
Article:
Flick, C., Zamani, E. orcid.org/0000-0003-3110-7495, Stahl, B. et al. (1 more author) (2020) The future of ICT for health and ageing: unveiling ethical and social issues through horizon scanning foresight. Technological Forecasting and Social Change, 155. ISSN 0040-1625

https://doi.org/10.1016/j.techfore.2020.119995

The future of ICT for health and ageing: unveiling ethical and social issues through horizon scanning foresight

Abstract

This paper uses horizon scanning as a foresight methodology to investigate the opportunities, challenges and futures of ICT for health and ageing, particularly focusing on identifying the ethical and social issues associated with this sector. It uses empirical evidence gained from the analysis of interviews, literature reviews, and policy documents to identify the primary signals within the areas of future technologies, future environments, future companies, and future older people. In addition, we build on contemporary internet-based discussions amongst the general public and the ICT start-up sector to identify weak signals regarding ethical and social issues, based on and around these areas. Our findings show that the key ethical and social issues identified are concerned with the issue of the elderly being seen as collections of diseases, the human face of ICT, privacy and informed consent, autonomy, stereotyping of older people, and general anxieties around ICTs. We conclude our paper with recommendations for addressing these ethical and social concerns, specifically through the adoption of responsible research and innovation practices.

Keywords: health, ageing society, ICT, responsible research and innovation

1 Introduction

ICT for health and ageing is a multibillion-dollar industry since years (Wolf, 2014). The ageing population is increasingly technology savvy and connected. At the same time, older people are demanding better standards of care, increasing access to care, and all the conveniences of the information age (Hussain et al., 2015). Relatives are turning to technology to help keep in touch with and care for their family members as they juggle the modern responsibilities of work and family life. Public health services are looking to cut costs and increase coverage of care through technologically enabled products and services. This creates a huge potential for business.

Technological advances today allow the multitude of systems and devices to monitor and collect data from the user and the environment in order to diagnose health issues, prevent accidents, make suggestions and more. Such advancements pose important ethical questions and touch upon issues of trust and privacy, but also issues that relate to the pertinence of the technology, and the designers' responsibility towards the end user, to only name a few. However, it is not always clear, how or if ICT designers and developers approach the implications of their technological products and services for the individual. Older people can be particularly vulnerable, have multiple health problems, and technology can sometimes be used in ways that exacerbate existing care gaps and leave some seniors at risk of harm. In addition, health ICTs are often treated as a means for "fixing a health condition", instead of "[sustaining] everyday life as a whole" (Ballegaard et al., 2008, p. 1807).

In this paper, we explore the future of ICT for health and ageing in Europe by applying foresight analysis, more specifically horizon scanning. The question we want to answer is which technical developments in the field of ICT for health and ageing can be expected and which ethical and social issues this is likely to raise. Answering this question is of high practical importance, as it provides the basis for technology developers and companies to position their

products and services accordingly. Due to the potentially large practical impact of these technologies, an awareness of future technologies and their ethical and social consequences is of large societal importance and critical for policy making.

For this study we use foresight analysis by way of horizon scanning. Foresight analyses, and horizon scanning specifically, have recently been attracting the interest of researchers and policy makers alike, because they support learning and allow for improved policy-making (Rhisiart et al., 2017). Our empirical material consists of interviews, case studies, existing foresight studies, and European policy documents, which we analyse for background primary signals. We also employ a qualitative analysis of social media, news articles, discussion fora and venture capital funders to capture the cutting edge of opinion on the future of the sector. These components are then analysed to determine the ethical and social issues that are likely to arise in the development of future ICTs for health and ageing.

The paper makes an important contribution to the foresight and in particular horizon scanning literature. It showcases strong and weak signals by describing possible futures under the headings of future technologies, future ICT companies, future older generations and future environments. These possible socio-technical futures are then analysed to identify ethical and social issues. The most important concerns are stereotyping older people, the human face of ICT, privacy and informed consent, autonomy and anxieties around ICT. This analysis shows that there are clear and recognisable ethical issues that arise from currently envisaged futures that can be considered and proactively addressed now. The paper outlines general implications and their consequences for innovators, companies and policymakers.

The paper is structured as follows. First, we present the method of horizon scanning in detail and discuss both our data and the data analysis approach. Then we present our findings and answer our research question with regards to the potential opportunities and challenges, as well as the ethical and social issues that need to be addressed when dealing with ICTs for health and ageing. We then offer our recommendations for avoiding ethical and social pitfalls in the sector, based on our findings. The paper concludes with implications for future research, as well as product and service design.

2 Background and Method

2.1 Horizon Scanning for foresight analysis

Foresight analysis helps businesses and organisations to identify and anticipate the outcomes of their decisions, and ultimately integrate foresight into their strategy (Booth, Durance and Monti, 2019). To date, foresight analysis has been used in many different contexts, such as strategy formulation for multinational corporations, business innovation, and policy making (Betz, Betz, Kim, Monks and Phillips, 2019), to name only a few. Earlier research also indicates that company use such tools also in the context of Responsible Research and Innovation (RRI), for instance in the context of anticipation and stakeholder engagement (Timmermans et al., 2017). However, in general, the use of such tools is still a challenge for companies as they use them in different maturity stages (Martinuzzi et al., 2018; Stahl et al., 2017).

Under the umbrella of foresight analysis, researchers have been using different techniques. One of the most influential methods is that of Horizon Scanning. Horizon scanning allows researchers to identify a set of future issues, so that these can be potentially addressed or mitigated early on in a research, innovation or development cycle (Schultz, 2006). Its purpose is to identify potential future scenarios within a particular context, as well as opportunities that could be exploited and challenges that should be addressed. To date, Horizon Scanning has

been used across many different fields. For example, it has been used as a method to increase and strengthen organisational preparedness (Rowe et al., 2017). Kim et al. (2018) have looked at the Korean policy research database using horizon scanning in order to discuss past, current, and, most importantly, future environments. Within the area of the healthcare industry in particular, horizon scanning has been quite an influential strategy for identifying innovation, trends and different issues. For example, Kolominsky-Rabas et al. (2015) propose that horizon scanning is a valuable approach for estimating the cost-effectiveness of a health-related ICT at an early stage of development. On a larger scale, the European Medicines Agency has been using horizon scanning to inform its Regulatory Science Strategy and the European medicines regulatory network strategy (Hines, Yu, Guy, Brand, Papaluca-Amati, 2019).

However, foresight analysis exhibits certain limitations in detecting weak signals and selecting experts on the research topic (Amanatidou et al., 2012). For this reason, scholars have been arguing for the use of web-based data, namely data from online social media, such as Twitter, and blogs (Pang, 2010; Kim et al., 2018). As a result, we use horizon scanning in this study by incorporating web-based data as well, in order to look at the future of the ICT sector for health and ageing, so as to ensure that our pool of empirical material and its subsequent analysis can account for weak signals as well. Our method is discussed in more detail in the following chapter.

2.2 Method

For applying the Horizon Scanning method, we follow the recommendations of Amanatidou et al. (2012) for combining the exploratory scanning with the issue-centred scanning approaches. The exploratory approach builds on the identification of weak signals. Weak signals are often difficult to detect but are critical for foresight as they are early indicators of potential change but are too incomplete to allow for an accurate estimation of their impact or even to determine their responses (Rossel, 2011). The issue-centred scanning approach builds on previously identified emerging issues (i.e weak signals) that either "reinforce the hypothesised emerging issue or reveal changes, modifications and disruptions of existing emergent issues" (Amanatidou et al., 2012, p. 211). Those signals that provide a substantial future narrative with a potentially high impact are considered primary signals and typically derive from publications that identify a future narrative that requires attention today, reporting on factual findings and being supported by reliable sources. In turn, secondary signals either support or deny the possibility of these issues to occur. Therefore, combining the two approaches, allows us to anticipate emerging issues with a higher degree of precision and accuracy, to further explore emerging concerns that were initially unidentified as well as to present a more complete evaluation along the scanning process.

