logic of the project's overarching structure. Here, we mainly focus on the empirical parts of the project. Therefore, the report commences with a background and overview of the project, followed by central findings from the mapping part before moving into the developments made in the project. In the third section, focus will be on the assessment strategies developed and used, before outline a few reflections on the role of RRI in the research and development of assistive technologies and, finally, policy recommendations for dementia care in the future based on the project's foresight.

Background

In this section, we will present some of the questions the Assisted Living Project attempted to answer, as well as the reasons for these specific questions from both a societal and a scientific perspective. Further, we introduce some central definitions. In the subsequent parts of the report, it will become evident how these questions transformed and took novel forms and directions according to the project findings and external as well as internal vicissitudes and limitations.

Responsible research and innovation

Responsible Research and Innovation (RRI) is an approach to the study, policy development, and governance of new and emerging technologies. This approach aims to understand and steer innovation towards societally beneficial objectives through a democratization of research and innovation processes. For research and innovation to be responsible, it must include the following aspects:

1. A specific focus on addressing significant societal needs and challenges.
2. A research and development process that actively engages and responds to a range of stakeholders.
3. A concerted effort to anticipate potential problems, identify alternatives, and reflect on underlying values.
4. A willingness from relevant actors to act and adapt according to 1–3.[1]

Consequently, RRI is a prescriptive approach to governing science and a commitment to reflecting on or understanding the purpose of research and innovation. A central tenet is that research and innovation must produce outcomes that are not only positive in an economic or industrial sense but are also socially beneficial.

Even though the notion and different practices of RRI have had a substantial influence in a limited circle for a decade, there have been few direct explorations of what it could mean to apply the policy and governance approach to actual research and innovation. One contribution of the Assisted Living Project was to explore how RRI can be understood and converted to a basis for research and innovation in practice. There are two different motivations for investigating RRI in the field of assistive technologies. The first is that assistive technologies have potentially wide consequences for individuals and groups as well as for society as a whole. Consequently, these technologies must be researched, developed, and implemented as responsibly as possible. Since assistive technologies aim to improve individual lives and to economize on health costs, while RRI aims to democratize technology and research and innovation, the second motivation is to find a means to combine the disciplines involved in developing assistive technologies, in order to create grounds for democratic technology development and, thus, improving quality of life in a dignified manner[2].

Going behind the promissory and theoretical nature of RRI, the Assisted Living Project was governed by the ambition of investigating whether and potentially how the procedures recommended in the RRI literature could have an effect on the outcomes or the products of a research and innovation process.

Operationalization of RRI in Assisted Living

The project addresses the challenge of an ageing society. In order to investigate what roles assistive technologies might play in this challenge, the project

- engaged older citizens through open Dialogue Cafés;
- investigated health professionals' understanding and perceptions of assistive technologies in home-based services;

- invited older citizens to participate in the appraisal and development of assistive technology;
- aligned the development of assistive technologies towards users' needs;
- invited input from and responded to stakeholders and experts;
- conducted internal reflection sessions on co-operation and transdisciplinarity;
- presented and discussed the results in a national conference;
- invited stakeholders and experts to a foresight workshop.

Assistive technology

Assistive technology is a generic term for a heterogeneous group of technologies, including videophones, robotics, GPS technology, and monitoring systems to enhance security and safety and enable people to live an independent everyday life at home and in the community.[3] Assistive technologies have the potential for accommodating persons to live at home for a longer period than they would without such solutions. Consequently, assistive technologies might lead to a higher quality of life and to savings in the expenditure on care services – as well as creating opportunities for industry. Even though there has been an expectation and a demand from states, regions, and local governments to implement assistive technologies, it has been a slow process, with a disparate selection of possible solutions due to both organizational and technological factors.

Some studies indicate that assistive technologies change the caring situation for caregivers and care recipients as these introduce technological intermediaries between the caregiver and care recipients – such as remote monitoring rather than physical visits. A few individuals experience these changes as affecting the dignity of caregivers and care recipients.

It was central to the Assisted Living Project to understand the actual use and valuation of current assistive technologies in daily living as well charting challenges for older adults in order to identify potentially novel products that would positively affect the lives of individuals as well as the care systems. In order to understand the factors, values, and practices underlying use as well as non-use of assistive technologies, the Assisted Living Project studied inclusion practices and employed methods with solid foundations in both health research and RRI through active engagement of users, professionals, and a wide range of stakeholders.

Machine learning

Machine Learning (ML) implies that a system is able to learn from the data it processes without being explicitly pre-programmed – that is, without being provided with an explicit recipe for this function. The Assisted Living Project used ML for acquiring systems with *Perception* and *Anticipation*.[4] To this end, the project aimed at activity recognition and prediction in the homes of older adults. Activity recognition and prediction are prerequisites for realizing intelligent support functions in smart homes, including functions to support older adults with mild cognitive impairment or dementia (MCI/D) to live a safe and independent life at home.

Drawing upon the insights from the state-of-the-art in algorithms for analysing sensor data as well as the insights from the understanding of the preferences, values, and challenges of older adults as documented throughout the project, the Assisted Living Project aimed at recognizing activities identified by older adults as central to their well-being.

Mapping

In this section, we present and discuss how we approached the task of understanding the respective disciplinary views on assistive technology, the use and non-uses of assistive technology, and inclusion of potential users and stakeholders in order to understand their appraisals of different solutions.

What is distinctive about the Assisted Living Project is the application of a range of different methods in order to approach knowledge needs in a combination of experimental and established approaches. We combined desk research with qualitative and quantitative approaches and engagement strategies. Consequently, one central challenge was how to integrate the different approaches into knowledge creation.

