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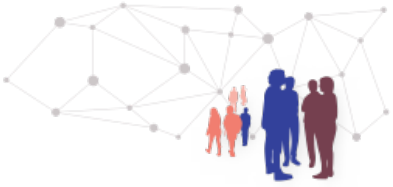

Artificial intelligence in medicine - Case Study «Prevention»

DSI Strategy Lab 2022

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This case study was created in a systematic and participatory process as part of the «Strategy Lab Artificial Intelligence of Medicine» of the Digital Society Initiative (DSI) at the University of Zurich. The process, which involved various stakeholders, extended from the beginning of 2022 to mid-2023. In particular, a workshop with experts in June 2022, a workshop with doctoral students of the DSI Excellence Program in August 2022, and the testing of excerpts of the case study in various events with stakeholders were decisive for the creation of the case study.

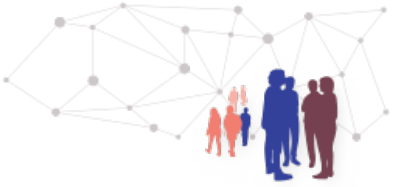
Participants in the expert workshop, in addition to the editorial team, were: Abraham Bernstein, Daniel Eberli, Philipp Fürnstahl, Sven Hirsch, Christian Kauth, Emanuela Keller, Birgit Kleim, Tanja Krones, Titus Neupert, Cristina Rossi, Bernd Stadlinger, Florent Thouvenin and Andreas Wicki. Participants of the PhD workshop were Anais Aeschlimann, Ibrahim Al Hazwani, Joe Baumann, Giulia Frascaria, Marius Furter, Alexandra Ioana Georgescu, Maël Kubli, Alexander Lill, Eanuele Martinelli, Judit Martínez Moreno, Matteo, Micol, Markos Mpadanes, Kimon Papadopoulos, Amina Saleh, Jana Sedlakova, Kateryna Shapovalova, Lukas Tribelhorn, Morley James Weston, Basak Yalman, Federica Zavattaro and Donatella Zingaro. We thank all of these individuals is for contributing to this process; in particular, Jeffrey David Iqbal for providing operational guidance throughout the Strategy Lab process.

Further information: dsi.uzh.ch/strategy-lab.

Structure and use of the case studies

The in total four case studies evolve along a temporal progression with a parallel increase in the level of autonomy of the AI application, as follows: the case study starts in the (fictional) «now» using AI with a very limited level of autonomy. It progresses to the «near future» with greater involvement of AI in the decision-making process. Finally, in a «far future scenario», it will be played out that an AI makes relevant decisions largely autonomously (as an «avatar» or «digital twin»). A precise temporal allocation of the scenarios is not attempted. The scenarios are fictitious in nature and were framed rather as «positive utopias» than «negative dystopias», although several aspects of the case studies are intended to be provocative and they should trigger ethical debates regarding the desirability of the scenarios as outlined here.

Comparatively simple language has been chosen; technical terminology has been avoided as far as possible so that lay people can understand the case studies. Factual statements are referenced only



minimally (the scenarios are, after all, fictional in nature), supported by few references that are as accessible to a general audience as possible. When creating the scenarios, care was taken to ensure that there were connections in terms of content between the fictional case stories.

The case studies are available «open access» with the intention that they can be used in educational settings and/or workshops discussing AI applications in medicine (license CC BY-SA). The keywords indicate topics that characterize the case studies. Suggested questions after each «step» further guide their use in workshops and discussions.

Keywords: AI, Cancer, Digital Twin, Health Data, Mobile Coach, Prevention, Social Media Data, Wearables

1 Introductory remarks

Many people continue to die from cancer, and cancer survivors often have a reduced quality of life due to the disease and side effects of cancer therapies. Cancer is one of the greatest health challenges of our time – also due to its frequency. In Switzerland, for example, approximately 51% of men and 39% of women will be diagnosed with cancer during their lifetime, with the risk increasing with age [1]. Around 19% (men) respectively 14% (women) of all deaths in Switzerland are caused by cancer.

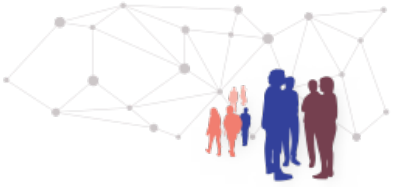
An important risk factors for the development of cancer is aging, attributed to cumulative exposures to carcinogens with increasing age and a decreasing endogenous repair capacity. However, hereditary factors may also play an important role. In addition, there are external risk factors such workplace and environmental exposures (e.g., air pollution, radon or other radiation exposures) or agents of chronic infections such as hepatitis B and C. Finally, behavioral risk factors also play an important role. These include smoking, alcohol consumption, unhealthy diet, lack of exercise, overweight and obesity, and UV radiation without adequate protection. Sociodemographic factors such as poverty are associated with many of these individual and environmental risk factors.