We began the horizon scanning process in 2015 by applying a two-round approach. The initial round revolved around the collection of weak signals, primary signals and secondary signals in 2015 (collecting sources from 2014-2015), and the second round was focused on collecting weak signals towards the end of 2017 (collecting sources from 2016-2017). The second round aimed at investigating potential changes that might have occurred over this three-year period, and exploring whether the emergent discussions were similar in nature or had shifted (e.g. a disruptive technology that could change the primary signals). The results from this round suggested that the primary and secondary signals had not changed significantly during the three years of investigation, so the focus of this paper is on the outcomes of the weak signal analysis. It is important to note that weak signals are touched on by primary/secondary signals, but are not discussed extensively, and need to be followed up to consider their plausibility. As such, they are not explicit predictions but a basis upon which to reflect on the current trajectory of

technology development in this area. A diagram and timeline of the method can be found in **Error! Reference source not found.**.

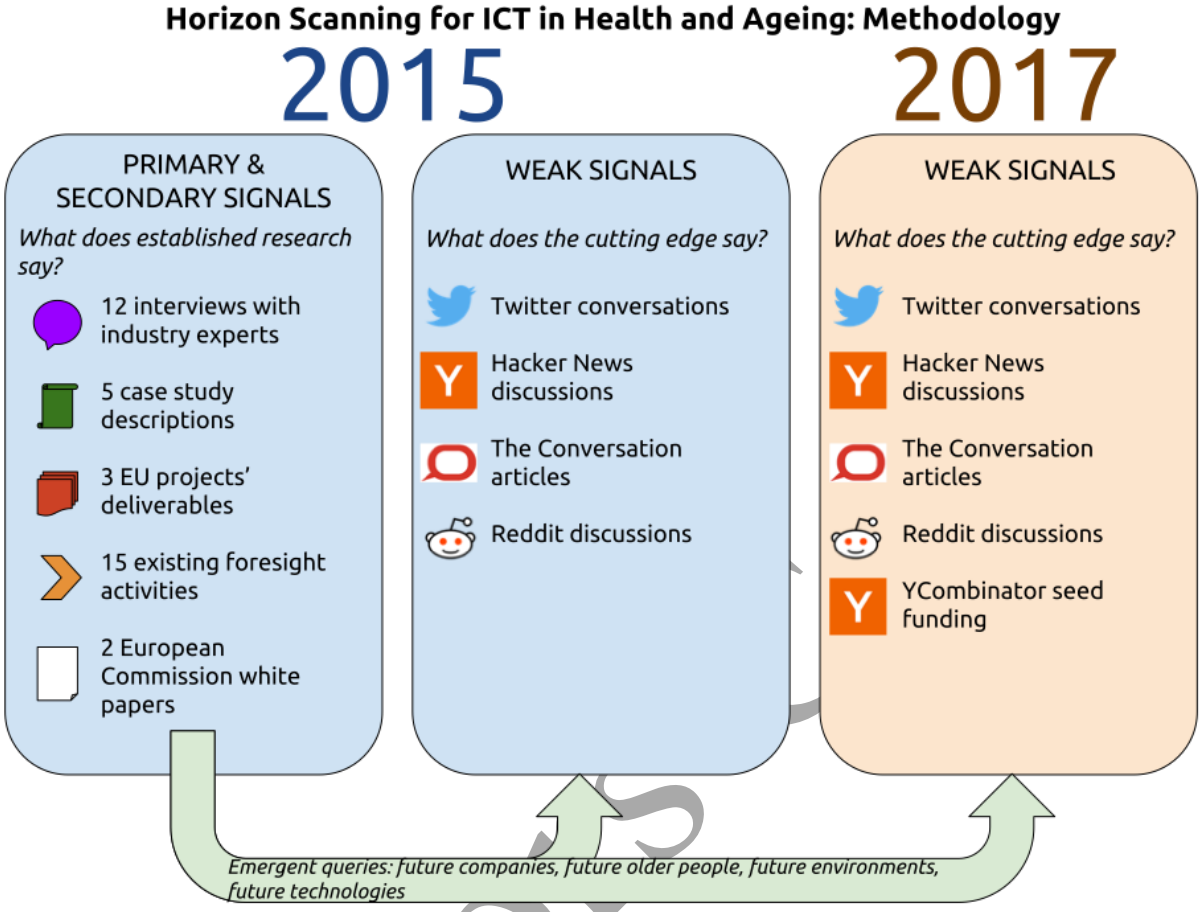

Figure 1. Method for Horizon Scanning (adapted from Amanatidou et al. (2012) and Hiltunen (2008))

The primary signals were gathered from the following sources:

- 12 interviews carried out with ICT that include experts from the health and ageing industry, namely company directors
- 5 published case studies, externally commissioned for this study (Schroeder, 2014);
- Deliverables from relevant EU- and UK-funded research projects that conceptualise and/or discuss social and ethical aspects of ICT for an ageing society (Cavallaro et al., 2014b, 2014a; Hin et al., 2014);
- Existing foresight activities in the area of ICT for an ageing society (Aceros et al., 2015; Compagna and Kohlbacher, 2015; Cuijpers and van Lente, 2015; Faulkner, 2015; Gallouj et al., 2015; Lassen et al., 2015; Loe, 2015; López Gómez, 2015; Neven, 2015; Östlund et al., 2015; Peine et al., 2015; Peine and Moors, 2015; Pritchard and Brittain, 2015; Saborowski and Kollak, 2015; Shergold et al., 2015; Suopajärvi, 2015);
- European Commission documents about ICT for health and ageing (European Union, 2015, 2009)
- Literature sources found through the Google scholar database using terms around foresight and ICT for ageing.

These sources were chosen because they cover a wide range of perspectives which include industry experts, research projects, existing, similar activities, and European policy documentation. They were then analysed using a thematic analysis approach to determine the

implicit and explicit indicators for the realisation of the narrative, with further clues identified (secondary signals) that helped us determine the likelihood of the realisation of the narrative.

The second part of the data collection was based on a more detailed understanding of the narratives, following secondary signals, policies, and any disturbances, such as changes in weak signals that may have changed the narrative (Amanatidou et al., 2012; Hiltunen, 2008).

Weak signals were identified and analysed using a critical approach, drawing from sources with a shorter updating cycle, such as social media, internet news sites, emerging technology blogs, and areas of industry start-up funding, following the recommendation by Pang (2010) and Kim et al. (2018). These sources, as shown below, further combine expert knowledge and semi-automated strategies. Specifically, we turned to the following sources:

- Twitter, a social media site;
- Hacker News, a start-up community forum;
- The Conversation, a cutting-edge news site contributed to by academics;
- Reddit, a news and social media forum; and
- Y Combinator, a highly popular seed funding investment organisation.

These were chosen because they host a large bandwidth of cutting edge/in the moment discussions around topics related to technologies in general, including ICTs for Health and Ageing. Since we were interested in future health care for ageing populations, our basic queries were chosen to investigate whether the in-depth weak signals correlated with online discussions. Namely, our search terms revolved around the disruption of future health innovations and future ageing technologies that had emerged from the primary signal analysis. Along these lines, we used semi-automated search strategies in social media and online spaces where the future is likely to be discussed, and where the results reflect expert knowledge. In more detail, our queries derived by analysis of the primary signals, which resulted in clusters of impactful future narratives, namely **future older people**, **future technologies**, **future companies**, **future environments**. For both the 2015 and 2017 data collection rounds, we used the following initial keyword searches for our queries, which are in line with the heuristic search profile proposed by Amanatidou et al. (2012):

- **Future technologies**: "future health technologies" and "future health innovation"
- **Future companies**: "future health companies" and "future technology companies"
- **Future environments**: "future health environment" and "future health spaces"
- **Future older people**: "future ageing" and "future elderly"

These queries were meant to open up the scene, and not to be restricted to the category they were devised under, as many of these are cross-cutting or complementary issues. Further searches were made using related terms that were identified by initial search term results, for example, "older people" instead of "elderly", or broadening the terms e.g., "future health". For Twitter in particular, we wrote a small Python program to assist with searching. However, due to the standard rate limits of the Twitter API, the results of our queries are a snapshot of the time in which they were requested, rather than an extensive assessment of all tweets throughout the timeline. We filtered out irrelevant results (e.g. spam) and duplicates (e.g. retweets).

Weak signals were discovered through a thematic analysis to identify emergent themes. Based on this analysis, we clustered the weak signals that emerged from the analysis of the primary signals into the categories of future technologies, future companies, future environments and future older people and assessed their significance. We then determined potential future areas of impact of the resulting clusters, and analysed them further to identify possible emerging opportunities and challenges, as well as the ethical and social issues they might raise. It is important to note that the identification of weak signals in and of itself and specifically as

deriving from internet searchers across a number of platforms, does not constitute a Horizon Scanning activity; however, when combined with the identification and analysis of primary signals and secondary signals as shown in Figure 1, it allows researchers to identify and anticipate issues that are more likely to have an impact, which is a characteristic feature of horizon scanning.