The literature reviews for health sciences, engineering, and RRI—performed by a PhD candidate in each field—were partially used to identify research needs. The reviews found insufficient research in the following aspects: explicit attention to dignity, human dignity understood as "the intrinsic dignity that belongs to every human being,"[5] in user-driven research and innovation; access to and analysis of real-world sensor data; and attention to how to assess new products in line with the normative demands in RRI. A different utilisation of the literature reviews was for the consortium to read through summaries in order to come up with recommendations for good practices in RRI within the research and development of assistive technology.[6]

The reviews documented the state-of-the-art and identified gaps where the Assisted Living Project could contribute. In particular, there was a dearth of research on the predictability of sensor-events in real homes; a lack of assessment of users with MCI/D and their perceptions of the usability and acceptability of assistive technologies in combination with studies of these solutions' effects on dignity; and an absence of systematic reflections on how to integrate the perspectives in RRI into studies of assistive technologies. Further, we identified several established practices, similar projects, and a multitude of commercial initiatives.

A central activity in understanding technology use was a study of which technologies that are being used by older adults residing at home and how they use different assistive solutions. The project trained 121 students to perform this study. As part of their practical training as nurses or occupational therapists, 60 students performed survey interviews and documented actual use as well as how the respondents perceived the devices and assistive technologies more generally. These findings were systematized according to established scales for health and quality of life.

Findings from survey and individual interviews

The studies of technologies in the homes showed:

- heterogeneity in the complexity of understanding opinions and use of technology among older adults;
- social alarm and stove timer appear to be well-known and in use together with phone and TV remote control;
- opinions of technology appear differently in the survey and in the interviews, which reveal a methodological issue or differences in the samples;
- although technology might be a good solution in everyday lives, there are a few concerns regarding privacy as well as technology replacing service from the healthcare officials;
- technology is considered more useful for the future or for other older adults than for themselves.

Overall, 31 bachelor's degree and 2 master's degree students in occupational therapy as well as 12 bachelor's degree students and 2 master's degree students in engineering used the Assisted Living Project as a resource for their work or contributed to the analyses in the project. One master's student studied the tablets we planned to use as an interface. She found that the residents used the tablet computers as a tool to maintain and develop social relationships with family and friends in their everyday lives and that they demonstrated new ways of performing activities with these tablet computers. However, daily support from the caretaker appeared to be of great importance.[7]

In addition, five focus groups were held in different locations in Oslo in order to explore how community health care workers with or without a bachelor degree enacted the current policy on technology for home-dwelling citizens with mild cognitive impairment (MCI) or dementia (D) – MCI/D. The findings revealed two main themes related to 1) current and future potential of technology and 2) barriers to implementing technologies.[8]

RECOMMENDATIONS for RRI in assistive technologies

A combination of actors and disciplines is needed in order to explore a wide range of concerns and produce workable solutions. However, we also recommend

- investigating disciplinary differences and the implications of using different paradigms to describe, analyze, and explain similar phenomena;
- identifying the areas where a common language or vocabulary is needed and subsequently find a common language;
- allocating time and resources for interaction and co-creation across disciplines;
- opening up discussions on differences in viewpoints of the nature and status of basic science vs. applied sciences and research vs. innovation at an early stage in collaborative projects;
- discussing differences, intersections, and overlaps in the use of and perception of different disciplinary research methods.

There are specific contextual factors in the health and care sector that warrant overarching attention. Therefore, we suggest:

- studying the mediators, as human mediation of solutions also configure technologies and their use;
- addressing differences in allocation of assistive technologies due to differences in the competence building among health and care workers, differences in the availability of informal caregivers and/or next of kin, as well as inequalities in health and care services and meaningful activities;
- discussing the appraisals—adequate appraisals and assessments of assistive technologies beyond a mere safety test must be made a priority in research and policy;
- developing technologies and products in integration with the organizational context and those involved;
- taking dignity seriously—the user group is vulnerable, and both caregivers and care recipients have concerns regarding privacy and technology replacing caregiving from health care personnel;
- performing a feasibility study before implementing technology, which is a complex intervention.

Reflect on the underlying purposes!

- Whether the purpose of a research and innovation project in assistive technology is to address specific needs or to improve overall quality of life, early commitment to one specific technology can create lock-ins.
- Consider the drivers underlying technology research and innovation:
  - ⇒ Where do the needs /the push for technology come from?
  - ⇒ Are they rooted in the needs of the elderly or other stakeholders in the field?
- What are the consequences of these drivers for the solutions developed?
- A sounding board of stakeholders can be useful for deeper reflections and discussions of the different steps and decisions made through the project.
- Discuss the different rationales for including users, services, health professionals, next-of-kin and other stakeholders.
- Be aware that such inclusion does not by itself provide new insights that lead to clear-cut answers for the direction of service or technology development.
- What should the purposes of socio-ethical assessments be?
- Adapt the assessment format to the purpose and to the recipients.

In order to integrate the outcomes of the reviewed literature, we invited the residents at an assisted living facility to discuss different dimensions of technologies in daily life. For these discussions, we developed a methodology called “Dialogue Cafés” which is a modification of world cafés based on suggestions from Kennedy and Ter Meulen, as part of the Assisted Living Project. They reviewed the literature on how to include persons with MCI/D. Through the Dialogue Cafés, we were able to focus on the research and development process, the possible effects on dignity, health and well-being, and different technological solutions.

The Dialogue Cafés, the focus groups and the ProjectSTEP input served as material for articulating the values that an assessment for assistive technologies must be able to take into account.[9] These values constituted the basis for the development of RRI assessment methodology of the Assisted Living Project.