In this hypothetical case study, the aim will therefore be to: 1) measure risks for developing cancer and predict individual probabilities of developing cancer, and 2) make recommendations for individual preventive measures to reduce the risks for developing cancer in the individual and in the population. The goal is to reduce both the prevalence of cancer in the population and the number of deaths from cancer. The case study will focus on prevention measures on behavioral risk factors (including diet and physical activity) and thus disease prevention. This involves digitized recording of lifestyle behavior and digitally supported measures for a health-promoting lifestyle. The case study does not exist in this form, all names of persons and companies are fictitious.

2 Case study level «Now»

2.1 Situating the scenario

An innovative team of health experts and data scientists, together with citizens, has developed a new interactive health record for cancer prevention: Interactive Cancer Prevention Record or «ICPR» for short. This enables personalized cancer prevention for any person, bringing together data from their own medical care (e.g. medical history, lab results, imaging) but also data from so-called «wearables» (e.g. smart watches), online behavior (e.g., extractable from social media posts) or data added manually (e.g. regarding diet or risk factors). The data collected in ICPR is linked with databases holding the latest



results of cancer research. In combination, these sources of information feed the training cycles of artificial intelligence algorithms, which learn to estimate individual probabilities for the occurrence of cancer and to make individual recommendations to reduce the risk. The corresponding information compiled in a report can be discussed with the primary care physician or prevention specialist.

We assume that ICPR's security standards are very high and are presented transparently. They are regularly reviewed by an independent institution. Only the person concerned and health professionals to whom the person allows access can view the personal data contained in ICPR. In anonymized form, however, the data can also be used for research projects that benefit all participants. Health insurance companies can also participate in the project but they also do not have access to the personalized data.

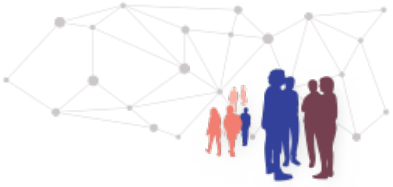
2.2 How it could work

Our leading character in the story is Reto. His father had colon cancer, as did his grandmother. Reto knows that exercise reduces the risk of developing cancer. He wants to act accordingly and therefore he bought a new smartwatch to better monitor his physical activity and improve his motivation to exercise. His health insurance company has also recently informed him about the cancer prevention file ICPR and Reto sees on social media that many are enthusiastic about it. Reto decides to participate in the project and looks closely at the information on the website. In particular, the security of the data, and what happens to it, is presented in detail. The website also explains what data can be fed in, how to do this specifically and which apps and wearables are compatible with ICPR. He is surprised at what can be measured and is excited about the idea that he can then get individualized recommendations for cancer prevention. He already knew that he should exercise 2.5 hours a week and that smoking is a problem – but he wants recommendations that will motivate him to adopt the right habits. Since he always wears his smartwatch and has it unlocked for ICPR, his exercise and sleep data are automatically transferred to the record.

He grants access to his primary care physician, who loves tech tools, and has uploaded all the medical information already available to ICPR. He also has no problem with his data being used in anonymized form for research. Because he donates his anonymized data for research, he gets a small reward, although his main motivation is altruistic. However, Reto opted to not share any data with his health insurance at this time, as he is not quite sure what they really want to do with this data. But he could imagine allowing the insurance company anonymous access to the data one day if his premium is reduced in return.

Next week he has an appointment with his primary care physician and he would like to talk about sensible lifestyle adjustments with him. That is why he has decided to use ICPR's analysis and reporting tool. The process for doing so is a bit more time-consuming as he has to agree in detail to each data source the AI can use and he as to decide upon sharing the results of the analysis. However, he feels that he understands what the data is being used for and what benefit each step yields.

After a short calculation, the result follows: The analysis shows an increased risk of colorectal cancer for Reto and he receives the recommendation to reduce red meat (he had a lot of beef steaks last month...) including possible alternatives (fish, tofu). He is also advised to double the amount of fiber and receives suggestions on how to easily implement those changes within his diet. Reto also receives recommendations regarding his training schedule and sleep hygiene. Therefore, he realizes that his data from the smartwatch was also taken into account in the analysis. He decides to activate a Plugin for his favorite chatbot, such that it can access the ICPR and coach him to implement his goals for food, sleep and exercise.



However, the increased risk of cancer in the report worries him a bit. Thus, he wonders whether behavioral changes are really the relevant way of reducing his cancer risk. He is living at a busy street and wonders, whether pollution is a factor as well – but leaving his cheap apartment is currently not an option. Therefore, he is glad that he will be seeing his primary care physician next week who is well-skilled in explaining everything clearly.