3 Results

This discussion combines the primary and weak signal analysis under the broad topics of "future technologies", "future companies", "future older people", and "future environments" to discuss what is likely to be the future of ICT for health and ageing. These are summaries of the complete findings. The results are transferred into scenarios and general possible futures, with some specifically referenced examples. These broad topics have resulted directly from the analysis of weak, primary and secondary signals, and their purpose is to be relevant and helpful for policy makers who design and implement RRI-sensitive policies in relation to ICTs for health and ageing.

The description of future technologies, companies, environments, and older people provides a narrative frame for the technological developments that our horizon scanning exercise highlighted. We constructed them in view of offering plausible accounts of the future of ICT in health and ageing. Our focus was less on the technical inventions, even though these are also mentioned, but more on the way in which they are likely to affect human lives. This approach gives an accessible account of the ICTs that we can expect to see in the future. In addition, it provides the basis for the more detailed analysis of ethical and broader social consequences that these technologies are likely to have. However, we want to clarify that the inclusion of a certain technology in this paper does not imply that we, the authors of this paper endorse these technologies. We simply give our account of the future as it emerged from our sources in the horizon scanning exercise.

3.1 Future technologies

For future technologies to be engaging and effective, they need to be motivating and useful, empowering older citizens, and serving their quest for meaning and identity. A technology needs to have a positively experienced predecessor for it to be "fascinating" to people or be brought "through life" from earlier ages (e.g. robots, televisions) so that they are established within everyday routines. Technologies that are substantially different from those that older people used in their middle-aged life are likely to be met with suspicion or anxiety. But what might these technologies look like?

Some recurring examples of how future technology might work for ageing populations is the smart house with 'welfare technology' (cameras, alarms, sensors) and automation where robots will do the chores, like cooking or cleaning. These robots will have significant AI, companionship and assistance (personal hygiene, medication dosing) abilities, as well as medical treatment functions. Technologies in these smart homes might have behavioural pattern recognition, the ability to estimate the self-care ability of their owner, as well as detect declines in health. Robots might be generic hardware platforms with "app stores", or generic entry points for a broad range of services and third-party apps.

Healthcare itself could come from these technologies, with fully-fledged "e-health" or "telecare" technologies allowing remote contact with healthcare professionals in the home. Along with fully-centralised medical records and streamlined health systems, temporary and

chronic illnesses could be better monitored and supported, leading to the optimisation of medication.

Seemingly "creepy" technologies such as blood transfusions from younger people are frequently used as a science fiction dystopian scenario to illustrate the potential impact of such technologies. One Reddit discussion on a bionic heart, for example, predicted "blood flow as a service" and "Terminator-like" post-apocalyptic worlds ("Towards a body-on-a-chip", n.d.). Organs on chips are more hopeful visions of future technologies: they could potentially reduce the clinical trial cycles by providing more reliable results and speeding up the time to market for new and potentially improved drugs. These organs-on-a-chip would be made of a synthetic material, about the size of a smartphone, and carry minute structures to which cultured human cells are attached. Under appropriate conditions, the cells arrange themselves and operate as they would in the human body ("Silicon chips that mimic the function of living human organs have won the Design of the Year award from the Design Museum in London. • r/Futurology", n.d.).

Future elderly people will also be assisted outside the home, with driverless cars, monitoring technology as a part of active and healthy ageing campaigns, and mobile applications that can easily be used by older people. Shopping requirements will be solved through home delivery by drones. Technologies such as these will allow people to have more time to enjoy life and enjoy their "elderly lifestyle" with specific lifestyle coaching, entertainment, and other supportive technologies, rather than focusing on care or disability. Ideally, this technology will be available to everyone in the world, regardless of nationality, socio-economic status, religion, ethnicity, gender, sexuality, etc., indicating at least a desire for a post-scarcity economy.

Disruptive technologies are equally likely. Cutting edge technologies (e.g., high tech spoons for people with degenerative conditions ("Google has acquired the maker of a high-tech spoon... • r/technology", 2015), and disruptive technologies (e.g., analytics, 3D printed organs (Todd, 2015)), mind control devices, exoskeletons, and nanobots ("Disruptions that will change the future of Healthcare • r/technology", 2015)) have been key areas of interest in online discussions as potentially life- and society-changing technologies. Many of these are related to advances in knowledge of the human body and its interactions with technology such as brain-computer interfaces.

The mainstream discourse was also focused on the future of robots , which also included robot hospitals that require doctors and nurses to only hold programming skills. A robot or AI-driven hospital could potentially lead to an improved "track record" as these ICTs would be operating based on strict protocols. Human-like robots might also help patients feel less overwhelmed or can help when they're unconscious or feel unsteady ("Robotic nurse lifts and carries a person • r/Automate", 2016).

Biotech, infotech, nanotech and cognitive science technologies are also considered to be likely to rapidly change society and accelerate technological processes "into something we have difficulty imagining" (Andersen and Rasmussen, 2015; Govette, 2016). Indeed, the sci-fi nature of all of these technologies and "real life tricorder" enable concerning futures, but in a different way, with commenters stating that "it would suck to die just before anti-ageing/biological immortality was invented" ("How Silicon Valley is trying to cure ageing", 2015).

Although we currently live in "smart" environments, equipped with smart meters, TVs, thermostats, health monitors etc., these are often underused, because people forget to charge, pair, or sync them. In a sense, the link between ICTs and a superior healthcare service is missing because it would be "too much of a hassle" (abrownn, 2016). Therefore, futuristic

health logging would need to be fully automatic. Some Y Combinator investments have been made in this direction, with health data companies founded in 2016 and 2017 such as PatientBank (Constine et al., 2016) and BloomAPI (Constine et al., 2017).

As is to be expected, much effort is going into predicting hype cycles, time to market and when future technologies, particularly those that can be used within the healthcare sector, will be successfully commercialised. Some 2017 commentators predict that approximately within the next 5 years, social virtual reality can be fully commercialised (Chispy, 2017), while others suggest that "[a]ging and age related diseases [will be] stopped by 2042" (Zatetics, 2017). This highlights that, depending on computing power, success with artificial intelligence etc., "anti aging could be just around the corner [and] seems more plausible" (ibid.).

3.2 Future ICT companies

Given the changes in technologies, it is expected that companies themselves are likely to change, too. As social media allows the public to discuss and interrogate companies, companies in turn may adjust their priorities to address the public's expectations, as the latter could affect shareholder return or investment potential. Future companies will likely be more heavily regulated, particularly when it comes to security ("Internet of Crappy Things | Hacker News", 2014). The impacts of technology "disasters" on company reputation are a significant concern to Hacker News readers, who are likely to be involved in or interested in start-up culture.

Companies, such as that of one of our expert interviewees, are starting to concern themselves explicitly with values, with the value of "good for humankind" being "a part of our [company's] soul and our spirit". The general shift toward social responsibility and public accountability could mean that more companies find their "souls" which will be beneficial to the users of medical technologies.

The increasing embeddedness of ICTs in business processes provides fuel for science-fiction predictions. For example, one Redditor created an entry titled "In the future, companies will advertise the fact that they have human workers" (TrouserTooter, 2017). In response to this, other commenters highlighted that some companies actually already advertise themselves as such, offering examples where humans roll up baby diapers and pack them rather than machines, and commenting that it is more about quality matters rather than business ethics. On the other hand, there are concerns that future ICTs (machines, robots etc.) may be so efficient that any human-made product would be treated as defective or of a poorer quality and that therefore, advertising the existence of humans within any organisation will not be useful for highlighting the quality of their products or services. Instead, it may be used to convey the image of human welfare or charity.

3.3 Future older people

Defining "ageing" and "the elderly" is one of the major issues when looking at future older people. Some definitions are more recognised than others. "Active ageing" focuses on capabilities, with technology enabling older people to take responsibility of their own bodies rather than treating them as patients. "Ageing in place" focuses more on treatment or monitoring to enable people to live in their homes rather than moving to care facilities. The problem with these is that people are often both actively ageing and ageing in place, and these are largely contradictory in terms of the technology provision, as it is often unable to manage the transition from in-home care to outside-of-home care. Alarms and sensors are the main technologies that are problematic, since fall detectors or activity monitors are unable to function when someone is outside of the home.