RRI product assessments must take into account the following aspects:

- The good life
- Risks and benefits before use
- Risks and benefits in use
- Distribution of risks and benefits
- Distribution of responsibilities
- Training

Development activities

In this section, we discuss the different development activities in the Assisted Living Project. A central challenge was how to configure the meeting places with older citizens, which became the Dialogue Café method. In addition, we developed a concept for inclusion of stakeholders and experts in the format of ProjectSTEP.[10]

ProjectSTEP

Given the Assisted Living Project's foundation in RRI thinking, a central premise was to establish a forum of stakeholders and experts who could contribute to discussing and reflecting upon the research questions, findings, proposed ways forward, and challenging situations. Experts in geriatrics, ethics, machine learning, and innovation were included. Stakeholders were nurses, occupational therapists, next-of-kin, technology developers, municipalities, assisted living housing, and the research council.

Based on an earlier study, we set up a forum for addressing the framings and assumptions in the project in order to arrive at a more informed situation analysis called ProjectSTEP.

The ProjectSTEP group met twice a year. During the meetings in the ProjectSTEP group, the project team did not respond immediately, but rather listened (and explained, when necessary). After the ProjectSTEP meetings, the project team discussed what had been learned and responded systematically to the input.

In the field of technology development, we assembled a prototype system, and used the experiences with this prototype to further the intervention methodology of the technology research in an appropriate manner. Towards the end, we present the research on machine learning and the development of the RRI assessment methodology.

Development of Dialogue Cafés

The feasibility study in the Assisted Living Project emphasized that an inclusive and flexible approach must be adopted by researchers.[11] A 'one-size-fits-all' methodology will not work due to the complex and idiosyncratic ways in which people have dementia and MCI. In these interventions, one should give careful consideration to issues such as informed consent. An ongoing process approach to informed consent is advised. Further, researchers must plan research sessions carefully, with attention to practical aspects, such as time and location, and also focus on the individual capabilities of participants. Appropriate communication and research tools will need to be utilized in the data collection, development, and testing stages of the design process. It cannot be assumed that methods developed for people with MCI/D will not need further adaptation to meet specific requirements of individual participants, or of the project. The involvement of other stakeholders (such as informal caregivers) as both informants and facilitators of the research can be rather beneficial to researchers. However, it is important to reflect upon their potential influence on the contributions of people with MCI/D in order not to undermine the inclusive aims of the participatory approach. Conducting research with people with MCI/D may progress at a slower rate than perhaps it would in other populations because of the variable and complex nature of MCI/D. Researchers must anticipate this when planning the project; in particular, it is vital to be understanding and maintain good research relationships with participants and other individuals involved. Important considerations when concluding research include enabling participants to provide feedback regarding their experiences of involvement as well as provision of feedback on the different research stages or the project as a whole.

Based on these recommendations, we explored methods where all participants are given the opportunity to talk about things that matter to them in structured ways, with the aim of

generating ideas, providing opportunities for joint decision-making, reflecting upon difficult issues, and discussing steps for further discussion or exploration—all based on democratic ideals. The outcome was a variety of World Cafés with small groups and one group moderator and one rapporteur per group in addition to a main facilitator.

The leaders in the assisted living facility, who had the role of gate-keepers, anchored the project. All residents were invited to a presentation of the project during one of their regular 'house meetings'. The researchers visited the assisted living facility approximately two or three times a week initially to become acquainted with the residents and inform them about the project.

Before each dialogue café, all researchers met and performed a 'dry-run café' enabling the group leaders and rapporteurs to obtain a common understanding of the scenarios, questions applied, and how to follow the method. After performing this dry run, we made the adequate adaptations and wrote final instructions for the project members. The researchers met one hour ahead of each café to agree on details. Further, preparing the context was important; café-tables for 3-6 participants were organized in the cafeteria at the assisted living facility. Coffee, tea, and sandwiches were offered at the beginning of each meeting. Two fictional narratives presented as "Helmer" (male, 85 years old) and "Nora" (female, 77 years old) were used to facilitate the discussions.

DIALOGUE CAFÉS

Based on evaluation in the project group, we found that

- dialogue cafés are optimistic ventures that can contribute to co-creation between assisted living residents, researchers, the Norwegian Board of Technology and a commercial technology partner in the process of developing technologies;
- drivers for positive outcomes are well prepared dialogue cafés, use of narratives, beginning with discussions of the residents' needs and challenges in everyday lives, presenting and testing possible technological solutions;
- barriers include skepticism in the beginning before everyone gets to know each other;
- the residents, researchers, public partner and the commercial technology partner enjoyed the dialogue cafés and the residents felt they were included and heard in this process of developing technology.

Intervention with reminder system

One central outcome of the third Dialogue Café was a prototype for a sensor-based reminder system. This system was one of several possible solutions discussed in the Dialogue Cafés – and was aimed at increasing safety at home. The sensors were magnetic sensors on doors, windows, and refrigerators as well as power meters connected to electric appliances with a risk of overheating or fire, and pyroelectric infrared (PIR) motion sensors. The overall intention of this reminder system is to check if the apartment is safe to leave by pushing a button by the exit door. The system then alerts, through a speaker, if everything is safe or if a certain appliance has been left open or on in the apartment. This reminder system would then be improved through machine learning so that there would be no need to push the button for control.

