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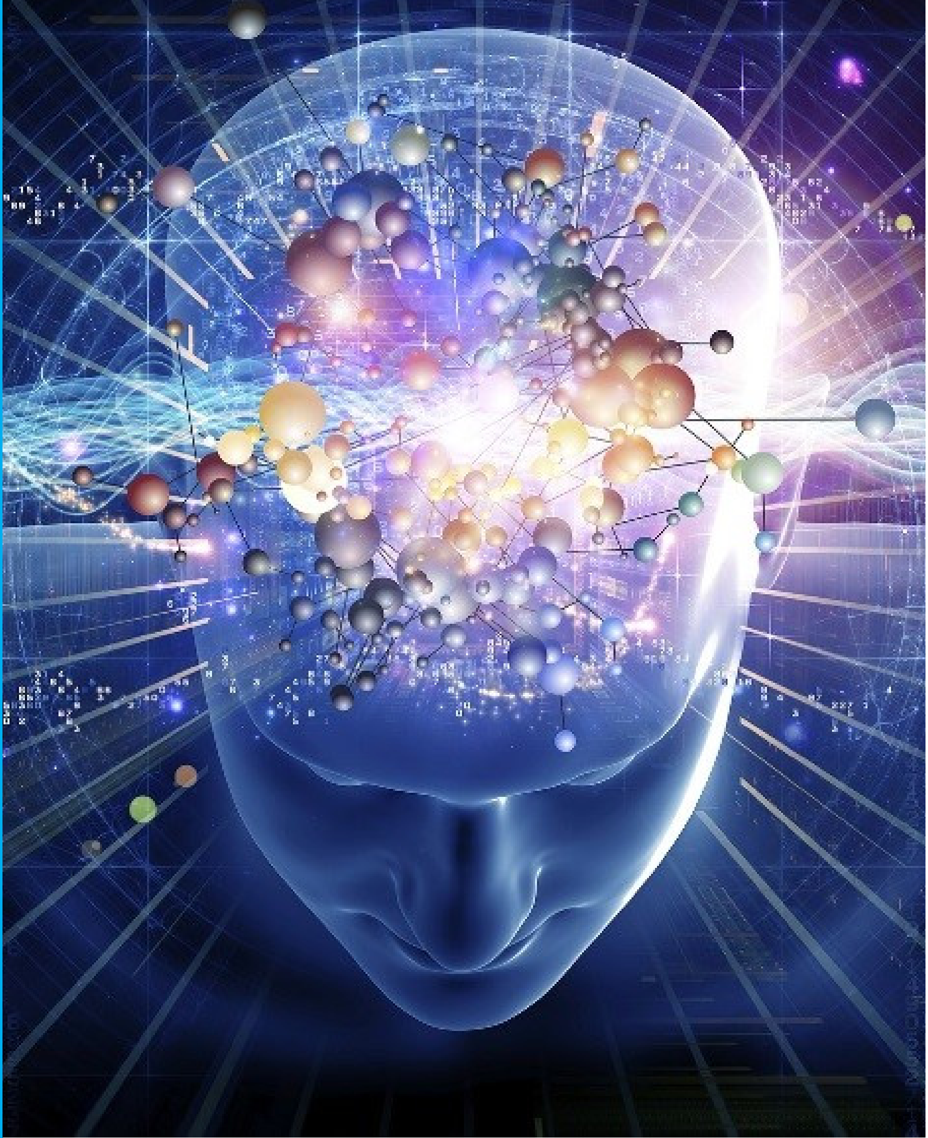

Strategic Research Agenda (SRA) on “Finnish Innovation Hub for Artificial Intelligence for Health (AI for Health)”

Ilkka Korhonen | Miikka Ermes | Jari Ahola

VTT

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1. Executive Summary

Industrial and emerging economies are undergoing major demographic and socio-economic changes that challenge the current healthcare system. Ageing society and unhealthy lifestyles cause increasing prevalence of chronic diseases, which contribute to over 75% of overall health care costs. Consumerism and the need to transform citizens into active co-producers of care are imminent. Personalised medicine progresses and allows for better matching of patients and therapeutics to improve care outcomes. There is an urgent need to find solutions that improve the value of each euro spent on health and social care.

Artificial Intelligence (AI) is intelligence exhibited by machines. Progress in AI has been estimated to lead to similar changes in economics as those that were created by machine automation in the manufacturing industry. It is estimated that 25-40% of the current human work will diminish or transform within the next 15 years due to AI and service automation. AI will significantly boost productivity in information-intensive industries, such as health and social care.

The effective utilisation of AI relies on the availability of data. Finnish health data registries and digital health data form a major national asset in AI for health. The strengths of the registries include their coverage, quality, longitudinity, and ability to connect data from different registries on an individual level. Finland already has a strong innovation ecosystem in health and wellness technologies and in information technology as well as good fellowship between different stakeholders. Competences are significant, but somewhat scattered. There are strong spearheads both in computational sciences and health and medical research in Finland. Export of healthtech, related services, software and nonregulated health and wellness goods is currently approximately 4B€. With the right investments, this could be doubled by 2025. AI is one key technology to boost in this progress.

AI for Health SRA aims towards the vision of making Finland a globally recognised leading health and wellness innovation hub "*Cape Health*", known for its research, development and real-life implementations of AI-based and data-driven health and wellness solutions, which improve citizens' health and boost productivity in health and social care. Cape Health continuously produces global success stories and breakthroughs in data-driven health products and services as well as new scientific discoveries. Citizens benefit from this through improved health and wellbeing, efficient and timely preventive, participatory, personal and personalised health and wellness services, and through increased economic growth. Cape Health activities improve health and wellness service productivity and health outcomes, increase exports of health and wellness technology goods and services, and generate new jobs for both technology companies and the health and wellness service industry.

The scoping work identified 6 priority research areas where the most benefits are foreseen with the use of AI for health and wellness: 1) Personalised care, 2): Automated health data analytics, 3) Continuous citizen-centric care, 4) Health and social care process development, 5) Service automation in health and social care, and 6) Informed society public health decisions. Priority research areas 1-3 leverage Finnish health data repositories and technology competences, have strong support within existing Finnish industrial players, and significant commercial potential globally in the event of successful development and validation. Priority areas #4-6 address areas with significant health and social care spending and focus on applications of AI for improving health and social care and wellness service productivity; hence their impact on health care costs may be very significant. In addition, activities related to key enablers for using AI for health should be promoted. These include the development of concepts and tools for security and the privacy-preserving solutions that are required to meet the regulatory and legal demands to manage the ownership, privacy and security of the patient data while using machine learning and AI solutions. These solutions may have significant global market potential and may play a key role while rolling out solutions to health and social care's real-life implementations.

To succeed in making R&D and business breakthroughs, the SRA action portfolio should: 1) establish strategic public-private partnerships (PPP); 2) focus R&D to leverage existing strengths; 3) secure access to Key Assets, especially data; 4) keep workplans agile with a focus on well defined objectives; 5) invest in continuity of R&D, from research to development and deployment, including commercialisation; and 6) ensure scaling and adaptation to market, from local to global, both from business, regulatory and commercial viewpoints.

2. Introduction

In 2016, the report "Way Forward - The Future Healthcare Innovation Environment of Finland", (by Ernst & Young for Team Finland Health Growth Program) identified key Finnish health sector assets and suggested a To-Be picture for the Finnish health sector with a roadmap of recommendations for the further development of the Finnish health sector ecosystem in order for Finland to become a globally recognised health care innovation hub. Issues to address (see Figure 1) included the need for close strategic collaboration between industry and academia, the need for solutions enabling monitoring and analysis of individual behavioral and health data to understand a condition, make early diagnoses and influence behaviour to take preventive action, and the need for solutions capable of measuring health outcomes. In February 2017, Tekes initiated a coordination and collaboration action to define a Strategic Research Agenda (SRA) to promote research, development and exploitation of Artificial Intelligence (AI) and the use of digital health data and big data in health and wellness research and business, and health and social care delivery ("AI for Health"). The SRA preparation was launched to propose actions to further analyse these needs and opportunities, and propose actions in the area of AI for health.

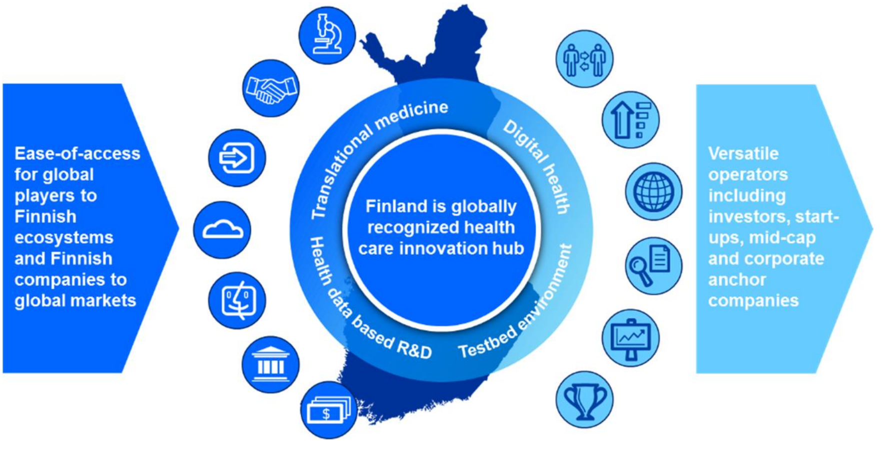

Figure 1. Vision of the Finnish health care innovation hub, with key elements and required actions as proposed by "Way Forward - The Future Healthcare Innovation Environment of Finland" report by Ernst & Young, 2016.

AI is currently a rapidly progressing topic which is forecast to significantly shape our economics, products and services, improving productivity and transforming jobs[1]. Health care, public services, and wellness and sports technologies are identified among the most potent application areas for AI in Finland[2]. Hence, it is natural to expect that AI will also play a significant role when targeting the vision of the Way Forward report.

The SRA work was coordinated by VTT and carried out in close collaboration with Finnish health technology and research ecosystem, i.e., academia, industry and care providers, with several contributors. A series of open workshops was organised in Oulu, Jyväskylä, Tampere, Turku and Espoo from 20-24.3.2017 to gather feedback on the needs, key challenges, and focus areas for the SRA. In total, 121 participants (36 from industry, 63 from academia, and 22 from other organisations, e.g., health providers, funders, etc) attended these workshops. After that, the SRA proposal was authored by VTT with key contributors (see Authors and Contributors on title page).

This document describes the key drivers, opportunities and challenges in the application of AI for health and wellness, and proposes an SRA, which aims to achieve a leap forward in the application and exploitation of AI for health and wellness in Finland, to promote research and development, and especially to generate global success stories for new products and services developed by the Finnish "AI for health" ecosystem.

The document is organised as follows. Chapter 3 presents the SRA vision in a nutshell. Chapter 4 briefly summarises the the global needs for transformation of health care. Chapter 5 briefly presents the state-of-the-art in AI. Chapter 6 presents the unique aspects of the Finnish ecosystem - health and social care system, health and AI research, and industry - and its unique strengths and characteristics, including essential data assets. Central legal, privacy, security, regulatory and ethical considerations are also discussed. Finally, Chapter 7 brings together the previous chapters and the outcomes of the scoping work (including the workshops) and proposes the SRA in terms of key breakthrough targets and KPIs, key enablers, research themes, and recommendations for action.

