

Future Trends Report 2019

Community studies: Healthcare

Group Members

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a. Introduction, Background and the Current Situation

What is the fourth Industrial Revolution?

The Fourth Industrial Revolution (4IR) is about rapid advancements in communications and connectivity (Schwab, 2016), ushering a new era when technology is merging with our physical lives (Schulze, 2019). There will be many profound effects on our society, affecting every single aspect of our lives. Such impacts include the massive loss of jobs in certain sectors, like the automobile industry, while also a manpower crunch in other sectors like the medical and retail industries. Up to 20 million jobs will be lost to AI by 2030 (Taylor, 2019). The healthcare industry, according to our interviews, in Singapore is facing a manpower crunch in the healthcare sector, where human touch and interaction are key, thus showing that manpower is vital in the healthcare industry.

Why Healthcare?

We chose to focus on the topic of healthcare, as it is a sector where many still feel that humans have a major role to play in it. Multiple researches have shown that human touch helps with fear, and also soothes our pain (Dobson, 2006). We also chose to further our research on Gynecology and Eldercare due to the wide applicability to the general population, and also due to the high vulnerability of their mental states during these periods. Hence, a manpower shortage, which might be brought about by automation, might influence the welfare of such communities, deteriorating public trust and confidence in the AI era of healthcare. Besides that, due to the fact that current healthcare AI system is not robust enough and is vulnerable to cyber attacks, as seen from the recent SingHealth Breach in Singapore, we aim to investigate some insidious problems facing the healthcare sector as far as AI is concerned.

Current Situation

1. Stage of AI application in Healthcare

AI is employed more and more widely in the healthcare industry, with a report published in 2018 showing that 86% of provider organizations, technology vendors, and life science companies use some form of AI by 2018. The rest 14% claim that they will do so by the year 2020. (Tata Consultancy Services, 2018) Healthcare professionals in Singapore are using artificial intelligence (AI) for clinical diagnosis more than their counterparts in most other countries, ranking the third in survey on the use of AI in healthcare. Among the 15 countries surveyed for the Future Health Index by Dutch technology company Royal Philips, Singapore had, at 28 per cent, the third-highest percentage of healthcare professionals who said they use AI to improve diagnostic accuracy. The figure is above the overall average of 21 per cent among the countries. (Kurohi, 2019). Hence, it is an irresistible trend that AI will play an important role in the years 2030 and beyond.

2. Stimuli for AI application in Healthcare

The advantages of AI have been extensively discussed in the medical literature. (Patel, Shortliffe, Stefanelli, 2009). AI can **i)** use sophisticated algorithms to ‘learn’ features from a large volume of healthcare data, and then use the obtained insights to assist clinical practice. It can **ii)** be equipped with learning and self-correcting abilities to improve its accuracy based on feedback. (Fei, Yong, Hui, 2017) An AI system can also **iii)** assist physicians by providing up-to-date medical information from medical journals, textbooks and clinical practices to inform proper patient care. (Pearson, 2011) In addition, an AI system can **iv)** help to reduce diagnostic and therapeutic errors that are inevitable in the human clinical practice. (Lee, Nagy, Weaver, 2013) Moreover, an AI system **v)** extracts useful information from a large patient population to assist making real-time inferences for health risk alert and health outcome prediction. (Administration UFaD, 2013)