The configuration and installation process of this prototype served as experience-building for the residents and for the Assisted Living Project. This process was the objective of the feasibility study in the project performed by those in the engineering and health sciences fields.[12]

We were not able to test the functionality of the reminder system. The project's main hypothesis regarding the non-functioning system is that the assisted living facility had an

abundance of Wi-Fi networks. All sensors, the controller and the loudspeaker communicated wirelessly. The abundance (60 +) of public and private—secured and unsecured—Wi-Fi networks beyond the project's control made it impossible to connect the loudspeaker to the same network as the other devices. In the lab, these devices communicated without problems. Thus, it is evident that the reconfiguration of existing homes to smart homes comes with challenges.

The simple fact that the reminder system did not speak was not an obstacle to collecting data from the sensors to a controller. The experiences of both the residents and the researchers were collected, analysed, and constituted on the basis of the installation of similar sensor-based systems for research on machine learning.

Recommendations from the Feasibility study

- Configuration takes time; prepare as much as possible outside the homes
- Secure a quick and efficient installation, distribution of tasks, and follow the plan
- Limit the number of visitors during the installation to avoid feelings of intrusiveness
- Carry out a 'site-acceptance test' to control access to and sustainability of network
- Check architectural prerequisites regarding mounting of sensors

Machine learning

Building upon the experiences from the reminder system, 8 apartments in the assisted living facility were equipped with binary sensors (motion sensors, power sensors, and magnetic sensors) and a depth video sensor, RoomMate.[13] Given the relatively limited number of sensors in the apartments, activity recognition and prediction in the engineering research was related to the place and/or function of each sensor, as illustrated in Figure 1. The underlying purpose of the sensors and the research in machine learning was to develop homes that could assist and, to a certain extent, adjust to the needs of the individual resident.

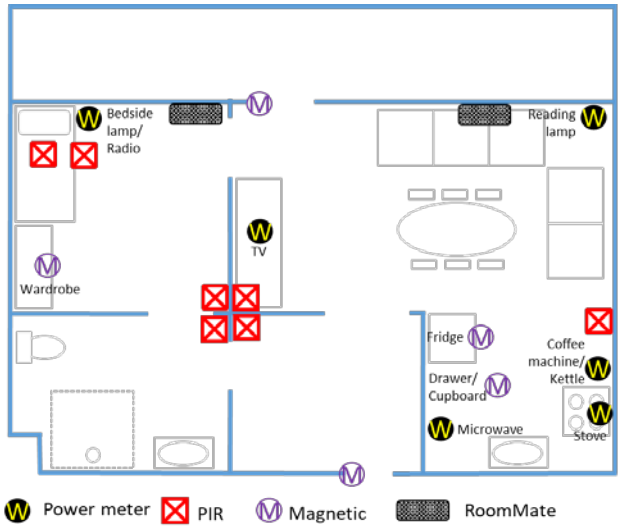

Figure 1 Typical field trial apartment and installed sensors.

In addition to the registrations from the binary sensors, we added time of day and time between sensor events as relevant parameters for analysing the events. In this context, events are sensor registrations, while *activities* are clusters of events defining an activity of daily living —such as watching TV, being in bed, being out, bedroom activities, living room activities, kitchen activities, bathroom activities, and transitions in bedroom/bathroom/entrance/living room in the current set up.

Earlier research on activity recognition was based on scripted events in labs. The Assisted Living Project is among the few that base activity recognition on data from actual homes. A central feature was to establish how different algorithmic prediction methods differed with respect to how many previous events one would need to attain a maximum prediction accuracy of the next event or activity[14] and to identify the maximum prediction accuracy with these sensors in an actual home.

The best attained sensor event accuracy was 83%, with all the 15 sensors and 87% with 7 motion sensors. This implies that in 83% and 87% of the cases, the prediction method managed to predict the next event accurately. There were interesting differences in that the probabilistic methods achieved a high prediction accuracy (close to their peak accuracy) with a relatively small training data set (approximately 1000 events). In contrast, the neural networks (long short-term memory network, LSTM) required a larger training data set (4000 to 7500 events) to attain an accuracy close to the peak. In general, our results have indicated that it is possible to achieve good prediction accuracy with much less data than previously believed.[15] With the inclusion of time of day and time between the events, the maximum degree of prediction was 85% and 82%, respectively.[16]

It is desirable to have prediction methods that can apply generally and are operational as soon as possible after the installation of the sensor system. In order to make this period as brief as

possible, we investigated a method called transfer learning—that is, to utilize the trained model from a number of apartments directly in a new apartment. Here, approximately 80% accuracy can be achieved straight away with very little data from the new apartment.[17]

When examining predicting activities—and not only events—based on the binary sensors, the prediction accuracy varies between 58%–90% excluding the time information in the input, and between 61%–90% including the time information in the input.[18]

The use of depth video data from the RoomMate sensor enables the recognition of activities of daily living. The project selected 'no movement', 'sitting down', 'standing up', and 'TV interaction' as rather basic activities for preliminary work. Using simple infinite impulse response (IIR) filtering combined with convolutional neural networks, we managed to recognize and distinguish between these four activities and achieved an overall mean peak recognition accuracy of 86%, with the accuracy of all classes (activities) reaching at least 85%. The method managed to identify TV-interaction actions with a peak accuracy of 97.5%.[19] On going work has achieved even better recognition and prediction accuracy on a larger set of activities (to be published).

Methods and Findings from Machine Learning

- Neural Networks (LSTM) are the most efficient method for high accuracy (binary) sensor event prediction in actual homes.
- Probabilistic methods require only a couple of days of data for achieving good (binary) sensor event prediction, whereas neural networks require approximately one or two weeks of data for achieving their peak sensor event prediction accuracy.
- A small number of sensors (15) can suffice for good sensor event prediction accuracy and for simple notification of irregularities in the home (such as no eating, no bathroom activity, etc.). However, a larger number of binary sensors is required for meaningful recognition of activities of daily living, and for the realization of well-functioning smart support functions.
- Low-resolution depth video cameras enable good activity recognition in an actual home and facilitate smart support functions, with minimal intrusion of privacy.
- A combination of binary sensors and low-resolution depth video cameras is promising for improved smart functions.