This study has been done under the guidance of the Tekes steering group (Auli Pere and Esa Panula-Ontto) and in collaboration with a large group of contributors: Saara Hassinen (FiHTA), Pekka Kahri

[1] Tuottoa ja tuottavuutta Suomeen tekoälyllä. VTT Policy Brief 1/2017.
[2] ibid

(THL), Reijo Kangas (University of Oulu), Michael Kearney (IBM Research), Olavi Kilkku (Orion Pharma), Juha Kinnunen (KSSHP), Jani Kivioja (Nokia Technologies), Timo Latomaa (University of Oulu), Martti Lehto (University of Jyväskylä), Birgit Paajanen (HUS), Maritta Perälä-Heape (CHT Oulu), Matti Ristimäki (Tieto), Minna Ruckenstein (University of Helsinki), Niilo Saranummi (VTT, emeritus), Simo (Aalto University), Osmo Tervonen (PPSHP), Hanna Viertiö-Oja (GE Healthcare). Furthermore, Heikki Ailisto, Mark van Gils, Marja Harjumaa, Tua Huomo, Jaakko Lähteenmäki, Juha Pajula, Antti Tolonen and Arto Wallin contributed to the project from VTT. We thank for all the contributors for their valuable comments and insights.

3. Vision

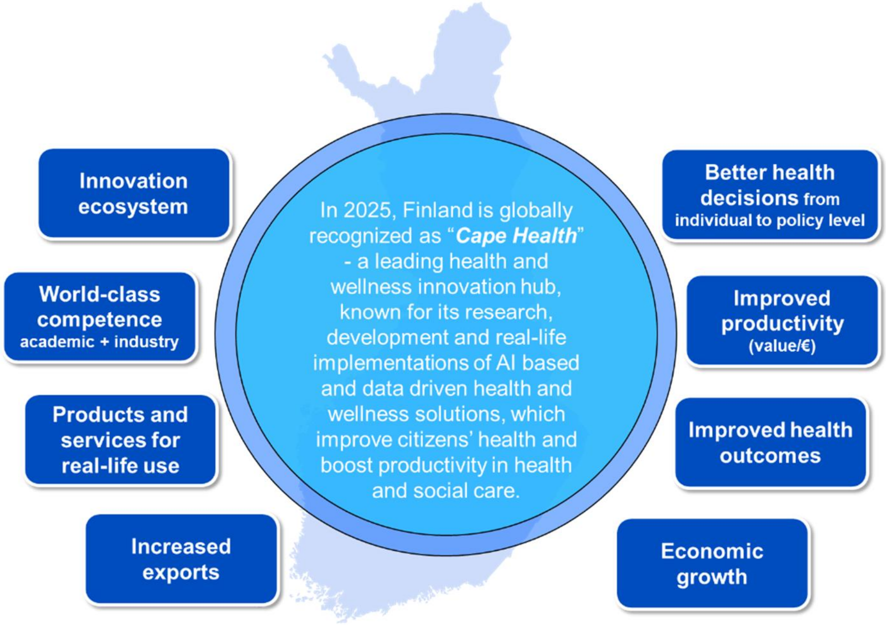

Figure 2. Vision of Cape Health.

In 2025, Finland is globally recognised as "*Cape Health*[3]" - a leading health and wellness innovation hub, known for its research, development and real-life implementations of AI-based and data-driven health and wellness solutions that improve citizens' health and boost productivity in health and social care.

The Cape Health ecosystem stakeholders include global technology companies who have established key R&D activities in Finland, as well as local start-ups and SMEs, in cooperation with health professionals, health and wellness service providers, and academia. The ecosystem is highly networked with cutting-edge international research and business. The ecosystem leverages unique Finnish health data assets as the foundation for creating novel AI-enabled health and social care and wellness applications. Cape Health's public-private partnership (PPP) model model with local care providers

[3] "*Cape Health*" is a working brand name for Finnish health and wellness innovation hub, wrt. *Silicon Valley*. The final name will be defined in the early stages of the SRA implementation, in collaboration with Team Finland.

attracts international investments to develop, experiment and validate new solutions. By 2025, Cape Health has implemented a paradigm shift where utilisation of data has changed from a passive retrospective mode to an active or proactive mode where the data is continuously collected, shared, harvested, curated and used in all levels of decision making, from legislation and administration to professional care and self-management by citizens. This has resulted in improved health outcomes at the same time that productivity in health and social care has been boosted.

Cape Health has forward-looking and adaptive rules, compliant with national and EU legislation as well as privacy and ethical principles, for collection and secondary access and use of health and wellness and other relevant data, working across partnerships, in compliance with every citizen's rights to hold dominion over his/her data and its use. It provides multiple easy-to-access sandboxes where different stakeholders can come together, access data, and develop and test solutions in real life. Human factors and determinants of human behaviour as well as various forms of societal impact of AI applications are actively explored and drive design of AI-based products and services, whether targeted for professional or consumer use. As a result, Cape Health continuously produces global success stories and breakthroughs in data-driven health products and services as well as new scientific discoveries. Citizens benefit from this through improved health and wellbeing, efficient and timely preventive, participatory, personal and personalised health and wellness services, and through increased economic growth. Cape Health activities improve health and wellness service productivity and health outcomes, increase exports of health and wellness technology goods and services, and generate new jobs for both technology companies and the health and wellness service industry.

4. Need - Improving health outcomes while containing costs

Industrial and emerging economies are undergoing major demographic and socio-economic changes that challenge the current healthcare systems. Ageing society and unhealthy lifestyles cause increasing prevalence of chronic diseases, which contribute to over 75% of overall health care costs. The share of the elderly (people over 64 years) in the EU population is projected to increase from

18.5% in 2014 to 28.7% by 2080 reflecting an additional 55.2 million elderly persons in the EU by 2080[4]. While the healthcare has been able to extend the population's life expectancy, the modern sedentary lifestyle with consequences such as obesity and physical inactivity significantly contribute to the increase of several chronic diseases such as cardiovascular disease and diabetes. The rates of adults being overweight and obese are increasing at a rapid rate with an estimated 51.6% of the EU's adult population being overweight in 2014. Chronic noncommunicable diseases cause a major burden for the healthcare system. For example, diabetes alone is estimated to cause 18% of the healthcare costs in Europe[5]. In parallel to chronic diseases, multi-morbidity, defined as the co-occurrence of two or more chronic conditions in one person, is increasingly a problem - two-third of Europeans nearing retirement age are living with two or more long-term conditions, which affect both their quality of life and ability to work. In order to contain the healthcare costs, there is an urgent need to both prevent these diseases as well as to treat them more efficiently. It is widely accepted that the next generation of healthcare delivery should shift a significant part of its resources from the treatment of diseases to their prevention.

The prevention of chronic diseases through improved lifestyle requires sustained daily commitment from the individuals. Because of that, there is a need to promote the citizens from passive recipients of treatments into active, informed co-creators of their health and wellbeing[6]. Health care reforms in various countries give rise to healthcare *consumerism* - transforming health benefit plans into one that puts economic purchasing power—and decision-making—in the hands of participants or citizens. It's about supplying the information and decision support tools that they need, along with financial incentives, rewards, and other benefits that encourage personal involvement in altering health and healthcare purchasing behaviours. While it is understood that data alone may not sufficiently affect the health behaviours, it is one of the key enablers towards citizen-centric health solutions. This citizens' active role calls for solutions which allow them to control, share and act on their personal health-related data, including genome data, health and wellbeing monitoring data and everyday behavioural data. Extracting value out of these data

[4] http://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_%E2%80%93_population_projections

[5] https://www.thl.fi/fi/web/kansantaudit/diabetes/diabeteksen-kustannukset

[6] Topol, Eric. The patient will see you now: the future of medicine is in your hands. Basic Books, 2016.

demands significant innovations in data discovery, transparency, openness, analysis, integration, interpretation, visualisation, privacy rights and business logic. To contain the costs, new paradigms and service models are needed to engage and motivate especially those individuals to actively manage their health and disease who suffer from or are at increased risk of developing multiple chronic conditions - 10% of the Finnish population spend 81% of the health care resources and nearly 100 % of the social care resources[7] (Figure 3).

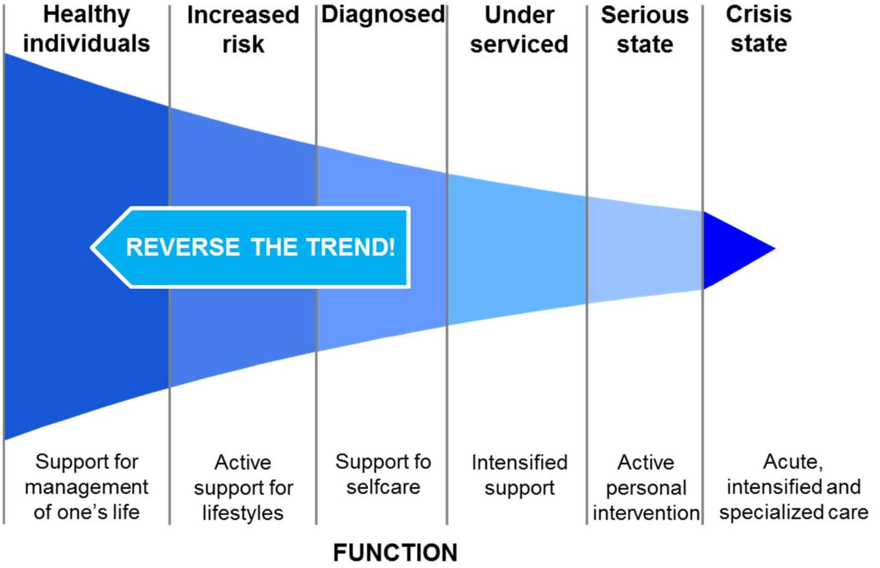

Figure 3. Healthcare functions and actions categorised by the progress of the condition. While a minority of the people have serious conditions, they use most of the healthcare resources. Thus, investing healthcare resources to the prevention of serious conditions can help to reduce overall cost of care. (Source: Prof Juha Teperi, Ministry of Social Affairs and Health, 2008).

While the uneven use of health and social care resources[8] is a major challenge, so is the inequal access to care. Socio-economic status (SES) characterised by factors such as location, unemploymency, living alone, and single parenting are significantly correlated with worse healthcare delivery and health outcomes. This inequality in

[7] Leskelä et al, Paljon sosiaali- ja terveyspalveluja käyttävät asukkaat Oulussa. Lääkärilehti 48/2013, s. 3163-3169
[8] ibid

the healthcare delivery has increased while the treatments have improved. Men with low SES are 4 times more likely to die of conditions that could have been prevented with healthcare actions compared to men with high SES. There is a significant societal need to deliver equal quantity and quality of healthcare services to the whole population.