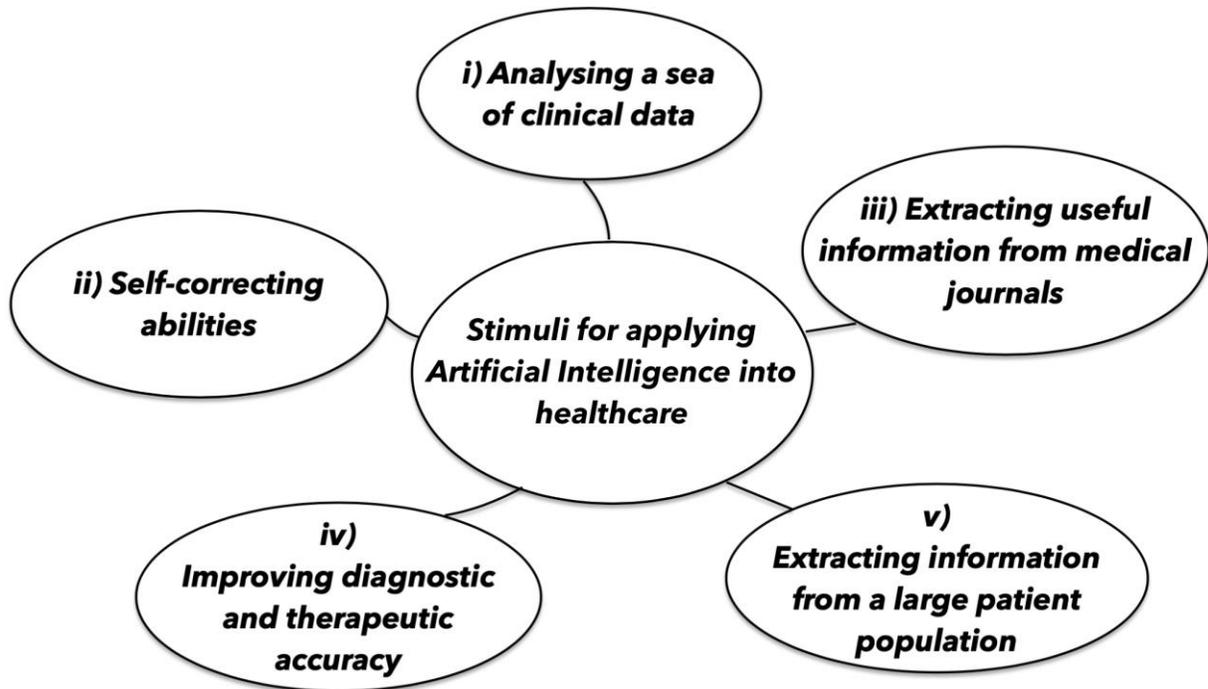


Figure 1: Stimuli for applying AI into healthcare. Source: Fei, Yong, Hui, 2017.

3. Healthcare Data

Before AI systems can be deployed in healthcare applications, they need to be ‘trained’ through data that are generated from clinical activities, such as screening, diagnosis, treatment assignment and so on, so that they can learn similar groups of subjects, associations between subject features and outcomes of interest. (Fei, Yong, Hui, 2017) These clinical data often exist in but not limited to the form of demographics, medical notes, electronic recordings from medical devices, physical examinations and clinical laboratory and images. (Administration UFaD, 2017) Specifically, in the diagnosis stage, a substantial proportion of the AI literature analyses data from diagnosis imaging, genetic testing and electrodiagnosis.

4. AI Devices

Healthcare AI devices mainly fall into two major categories. The first category includes machine learning (ML) techniques that analyse structured data such as imaging, genetic and EP data. In the medical applications, the ML procedures attempt to cluster patients’ traits, or infer the probability of the disease outcomes. (Darcy, Louie, Roberts, 2016). The second category includes natural language processing (NLP) methods that extract information from unstructured data such as clinical notes or medical journals to supplement and enrich structured medical data. The NLP procedures target at turning

texts to machine-readable structured data, which can then be analysed by ML techniques. (Murff, FitzHenry, Matheny, 2011).