Developing assessments

Closely connected to this prototype development was the question of how to assess these products in line with the values articulated through the literature on RRI and through the values of users, caregivers, and other stakeholders. In addition, interventions in the health field are evaluated for safety, security, cost, and effectiveness through Health Technology Assessments (HTA). HTA are not a suitable method for assistive technologies by themselves, as HTA focus solely on health, while assistive technologies typically have indirect effects on health, quality of life, and/or well-being. The project reviewed several existing structured assessment approaches and their ability to encompass relevant values as well as having an interface for HTA, so as to develop a suitable assessment methodology for assistive technologies. In order to target the specificities of interventions in the care services, secure general societal dimensions, and include the value concerns, the project developed the Ethical HTA Matrix—a combination of the Socratic approach and the Ethical Matrix.[20] More on this in the next chapter.

Assessing

Assessing the different outcomes of the project played an important overall role. The ambitions of relating the assessment to improvement in health or quality of life proved difficult because of the problems with the reminder system. In this section, we present the results from the Dialogue Cafés as a means for co-creation, and the Ethical HTA Matrix. Towards the end, we present findings and reflections from an investigation of two other projects in assistive technology and analyse how RRI is operationalized in these and in the Assisted Living Project.

Dialogue Cafés

The Dialogue Cafés were a connecting thread throughout the project and created a common arena for the researchers of the Assisted Living Project to discuss, plan, and reconfigure the project.

Evaluating the Dialogue Cafés, we witnessed a process where the participants were invited to explore/discuss the challenges of their everyday life. These discussions were followed by presentations and demonstration of different technological solutions and possibilities to test technological solutions. Towards the end of the series of dialogue cafes, we presented and discussed machine learning. The researchers were in continuous dialogue with the participants for discussions and opinions with the intention to enhance co-production.

There are several dimensions to the experiences of both the participants and the project team. There was an ‘idealism’ in the project team, illustrated by how the cafés were very well planned in advance by written instructions and dry runs, followed up with discussions after each café, all of which contributed to continuously determine adaptations to the participants’ responses and striving for co-production. A means of ‘realism’ was also revealed, which was related to the aspect that the project team group leaders initially did not know the participants and found it difficult to run the group process. Moreover, the findings reveal a form of ‘scepticism’ among the participants before the project commenced, exemplified by the fact that they said that they were surprised to be included and asked about their opinions and not merely to be informed, which is what they had expected in advance. A common denominator among the participants and the project team was ‘enthusiasm’, as they were all very satisfied after each café and expressed ‘enjoyment’.

These experiential dimensions indicate a few contrasts and certain zones of convergence. Viewed from a normative perspective the inclusion of older citizens – a category often neglected in technology research and development – must be recognized as valuable in and of itself. However, did the Dialogue Cafés have an instrumental function of leading the project towards an improved solution? Or did they provide an increased understanding as a variety of older citizens were included at different stages, and for a series of purposes? The Assisted Living Project team do report having learnt a lot about the users and the users’ life-worlds. However, the space for actually contributing to functioning products and benefiting from these products appears to have been restricted. These restrictions originated from a pre-set research agenda as well as a limited supply of possible solutions from the technology company. In retrospect, the availability of possible solutions should have been introduced earlier; not being aware of the space and limits for influence appears to counter the co-creation thought process.

RRI assessment method

The Assisted Living Project’s method for assessing assistive technologies, the Ethical HTA Matrix, was tested, in cooperation with Sensio, on a case of GPS localization systems with informal caregivers as first responders. The Ethical HTA Matrix provided detailed information concerning how the different stakeholder categories were affected by the introduction of such a system. The Ethical HTA Matrix follows three steps:

1) Literature searches for an extensive overview of how the technological system affects different stakeholders with respect to well-being, dignity, and fairness.
2) Discussion of the value and importance of these impacts with representatives from the stakeholder categories.
3) Presentation of the values and impacts for the different stakeholders to decision-makers or producers of said technology.[21]

The intention of the Ethical HTA Matrix was to facilitate the assessment of an assistive technology. However, the interviews with decision-makers, civil society, and producers revealed that the main advantage of the matrix was that it functioned as a device for reflecting upon what forms of value might be realized through assistive technologies. Representatives stated that it is valuable to have a structure that enables articulation of non-economical values, since these are typically difficult to isolate for evaluation. Underlying these reflections was a sentiment that the Ethical HTA Matrix provided a comprehensive view of the consequences of assistive technologies, but that the amount of information it contained was too large for making a swift decision regarding the desirability of a specific assistive technology.

Thus, although it provided a comprehensive picture, the Ethical HTA Matrix is not sensitive to contextual factors such as co-morbidity or changes in perception of the technology over time.[22]

International practices for innovating in assistive technologies

As the Assisted Living Project investigated how to research and develop assistive technologies based on RRI, one aspect of the project was to study and analyse the place of the AIRR dimensions (anticipation, inclusion, reflexivity, and responsiveness) in existing international projects aiming at health and care through technological solutions.[23] We selected two projects: the SPHERE project[24] of the University of Bristol in the UK and the QuartrBack project[25] of the Karlsruhe Institute of Technology in Germany. Neither project was explicitly based on the concept of RRI, but both implicitly included AIRR dimensions and values that can form the basis of comparisons and shed light over how to incorporate RRI in assistive technologies.