Although the primary focus of the health care is to increasingly move the care outside institutional settings, this will not eliminate need to improve also specialised care in e.g. hospitals. The number of people with co-morbidities and severe illnesses treated in the hospitals is increasing in all levels of care from general wards to intensive care. Information overload continues increasingly to challenge efficient and effective care also in hospital settings, thanks to the rapidly increasing monitoring technologies and access to full patient history. There is a tremendous need to effectively transform these data into actionable information that will help clinicians prevent the patients' deterioration and improve their outcomes while containing the overall costs of care also in institutional settings, and to bridge the care from a care environment to another (e.g, from hospital to home, and from acute care to chronic disease management, and vice versa). In general, fluent access and utilisation of data is a key for enabling continuous care of a citizen in different phases of life and stages of health.

Development of new diagnostics and therapies, while improving health, increase health care costs on the short-term, and also widen the gap between what can be treated, and what can be afforded to be treated due to limited resources and budgets. As a result, health care costs, as well as health technology markets, grow at a faster rate than gross national products (GNPs) globally, yielding to major health care reforms in essentially all major economic areas and wealthier countries. These reforms aim to contain the costs while delivering improved health outcomes. Since health care is one of the most information-intensive industries in the world, this is a huge opportunity for information technology tools and business solutions that would facilitate the required health outcomes and productivity leap in health and social care delivery.

The need for more effective treatments is challenging the current evidence-based medicine (EBM) which, for the past decades has been the cornerstone of modern healthcare. In general, EBM seeks treatments that work sufficiently well within a specific target population.

However, individuals vary substantially from the population norms. More targeted approaches to developing new treatments have been said to overcome some of the challenges of EBM and the personalised medicine paradigm has been suggested as the next major revolution in healthcare[9]. The term refers to a procedure where healthcare treatments are designed specifically to match the unique characteristics of a given individual, instead of a given target population. Growing knowledge demonstrates the need for such an approach to health and disease based on causative pathways that include genes, environment and life-style, with treatment according to etiology, often with multiple dimensions. This development leads towards health interventions that are increasingly personal. However, before the potential for personalised medicine can be realised in healthcare, research is needed to integrate population-level genetic, lifestyle and environmental data to understand in more detail how these interactions shape individual responses to disease and treatment. Vital signs, symptoms of diseases and life conditions need to be monitored on an individual basis. All this generates massive amounts of data, whose analysis is not possible by conventional methods.

5. Enabler - Progress in artificial intelligence technologies and applications

5.1 Artificial intelligence

Artificial Intelligence (AI) is intelligence exhibited by machines[10]. AI has been studied for more than 60 years, with several ups and downs. In a broad sense, any system that perceives its environment and takes actions that maximise its chances of success in some goal may be defined as AI. When talking about AI, it is common to make a distinction between artificial general intelligence (AGI), and so-called “narrow AI”. Artificial general intelligence refers to systems which are capable of performing any intellectual task that a human being can. Whereas narrow AI refers to systems which are limited to a specific domain, such as playing chess, or making medical diagnosis. Here, the term AI refers to the narrow AI.

[9] http://www.nature.com/nrclinonc/journal/v8/n3/full/nrclinonc.2010.227.html
[10] https://en.wikipedia.org/wiki/Artificial_intelligence

Recently, AI has been recognised as one of the key technologies reshaping our future[11]. Progress in AI and its applications in various domains of business has been estimated to lead to similar changes in economics as machine automation did for the manufacturing industry. According to researchers, 25-40% of the current human work will diminish or transform within the next 15 years due to AI and service automation. This is especially true for routine information-centric service tasks, which are well defined, repetitive and require little human interaction and creative problem solving. Examples of such tasks include baseline customer service, claim processing, and various counseling tasks. This will significantly boost productivity in business sectors where these kind of tasks are common. Healthcare, as an information-intensive industry, is clearly one of the potential beneficiaries of this leap in productivity.

In recent years, rapid development has taken place in the field of AI. The most widely publicised examples of this development are IBM Watson's success in the Jeopardy quiz show and AlphaGo's victory against the best human Go players, while everyday examples include information search engines, natural language processing (NLP)-based user interfaces (e.g., Siri in Apple products), and navigation. The AI development is driven by the combination of three major forces. Access to data has improved as more and more devices generate and store digital data and also any business data such as health record data are increasingly available in digital format and accessible via several systems. Advances in computer hardware mean that computational power has improved steadily for decades, which allows for the processing of the huge amounts of complex data in real time or close to real time. Thirdly, advances in machine learning research, namely in the class of methods called deep learning, have enabled training of more complex models that are able to fully utilise the available data and computational resources.

Commercial cloud-based AI services have emerged, with functionalities such as face recognition, image classification and speech recognition. Some of the most prominent international providers of these services include IBM, Google, Microsoft and Amazon. Only a few years ago, many of the algorithms and methods offered by the services were mainly academic research topics; now they can be incorporated into software using simple application interfaces.

[11] http://www.gartner.com/smarterwithgartner/gartners-top-10-technology-trends-2017/

AI and machine learning technologies have great potential in the analysis and interpretation of large and complex data, such as multidimensional and multimodal health data ranging from imaging to genomics and unstructured electronic health record data. AI technologies can efficiently combine and analyse such data and, e.g., identify significant patterns, find similarities between cases, and suggest optimal treatment paths or diagnoses. AI technologies have been successfully used in a variety of health applications, from decision support for personalised and early diagnosis, to personalised treatment planning, drug discovery, prediction of disease progression and health care process analysis and optimisation. The opportunities for AI in health data analysis are vast, and driven both by increased access to and curation of data and improved analysis methodology and tools.

Based on Forrester's analysis, Gil Press has listed the most important AI technologies. They are Natural Language Generation, Speech Recognition, Virtual Agents, Machine Learning Platforms, AI-optimised Hardware, Decision Management, Deep Learning Platforms, Biometrics, Robotic Process Automation, Text Analytics and Natural Language Processing (NLP).[12](Figure 4)

[12] Gil Press, Top 10 Hot Artificial Intelligence (AI) Technologies, Forbes January 23, 2017

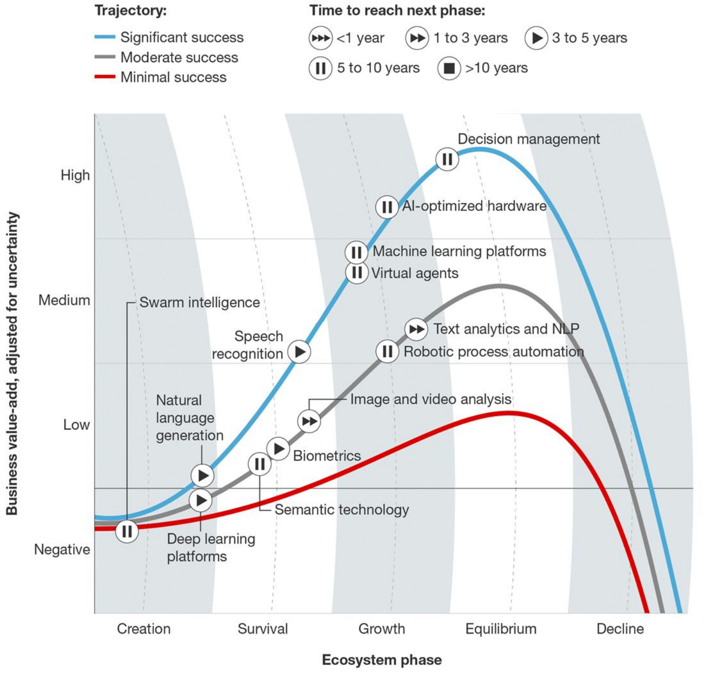

Figure 4. Artificial Intelligence technologies Q1/2017, Forrester Research Inc.

Due to the huge potential of AI in improving productivity in various business domains, investments in AI are rapidly growing. The new wave of AI applications, fueled by a combination of big data and processing capabilities, have garnered over $15B in funding for AI startups in just the last 5 years.[13] The market for AI technologies is also flourishing. A Narrative Science survey found last year that 38% of enterprises are already using AI, growing to 62% by 2018. Forrester Research predicted a greater than 300% increase in investment in artificial intelligence in 2017 compared with 2016. IDC estimated that the AI market will grow from $8 billion in 2016 to more than $47 billion in 2020.[14]

AI for health seems also to boost. CB insights tracked 100 AI-focused healthcare companies, and noted that 50 had raised their first equity round since January 2015, with rapily increasing number of

[13] CBInsights, Cortica, Numenta Hold Top Patents in Artificial Intelligence, April 27, 2017
[14] Gil Press, Top 10 Hot Artificial Intelligence (AI) Technologies, Forbes January 23, 2017

deals during last year[15]. A recent survey[16] found that a third of healthcare organisations plan to leverage AI within two years — and more than half intend to do so within five. The biggest challenges in AI for health include regulatory barriers, interoperability with legacy IT systems, and access to quality data.

5.2 Service automation

Service automation is one of the most prevalent applications of AI. It refers to the reduction and ultimately removal of human intervention from service processes and organisational routines with the objective of improving quality and efficiency. Application of information and communication technologies in healthcare and social services (e.g., Electronic Health Records and online services) have already increased the efficiency by freeing the personnel from routine tasks. AI will enable the removal of human intervention even from demanding tasks and complete service processes, enabling the work of healthcare professionals and support personnel to be focused on most essential tasks. At the same time, quality of services is expected to be improved as AI enables human errors to be avoided or detected.

In the health and wellness domain, services targeted at customers and professionals alike are subject to automation. Routine office work and data processing tasks are very much a potential area for Robotic Process Automation (RPA). RPA refers to a software application that replicates the actions of a human being interacting with the user interface of a computer system, for example, entry of patient information. According to some studies, 36% of work hours in healthcare and social assistance could be automated today[17]. The study names data processing and collection of most of the potential applications. Since office work and data processing take up a significant portion of the working hours of healthcare professionals – not only secretarial staff - automation of these tasks would result in substantial improvement in productivity by freeing up professionals for actual patient work.

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[15] https://www.cbinsights.com/blog/artificial-intelligence-startups-healthcare/

[16] http://www.healthcareitnews.com/news/half-hospitals-adopt-artificial-intelligence-within-5-years

[17] http://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works

Customer guidance is rapidly moving from personal telephone-based services to internet-based guidance. AI is now changing the way information is delivered through web pages. Instead of browsing through large hierarchial information contents the customer is assisted by chatbots where questions can be presented using natural language and answers are provided by the computer[18]. The scope of automatic guidance may range from general service information to advanced personal health consultation. Remarkable cost savings are expected to be achieved by AI-enabled symptom checker and triage systems, which enable automatic or semi-automatic service path allocation and priorisation for customers. Current systems are typically stand-alone, rule-based engines providing output in response to the user's input on a web form. The next generation of AI-enabled symptom checkers will exploit wider input data, in particular the clinical data of the individual and local epidemiological data along with the data entered by the patient[19].