2.3 Possible questions for discussions

What do you like about the ICPR, what do you dislike? What are the dangers? Which consequences would have such a close monitoring of the individual health on hypochondriac characters? Would you use ICPR yourself? Which aspects of the scenario do you consider realistic, which not? How should the scientific basis for the recommendations be found?

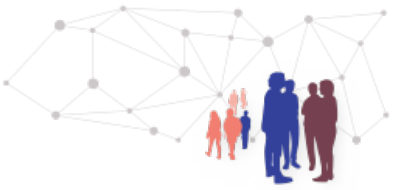
3 Case Study Level «Near Future»

3.1 Situating the scenario

The interactive cancer prevention file ICPR, a service that several providers are offering under state-supervision, has gained widespread adoption and has been constantly improved. 75% of the population participates, in particular younger people. Cancer risk in the population has decreased significantly and dietary and physical activity habits have improved. Consequently, the frequency (prevalence) of other lifestyle diseases such as diabetes has also decreased. The record processes for the ICPR have been significantly improved and data transfer is easy and works with almost all wearables and apps. Data sources have been expanded to include sensors in the home and car as well as environmental data. The analyses and recommendations are individualized, use different AI models that are constantly learning and take place *just in time.* ICPR provides tips and tricks for everyday life that are adapted to the relevant situation. One can choose between different «mobile coaches» and even include family and friends as social support. One such coach is LITO; an AI chatbot that you can configure so that you enjoy listening to it.

In the meantime, health insurance companies have also become more involved in ICPR. If people book ICPR with their health insurance company, they can chat directly with a human health coach or a physician. Health insurance premiums are also significantly lower if you participate - certainly one reason for the widespread adoption of the ICPR. Furthermore, public health is also using ICPR data to improve general living conditions that also affect cancer risks. For example, ICPR data is used to change labor law in order to improve the protection of employees working in certain industries.

However, a minority has reservations about the ICPR ecosystem. Many of them are associated with the «Back to Analog» (BATA) movement, which is generally skeptical of digital technologies dominating everyday life. Some feel manipulated by apps like ICPR while others want to accept more risk for greater enjoyment of life. Those may not enjoy being reminded by ICPR that it is not a good idea to eat this bratwurst or smoke that cigar. In addition, there are increasing reports in the media of a new condition, «lifestyle optimization stress», which causes physical and psychological symptoms. This, in turn, was used as an opportunity to implement regular stress measurements in ICPR and to individualize the communication of the analysis results and recommendations in such a way that they trigger as little stress as possible in the individual person.



3.2 How it could work

For many people, it is hard to imagine everyday life without ICPR. Reto is one of them. Due to his family history, Reto is afraid of getting cancer and desperately wants to age in full health. He has therefore decided to make maximum use of ICPR. However, his wife Rahel – she is not quite sure whether she sympathizes with BATA – has reservations, because she does not like to be patronized, not even by technology. Thus, she is more reserved and she has opted for minimal support from ICPR. While she also wants to reduce her cancer risk and has her diet and exercise monitored, she has decided against just-in-time analysis and ongoing recommendations. Instead, she requests a report every month, which she then discusses with a health coach. As a result, Rahel is willing to pay more for her health insurance than Reto. She also reads the security reports on ICPR every month, as she remains concerned that her data is not as secure as promised.

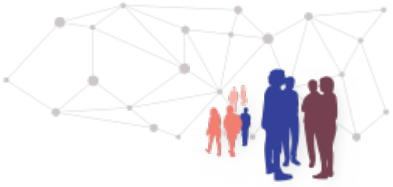
Reto, on the other hand, loves it digital and likes to save on health insurance premiums. He chose LITO as his «mobile coach». He has also had all other available data sources linked to ICPR. For example, it allows him to check the extent to which a particular airplane trip will change his risk of developing cancer (because of high-altitude radiation) before he books. He has not seen his own primary care physician for a long time. When he gets sick, he follows LITO's recommendations. He has also installed new sensors in the apartment that measure, for example, exhalations in the air he breathes, which can indicate cancer risks. His son – who works for a startup in the field – has set the sensors to capture only the data of Reto and not the data of Rahel (a new technology called «selective privacy»). Eventually, he hopes to convince Rahel to take advantage of ICPR's full functionality, too. Then he could switch to sensors that can measure much more data more precisely.

For Reto, it is part of his daily routine that the sensors assess which food he is eating and then to receive recommendations that can be implemented directly – for example, that he should better have fruit instead of chocolate mousse for dessert. He also likes it when LITO praises him when he implements the recommendations. He does this even better since he formed a group with three colleagues, who are all coached by LITO and who can comment on their recommendations. LITO makes sure that they motivate rather than frustrate each other. Reto listens intently as LITO tells him how each recommendation will affect his cancer risk.