All three projects—SPHERE (a Sensor Platform for HEalthcare in a Residential Environment), QuartrBack (Intelligent Emergency Chain in Quarters as a Backup Structure for People with Dementia), and the Assisted Living Project—share a commitment to high-tech solutions as a central and valuable part of health and care services in order to improve the quality of life for persons with different medical and social needs. Further, and this is why they are relevant in this context, they have all involved scholars and practitioners from the social sciences and humanities in order to assess the social dynamics of the innovative solutions and enhance the integrative potential of the technical interventions.

Despite the fact that the projects share these aspects, they also differ substantially from each other. As it has become evident through this sub-study, the outcomes of the inclusion of RRI-elements are not translated into products per se, but rather into ideas of how products might be configured in order to be ethically good and socially beneficial or acceptable. Each step underlying the development of assistive technologies has been informed by RRI concepts; it is precisely the scope and ambitions of these steps or phases that are of interest here.

The common denominator of these three projects, with vastly different budgets and outreach, is different aspects of machine-learning techniques and the use of algorithms. The core differences and similarities are listed in Table 1.

Table 1 Comparison of Assisted Living, QuartrBack and SPHERE

	Assisted Living	**QuartrBack**	**SPHERE**
Structure	RRI-led	Services-led	Technology-led
Underlying technology	Machine-learning techniques and algorithms	Machine-learning techniques and algorithms	Machine-learning techniques and algorithms
Main purpose	Basic research and development of a commercial product	Development of a commercial product	Basic research

The differences in structure are the most striking aspect of the comparison. QuartrBack is led by a commercial service developer, while services are not specifically included in SPHERE and Assisted Living. Further, the intended objective of Assisted Living and QuartrBack is the development of commercial products, whereas SPHERE is dedicated to basic research. Basic research is a central element in Assisted Living as well, but as we demonstrate in this report, the timeframe and directions of the activities oscillated between these two purposes.

Anticipation

User or stakeholder engagement leads directly to reflections regarding the future. Questions related to privacy and data protection are of particular concern among users: What happens if data are leaked? What happens if one specific member of the household does not wish to be monitored? Here, attention is directed at avoiding negative aspects of new technologies.

All three projects focused on anticipatory aspects and unintended consequences and turned such reflections towards the realization of possible goods through structured engagements with non-experts. A central theme in this respect was empowerment of the main users. The QuartrBack and the Assisted Living Project engaged experts in different forms of anticipatory activities. Whereas the Assisted Living Project conducted a foresight (see next section), the QuartrBack project involved experts from various areas (ethical, legal, social, etc.), addressing broader questions, such as whether the technology can change existing societal arrangements and the connectivity among actors. This leads to the following questions: How can the needs of people with dementi be catered to in a just way, while also supporting their self-determined life? How can such ethical issues be resolved and what can potential solutions look like?

In addition to formal inclusion in project descriptions, the drivers for anticipation must increase acceptability as well as take into account the expectations, capabilities, and needs of the stakeholders. The barrier to successful anticipation is an orientation towards a fixed technological solution and downplaying of social perspectives. In addition, the choice of participants influences the democratic representability as well as the epistemic quality of anticipatory activities.

Inclusion

Inclusion of different voices and experiences is commonplace in the research and development of assistive technologies, as they aim for the realization of certain values for users, industry, and the care system. Consequently, success criteria are suitable for development with representatives for these groups.

Therefore, a central motivation for inclusion is to develop or find knowledge on what users or other stakeholders deem necessary. This is a knowledge gap on the part of the developers that was further explored through the inclusion of a series of disciplinary experts in the QuartrBack project and through professionals in the care occupations in SPHERE and the Assisted Living Project. In addition, SPHERE used laypeople in setting priorities for additional research questions that were not part of the original project conceptualization. None of the projects worked with groups mixing experts and users or mixing different stakeholder and user groups. In the Assisted Living Project, this choice was intended on the basis of the development report for inclusion of persons with MCI/D.[26]

A different motivation for the inclusion of users is to explain how different technologies work. Often, there is an underlying assumption that opposition to a certain technology is caused by lack of knowledge of how it ‘actually’ works. Once this knowledge is in place, acceptance will follow—that is, there is a knowledge gap on the part of the users. This has been only partially confirmed in these projects. Although enhanced knowledge appears to alleviate some of the original concerns (e.g. usefulness of the system), it does not eliminate most of the ethical issues associated with the technology (e.g. privacy). Even though systems work correctly—or are useful—they might conflict with how people wish to lead their lives. This is particularly so with systems based on predictions and alarms, since these intervene in people’s lives.

Reflexivity

Organized reflexivity was solely a feature of the Assisted Living Project since it was a part of the project description. The aim of the activities was to learn more about others' and one's own problem-solving strategies and what it means to work in a transdisciplinary manner. As the Assisted Living Project was organized around RRI, there was a clear emphasis on ethics and broader social impacts.

Reflexivity is also visible in the work of the 'friend of SPHERE', in which different aspects of the project were discussed. Concerns regarding the benefits of SPHERE technology vis-à-vis other social aspects, such as social exclusion and loneliness, were raised. Further, SPHERE initiated a project to understand how researchers framed research ethics and to refine their understanding through professional development programs. In QuartrBack, reflexivity was not formally addressed, but activities such as stakeholder inclusion and interdisciplinary work entail a certain level of implicit reflexivity.