5.3 Big data

Big data is a loosely defined term for such **"**extremely large data sets that may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions[20]". In the context of health and care, big data can be seen, e.g., as such data that are too complex to be utilised in healthcare decision making by using the current tools. Thus, big data is essentially creating a need for AI technologies so that the potential of the data can be exploited. The number of published articles on big data and health has increased exponentially since the year 2012[21]. However, many other sectors are exploiting big data more extensively than healthcare. The major reason for this is the stricter requirements for data security and privacy in healthcare compared to other industries. For example, consumer behaviours are today commonly analysed by combining big data from various sources such as loyalty cards data and social media activities in order to understand upcoming trends and to provide targeted marketing. The healthcare industry has so far also been lagging behind in the interconnectivity between various IT platforms compared to the situation in other business sec-

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[18] http://www.jahonline.org/article/S1054-139X(10)00430-1/abstract
[19] http://www.bmj.com/content/351/bmj.h3480
[20] https://en.oxforddictionaries.com/definition/big_data
[21] de la Torre Díez, I., Cosgaya, H.M., Garcia-Zapirain, B. et al. J Med Syst (2016) 40: 209. doi:10.1007/s10916-016-0565-7

tors. This has delayed the application of big data in healthcare because the value of big data typically is revealed when data are combined from multiple sources. The interoperability and interfacing of electronic medical records have improved significantly and also their data processing capabilities have improved[22]. It is possible today to collect diverse data from patients, including genomics, proteomics, metabolomics, imaging, historical, diagnosis, physiological and behavioural data. Moreover, communication, wearable solutions and mobile health technologies provide new opportunities for measurements 24/7. In order to exploit big health data, privacy preservation must be duly enforced. Attention to the risks associated with the possible leak of personal sensitive data is to be paid. Risks include disclosure of sensitive data, identity theft up to even sabotage. If proper actions are taken to mitigate such risks, the combination of AI and big health data has the potential to reveal new actionable knowledge relating to, e.g., prevention, early intervention and optimal management[23] providing opportunities to shift from generic to individualised patient-care and personalised medicine[24].

6. Assets - Finnish ecosystem

6.1 Finnish health and social care system

The strengths of the Finnish health and social care system include wide coverage, high quality of care, equality, and reasonable costs. Although the Finnish system has been a success story in many aspects, there is a wide consensus that a major reform is needed. The current service system relies on municipalities to organise and finance primary healthcare and social services. Currently there are 295 municipalities (2017 excl. Åland), some with very small populations. Secondary healthcare is organised in 21 hospital districts. A major concern is the pressure on fiscal sustainability resulting from the increasing expenditure on healthcare and social benefits, due to several reasons as described in Chapter 4. Even though the current Finnish level of healthcare expenditure (9.6% of GDP, 2015) is only

[22] Groves, P., Kayyali, B., Knott, D., Van Kuiken, S., The ”big data” revolution in healthcare, McKinsey&Company report, 2013

[23] J. Andreu-Perez, C. C. Y. Poon, R. D. Merrifield, S. T. C. Wong and G. Z. Yang, "Big Data for Health," in IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 4, pp. 1193-1208, July 2015.doi: 10.1109/JBHI.2015.2450362

[24] Godman, B., et al. Personalizing health care: feasibility and future implications, BMC Medicine, 2013, 11:179

slightly above the EU average, there are broad fiscal constraints alongside deficit reduction targets that go beyond the health and social care sectors.

The health and social care reform is expected to radically shape the Finnish social and healthcare provider arena and have significant consequences in the health IT landscape. According to the current plan, care will be re-organised based on 18 regions that will have the responsibility to organise and fund the services in their areas. Furthermore, citizens will be provided the power to relatively freely choose their care provider, whether public or private, giving further rise to consumerism. It is estimated that as the amount of public service organisers and public providers will radically be reduced, a significant consolidation and renewal of existing large IT systems will also take place in the next 5 to 10 years. On the other hand, provider competition in primary healthcare may fragment the market and create room for smaller and SaaS-based IT-system and service vendors. Regions as service organisers and payers will need new IT systems and services for, e.g., customer, provider and contract management, business-intelligence, data analytics and consultation/ interpretation services. In summary, the planned reform will create a significant need and market for new IT systems and innovations, providing a window of opportunity for AI for health solutions and their pilot and reference implementations.

The need for data and information cuts across the reform. Finland has a developed national health data and information system, which has to be adopted to be in line with the new service system design and the reform's information needs, including interfaces to new services and service providers. Finnish national registries and related health statistics are recognised to be of very high quality. Despite the availability of high-quality data, there have been concerns whether there is sufficient capacity and culture of making use of the information in decision-making and operative management of health and social services.

Interoperability of the IT systems will be crucial in order to fulfill the integration and coordination of health and social services. Planning and execution of integrated care models is not possible without access to the health and social information as widely as each individual case requires. Finland has achieved a lot in national interoperability, especially on patient health records through Kanta services, which have the potential to fulfill some of the information needs in service integration. Similar databases related to other sectors of life must be made available and usable parallel to health care data in Kanta.

6.2 Digital health data registers and digital health data

Finnish health data registries and digital health data form a national key asset in AI for health. Strengths of these data registries and EPR include their coverage, quality, longitudinity, and ability to connect data from different registries on an individual level. Especially the unique strength of the Finnish health datasets lies in the opportunities to link data from multiple repositories: biobanks, medical history, health status, nutrition, exercise, smoking, alcohol consumption, sleep, clinical examinations, laboratory measurements, omics data and follow up data from national health registers. In this chapter, a short summary of the most important data assets are briefly described. Legal and regulatory aspects of the data access are discussed in Chapter 6.5.

Today, the documentation of patient data in Finnish healthcare system is 100% digitalised. In public hospitals, the electronic patient record (EPR) availability has been 100% since 2007. In public primary healthcare centers, the 100% availability was reached in 2010 and in private health care service providers even earlier than that. National Kanta services include ePrescription, MyKanta Pages and the Patient Data Repository. Patient information created by health care service providers is transferred to the national patient data repository, where it can be accessed - with patient's consent - by any service provider delivering care to the individual. All public healthcare providers and the majority of private providers are already linked to Kanta services (situation in the end of 2016) with 20 different certified EPR systems. Health and ePrescription information can be accessed by citizens via the MyKanta Pages, which is widely used by the general population, with around 1 million logins per month (1/2017). National Kanta Data archive stores and transmits providers' medical records and the central repository already contains more than 600 million documents of more than 5.4 million Finns (situation 12/2016). Electronic prescription is mandatory since the beginning of 2017 for all physicians prescribing medicines and currently about 5.35 million ePrescriptions are issued monthly, with 170 million ePrescriptions cumulatively to date. Infrastructure, first pilots and legislation are underway to include the social welfare sector in Kanta services with estimated major roll-outs starting in 2018-19. Kanta services will in the near future also include Personal Health

Record (PHR) functionality, which will allow for storage, management and utilisation of health data generated by the citizens themselves in the same national, secure and high-performance infrastructure as data generated in the social and healthcare services (estimated September 2017). There are multiple national or nationally significant developmental projects in the social welfare and health care area currently in progress. One example is the expansion of Kela's Kanta-services to cover health care and also social welfare data pools and information system services, in addition to health care districts' and municipalities' customer and patient record system projects (Apotti[25], UNA[26]) and digital services geared towards citizens.

Finland has extensive national registries, survey datasets and related health and welfare statistics. The main dataset holders are the National Institute for Health and Welfare (THL), Statistics Finland, Kela (National social insurance institution) and ETK (the Finnish centre for pensions). THL holds the national primary care and hospital discharge registers, birth and related child health registers, national cancer register and several other special registers. THL also holds extensive population survey and clinical study datasets, which are routinely combined with administrative register data for research purposes. Statistics Finland holds the causes of death register and socio-economic population datasets. Kela has data on social benefits and drug reimbursements and ETK on pensions.

Currently there are eight registered biobanks in Finland, with two nationwide biobanks (THL biobank with population cohorts and FHRB Biobank focused on hematology) and six clinical biobanks run by universities and hospital districts. Large Finnish population cohort studies have long had a major focus on genomics research and currently THL biobank includes samples and data from 126,000 study participants with DNA from 70,000 participants. Further transfer of existing collections to biobank during 2017-18 will include up to 100,000 study participants, and three new population cohort collections are underway with an objective to collect up to 35,000 new samples by 2018. HUS biobank, in turn, currently has 1.4M samples. Finland has recently decided to invest in the creation of a national genome center and a national cancer centre, and in the coming years, the coverage of the biobank and genome data will be rapidly

[25]http://www.apotti.fi/

[26]https://www.kuntaliitto.fi/asiantuntijapalvelut/una-asiakas-ja-potilastietojarjestelmien-uudistamisyhteistyo

increasing. The Finnish biobanking activity and co-operation will be boosted to the next level with the proposed founding of a national biobank operator, which aims to create a common data management and sharing infrastructure to facilitate the utilisation of biobank data. Current research questions in population cohort studies are linked to genotype data combined with patient record and health registry data. This can provide insights into how genetic variation can influence the onset, prevention and treatment of diseases and how this information may be used to develop new therapeutics.

The issue with integrating data from various current social welfare and health care information systems is poor compatibility and interfacing between the systems. Health and social care information system architecture has approximately 400-800 systems, with more than 500 connections between them, around 10,000 expert users and 10-100 system owners. The integration of data from this setting remains a challenge to be solved in order to unleash the full potential of the Finnish health data. Open health data ecosystem should be targeted, with focus on open interfaces to access data as well as in general transparency, access and usability of information. The consolidation of uniform data requires a unified understanding of data content and data classification that are commonly agreed upon. [27]

While Finland has several health data registries managed by the public authorities, the active role of the citizens as the producers and managers of their personal health data is promoted by the MyData concept. MyData is a term used to describe an individual-centric approach in managing personal data. Under the Mydata approach, people have the control to manage the access to their data. This simplifies data flow and opens new opportunities for businesses to develop innovative personal data-based services. Shared MyData infrastructure enables decentralised management of personal data, improves interoperability, makes it easier for companies to comply with tightening data protection regulations, and allows individuals to change service providers without proprietary data lock-ins. Thus, Mydata provides a good basis for future health services promoting citizens as co-creators of health. There are challenges in promoting Mydata principles, since many digital business models rely on monetising users' digital data. Mydata principles may also challenge the current ways of collecting and managing population-level datasets

[27] Petri Virtanen, Jari Smedberg, Pirkko Nykänen ja Jari Stenvall, Palvelu- ja asiakastietojärjestelmien integraation vaikutukset sosiaali- ja terveyspalveluissa, Valtioneuvoston selvitys ja tutkimustoiminnan julkaisusarja 2/2017, 10.1.2017

for public administration and research. In terms of AI and health, the MyData agenda can be extended in ways that foster a society that is fair and workable for its citizens. To enable MyData in full in health and social care and wellness, data should be open and accessible. In order to get the most of MyData services, they need to be designed and implemented in a manner that supports the human-machine collaboration.

6.3 Industry - AI for Health industry in Finland

Digitalisation of health, big data and AI are disrupting technologies which create new business opportunities for both current health and wellness technology companies but also for new players, varying from start-ups into existing players with core competence especially in ICT and AI technologies. Here, we call these companies "*AI for Health industry*". This covers all the companies which develop and offer products or services based on AI for health and social care or wellness.