There is also a conflict between the desire for active ageing and ageing in place. People tend to assume that older people are housebound for the most part. In fact, families often prefer this

so that they know their family member is safe. This is, however, often not the case, because active older people want to exercise both mentally and physically, which often occurs outside the home. These preconceptions are enforced by definitions as well: Older people often do not consider themselves as a part of the "elderly". In their eyes, this suggests infirmity or disability, which is why they sometimes refer to "the elderly" as the others, usually with negative aspects, such as lack of technology understanding.

The result of society, technology designers and, often relatives as well, not appreciating actual abilities is that older people can be made to feel stupid, patronised, alienated, forced into using a technology they don't want to use, and they could be exploited, or technology companies wouldn't feel that important issues need addressing (e.g. consent issues). One industry expert stated "I do not think that presently the users have such clear knowledge of privacy issues [...] that they would prefer the services offered by a company that guarantees more effectively the data protection [sic]". Yet, our interviews revealed that older people seem well aware of certain security issues (pertaining to internet banking, email breaches etc.).

People that were identified as members of the ageing society have many concerns about future technologies. They can be anxious about using new technologies, especially in public places, they often need to ask questions about technologies (often repeatedly), and about their friends or others knowing that they have to use "technology for old people". Older people and their relationship with technology is often stereotyped. While this may occur with good intentions, it often leads to alienation or making older adults feel forced to use technology they do not feel comfortable with. Some assumptions relate to people's physical abilities (e.g. eyesight and motor control), but not all older people experience such issues. Other assumptions relate to ability and willingness to engage with new technologies, that technology needs to be simple so that "people with limited IT skills can understand it" (Schroeder, 2014), that older people have time to "spend hanging around in the city center and [use] novel technologies" in smart cities (Suopajärvi, 2015), and that "researchers and developers often think it is impossible to get the view of people with dementia" (Schroeder, 2014). The shame of not knowing how to use or not understanding popular technologies, or feeling incompetent to use them, is a big concern for older people. This is despite many older people having a desire to know about or understand these technologies, especially if they have had education or training in technology (e.g., engineering).

There are also concerns about technology becoming so ubiquitous that it replaces humans, or that people become dependent on the technology, with an associated fear of losing their autonomy, as companies who make the technology become more controlling. Older people are anxious about using the computer "for too long" at a time and are worried that they would become addicted to it (Suopajärvi, 2015). A significant concern is about the dehumanising nature of technology – older people don't just want to be seen as a collection of disabilities or ailments but as people with legitimate concerns and opinions about the technologies they integrate into their lives.

More specific concerns centre around the fear of mortality – where the use of technology (e.g., push-button alarms) reminds older users that they are old and likely to die soon. These powerful feelings can also be present when older users compare their abilities with younger users. Marginalisation of "the other" elderly, that cannot or don't want to engage with technology, was a concern expressed by older people who were more interested or able. Technology increasing social isolation was also a concern, especially with the "ageing in place"-types of technologies not allowing older people to go out without some alert being triggered.

3.4 Future environments

The contextualisation of technology and how it is being used within a wider saturated technological environment is extremely important. In this environment, there is a danger of letting people "slip through the cracks" as those who have been left behind technologically are often not able to participate in modern healthcare. The conflict between individualised medicine and generification of medicine will also contribute to structuring this wider healthcare environment. Against this backdrop, the requirements of national medical services and private for-profit industry can only add complexity.

Many of the technologies and outcomes mentioned above are already in place in some way. For example, smart houses are becoming increasingly networked through high-availability, affordable broadband and many internet-enabled devices. ICTs for health and ageing include ambient alarms (e.g., care and fall alarms), blood pressure measuring devices, as well as activity and glucose alarms. There are home-based touch screen devices for caretaker services, pharmacy delivery, meals and grocery orders, and others that monitor diseases or provide cognitive stimulation. There are even some rudimentary in-house care robots, such as vacuum cleaner robots, or "pet" robots.

Some technologies (e.g., software that optimises nurse visits, medical interventions for dementia care, stem cell treatment, regenerative medicine, and early diagnostics) make health care more efficient. These are sometimes primitive but show the possibilities for future technologies. Data sharing and open platforms are becoming more available, with academic research data becoming available to the public, and more publicly accessible research results. "Generic entry points" are also already available, with touch screen devices, smartphones, and other devices providing "app stores". However, many of these are not developed in line with older users' needs.

Some other aspects of the environment that will need to play a larger role in the future include the issue of mortality and the approach to data handling in such situations. Some companies are already active within this area by handling social media accounts after a user's passing. While the focus is on dealing with such data in a respectful manner, other users may also be affected. For example, it may be unnerving to come across a dead friend's social media profiles. In other end-of-life areas, developers of yesterday's legacy systems will need to address maintenance issues, even if society has moved on to new technologies.

The four sub-sections above describe future technologies, companies, older people and environments and highlight the main aspects of technical change and its results for the socio-technical environment in ICT for health and ageing. Our attempt to describe these in a way that leads to the identification of ethical and social issues is probably obvious and highlighted some of these issues. However, in the next section we focus specifically on the key social and ethical issues that emerged from the data: older people and illness, the human face of ICT, privacy and informed consent, autonomy, stereotyping and anxieties around ICTs.

4 Ethical and social issues in ICT for health and ageing

The aim of this Horizon Scanning approach was to identify technological advances in the field of ICT for health and ageing that show an increased potential to trigger social and ethical issues. Through the investigation of weak, primary and secondary signals, we identified a series of potential ICTs, which we classified under four different categories, namely: future technologies, companies, environments, and older people.

The integration of current technologies is similar to previous generations' integration of technologies (e.g. the car, telephone, or any other past society-changing technology). However, the increasing complexity of technologies requires a special interest in them. In addition, discussions about innovation motivation seemed focused on relationships and values and good leadership of companies which also relates to "future companies" discussions. Explicit concerns regarding "values" is seen as a good thing in an era where more and more technology is being embedded in everyday items (e.g., the Internet of Things), environmentally and contextually aware (ambient intelligence), and with great power to change peoples' behaviour, habits, and daily life. Yet, with such power comes great responsibility and companies will need to be aware of the impact of their technologies, however small, in a largely technically saturated environment, to avoid the risk of creating ethical and social problems along with their technologies.

This section outlines some of the significant ethical and social issues that resulted from the analysis and specifically affect ICT for health and ageing. We refrain from defining the concept of 'ethics' in this paper and use our understanding of the data to determine which aspects are described as problematic, worrying or unacceptable. We thus in practice adopt a concept of ethics that is open and pluralistic, an approach often found in empirical work on ethics and technology. It is furthermore an appropriate concept of ethics for the purpose of this paper that aims to identify a broad range of ethical concerns that can affect the development and use of technologies, independent of the cultural, religious or philosophical contexts in which they arise.

4.1 Stereotyping older people

A key concern arising from our analysis is the question of how potential users are conceptualised and treated. This can be based on biases and stereotypes which are unhelpful for understanding the actual needs of users and can perpetuate prejudices and lead to exclusion. As mentioned previously, older people voice concerns about not being seen as people, but as a set of symptoms and illnesses, thus robbing them of their dignity and personality.

One of the trends in technology development is the creation of "fictional users" to assist in developing the targeted technology. The use of "fictional users" may not accurately capture the actual users' needs and capabilities as they are constructed from, usually, a younger person's perspectives of older people, and sometimes correspond to idealised users that "exist out there". This ties into the issue of "solutions looking for problems" types of technologies that are often created based on a younger person thinking they have found a market segment for their technology (e.g. the shopping trial in (Östlund et al., 2015)). If younger developers rely on stereotypes of older users, either in these "fictional user" scenarios or other similar methods, they are likely to cause anxiety or pushback against the technology they develop.

Instead, it is important to understand that "aging adults are not a homogenous group [...] in fact [they are] the most heterogeneous when we look at the age group" (Suopajärvi, 2015). In addition, even positive descriptions ("silver surfers" etc.) can "affect the ways elderly people experience their own relationship with ICT and themselves as members of the information society" (Suopajärvi, 2015).