What appears to open up the possibilities for reflexivity is problems in certain parts of the project or the work process; however, such problems might also be a challenge for second-order learning if one concentrates on problem-solving rather than self-learning. In QuartrBack, the solution of using a well-known format for the technologists to address appears to be an instance of such problem-solving, which had positive effects for the project. In the Assisted Living Project, the participants reported having learned that transdisciplinary work is difficult, that their own discipline is not sufficient to solve complex problems, and that general innovation approaches are inadequate and must be adapted. However, a small amount of positive second-order learning—that is, learning about how to address a problem, not merely problem-solving—appears to have emerged.

Responsiveness

Responsiveness refers to how to change the direction as well as the pace of research and innovation during the project phase.[27] Consequently, it also implies a change in the goals and means of research and innovation.

QuartrBack practiced an openness throughout the project with consequent adaptations to field tests, citizen input and testing protocols with caregivers. Further, QuartrBack worked towards a format of making specific Action Sheets that translated this input into technical requirements. This highlights the need for discussions concerning translation and format as preconditions for responsiveness. SPHERE did not include responsiveness as an element in the project design. However, the inclusion activities raised the question of 'how far we can allow the preferences of the users to direct the design of technology'? What input from the users can be included and what cannot be included? A similar experience was found as part of the Assisted Living Project. The Dialogue Cafés provided several directions for research and development, but it remained unclear what to emphasize and what to leave out. The principal direction was given by the commitment to a specific technology—that is, machine learning. However, the consortium worked by modifying the project according to the input from the Dialogue Cafés.

The pre-commitment to a specific technology is one central barrier to responsiveness. This barrier is, in certain instances, a consequence of the lack of flexibility in the management of research grants. Once a project is funded, there is little space to negotiate changes in the milestones and in the general goals described in the original proposal. The Assisted Living Project had more flexibility in making changes, but also here there was friction between the research and development goals. This might be an indication of a different barrier, namely, the lack of incentives for researchers to pursue non-scientific goals—such as co-operation and transdisciplinary activities. In addition, the Assisted Living Project had engaged three PhD students who needed to pursue certain research aims, a fact that limited the flexibility of the

project aims. Through the installation of sensors, participation in Dialogue Cafés, and in the integration of literature reviews, these PhD students needed to adapt to each other.

Outlooks on assistive technologies

As a final activity to communicate the findings of the Assisted Living Project, and to direct attention towards policy-making in the area of dementia and assistive technologies, the Norwegian Board of Technology organized a Foresight, a method for making policy choices based on scenarios.[28]

The Foresight had as it's backdrop that dementia and cognitive impairment cause extensive use of health and care services and will constitute an increasing societal challenge in the coming years. We created three scenarios for how Norway's dementia care could look in 2035 and gathered a variety of stakeholders to discuss them. The goal was to identify opportunities and dilemmas, and to develop a plan of action for policy makers..

Foresight: Scenarios as a method in the Assisted Living Project

Scenarios are plausible and knowledge-based stories regarding the future. They function well as a tool for discussing various future alternatives. Are community health and care services ready to meet the needs described in the scenarios? What is the maneuvering room, and what are the key questions that must be addressed by politicians in the coming years?

The project identified trends considered to have a high degree of certainty.

Certain trends:

- More people living with dementia
- Healthier elderly people
- Higher proportion of older citizens in rural areas
- Lower public income
- Lower proportion of people of working age
- Smart surroundings
- Artificial intelligence
- Cognitive and emotional support
- Physical support
- Diagnosis

New actors:

- New ways to organize services
- Platforms provide power

There are questions that we do not know the answers to, but where political decisions will have considerable influence.

- Collective axis: How are we going to organize work?
- Individual axis: What do we value the most—control over the disease or autonomy?

Based upon these axes, the three scenarios were developed and discussed in a four-hour workshop with participants from the voluntary sector, the public care and health sector, and research and industry.

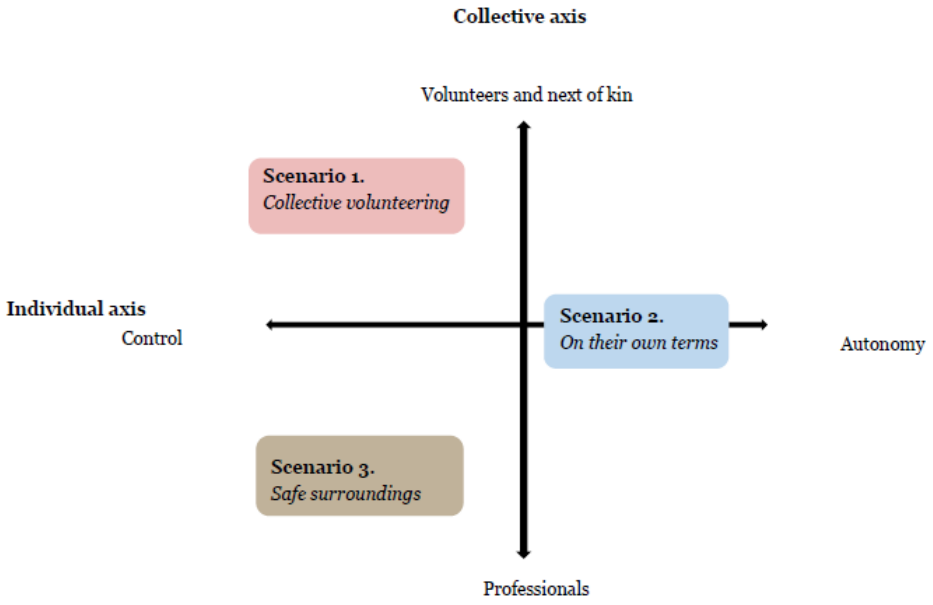

Figure 2 The three scenarios mapped within the axes of Collective vs Individual orientation.