Today, healthtech - regulated medical and health technology for use primarily by health professionals - is the biggest high tech export domain in Finland, with ~10,000 jobs in ~300 companies, export of €2.11B (2016) with an annual increase of 9.7% (Figure 5). This figure is based on custom reports and primarily includes regulated medical products, and excludes, e.g., related services and software sales, and hence the true total export value of the healthtech is currently over €3B. 95% of the Finnish healthtech production is exported. Surveys among the industry indicate continued growth in the segment. The export and trade surplus in the healthtech segment has grown steadily with a long-term average of 6.2% annually, especially to the USA and Asia. The strongest sub-segment is medical equipment, which contributes nearly 90% of the exports. Within this industry, novel business opportunities are seen especially in healthcare and wellness software and increased intelligence, as well as the service industry.

Figure 5. The health technology trade in Finland 1996-2016 (Source: Healthtech Finland, 2017).

In addition to the regulated b2b medical markets, Finland has several successful companies and strong research and industry ecosystem in non-regulated wellness and health areas, including sports device brands (Polar, Suunto, etc), wellness technology companies (Firstbeat, Beddit[28], Nokia/Withings, etc), and a vivid portfolio of health start-ups (some listed in http://www.healthspa.fi/members/), which are not included in the figures above. In total, their revenues exceed €1B. These companies especially have competence in wearable sensors, biosignal processing and analytics including AI technologies, wireless technologies, and mobile and web and cloud technologies mainly applied for consumers in sports, fitness and wellness domains, but also including B2B businesses such as corporate wellness.

A special challenge for the Finnish AI for health industry is relative lack of growth companies - only few startups and SMEs have been able to grow into significant global size during the last two decades, and several promising early stage companies have been acquired by international companies before their commercial breakthrough (e.g., Beddit, Protogeo). Accelerating the international growth of the SMEs and start-ups and keeping their core operations in Finland

[28] Acquired by Apple in May 2017

should be targeted to ensure return-of-investment and active growth of the Finnish ecosystem.

There are several drivers in the healthtech business landscape that create new openings. The social and health care reforms (both in Finland and in various target markets) will disrupt and revolutionise the current business-as-usual in healthcare and will create opportunities for completely new business models both for healthtech companies and new players coming from other domains. In addition, the ageing population, increasing prevalence of lifestyle diseases, and consumerism in health call for solutions that can prevent diseases and support people in managing their own health, blurring boundaries between regulated and non-regulated applications. AI technogies have the potential to create new solutions to match these openings. The Finnish AI for the health industry is well positioned for the change and seeking new partnerships outside the traditional healthtech players. The Finnish healthtech and wellness industry is in a particularly appealing position as the domestic health care reform is seeking new technical solutions, which the industry should be capable of offering at early phases of development. The healthtech industry has traditionally had an excellent dialogue with governmental innovation administration and with the research community. This is particularly important for the new and complicated, both from clinical, technology and regulatory perspectives, areas such as healthcare.

To facilitate further growth and new business opportunities in healthtech, continuum from research to commercial activities and cross-domain co-operation should be supported and test-bed actions to evaluate and validate novel solutions locally first before scaling to international markets should be promoted. Commercialisation expertise should be emphasised in the healthtech research and in particular, the understanding of technology transfer IP creation. Fluent access to national health data should be guaranteed with proper control mechanisms. Finland should be promoted as an attractive target for international investments.

For the industry operating in Finland, it is crucial that the systems and technologies are aligned with the systems and technologies in other countries, in the EU and globally as much as possible. The Finnish market is far too small to justify national solutions in the long term. Therefore, the regulation, legislation and specifically the rules on how to manage the personal data must be harmonised between the countries and especially between the EU member states. Otherwise, solutions, even if provided by large international companies, when developed for Finland alone will be unbearably expensive.

6.4 Research - health and computational sciences

6.4.1 Research volume and quality analysis

Finland ranks 5th in the number of scientific publications per capita globally, after Switzerland, Denmark, Sweden and Norway, but only 15th in the ranking if the impact of the science is taken into account[29]. The key sciences for AI for Health SRA include ICT and electronics (especially computational sciences), medicine, health sciences and behavioural sciences. These appear also as strong areas for Finnish research, making in total 46% of all scientific publications in Finland. Of all scientific publications, 16.0% and 12.3% are in clinical sciences and ICT and electronics, with impact clearly above world's average. For ICT and electronics, Aalto (32% of all publications), Tampere University of Technology (22%) and the University of Oulu (14%) are the most active in publishing. In clinical medicine, the Universities of Helsinki (31%), Turku (19%) and Tampere (14%) product most publications, while in behavioural sciences Universities of Helsinki (35%), Jyväskylä (21%) and Turku (12%) make the top three in publishing. Finland has significant resources in these sciences. There are 226 professors and more than 2000 researchers in Finnish universities for ICT and electronics. The number of professors is also significant in biomedicine (179), clinical medicine (221), health sciences (88) and behavioural sciences (167). These figures do not inclide research professors working at research institutes. In total, Finland hence has around ~900 professors in the domains relevant for the AI for Health SRA. Competed funding (EU, Tekes, Finnish Academy) between 2012-14 for Finnish universities was 221.2M € for ICT and electronics, 204.9M€ for biomedicine, 57.0M € for clinical medicine, and 46.9M € for behavioural sciences, totalling 530M€ for 2012-14, averaging 177M €/year. This number excludes funding in research institutes (e.g., VTT and THL), as well as direct government funding for the universities, which is on average 56.4% of the total funding. Hence it may be estimated that research investments in Finland for the sciences relevant for AI for Health SRA are in the order

[29] Suomen Akatemia. Tieteen tila 2016.

of 500M €/year. The investments and scale of activities is significant, but the efforts are scattered and non-coordinated.

Although clinical medicine produces the highest volume of medical publications in Finland, biomedicine attracts significantly more external funding. Some medical research areas which have been recognised as particularly strong areas are listed in Figure 6. Despite strong medical research, investments in healthtech and biotech companies have been relatively small, resulting in few commercial success stories based primarily on medical research[30]. Successful healthtech commercialisation has been based more on innovative technology research and close and fruitful collaboration between technology developers and medical experts rather than utilisation of the world-class expertise within domestic health and medical research.

Figure 6. Areas with world-class medical research and especially disease pathway research competence in Finland (Source: The Future Healthcare Innovation Environment of Finland. Project Way Forward final report. Ernst & Young, 2016).

ICT and electronic research as well as biomedical engineering have been traditionally very strong and a driving force for the success of

[30] The Future Healthcare Innovation Environment of Finland. Project Way Forward final report. Ernst & Young, 2016.

healthtech Finland. Technology research has also resulted in global breakthoughs in, e.g., mobile and wireless technologies and intelligent machines. The total volume of ICT and electronics research in Finland is major. Research in AI and computational sciences is carried out in all major Finnish universities and research institutions, e.g., VTT. Strong research areas include image and signal processing and analysis, neural networks, machine learning and pattern recognition, intelligent machines and robotics, and computational intelligence. Some research groups have had a strong, globally recognised academic track record in these areas. For example, professor Teuvo Kohonen is one of the globally recognised pioneers in neural network research. Aalto University has several groups at the Center of Excellence level, e.g., the Finnish Centre of Excellence in Computational Inference Research (COIN[31]), led by professor Samuel Kaski. Algorithmic Data Analysis Centre-of-Excellence (Algodan[32]) at the University of Helsinki develops new concepts, algorithms, principles, and frameworks for data analysis for applications in biology, medicine, telecommunications, environmental studies, linguistics, and neuroscience. Tampere University of Technology and University of Helsinki are also members in the Center for Visual and Decision Informatics[33] which focuses on becoming a national Centre of Excellence in data science, big data analytics and visual analytics. In addition to these examples, significant research is also being done in several other universities, but an exhaustive listing of these activities is beyond the scope of this report.

[31] http://research.cs.aalto.fi/coin/
[32] https://www.cs.helsinki.fi/research/algodan/
[33] http://www.nsfcvdi.org/wordpress/

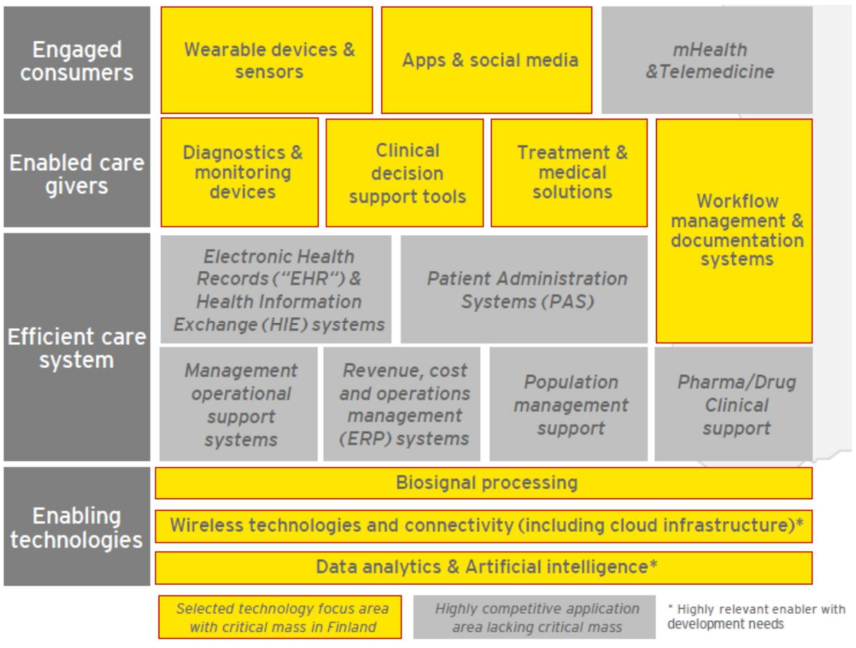

Figure 7. Technology areas with critical mass to solve health sector challenges and the size of the commercial opportunities (Source: The Future Healthcare Innovation Environment of Finland. Project Way Forward final report. Ernst & Young, 2016).

In addition to AI research, research in health technologies has been very successful, and Finland has world-class competence in wearable sensors and devices, diagnostics and monitoring devices, clinical decision support tools, treatment and medical solutions, and workflow management and documentation systems (Figure 7). These are clearly recognised technology research spearheads which enable development of AI for Health solutions for various applications.

6.4.2 Research needs and challenges

Breakthroughs in AI are critically dependent on access to data with sufficient quantity and high quality: "*no matter how big and powerful the technology company may be, the availability of patient data is what makes the difference between a buzzword or an algorithm that can diagnose or predict outcomes*"[34]. Unlocking AI's true full poten-

[34] http://www.mobihealthnews.com/content/depth-ai-healthcare-where-we-are-now-and-whats-next

tial requires strategic partnerships, quality data, and in depth understanding of both the AI and context (health, wellness, social and behavioural issues), including legal and regulatory as well as ethical issues. Problems to be solved are complex and require a significant learning curve. Health outcomes are dependent on both genetics and health care actions and on behavioural and societal factors, and even 60% of the variance in health outcomes are related to variations in the latter[35],[36]. Hence, behavioural, motivational, and societal factors are increasingly important to be understood in connection with genetic factors. New strong research consortia committed to close interdisciplinary collaboration over sufficiently long period are required. Successful AI for health calls for truly interdisciplinary and transdisciplinary research, especially between technology (especially, the computational sciences, biomedical engineering, ICT and electronics), biomedicine and clinical medicine, health sciences, and behavioural sciences. Data related to health and especially health behaviours includes not only traditional health related data but any other, often unstructured data, which may be used to profile an individual's personality, preferences, motivations, and societal factors, in addition to health status. A special challenge is that people's subjective experiences of mental and affective states are very difficult to observe with objectively gathered data. Big data and AI provide tools to address these needs.