Another problem is the equation of age and illness. Not all older users are ill and not all younger ones are healthy. However, age does often lead to the decline of some physical and mental abilities and the older a user gets, the more likely they are to display some symptoms of disease or decay. Sometimes the technological approach to deal with these illnesses and symptoms can exacerbate others - comorbidities are rarely taken into consideration, and if they are, a particularly cautious approach might be taken, such as assuming that a person with mobility

issues is likely to be staying at home all the time. A concern this raises is that these ageing in place technologies might become the 'default' and people become prisoners in their own homes. This is particularly problematic when technologies are picked up by large healthcare systems and approved as the main assistive devices to deal with a particular health issue.

4.2 The human face of ICTs

The contextualisation of technology and future environments raised some significant questions. The main one was concerned with whether technology does a better job than its human counterpart. It is important to highlight that, given the push for technology to fill funding gaps in healthcare and reduce the burden on welfare, it is likely that financial considerations will play a larger role. Since successful technologies are likely to increase life expectancy and health in later life, there could be knock on effects such as shifts to later retirement ages and associated questions about expectations for retirement (such as who pays for it; who deserves it; etc.). Arguments about retirement could cause major shifts in society: technology needs to acknowledge and be thoughtful about its role in this sort of societal shift. At any rate, the general concerns appear to be focused around potential future overpopulation and considering people as individuals rather than numbers. Some of the more discussed ethical and social issues of future technology include the probability that there will be increased unemployment and deskilling as technology takes over human tasks, that the replacement of humans with robots could lead to de-socialised people (i.e., able to talk to robots and not to humans), and that telecare could lead to very ill people being visited only electronically and losing all social interaction. Strict protocols when working with ICTs can be obstacles in a health practitioners' profession, through causing "protocol fatigue" (Jaiprakash et al., 2016). One article asked "who do you sue if your medical treatment goes tragically wrong and no human has touched you?" (Jaiprakash et al., 2016). Other concerns about diagnosis relate to striking a balance between cost savings and patients' feelings (e.g., while being diagnosed by a robo-nurse) ("Robotic nurse Patrick joins emergency staff at RUH • r/saskatoon", 2014).

Social isolation is also likely to be a problem - with family and friends able to contact older relatives electronically, there is a likelihood that these 'easier' options might be taken instead of visiting and caring for the relative in person. This could lead to depression and loneliness in that person, especially if they are generally averse to ICTs in the first place. Retirement is an issue affecting the future elderly, with concerns about retirement ages rising. As people age, and when they retire, they increasingly rely on communities which ties into the above needs for both offline and online social networks. This can be especially seen in indigenous communities (Maguire and Wenitong, 2012). Similarly, the life cycle of technologies can significantly affect how these technologies are used by older people. In this regard, even technology that is considered "simple" may as well require extensive social and family networks for older relatives, which shows the value of these networks for assistance and also relates to the importance of a community (shahocean, 2015).

4.3 Privacy and informed consent

Our findings raised ethical concerns about the extent of monitoring, and whether having an illness detected is worth the invasion of one's privacy, especially cocnerning vulnerable people. Based on this, increasing efforts for maintaining the constant monitoring and checking technologies will be required especially regarding updates to privacy aspects and security against hacking.

In fact, any linking of health data with commercial activities (e.g. supermarket shopping) or commercial gains from medical data are considered extremely problematic within the data sets. Informed consent is a major potential disruptive aspect of future technologies. In 2015 it was

not taken particularly seriously with unregulated devices, but for future devices that integrate medical care, there could be serious issues with giving consent to providing large amounts of data that could be misinterpreted. Legislation responding to these concerns has now been enacted through the General Data Protection Regulation (GDPR) in European law.

Additionally, commercialisation remains a potential problem, whereby health profiles could be sold to the highest bidder. Legislation such as the GDPR in Europe is working to solve this problem, but many jurisdictions do not yet have similar laws. We have already seen companies such as 23andMe giving access to their data to large pharmaceutical companies (Molteni, 2018) and with increased data collection there is no reason to see that this will change any time soon.

In our analysis, concerns about privacy, profit motives and hacking were more prevalent than informed consent (Prince and Fitton, 2014) and online commenters were concerned about anonymity for Facebook's upcoming social networking support for healthcare (as opposed to Facebook's requirements for real names) ("Facebook is plotting its first steps ... • r/technology", 2015), and "how cyber security will evolve as patients slowly become stewards of their own medical data" (Govette, 2016). These observations are only more profound after the Cambridge Analytica (Cadwalladr and Graham-Harrison, 2018) and other informed consent scandals (Flick, 2016) that Facebook has recently endured. Social media healthcare support, a general reduction in expectations of privacy of healthcare data, and robots and assistive hardware, such as robots for lifting and turning patients ("RIBA", 2016), raised concerns about patients being able to self-diagnose their condition without medical training and the potential for misdiagnoses. Additionally, the outsourcing of healthcare to robots where human care may be preferable to deal with public health budgets in an increasingly ageing population. Last but not least, it should be also noted that also the young generation (so called Millenials) also care about privacy influencing their behavioral intentions (Fodor and Brem, 2015).

4.4 Autonomy

While older people are often looked down on in terms of their technological capabilities, as we outlined earlier, there are many older people who actually want to understand how the technologies in their lives work. In fact, people with a desire to understand can feel joy at being able to control technology but can also be concerned about the fast pace of technological advancements and the increasingly complicated usability, which can lead to a feeling of lack of control. The elderly of the future are likely to be quite technically minded, and, because of advances in medicine and technology, may remain engaged in enjoyable activities, mentally active, and may be part of wider online communities.

There is a potential tendency for technology to try to take over aspects of older peoples' lives by sending their data out to remote processors and decision-makers. This is potentially problematic for users of any age, as it can pre-structure how much control over their day to day lives, data, and decisions users retain. This issue is related to data protection with current data protection regimes, such as the GDPR, requiring the minimisation of data and thereby pointing to other, less centralised computing paradigms. The problem that technology reduces the user's autonomy could also be addressed in parts by a closer focus on the needs, usability, training, and decision-making for the user to ensure they retain their (feelings of) control, and thus improve the acceptability of future technologies.

4.5 Anxieties around ICTs

Many people experience anxiety when encountering new ICTs, but this may be particularly problematic for older people who grew up surrounded by non-digital technologies. Not dealing with the ethical and social issues discussed above can directly contribute to these anxieties. In

general, anxiety could be caused by a lack of understanding of how the ICTs work, degenerative illnesses that make new routines anxiety-causing, or due to the implications of the ICTs (feelings of being "old", lack of control, etc.). Specific technologies, such as robot diagnosis ("Robotic nurse Patrick joins emergency staff at RUH • r/saskatoon", 2014), could be more anxiety-inducing than others.

Furthermore, as technology becomes more ubiquitous, care workers that are replaced or partly replaced with technology are likely to protest, and this could put people off from using the technology (as could losing a trusted carer to technology). Other issues along these lines include dealing with the handling of yesterday's cutting-edge technologies, that will inevitably become tomorrow's legacy systems. A lot of maintenance will be involved but most importantly, abruptly removing technologies that people rely on can be potentially problematic if the technologies have been successfully integrated into daily life. Recalling that "today's technology is the technology of the future" for today's mid-life citizens and committing to supporting that technology will be key for future integration and use of technology in older peoples' lives.

In this section we have summarised key ethical and social concerns that our horizon scanning work has highlighted. We have described these in an active manner, as if they are about to become reality. However, we understand that the future is open. Moreover, the main purpose of our study was to identify these concerns with the purpose of addressing them proactively and avoiding or overcoming them whenever possible. The next section therefore discusses how these issues can be addressed and develops recommendations on how to realise opportunities in an acceptable manner.

5 Implications and Conclusion

Many people believe that technologies will solve many problems that are associated with ageing. It appears likely that citizens of industrialised countries will be living longer and healthier lives in the future, even though it is important to realise that this is not an immutable law and there are indications of a reversal of the trend towards longer lives (Pike, 2019).

There is, furthermore an expectation that current technologies will continue being large parts of the future landscape of ICT for health and ageing, as these technologies are the ones that current middle-aged people are generally comfortable with. It is thus probably safe to say that digital technologies will expand further and play an important role in the lives of all humans, including those who are considered older.

Our findings suggest that there are significant ethical and social issues that innovators in the ICT for health and ageing sector will need to consider. A key question arising from this is how these can be addressed. There are many different answers one can give to this. Technology ethics (Vallor, 2016), science and technology studies (Hackett et al., 2007), technology assessment (Grunwald, 2018) and, more recently, RRI (Owen et al., 2012; von Schomberg, 2013; EPSRC, 2015) are streams of research and practice that were developed to proactively engage with ethical and social questions in emerging technologies. In line with our pluralistic interpretation of the concept of ethics, we will not endorse a particular approach to dealing with these ethical issues, but highlight them and suggest some possible mitigation strategies, which we believe to be compatible with all of the listed approaches.