Scenario 1: *Collective volunteering* is based on volunteers being the main resource for people with dementia. These can be their families, charitable organizations, neighbours, students, etc. The local governments are in charge of coordinating the resources. Technology is used to monitor the progression of the disease and to provide personalized care.

Scenario 2: *On their own terms* is centred on the person with dementia and their need for autonomy and interaction. Volunteers deliver different services and are paid through the municipality's time banks. Technology is used for and with the person with dementia.

Scenario 3: *Safe surroundings* indicates that Norway places a systematic focus on early diagnosis and prevention through the dementia program. The municipality's role is to ensure consistent supervision and data collection through new technology.

Foresight recommendations:

- Develop digital solutions for follow-up and coordination of physical meeting places that can provide support for the next of kin.
- Use platform technology in connecting key welfare services with available resource persons as a means to free up resources in the health and care sector.
- Create arrangements for compensation and flexibility to help others regardless of family relations.
- Extend the national assistive technology program beyond 2020.
- Ensure reliable Internet access for all.
- Ensure that everyone creates an aging plan that considers what kind of old age experience one wishes to have.
- Conduct a GPS promotional campaign in the municipalities or from a higher level.
- Standardize procurement competence when acquiring assistive technology.
- Build generation villages.
- Build a dementia-friendly society.
- Ensure that all municipalities have an assistive technology ombudsman.
- Increase focus on digital competence among next of kin and health personnel.

Project recommendations

The combination of different explorative research avenues in the Assisted Living Project was bold. One novelty was the translation of RRI to a project tool and adapting the thinking in RRI to assistive technology. Similarly, the combination of engaging in novel methods of inclusion and co-creation with path-breaking research in machine learning had not been attempted earlier. In addition, we had the ambition of creating useful products that could maintain or even increase dignity for home dwelling older adults with or without MCI/D What physically remains after the project is Edna's lamp. However the residents address the importance of being "heard' and included in discussions concerning everyday life and technological solutions.

Based on the experiences, failures, and successes in the Assisted Living Project, we identified a few central areas and issues that we believe must be taken into account for assistive technologies to be researched, developed, and innovated in a socially responsible and resilient manner. These are not unique to the Assisted Living project, but resonate with recommendations and experiences from other projects and experiments in assistive technologies in national and international settings:[29]

A combination of different disciplines and actors is needed in order to explore a wide range of concerns and produce workable solutions. However, we also recommend

- investigating disciplinary differences and the implications of using different paradigms to describe, analyse, and explain similar phenomena;
- identifying the areas where a common language or vocabulary is needed and identify a common language;
- allocating time and resources for interaction and co-creation between disciplines;
- opening up for discussions on differences in views regarding the nature and status of basic science vs. applied sciences and research vs. innovation at an early stage in collaborative projects;
- discussing differences, intersections, and overlaps in the use and perception of different disciplinary research methods.

There are specific contextual factors in the health and care sector that warrant overarching attention. Therefore, we suggest

- studying the mediators, as human mediation of solutions also configure technologies and their use;
- addressing differences in allocation of assistive technologies due to differences in competence building among health care workers, differences in availability of informal caregivers and/or next of kin, and inequalities in health and care services and meaningful activities
- discussing the appraisals—adequate appraisals and assessments of assistive technologies beyond a mere safety test must be made a priority in research and policy
- developing technologies and products as integrated with the organizational context and those involved;
- taking dignity seriously—the user group is vulnerable, and both caregivers and care recipients have concerns regarding privacy and about technology replacing care given by healthcare personnel;
- performing a feasibility study before implementing technology, which is a complex intervention.

Reflect on the underlying purposes!

- Whether the purpose of a research and innovation project in assistive technology is to address specific needs or improve overall quality of life, early commitment to one specific technology can create lock-ins.
- Consider the drivers behind technology research and innovation
  - Where do the needs /push for technology comes from?
  - Are they based on the needs of the elderly or other stakeholders in the field?
  - What are the consequences of these drivers for the solutions developed?
  - A sounding board of stakeholders can be useful for deeper reflections and discussions of the different steps and decisions made through the project.
- Discuss the different rationales for including users, services, health professionals, next-of-kin, and other stakeholders.
  - Be aware that such inclusion does not by itself provide new insights that provide clear-cut answers for the direction of service or technology development.
  - What should the purposes of socio-ethical assessments be?
  - Adapt the assessment format to the purpose and the recipients.

About the Assisted Living Project

The project was funded under the Research Council of Norway's SAMANSVAR program, a program for research on responsible innovation and Corporate Social Responsibility (CSR) and the ICT Pluss Program; it ran for the period 2015–2019.

The Assisted Living Project group included the following members:

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- Dr Mario Pansera, University of Bristol
- Dr Miltos Ladikas, Karlsruhe Institute of Technology
- Dr Julia Hahn, Karlsruhe Institute of Technology

The study was conducted in accordance with the Helsinki Declaration, including informed written and oral consent and confidentiality. In accordance with Norwegian law, the study was formally evaluated by the Regional Committee for Medical and Health Research Ethics, which decided that the study was outside their field of responsibility because it was regarded as 'health service research'. Therefore, the study was assessed and approved by the National Data Protection Official for Research and the local data protection ombudsman at OsloMet.

According to the procedures at OsloMet, the project manager and team conducted a risk and value assessment upon starting; this was revised throughout the project period. The risk assessments included the technical solutions/services for the secure storage of research data. All sensitive personal data from the health and technology research in the project was stored in TSD 2.0 Service for sensitive data at the University of Oslo.

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