Successful AI for Health research requires deep collaboration between many partners and organisation types. Progress in medicine and health are driven by progress in technologies. For example, in personalised medicine and research on disease pathways, medical and biological knowledge is needed for understanding the disease or disorder mechanisms, while complex new technologies are needed to acquire the necessary data and AI technologies for transforming the data into knowledge. Similar collaboration is required with behavioural and social sciences when targeting behavioural interventions and empowered citizens. Real-life experimentation and successful exploitation requires the participation of the health care providers, both private and public ones. There is a need for a new kind of approach in the research and development for health care system to focus on the real health care processes instead of organisational structures. The ability to facilitate this cross-disciplinary and

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[35] SA Schroeder: We Can Do Better - Improving the Health of the American People. *N Engl J Med* 2007; 357:1221-8

[36] McGinnis et al., *Health Affairs 21(2)*, 2002

cross-organisational collaboration has been one of the strengths of the Finnish health research, and that should now be further elaborated and expanded to cover an even wider range of disciplines and organisations to achieve world-class results in the future.

Finnish research in AI for the health sector has significant volume, but is highly scattered across different universities and research groups. Success is usually based on some prominent principal investigators and not always sustainable. In the future, the successful research units will be those which are capable of both national and international networking where even small research units with highly innovative ideas, world-class expertise, and unique data can have an impact. It is critical that close collaboration is favoured over competition e.g., via funding mechanisms.

Traditionally, unique data assets in health research have been based, e.g., on birth cohorts with repetitive health-related data, which have been collected by systematic research investments spanning decades. The role of these kind of data is rapidly changing as similar data is collected operatively in increasing amounts in digital health records and other operative data sources. Combining existing cohort data with operative data offers unique longitudinal high-quality data sets which are impossible to replicate in a short time.

6.5 Legal, privacy, regulatory and ethical issues

As all documentation of patient data in Finland is digitalised and as the same will soon also apply for data on social services, there are versatile opportunities for the secondary uses of health and social care information. Primary use of health data means use of the data for the purpose it has been gathered for. Secondary uses mean *all other handling and analysis of sensitive patient / customer data than what is needed for treatment, care and services received by the individual him/herself*. Secondary uses include, e.g., generation of statistics and indicators, research and product/service development, service operations management and planning, supervision and service system monitoring/surveillance. The potential of secondary uses in Finland is especially high since data from different administrative and EPR sources can efficiently be linked with unique identifiers (personal ID, organizational ID, service events/instances, geographic coordinates, etc.). Benefits of the AI for health may be to a great extent, materialised by maximising the value of the data for its primary use (e.g., to improve diagnostics, prediction and selection of treatment for an individual patient). Secondary use of the data is, however, critical to enable development of data-driven AI applications and services.

The legislative framework in Finland for secondary uses is currently under reform. The main objectives of the new legislation is 1) to align the national regulations with the European General Data Protection Regulation (GDPR), which enters into force in spring 2018; 2) to broaden the possible secondary use cases of health and social welfare data; 3) to enable the use of Kanta Data Archives as sources of data for secondary uses 4) to remove administrative bottlenecks and unnecessary bureaucracy and to create centralized services for accessing national health and social welfare data resources. The legislation is planned to enter into force in the beginning of 2018 and respective national services are currently under development in collaborative projects between THL, Statistics Finland, Social Sciences Data Archive, National Archives of Finland and major Hospital Districts.

The Finnish biobank Act (2013) provides a globally unique framework for versatile basic and clinical research on data extracted from human biological samples and combined with other data. The Biobank Act's explicit objectives include the support of research that utilises human biological samples to promote openness in the use of samples and data, and to secure the protection of privacy and self-determination when processing samples and data. The Act applies to both public and private biobank entities, and covers clinical, population, and research-based biobanks. The biobank act defines how biobanks are registered, how a broad "biobank consent" can be given by participants and how the rights of participants are protected. Transfer of existing sample and data collections to biobanks has been widely implemented and can be done with an opt-out procedure. Collection of new biobank samples is possible in routine hospital processes as well as in population cohort or clinical studies. The biobank act allows the possibility to recontact consented donors/participants and enables research collaboration with industry. The possibility to collect samples and data from the health care is complemented with possibilities to link biobank samples with hospital data (EPR) and data from national registries (hospital discharges and procedures, outpatient visits and procedures, causes of death, pharmaceutical purchases and reimbursements).

The gold standard method for proving the effectiveness of any treatment or medicinal product is a randomised, blinded, and controlled study design. The new EU regulation on clinical trials of medicinal products expected to come into force in 2018 is anticipated to facilitate the conduct of cluster-randomized trials, by allowing studies with simplified informed consent process in phase IV studies of licensed medicinal products (Article 33). This change in the EU regulation, combined with the comprehensive access to routinely accumulating nationwide digital health data in Finland, provide unique opportunities to conduct nationwide comparative studies, and to measure the public health impact on all levels of health care, starting from self-medication/primary care use, and ending to hospitalizations or even fatalities. The ability to conduct top-quality comparative trials - with a considerably lower cost - has the potential to develop into an established public-private collaboration infrastructure, also with major public health benefits through more effective health care. The new EU regulation limits the application to medicinal products, but similar processes should be adopted to be allowed in studies of any established treatments or other methods of health management.

With collection and handling of sensitive data, specific attention on data security and governance is needed. A single serious breach of confidentiality could lead to major problems, for example, if large numbers of people lose trust in collection, sharing and utilisation of sensitive personal data. Data security and privacy are partially open issues in AI solutions, which utlize cloud-based AI platforms with access to sensitive private health data at the level of detail making it possible to reidentify persons even when direct identifiers are removed. AI solutions for legal, secure and privacy-preserving data management are needed, and compliance with these requirements is an essential part of the research and development work. For example, it should be solved how we can carry out machine learning from different data storages without combining them.

AI applications have several potential ethical issues, which need to be properly recognised and addressed. These include issues related to preservation of privacy, an individual’s right to opt-out (e.g. decline to consent for secondary use of his/her data), and managing access rights for the data and related conclusions. For example, insurance companies and other payers as well as employers might use the risk profile of the individual for the purposes of client or employee selection in an unethical manner. Liability issues need also be solved - if AI is making decisions, who is liable for potential adverse outcomes?

As stated earlier, application of AI will cause significant changes in healthcare delivery during the next decades, change professions and jobs, and have potentially large economical impact. Public debate about these changes is necessary so that the citizens can understand the ethical issues and societal impacts caused by the use of AI for Health.

7. Opportunity - Strategic Research Agenda "AI for Health"

7.1 Summary of workshop outcomes

To initiate the scoping work towards the SRA, a series of open workshops was organised in in five cities: Oulu, Jyväskylä, Tampere, Turku and Espoo from 20.3. to 24.3.2017. An open invitation to participate was published on Tekes' web pages and emailed to potential interested organisations via VTT and Healthtech Finland mailing lists. The primary form of the work in the workshops was group discussions around a set of predefined topics. 121 experts (36 from industry, 63 from research/universities, and 22 from other organisations, e.g., health providers, funders, etc) took part in the workshops. All discussions were stored and analysed.

Overall, the use of AI technologies in health and wellbeing was well received among the participants and they felt the window of opportunity for an SRA AI for Health is now. Building on top of Finland's unique capabilities (high-quality longitudinal data registries, high-quality health and social care system, high competence in some spearhead areas) was considered important. Building partnership projects with critical mass, multidisciplinary collaboration and operative efficiency was seen as keys to success. Many of the technology-related challenges were considered easier to solve than non-technical issues such as attitudes and legislation. Support for the sufficiently large consortia to have impact, but sufficiently small enough to maintain synergy and efficiency was seen as important for the implementation of the SRA. The participants wished for long-term commitments from the public funding bodies to support translation from research into business. As the competitive landscape and technology is changing fast, quick progress from the idea phase to the funding approval and implementation were considered critical. Several participants emphasised the role of care providers in the research projects. Transparency of evaluation and ranking criteria for project selection should be emphasised and improved. A detailed report on workshop outcomes is available[37].

Based on the workshop feedback and the follow-up feedback via e-mail, the rest of Chapter 7 presents the suggested key targets, research themes, assets, and actions framework that provide the foundation for the AI for Health SRA.

7.2 Key breakthrough targets

AI for Health SRA targets towards the vision presented in Chapter 3, i.e., to make Finland globally recognised as a leading health and wellness innovation hub, known for its research, development and real-life implementations of AI-based and data-driven health and wellness solutions, which improve citizens' health and boost productivity in health and social care. Its breakthrough targets by 2025 are:

1. To become globally recognised as Cape Health - a leading health and wellness innovation hub in research and data-driven, AI-based health care and wellness products and services

2. To build a trusted high-quality innovation ecosystem attracting global investments in Finnish companies and research, characterised by

    a. An efficiently functioning PPP model for R&D and real life-experimentation, assessment and exploitation of AI for health approaches, which are attractive to both private and public partners, from industry (incl. both large-scale industry and SMEs) to academia and care providers;

    b. A technical, legal and funding infrastructure facilitating and accelerating development and research with easy access to necessary data assets and real-life experimentation and validation environments with risk sharing for activities targeting world-class scientific and/or commercial breakthroughs.

[37] Available on request

3. To foster economic growth of the Finnish AI for Health industry cluster[38], increasing the exports from the current ~€4B to ~€8B by 2025, and especially to facilitate high-growth of the SMEs into large spearhead companies in their domain

4. To significantly improve health and social care and wellness service productivity, and health outcomes

5. To improve health and social wellbeing-related decision making on individual, organisational, and societal levels via systematic and intensive use of data.

7.2.1 Key Performance Indicators (KPI)

The main Key Performance Indicators (KPIs) for the AI for Health SRA are listed below. Their numeric values can be set only when further details of its implementation are defined, including the level and form of funding, organization and consortium members, etc. The KPIs will be used as measurable criteria to assess progress towards the key breakthrough targets. The KPIs include:

1. economic growth to be compared between involved member companies vs non-involved members (control group), in terms of
    - number of jobs (#)
    - exports (€)
    - revenues (€)
    - private investments (esp. international investments) in member companies, new start-ups or by establishing new R&D operations in Finland (€)
    - new start-ups / spin-offs (# + revenues € after 3-5y)
2. new intellectual property
    - number of patents (#)
    - number of other registered or commercialised IP (e.g., SW)
    - number of new products or services (#)
3. scientific impact
    - scientific publications in peer-reviewed scientific journals and conferences with JUFO rating 2-3 (#) or 1 (#)
4. real life implementations

[38] Including: current Healthtech industry, software and service export, and non-regulated health and wellness products and services

- number of validated AI-based proof-of-concept solutions (#)
- number of nationally exploited AI-based solutions (#)
- number of internationally exploited AI-based solutions (#)

In addition, AI for Health SRA targets to improve health and social care productivity significantly as well as health outcomes (e.g., reduced morbidity, increased effectiveness and efficacy of interventions, QALY). However, these measures are not taken as KPI for the SRA as their quantification and especially identification of the specific impact of the current SRA on these targets within a relatively short timespan is impossible.