The previous section has highlighted concerns about the stereotyping of older users, the human face of ICT, privacy and informed consent, autonomy and anxiety around ICT as headline issues that appear to be particularly prevalent in ICT for health and ageing. One important

general implication to be drawn from this is that concepts and definitions are of high importance. Our findings suggest that definitions need to be contextualised (what ageing is in the context of a particular technology) and need to account for issues like the increased acceptance of technologies in laboratory settings, the need for "real life" settings, and the need for definitions that are co-created with stakeholders. These definitions can be positive or negative, focusing on the capacities or deficiencies of older people. Questions about what "normal" or "good ageing" is, could be useful to determine the contexts in which the technology is developed (even though this is unlikely to be answered, asking such questions can help with reflecting on the design of technology).

Misleading labels and stereotypes can constitute an ethical issue in their own right, as people feel misrepresented or excluded. They can also be seen as impediments to the adoption of technology. Focusing specifically on future ageing technologies, Suopajärvi (2015) argues that even if older users improve their skills, they feel as though they could never be as competent as younger people. These feelings of "being old" and "not being as good as they used to be" can be powerful motivators to avoid the use of technology. Furthermore, some older people are just not interested in technology, which can cause conflict if it is inflicted upon them. Such forced technologies can lead to the deliberate non-use of a technological device, although non-use may also be related to forgetfulness, and therefore attributed to other issues, such as dementia or infirmity.

Individual innovators, researchers, technologists or designers would benefit from an understanding of these ethical and social concerns. Such an awareness would focus on person-centred design vs. designing on the basis of scientific knowledge about ageing processes which could help to mitigate some of these issues. Innovators would benefit from involving older users and creating open communication channels with them. This would help to avoid stereotyping users, especially with regards to their capabilities, such as generalisations concerning their cognitive ability. Direct engagement will also support designers in recognising the users' strong will to remain mobile and independent – understanding previous negative and positive experiences with technology is essential.

It is also important that innovators recognise the relationship between users' online and offline interactions and determine whether design could reinforce offline social relations. This highlights that innovators need to appreciate the differences between lab and real-life settings before they start developing technology by understanding the user (not just their carers or physicians) and what role their device serves in the user's life. Designers also need to recognize that the awareness of being monitored alters behaviour (often negatively) and that users often wish to please designers. This could be mitigated through ongoing evaluation, which should be integrated into testing procedures. Another mitigation strategy would entail being flexible with timelines so as to allow users to give useful feedback, after having sufficiently evaluated the technology. Additionally, designers should not impose a technology on users that is not working, and refrain from persuading or manipulating them through peer/family influence, as this would go against the perspective of informed consent and individual autonomy.

Along these lines, companies will need to determine whether their products are lifestyle or care devices, as these may affect the terminology used and the context of use. Similarly, it is imperative that they decide early on whether their focus should be on personalisation (i.e., ICTs tailored to one's needs) or generification (i.e., ICTs designed to fit more situations and to be more ubiquitous). Each approach has advantages and disadvantages that can often be contradictory, further impeding the development of technology that performs well across both fields.

Future technologies need to help to overcome potential ICT-related anxieties that might be experienced by older people when learning to use them. For this purpose, they should capture the minimum necessary information to solely improve a user's care, rather than profile building. Companies should discuss the impact of monitoring with users; assessing whether proactive monitoring involving feedback and interventions for developing health conditions are useful or necessary. Users should be given control over their devices, allowing them to turn them on and off, or to temporarily disable monitoring.

This requires companies to provide an environment in which attention to ethical and social issues is valued. For example, staff need to be trained properly and supported. In this respect, by committing to engage with the system responsibly, companies can incorporate good practices, self-assessment tools, and corporate social responsibility into their everyday practice. In addition, by innovating responsibly, they can exchange best practices with other companies for overall better business approaches.

Important concerns in these technologies include those of privacy and the use and potential abuse of health data. Future ageing environments may require a more fundamental, top-down approach, involving policy makers, governments and other high-level stakeholders in order to create spaces where the ageing population can experience active and healthy ageing. Policymakers are in a position to emphasise ethical and social concerns of emerging technologies and develop incentives to address these. The current discussion of the ethics of AI, for example, shows that sensitivity to these issues exists and that policymakers can explore creative ways to address these. Some of the AI debate will be relevant for the topic of ICT for older people. But additional attention can be paid to the issues identified earlier. This could be done through a range of policy options, ranging from regulation and legislation (e.g. the GDPR) to standardisation and softer instruments like industry commitments or codes of ethics.

In conclusion, the role that technology will play in the lives of older people in the future is largely aspirational. It is in this area where sensitivity to ethical and social issues can help to prevent failure or poor reception of such technologies, which, while coming from a distinct desire to help, can fall into the traps of stereotyping, discriminating, and widening digital divides instead of helping to solve the real problems that older people have.

This paper's academic contribution lies in the application of a rigorous future study method to approach the pressing social question of the future of ICT for health and ageing. It provides a sound account of expected technical development and, based on this, describes likely ethical and social issues. It thus goes beyond the frequent focus on either technologies or social issues and shows how these can be thought of in conjunction. This is scientifically of interest to the academic communities of foresight scholars as well as the technical research communities engaged in ICT for health and ageing. We believe that the contribution of the paper goes beyond these academic target audiences and covers other stakeholders, notably industry, policy and users. We have developed suggestions to move beyond the purely descriptive part of the paper and find ways of integrating stakeholder positions into technology development.

Overall, our work has shown that there are significant areas in the ways that we understand ageing, technology's relationships with ageing, and the actual ageing population that need to be dealt with before we are able to truly attempt to use technology to identify and solve these problems.

There are some limitations in the interpretation of our results. First, the geographical space is restricted largely within the European and North American populations because we concentrated on the English-speaking world in terms of weak signals as stemming from our search across social media and academic papers. Second, existing research investigates ageing

and older adults through concrete groups, typically age-related subgroups, classifying the elderly as pre-seniors, young-old, and old-old (e.g., Lee, Chen and Hewitt, 2011); however, we considered that using such classification and limiting our work specifically around age groups could potentially restrict our queries because looking for discussions about potential futures could cross into other demographics as well, which is confirmed by our findings. Third, our Horizon Scanning approach should not be seen as a means to predict potential issues; instead, it helps us solely to identify impact-rich areas that could require particular attention. Further, this activity is not a 'big data' analysis project, as findings need to be contextualised in order to be understood. Instead, it reinforces the need to understand the identifiers of emergent issues and debates surrounding them, "taking into account the interests, emotions and attitudes of different stakeholders as well as experts" (Amanatidou et al., 2012, p. 219). Last but not least, we encourage future researchers to use also longitudinal data for further insights.

REFERENCES

abrownn, 2016. The Future of Health Data Logging • r/Futurology [WWW Document]. reddit. URL https://www.reddit.com/r/Futurology/comments/55azej/the_future_of_health_data_logging/ (accessed 8.3.17).

Aceros, J.C., Pols, J., Domènech, M., 2015. Where is grandma? Home telecare, good aging and the domestication of later life. Technol. Forecast. Soc. Change 93, 102–111. https://doi.org/10.1016/j.techfore.2014.01.016

Amanatidou, E., Butter, M., Carabias, V., Konnola, T., Leis, M., Saritas, O., Schaper-Rinkel, P., van Rij, V., 2012. On concepts and methods in horizon scanning: Lessons from initiating policy dialogues on emerging issues. Sci. Public Policy 39, 208–221. https://doi.org/10.1093/scipol/scs017

Andersen, L.R., Rasmussen, S., 2015. Tomorrow's technology will lead to sweeping changes in society – it must, for all our sakes [WWW Document]. The Conversation. URL http://theconversation.com/tomorrows-technology-will-lead-to-sweeping-changes-in-society-it-must-for-all-our-sakes-36023 (accessed 8.3.17).