However, Rahel has alerted him to the fact that lately he seems to be very stressed when the cancer risk goes up. He himself realized that when checking his heart rate. Therefore, he has participated in a new ICPR pilot project where LITO checks his stress level after each recommendation my measuring various parameters such as heart rate. He notices that LITO started communicating risk to him in a way that is less upsetting.

3.3 Possible questions for discussions

What do you like about ICPR, what do you dislike? How wide should the «decision space» for ICPR be? Would you use ICPR yourself and in what form? What are the dangers? What do you like about the mobile coach, what do you dislike? Which aspects of the scenario do you consider realistic, which not? Do you believe that a system like ICPR really would work; if not, what would be the reasons for potential failures? How realistic do you consider the risk for «lifestyle optimization stress»?



4 Case Study Level «Far Future»

4.1 Situating the scenario

Now we are in a distant future in which everyday life is so naturally determined by digitalization that hardly anyone notices it. Data security and data ownership are regulated and there is no need to worry about them under ordinary circumstances. Health prevention is widespread – and not just for cancer. Health profiles are being created for individuals as well as the population, incorporating all available data including genetics, family medical history, social determinants of health, environment, pandemic predictions, etc. The AI models that generate these profiles are constantly learning. Diseases have become rare or are detected early and people have reached a life expectancy of almost 100 years. Many people now use the service of a «digital twin» that can be used to simulate the effects of certain medical interventions to avoid mistakes. Mobile coaches such as the former LITO, which were still available as voice-only apps, can now appear as true-to-life holograms and thus interact with people. Technical implants or replacing body tissues and organs grown by stem-cell technologies are also available, although social differences still manifest themselves here – not everyone can afford the best implant available in each case, for example.

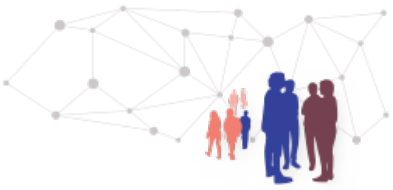
Many people are willing to be coached in their behavior by AI. For example, food orders can be triggered automatically based on the measurement of physiological parameters – you get the appropriate nutrients at the right time. Nevertheless, it is up to people to decide to what degree they want to delegate such decisions to AI systems. People can also choose between different health models and digital twin services. They can still have personal contact with health workers if they want to. However, health insurance premiums depend on the model chosen. Almost all people have chosen a digital health model that coaches people comprehensively, so they do not have to worry about almost anything regarding their health. But there is a small community of people who fundamentally reject such a way of life. These have built a parallel society with its own schools and medical care. They may have a shorter life expectancy, but they seem happy.

4.2 How it could work

Neni flies on vacation with her friend Rita. They thought it over carefully and checked their risk profiles because of the radiation exposure when flying. They have also chosen the vacation destination according to recommendations from their AI. They will continue to rely on their AI during the vacation to live as healthy as possible. Both are aware of their basic risks: Rita has a slightly increased risk of breast cancer due to a genetic predisposition and Neni had injured several ligaments in her foot while playing basketball 3 months ago and had not in her usual exercise routine since then.

Rita subscribes to a model where she can also have consultations with health care professionals, which she likes to use to discuss her AI's recommendations. However, she also pays higher premiums for her health insurance because of this. Both use a digital twin service. Rita listens to the suggestions from the real-time simulations, which her avatar delivers with humor – just the way she likes it – and then decides.

However, Neni has chosen – because her grandfather Reto advised her – a very comprehensive digital health model where all health-related decisions are made by AI. This results in savings on health insurance premiums. She trusts that the recommendations will be directly implemented by AI, for example by adjusting her food order or automatically modifying her exercise program, in which her mobile coach appears as a hologram. In addition, the physiological measurements in her implants are constantly adjusted by AI to the new situation without her even noticing. She is glad that she decided



to get an inner ear implant 3 years ago, when her hearing decreased a bit; this way she can play the violin better again, but can also receive podcasts directly in her ear.

On the flight, Neni is fascinated to hear about a community of dropouts who reject everything digital and have retreated to the Swiss mountains. Retreats are offered there for digital detox. She has to laugh about it. And then her thoughts turn to her foot: if it doesn't work perfectly again in the next 6 months, she would have a foot prosthesis made, as recommended by her AI, so that she can participate in the marathon again without any problems.

4.3 Possible questions for discussions

What kind of health care model would be interesting for you, that of Rita or that of Neni? What do you think about digital twins? Which aspects of the scenario description do you consider desirable, which not? Where do you see dangers? How realistic do you consider such a «best-case» scenario? Which of the current global problems may counteract the evolution towards such a «best case» scenario? And it this really a «best case» scenario?

5 References / Links

[1] https://www.bfs.admin.ch/bfs/de/home/aktuell/neue-veroeffentlichungen.assetdetail.19305696.html