7.3 Key assets required for AI for Health activities

Key Assets are cross-cutting requirements to successfully implement the R&D in each of the priority research areas listed in Chapter 7.4. They are existing properties of the Finnish ecosystem that can give significant competitive advantage to the solutions to be developed. **Each activity implementing the SRA should address these Key Assets**.

Key asset #1: Data. The most significant Key Asset in Finland for AI for Health is the strength and uniqueness of the Finnish data repositories - especially their coverage, longitude, quality (but not size), and ability to link different data sources at the individual level. The quality of AI solutions is sensitively dependent on the quality and representativeness of the data and hence efficient utilisation of this Key Asset should be the main driver of the AI for Health SRA. Access to high-quality, longitudinal, large-scale multidimensional and multimodal biological, health care, and/or wellness (consumer-generated) data and possibility to use it for research and development should be ensured at a large scale to develop breakthrough AI-based innovations. This is especially important in Priority Research Areas focusing on improving prevention, prediction, diagnosis, and care of the patients. Also novel combinations of health data and other related data sources such as environmental monitoring, transportation, use of public services, and social media have the potential to become a key enabler of R&D breakthroughs. While access to valuable data repositories requires ethical and organisational approvals and patient consents, the activities intending to make use of such data repositories should provide a clear data access and management plan as a part of their project plans. The SRA activities should optimally support national initiatives to foster centralised data management (e.g., national biobank operator initiative), but should not be designed to be dependent on their timely implementation but rather ensure their access to critical data assets from early stages of the projects.

Key Asset #2: Fellowship. Commitment to true and strategic, long-lasting collaboration between key stakeholders in healthcare, academia and business is one of the key strengths of the current Finnish health technology ecosystem. Such a fellowship can foster innovative co-creation of future breakthroughs. Finland has high-level competences (education + research) in all key areas of AI for Health research agenda, with some clear spearheads, as well as strong core industry ecosystem with some spearhead companies and a strong SME cluster. Most importantly, Finland has a strong culture of public-private as well as medicine - engineering collaboration. This Finnish ecosystem, with its spread of skills, experience in winning in global markets, and commitment and ability to collaborate towards shared goals is a Key Asset, which the AI for Health SRA should further enforce and harvest. Activities should engage balanced consortia with a critical skillset and strong commitment to collaborate. Activities should engage with expertise in understanding legal, regulatory and other requirements in order to fulfill all the needed medical device and other applicable requirements on time to smoothen transforming results into global business. Creating business models on top of these solutions will require understanding the value network of social and health care services and the changing data-driven relationships between regulators, payers, public providers, market providers, technology providers and individuals.

Key asset #3: Infrastructure. Finland has a forward-looking and novel legal and operative health information infrastructure with a wide coverage of electronic health records, a modern biobank act, an act on secondary use of health information[39], a universal national identification number for citizens, and a long tradition in public funding for public-private, industry-academia, and biomedical engineering partnerships. In addition, there is a plan to create a nation-wide access system to health data repositories (incl. biobanks) in the com-

[39] In progress, to be approved during 2017

ing years (e.g., ISAACUS, biobanks). All this will offer unique opportunities for development and validating AI-enabled data-driven health and wellness services. However, it should be recognised that the current infrastructure is by no means complete and ready to optimally support AI for Health SRA. **Further significant strategic investments are required to implement the national health data infrastructure**, including interfaces, consent management, etc. Furthermore, to scale actions towards global dissemination and exploitation, it is necessary to analyse and take into account relevant international legal and regulatory frameworks, data sharing principles, data privacy and security, and ethical and societal issues. Activities should further leverage the Finnish ecosystem, infrastructure and its capabilities, contribute to enhancing the data infrastructure, and facilitate in attracting further investments (both public and private) to Finnish AI for Health innovation hub and related facilities.

7.4 Priority Research Areas for AI for Health

In the following, the Priority Research Areas (PRA) where the most benefits are foreseen with the use of AI for health and wellness are described. All PRA activities should target developing new innovations, products and/or services and utilise and elaborate the Key Assets (chapter 7.3 and Figure 8). Each PRA is aimed is assessed in terms of:

- <u>Data</u> - does the Finnish ecosystem provide access to unique data assets, which might generate unique competitive advantages in a global perspective?
- <u>Competences</u> - are necessary competences to address the PRA challenges available in the ecosystem, both in terms of quality (world class competence) and in sufficient critical mass, including potential industrial partners to exploit the results commercially.
- <u>Impact</u> - what would be the impact on *health and social care or wellness services* in case of success, especially in terms of health outcomes and/or productivity?
- <u>Global market potential</u> - what is the commercial exploitation potential of the results for global markets?

Potential impact on social and health care is differentiated from global market potential as the latter may often be reached by very focused, even niche, products and services, which may have an impact on the health outcomes of a limited number of individuals (e.g., care of rare illnesses) and are not sensitively dependent on national infrastructures and practices, while the former calls for addressing issues which constitute a significant fraction of the social and health care costs or productivity-related factors. Both forms of impact are addressable by the SRA as a whole, but through different actions.

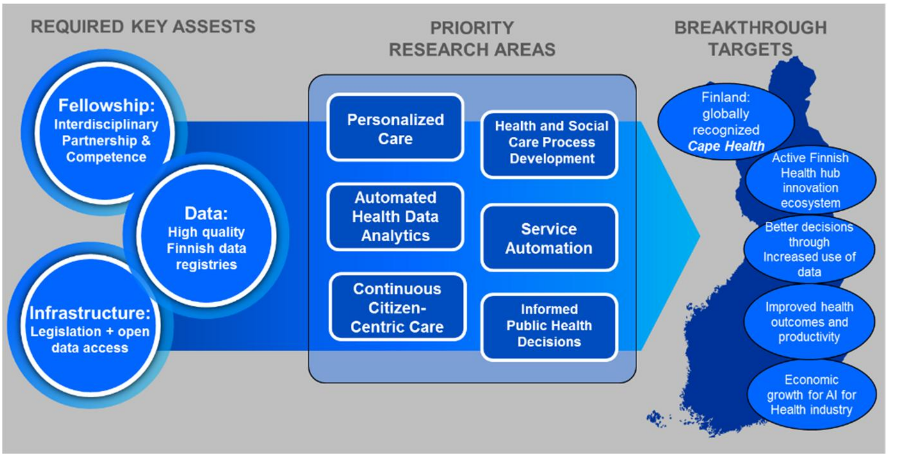

Figure 8. High level view of AI for Health SRA.

PRA #1: Personalised care[40]: Personalized medicine applies especially genetics and genomics to match patients and treatments and has been suggested as the next major revolution in healthcare[41]. Personalized care as a broader platform also includes any other information that helps predict risk for a disease or how a patient will respond to treatments. This PRA refers to procedures where health care treatments are designed specifically to match the unique characteristics of individuals. Relevant data may include (but is not limited to) genomic and other ‘omic’s data as well as other health and behavioural data including data from sensors. AI is a vital component in personalised medicine to analyse massive amounts of data e.g. to identify similarities between data from prospective individuals and the datasets of individuals who have been assessed earlier (e.g., biobanks) to identify the most promising individualised treatments. Activities in this PRA include: the development of methods for patient profiling (incl. in-silico models), diagnostics and/or personalised treatment selection based on large amounts of data from individuals as well as peer cohorts; data driven exploration and modelling of

[40] https://health.clevelandclinic.org/2012/05/what-is-personalized-healthcare/
[41] http://www.nature.com/nrclinonc/journal/v8/n3/full/nrclinonc.2010.227.html

disease mechanisms and progression models; real-life implementation, validation and evaluation of personalised care applications. The primary target is to improve health outcomes of individuals by timely and personally optimal interventions, either preventative or curative.

#1: Personalized care	Data: Unique data assets, especially quality, longitudinity and ability to combine data from different registries on individual level Competence: World-class medical research, big data analytics and AI, some spearhead companies Impact: Potentially significant impact on health outcomes on individual patients Global market potential: Significant global market potential, solutions often exploitable/scalable in global markets with reasonable effort

PRA #2: Automated health data analytics: Challenges in data driven health and social care are transferring from acquisition and providing access to data into its interpretation with an affordable amount of human labor. Up to 80% of the effort in AI solutions is ofter required for data pre-processing - curation, cleaning and quality assessment. Automated analysis and curation of complex health data - from biological to imaging, electronic health record, and sensor data - require expert knowledge, skill and manual labor for reliable quantification and interpretation. Examples of such tasks include automated segmentation and analysis of medical images, annotations of long-term recordings of biomedical signals, analysis of long-term wearable sensor data (e.g., multimodal monitoring of patients and elderly at home with unobtrusive sensors, or 24/7 monitoring of activity and beat-to-beat heart rate of the employees for stress and recovery analysis). With the development of IoT technology and wearable sensors, the challenges of applications in health and wellness are transforming from acquisition of the data into its interpretation with affordable amount of human labor. This PRA calls for activities to develop and validate AI-based methods to automate the curation, pre-processing, validation, cleaning, quantification and interpretation or classification of complex, multimodal health and wellness data, with applications ranging from critical care to consumer wellness. The applications should demonstrate valid performance as compared to manual work as well as improved cost-effectiveness.

#2: Automated health data analytics	Data: Significant and sometimes unique data assets, including imaging, wearable sensor data, physiological databases. Competence: World-class biosignal and image processing, data analytics and AI, several spearhead companies Impact: Potential high impact on health outcomes and on healthcare productivity Global market potential: Significant global market potential, results often exploitable by global markets

PRA #3: Continuous citizen-centric care: Prevention and management of chronic conditions require continuous, predictive, personalised and participatory actions, including lifestyle support / counselling. In this approach, the citizen is the key co-producer of health. This PRA includes actions to improve continuous proactive and preventive management of health and wellbeing of individuals by automatically monitoring and integrating information from various sources and utilizing AI to provide intelligent analysis and interpretation of the current health status as well as forecasting its progress. Activities may contribute to AI-based coaching to improve engagement, adherence and motivation of the individuals towards healthier lifestyle in community settings, with minimal professional participation; and real-life implementation, validation and evaluation of AI-based health and wellness management applications. Applications may range from elderly care to chronic disease management or prevention, and to improvement of wellbeing and performance in healthy individuals (e.g. sports, corporate wellness). A specific challenge is to develop AI solutions able to engage people (and keep them engaged in the long term) in maintaining and / or improving their health.