Ballegaard, S.A., Hansen, T.R., Kyng, M., 2008. Healthcare in everyday life: designing healthcare services for daily life, in: CHI '08 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM Press, pp. 1807–1816. https://doi.org/10.1145/1357054.1357336

Bell, F., Fletcher, G., Greenhill, A., Griffiths, M., McLean, R., 2013. Science fiction prototypes: Visionary technology narratives between futures. Futures 50, 5–14. https://doi.org/10.1016/j.futures.2013.04.004

Betz, U. A., Betz, F., Kim, R., Monks, B., & Phillips, F. (2019). Surveying the future of science, technology and business–A 35 year perspective. Technological Forecasting and Social Change, 144, 137-147.

Bootz, J. P., Durance, P., & Monti, R. (2019). Foresight and knowledge management. New developments in theory and practice. Technological Forecasting and Social Change, 140, 80-83.

Cadwalladr, C., Graham-Harrison, E., 2018. Revealed: 50 million Facebook profiles harvested for Cambridge Analytica in major data breach. The Guardian.

Cavallaro, F., Obach, M., Schroeder, D., Chennells, R., Snyders, L., Steenkamp, A., Bierwirth, A., Kumar, A., 2014a. PROGRESS D4.2: RRI and End Users.

Cavallaro, F., Schroeder, D., Bing, H., 2014b. PROGRESS D4.1: RRI - Best Practice in Industry.

Chatfield, K., Iatridis, K., Stahl, B., Paspallis, N., 2017. Innovating Responsibly in ICT for Ageing: Drivers, Obstacles and Implementation. Sustainability 9, 971. https://doi.org/10.3390/su9060971

Chispy, 2017. I believe we're going to see some very big technologically mediated cultural shifts within the next 5 years. TMBR! • r/TMBR [WWW Document]. reddit. URL https://www.reddit.com/r/TMBR/comments/5ojlsk/i_believe_were_going_to_see_some_very_big/ (accessed 8.3.17).

Compagna, D., Kohlbacher, F., 2015. The limits of participatory technology development: The case of service robots in care facilities for older people. Technol. Forecast. Soc. Change 93, 19–31. https://doi.org/10.1016/j.techfore.2014.07.012

Constine, J., Lawler, R., Buhr, S., 2017. The 52 startups that launched at Y Combinator W17 Demo Day 1. TechCrunch.

Constine, J., Mannes, J., Lynley, M., 2016. The 48 startups that launched at Y Combinator S16 Demo Day 2. TechCrunch.

Cuijpers, Y., van Lente, H., 2015. Early diagnostics and Alzheimer's disease: Beyond 'cure' and 'care.' Technol. Forecast. Soc. Change 93, 54–67. https://doi.org/10.1016/j.techfore.2014.03.006

Disruptions that will change the future of Healthcare • r/technology [WWW Document], 2015. . reddit. URL https://www.reddit.com/r/technology/comments/2qgpqe/disruptions_that_will_change_the_future_of/ (accessed 8.3.17).

EPSRC, 2015. Anticipate, reflect, engage and act (AREA) - EPSRC website [WWW Document]. URL https://www.epsrc.ac.uk/research/framework/area/ (accessed 10.19.2017).

European Union, 2015. Eurobarometer Qualitative Study: Public Opinion on Future Innovations, Science and Technology.

European Union, 2009. Lund Declaration.

Facebook is plotting its first steps into the field of healthcare. According to resources, the company is exploring creating online "support communities" that would connect Facebook users suffering from various ailments. • r/technology [WWW Document], 2015. . reddit. URL https://www.reddit.com/r/technology/comments/2i61w8/facebook_is_plotting_its_first_steps_into_the/ (accessed 8.3.17).

Faulkner, A., 2015. Usership of regenerative therapies: Age, ageing and anti-ageing in the global science and technology of knee cartilage repair. Technol. Forecast. Soc. Change 93, 44–53. https://doi.org/10.1016/j.techfore.2014.02.020

Flick, C., 2016. Informed consent and the Facebook emotional manipulation study. Res. Ethics 12, 14–28. https://doi.org/10.1177/1747016115599568

Fodor, M., & Brem, A. (2015). Do privacy concerns matter for Millennials? Results from an empirical analysis of Location-Based Services adoption in Germany. Computers in Human Behavior, 53, 344-353.

Gallouj, F., Weber, K.M., Stare, M., Rubalcaba, L., 2015. The futures of the service economy in Europe: A foresight analysis. Technol. Forecast. Soc. Change 94, 80–96. https://doi.org/10.1016/j.techfore.2014.06.009

Google has acquired the maker of a high-tech spoon that helps people suffering from neurodegenerative tremors to eat, the Internet company's latest foray into the healthcare and biotechnology market. • r/technology [WWW Document], 2015. . reddit. URL https://www.reddit.com/r/technology/comments/2g1ode/google_has_acquired_the_maker_of_a_hightech_spoon/ (accessed 8.3.17).

Govette, J., 2016. 15 Amazing Healthcare Technology Innovations in 2016 | referralMD. Patient Access Ref. Manag. E-Consult Softw. - ReferraMD.

Grunwald, A., 2018. Technology Assessment in Practice and Theory, 1 edition. ed. Routledge, Abingdon, Oxon ; New York, NY.

Habegger, B. (2010). Strategic foresight in public policy: Reviewing the experiences of the UK, Singapore, and the Netherlands. Futures, 42(1), 49-58.

Hackett, E.J., Amsterdamska, O., Lynch, M., Wajcman, J., 2007. The Handbook of Science and Technology Studies, 3Rev Ed edition. ed. MIT Press, Cambridge, Mass.

Hiltunen, E., 2008. Good Sources of Weak Signals: A Global Study of Where Futurists Look For Weak Signals. J. Futur. Stud. 12, 21–44.

Hin, G., Daigney, M., Haudebault, D., Raskin, K., Bouché, Y., Pavie, X., Carthy, D., 2014. Introduction to Responsible Innovation Criteria: a guide to entrepreneurs and innovation support organisations. KARIM Project, Paris, France.

Hines, P., Yu, L. H., Guy, R. H., Brand, A., & Papaluca-Amati, M. (2019). Scanning the horizon: a systematic literature review of methodologies. BMJ open, 9(5), e026764.

How Silicon Valley is trying to cure ageing: Death has always been considered one of life's only real certainties, but now some of the world's top scientists are challenging the assumption • r/technology [WWW Document], 2015. . reddit. URL https://www.reddit.com/r/technology/comments/2vx0tz/how_silicon_valley_is_trying_to_cure_ageing_death/ (accessed 8.3.17).

Hussain, A., Wenbi, R., da Silva, A.L., Nadher, M., Mudhish, M., 2015. Health and emergency-care platform for the elderly and disabled people in the Smart City. J. Syst. Softw. 110, 253–263. https://doi.org/10.1016/j.jss.2015.08.041

Internet of Crappy Things | Hacker News [WWW Document], 2014. URL https://news.ycombinator.com/item?id=9088549 (accessed 8.3.17).

Jaiprakash, A., Roberts, J., Crawford, R., 2016. Robots in health care could lead to a doctorless hospital [WWW Document]. The Conversation. URL http://theconversation.com/robots-in-health-care-could-lead-to-a-doctorless-hospital-54316 (accessed 8.3.17).

Kim, H., Ahn, S.-J., Jung, W.-S., 2018. Horizon scanning in policy research database with a probabilistic topic model. Technol. Forecast. Soc. Change. https://doi.org/10.1016/j.techfore.2018.02.007

Kolominsky-Rabas, P.L., Djanatliev, A., Wahlster, P., Gantner-Bär, M., Hofmann, B., German, R., Sedlmayr, M., Reinhardt, E., Schüttler, J., Kriza, C., 2015. Technology foresight for medical device development through hybrid simulation: The ProHTA Project. Technol. Forecast. Soc. Change 97, 105–114. https://doi.org/10.1016/j.techfore.2013.12.005

Lassen, A.J., Bønnelycke, J., Otto, L., 2015. Innovating for 'active ageing' in a public–private innovation partnership: Creating doable problems and alignment. Technol. Forecast. Soc. Change 93, 10–18. https://doi.org/10.1016/j.techfore.2014.01.006

Lee, B., Chen, Y., & Hewitt, L. (2011). Age differences in constraints encountered by seniors in their use of computers and the internet. Computers in Human Behavior, 27(3), 1231-1237.