#3: Continuous citizen-centric care	Data: Unique data assets, especially quality, longitudinity and ability to combine data from different registries on individual level (both health and social care, and wellness data) Competence: World-class medical, health and wellbeing research, data analytics and AI, some spearhead companies Impact: Potentially significant impact on health outcomes on individual patients and health care transformation to P4 approach Global market potential: Significant global market potential, results often exploitable to global markets

PRA #4: Health and social care process development: Effective and efficient health and social care aims to provide *right actions at right time on right patients/clients.* This PRA applies AI to improve the productivity, i.e., *value produced per euro spent*, in health and social care as well as wellness services. Activities include AI and data driven intelligent forecasting of resource needs, optimal and predictive care path planning, predictive outcome analysis, and intelligent scheduling and resource organisation. Activities should target a productivity leap (in health and social care or wellness service provision based on more efficient use of resources, improved outcomes, improved throughput rates and/or reduced waste of efforts. Utilised data includes typically organisational and/or population (cohort)-based data but may also include individual-level data.

#4: Health and social care process development	Data**:** A lot of data available, uniqueness in combination of different data sources. Competence: Data analytics and process optimisation for primarily domestic applications in some instutions and companies. Impact: Potentially very significant impact on health and social care productivity Global market potential: Solutions often local, not easy to globalise.

PRA #5: Service automation in health and social care: AI can enable new ways to deliver health and social care as well as to improve productivity by reducing the need for routine human intervention and customer interaction, freeing personnel time to focus on the most value-adding care activities. This PRA focuses on applications of service automation in health and social care. Activities include: application of chatbots (e.g., counseling, time booking, information enquiry, triage), development of AI-based user interaction for health and social care systems, automated transformation of information between different systems, and NLP (Natural Language Processing) applications. An essential component of the automated processes enabled by the AI is the accurate identification of situations where human communication is required instead of AI (e.g., identification of life-threatening conditions). Activities should target disruptive products and services, which utilise AI and demonstrate improved productivity, improved access to care and/or reduced wait times, better client satisfaction, and improved accuracy of management of unstructured information (esp. text, speech).

#5: Service automation in health and social care	Data: A lot of data available, but no national unique assets. Competence: Some academic research + SMEs specialised in the processing of Finnish and Swedish languages. Impact: Potentially very significant impact on health and social care productivity Global market potential: Solutions often language and culture specific, global market reach challenging/limited

PRA #6: Informed society public health decisions: The impact of health-related policy decisions in society are difficult to predict and require complex modelling of the entire system (society). Single actions such as changing the taxation of alcohol or reducing the reimbursement rate of prescription medication may have unexpected long-term effects that are caused through complex networks of causal changes. The target of this PRA is to improve health and social wellbeing related decision making on individual, organizational, and societal levels via systematic and intensive use of data. Big data analytics and AI can help in planning the optimal population-level strategies, e.g., for disease screening and other public health campaigns.

#6: Informed society public health decisions	Data: A lot of data available, uniqueness in combination of different data sources (nation wide registries) Competence: Competencies in health care and health economics research and big data analytics, very limited number of companies Impact: Potentially significant impact on health and social care productivity, health outcomes and public policy in the long term Global market potential: Very limited commercial exploitation potential but may help in building Cape Health brand

The following table summarises the different priority areas in terms of their assets in data and competence and in their potential for health and social care impact and successful global market exploitation.

Priority Research Area	**Access to unique data**	**World-class competence**	**Healthcare impact**	**Global market potential**
#1: Personalized care	+++	+++	++	+++
#2: Automated health data analytics	+++	+++	+	+++
#3: Continuous citizen-centric care	+++	+++	++	+++
#4: Health and social care process development	++	+	+++	+
#5: Service automation in health and social care		+	+++	+
#6: Informed society public health decisions	+	++	++	
Rating +++	significant competitive edge or potential impact			
++	moderate competitive edge or potential impact			
+	some competitive edge or potential impact			

The AI for health PRAs presented above vary significantly in terms of their potential health care impact on one hand, and global market potential on the other:

- PRA #1-3 leverage Finnish health data repositories and technology competences, have strong support within existing Finnish industrial players, and significant commercial potential globally in case of successful development and validation. The client for the resulting products and services is typically either a health care professional or in some cases an individual citizen and the impact on health outcomes and/or treatment or management specific diseases may be significant. These PRAs may be supported, e.g., by innovation funding and investments in technology development, testing, validation (evaluation) and exploitation.
- PRA #4-6 address areas with significant health and social care spending and focus on applications of AI for improving health and social care and wellness service productivity;

hence their impact on health care costs and/or health outcomes may be very significant. The client of the resulting services is often a health and social care provider. These PRAs are strongly driven by health care cost crisis and health and social care reform, and resulting products and services have often strong dependencies on cultural and national factors such as language, reimbursement policies, and overall health data infrastructure implementation. The development of these innovation areas may be supported by innovation funding, but also by innovative procurement practices and close public-private partnerships in development and early use of novel solutions.

AI for Health technology enablers: In addition to the above mentioned PRAs, activities related to key technology enablers for using AI for health should be promoted. These include especially the development of concepts and tools for security and privacy preserving solutions which are required to meet the regulatory and legal demands to manage the ownership, privacy and security of the patient data while using machine learning and AI solutions. These solutions may have significant global market potential and may play a key role while rolling out solutions to health and social care real life implementations.

7.5 Action recommendations

To succeed in making R&D and business breakthroughs, the SRA action portfolio should follow these recommendations:

Action recommendation #1: Establish strategic public-private partnerships (PPP). Addressing the PRAs successfully requires close strategic collaboration, spanning over several years and often beyond a single project, between industry partner(s) and SMEs, health care organisations and professionals, and research partners. The consortia need to be balanced in terms of type of organisations and competences, and have a strong commitment to collaborate towards a shared vision. Clear rules and model contracts and practices for data access, including a financial cost model and IPR are essential. Company-driven PPP projects must be ambitious and accountable for reaching the results, and success should be awarded, e.g., as next stage funding, e.g., as innovative public procurements.

Action recommendation #2: Focus R&D to leverage existing strengths. Actions should be focused and leverage existing spear-hed competences and assets where globally significant competitive edge may be identified. Taking into account the rapid pace of development in AI, the PRAs should not be considered restrictive and they should be updated during the implementation of the SRA.

Action recommendation #3: Secure access to Key Assets. Actions must demonstrate timely and sufficiently wide access to the necessary data assets (quality & quantity) from the early phases of the project. Projects which take advantage of the unique health data assets should be prioritised. Consortia must include critical competences with world-class quality and critical mass in key areas, with will and experience in successful interdisciplinary collaboration, and strong commitment to the project and collaboration. Actions must specify how they ensure compliance with legal, privacy, regulatory and ethical requirements.

Action recommendation #4: Keep workplan agile with focus on well defined objectives. Project implementation should follow agile principles where objectives are well defined but workplan may be dynamically adapted when and if needed to reach the objectives. Workplans should define final targets and vision, measurable milestones, and concrete KPIs, including plans for commercialisation and international dissemination. Detailed workplans should only be provided a maximum of one year at a time to avoid over-planning and fixation to tasks instead of goals.

Action recommendation #5. Invest on continuity. Funding should be committed for 3-5 years to ensure continuity and reduce overheads of forming the consortia and ramp up / ramp down costs, and to enable participation of different partners with different planning horizon. Progress should be reviewed at least annually, with possibility to budget re-allocation within consortium, including controlled changes in the consortium. Different funding instruments should be applied for different PRAs and/or different stages of the R&D. Sufficient academic research funding (e.g., via the Academy of Finland) is critical to maintain and improve competiveness of the domain in the long term. Coordinated funding via various instruments would increase impact, and participation of varying funding instruments, including private funding (e.g., VC funds) in later phases of the roadmap is desirable.

Action recommendation #6: Ensure scaling and adaptation to market, from local to global. Actions must support new innovations, products, and services targeting selected global markets in the long-term, or significant health and social care impact. Finnish infrastructure should be used as a launch pad towards selected target markets, and as a reference/spearhead implementation demonstrating the value of AI for Health applications. The regulatory environment and legislation in the target markets need to be included along the way towards the adaptation to these markets. Concrete international collaboration and dissemination must be on the roadmap. Real-life implementations with sufficient scale to validate solutions and evaluate their impact with convincing power should be targeted.

Appendix A. List of interviewee's

The following individuals were (informally) interviewed during the SRA preparation process:

Timo Ali-Vehmas, Nokia Technologies

Saara Hassinen, FiHTA

Visa Honkanen, HUS

Holly Jimison, Tampere University of Technology & Northeastern University, Boston, USA

Pekka Kahri, THL

Michael Kearney, IBM Research

Juha Kinnunen, KSSHP

Jani Kivioja, Nokia Technologies

Harri Kulmala, DIMECC

Juha Laurila, Nokia Technologies

Martti Lehto, University of Jyväskylä

Pekka Neittaanmäki, University of Jyväskylä

Reijo Paajanen, Prinnox

Misha Pavel, Tampere University of Technology & Northeastern University, Boston, USA

Matti Ristimäki, Tieto

Niilo Saranummi, VTT (emeritus)

Tero Silvola, BC Platforms

Pasi Tyrväinen, University of Jyväskylä

Chris Ulum, IBM Research

Hanna Viertiö-Oja, GE Healthcare

Matti Vänskä, Nokia Technologies

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Title	**Strategic Research Agenda (SRA) on “Finnish Innovation Hub for Artificial Intelligence for Health (AI for Health)”**
Author(s)	Ilkka Korhonen, Miikka Ermes & Jari Ahola
Abstract	In February 2017, Tekes initiated a coordination and collaboration action to define a Strategic Research Agenda (SRA) to promote research, development and exploitation of Artificial Intelligence (AI) and use of digital health data and big data in health and wellness research and business, and health and social care delivery ("AI for Health"). The SRA preparation was launched to propose actions to further analyse these needs and opportunities, and propose actions in the area of AI for health. AI for Health SRA aims towards the vision of making Finland a globally recognised leading health and wellness innovation hub "Cape Health", known for its research, development and real-life implementations of AI-based and data-driven health and wellness solutions, which improve citizens' health and boost productivity in health and social care. In this vision, Cape Health is continuously producing global success stories and breakthroughs in data-driven health products and services as well as new scientific discoveries. Citizens benefit from this through improved health and wellbeing, efficient and timely preventive, participatory, personal and personalised health and wellness services, and through increased economic growth. Cape Health activities improve health and wellness service productivity and health outcomes, increase exports of health and wellness technology goods and services, and generate new jobs for both technology companies and the health and wellness service industry. The scoping work identified six priority research areas where the most benefits are foreseen with the use of AI for health and wellness: 1) Personalised care, 2): Automated health data analytics, 3) Continuous citizen-centric care, 4) Health and social care process development, 5) Service automation in health and social care, and 6) Informed society public health decisions. To succeed in making R&D and business breakthroughs, the SRA action portfolio should: 1) establish strategic public-private partnerships (PPP); 2) focus R&D to leverage existing strengths; 3) secure access to Key Assets, especially data; 4) keep workplans agile with a focus on well defined objectives; 5) invest in the continuity of R&D, from research to development and deployment, including commercialisation; and 6) ensure scaling and adaptation to market, from local to global, both from business, regulatory and commercial viewpoints.
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Strategic Research Agenda (SRA) on "Finnish Innovation Hub for Artificial Intelligence for Health (AI for Health)"

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