Loe, M., 2015. Comfort and medical ambivalence in old age. Technol. Forecast. Soc. Change 93, 141–146. https://doi.org/10.1016/j.techfore.2014.04.013

López Gómez, D., 2015. Little arrangements that matter. Rethinking autonomy-enabling innovations for later life. Technol. Forecast. Soc. Change 93, 91–101. https://doi.org/10.1016/j.techfore.2014.02.015

Maguire, G., Wenitong, M., 2012. Indigenous ageing: walking backwards into the future [WWW Document]. The Conversation. URL http://theconversation.com/indigenous-ageing-walking-backwards-into-the-future-7355 (accessed 11.24.17).

Martinuzzi, A., Blok, V., Brem, A., Stahl, B., & Schönherr, N. (2018). Responsible research and innovation in industry—challenges, insights and perspectives.

Molteni, M., 2018. 23andMe's Pharma Deals Have Been the Plan All Along. Wired.

Neven, L., 2015. By any means? Questioning the link between gerontechnological innovation and older people's wish to live at home. Technol. Forecast. Soc. Change 93, 32–43. https://doi.org/10.1016/j.techfore.2014.04.016

Nordhaus, W.D., 2015. Are we approaching an economic singularity? Information technology and the future of economic growth (WORKING PAPER 21547). National Bureau of Economic Research.

Östlund, B., Olander, E., Jonsson, O., Frennert, S., 2015. STS-inspired design to meet the challenges of modern aging. Welfare technology as a tool to promote user driven innovations or another way to keep older users hostage? Technol. Forecast. Soc. Change 93, 82–90. https://doi.org/10.1016/j.techfore.2014.04.012

Owen, R., Macnaghten, P., Stilgoe, J., 2012. Responsible research and innovation: From science in society to science for society, with society. Sci. Public Policy 39, 751–760. https://doi.org/10.1093/scipol/scs093

Peine, A., Faulkner, A., Jæger, B., Moors, E., 2015. Science, technology and the 'grand challenge' of ageing—Understanding the socio-material constitution of later life. Technol. Forecast. Soc. Change 93, 1–9. https://doi.org/10.1016/j.techfore.2014.11.010

Peine, A., Moors, E.H.M., 2015. Valuing health technology – habilitating and prosthetic strategies in personal health systems. Technol. Forecast. Soc. Change 93, 68–81. https://doi.org/10.1016/j.techfore.2014.08.019

Pike, H., 2019. Life expectancy in England and Wales has fallen by six months. BMJ 364, l1123. https://doi.org/10.1136/bmj.l1123

Prince, D., Fitton, O., 2014. Why Apple is pitching for the health market [WWW Document]. The Conversation. URL http://theconversation.com/why-apple-is-pitching-for-the-health-market-27781 (accessed 8.3.17).

Pritchard, G.W., Brittain, K., 2015. Alarm pendants and the technological shaping of older people's care. Technol. Forecast. Soc. Change 93, 124–132. https://doi.org/10.1016/j.techfore.2014.07.009

Responsible Industry [WWW Document], 2017. . Responsible Ind. URL http://www.responsible-industry.eu (accessed 6.22.17).

Rhisiart, M., Störmer, E., Daheim, C., 2017. From foresight to impact? The 2030 Future of Work scenarios. Technol. Forecast. Soc. Change 124, 203–213. https://doi.org/10.1016/j.techfore.2016.11.020

RIBA Official Page RIKEN-TRI Collaboration Center for Human-Interactive Robot Research (RTC) [WWW Document], 2016. URL http://rtc.nagoya.riken.jp/RIBA/index-e.html (accessed 8.3.17).

Robotic nurse lifts and carries a person • r/Automate [WWW Document], 2016. . reddit. URL https://www.reddit.com/r/Automate/comments/3h5mkv/robotic_nurse_lifts_and_carries_a_person/ (accessed 8.3.17).

Robotic nurse Patrick joins emergency staff at RUH • r/saskatoon [WWW Document], 2014. . reddit. URL https://www.reddit.com/r/saskatoon/comments/24v3vn/robotic_nurse_patrick_joins_emergency_staff_at_ruh/ (accessed 8.3.17).

Rossel, P., 2011. Beyond the obvious: Examining ways of consolidating early detection schemes. Technol. Forecast. Soc. Change 78, 375–385. https://doi.org/10.1016/j.techfore.2010.06.016

Rowe, E., Wright, G., Derbyshire, J., 2017. Enhancing horizon scanning by utilizing pre-developed scenarios: Analysis of current practice and specification of a process improvement to aid the identification of important 'weak signals.' Technol. Forecast. Soc. Change 125, 224–235. https://doi.org/10.1016/j.techfore.2017.08.001

Saborowski, M., Kollak, I., 2015. "How do you care for technology?" – Care professionals' experiences with assistive technology in care of the elderly. Technol. Forecast. Soc. Change 93, 133–140. https://doi.org/10.1016/j.techfore.2014.05.006

Schroeder, D., 2014. Responsible-Industry D1.2: Case Study Descriptions.

Schultz, W.L., 2006. The cultural contradictions of managing change: using horizon scanning in an evidence-based policy context. Foresight 8, 3–12. https://doi.org/10.1108/14636680610681996

shahocean, 2015. At 90, She's Designing Tech for Aging Boomers [WWW Document]. Hacker News. URL https://news.ycombinator.com/item?id=8996318 (accessed 12.1.17).

Shergold, I., Lyons, G., Hubers, C., 2015. Future mobility in an ageing society – Where are we heading? J. Transp. Health 2, 86–94. https://doi.org/10.1016/j.jth.2014.10.005

Silicon chips that mimic the function of living human organs have won the Design of the Year award from the Design Museum in London. • r/Futurology [WWW Document], n.d. . reddit. URL https://www.reddit.com/r/Futurology/comments/3axhda/silicon_chips_that_mimic_the_function_of_living/ (accessed 8.3.17).

Suopajärvi, T., 2015. Past experiences, current practices and future design. Technol. Forecast. Soc. Change 93, 112–123. https://doi.org/10.1016/j.techfore.2014.04.006

Stahl, B., Obach, M., Yaghmaei, E., Ikonen, V., Chatfield, K., & Brem, A. (2017). The Responsible Research and Innovation (RRI) maturity model: Linking theory and practice. Sustainability, 9(6), 1036.

Timmermans, J., Yaghmaei, E., Stahl, B. C., & Brem, A. (2017). Research and innovation processes revisited–networked responsibility in industry. Sustainability Accounting, Management and Policy Journal, 8(3), 307-334.

Todd, I., 2015. It's not just hype – 3D printing is the bridge to the future [WWW Document]. The Conversation. URL http://theconversation.com/its-not-just-hype-3d-printing-is-the-bridge-to-the-future-43493 (accessed 8.3.17).

Towards a body-on-a-chip: The first organ chips are coming to market and will speed up drug testing and reduce the use of laboratory animals. • r/Futurology [WWW Document], n.d. . reddit. URL https://www.reddit.com/r/Futurology/comments/39kdtr/towards_a_bodyonachipthe_first_organ_chips_are/ (accessed 8.3.17).

TrouserTooter, 2017. In the future, companies will advertise the fact that they have human workers. • r/Showerthoughts [WWW Document]. reddit. URL https://www.reddit.com/r/Showerthoughts/comments/5t55hk/in_the_future_companies_will_advertise_the_fact/ (accessed 8.4.17).

Vallor, S., 2016. Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting. Oxford University Press.

von Schomberg, R., 2013. A Vision of Responsible Research and Innovation, in: Owen, R., Bessant, J., Heintz, M. (Eds.), Responsible Innovation. John Wiley & Sons, Ltd, Chichester, UK, pp. 51–74. https://doi.org/10.1002/9781118551424.ch3

Wolf, M., 2014. Here's Why Elder Care May Be The Next Billion Dollar Technology Opportunity [WWW Document]. Forbes. URL

https://www.forbes.com/sites/michaelwolf/2014/04/24/heres-why-elder-care-may-be-the-next-billion-dollar-technology-opportunity/ (accessed 8.15.18).

Wyatt, S. M. (2003). Non-users also matter: The construction of users and non-users of the Internet, in Now users matter: The co-construction of users and technology, Ed. Oudshoorn, N., Pinch, T. MIT Press: 67-79.

Zatetics, 2017. 5, 10, 25, 50 and 100 year predictions • r/Futurology [WWW Document]. reddit. URL https://www.reddit.com/r/Futurology/comments/5leqt9/5_10_25_50_and_100_year_predictions/ (accessed 8.3.17).