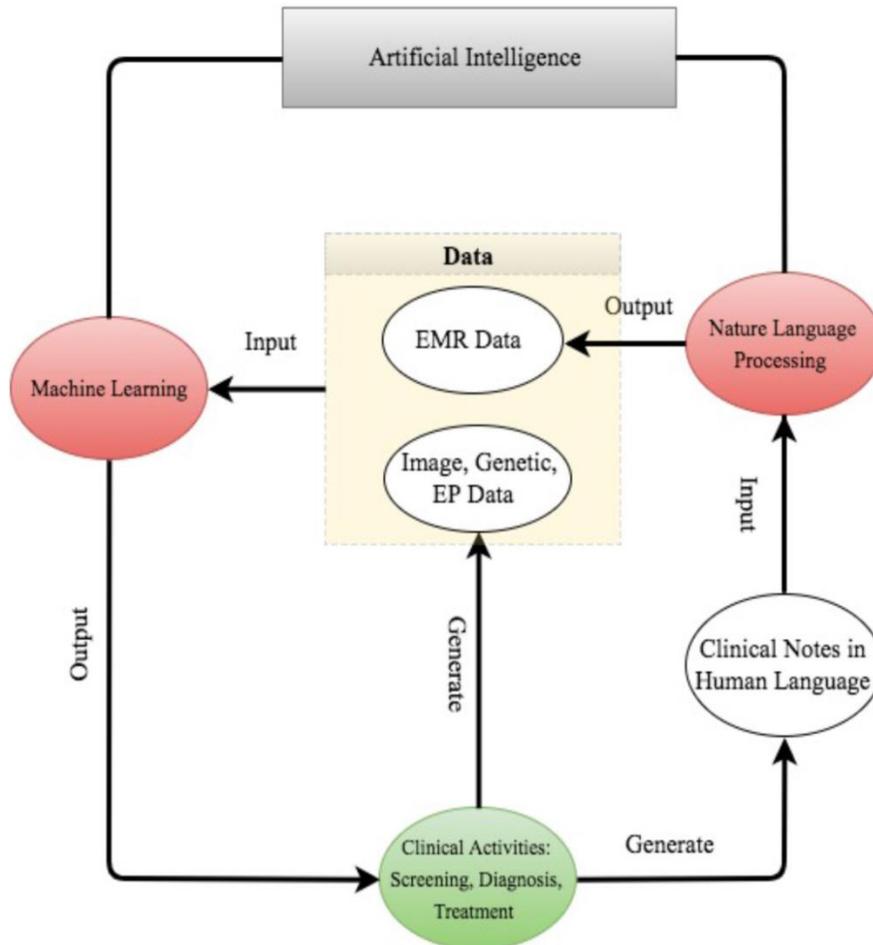


Figure 2: The road map from clinical data generation to natural language processing data (NLP) enrichment, to machine learning (ML) data analysis, to clinical decision making. EMR: electronic medical record; EP: electrophysiological. (Fei, Yong, Hui, 2017)

5. Disease focus

With the increasingly rich AI literature in healthcare, medical AI has been integrated into treating many disease types, such as but not limited to:

1. *Cancer*: IBM Watson for oncology would be a reliable AI system for assisting the diagnosis of cancer. (Somashkhar, Kumarc, Rauthan, et al, 2017). In Japan in 2015, a woman was treated for Leukemia by a supercomputer by synthesizing 20 million cancer research papers. (Monegain, 2018)

2. *Neurology*: Bouton et al developed an AI system to restore the control of movement in patients with quadriplegia. (Bouton, Shaikhouni, Annetta, et al, 2016) Farina et al tested the power of an offline man/machine interface that uses the discharge timings of spinal motor neurons to control upper-limb prostheses. (Farina, Vujaklija, Sartori, et al. 2017)

3. *Cardiology*: AI system, in the future, might be able to diagnose the heart disease through cardiac image. (Dilsizian, Siegel. 2014).

All three diseases are leading causes of death; therefore, early diagnosis is crucial to prevent the deterioration of patients' health status. Furthermore, early diagnosis can be potentially achieved through improving the analysis procedures on imaging, genetic, EP or EMR, which is the strength of the AI system. Hence, AI system may effectively improves the healthcare system. (Fei, Yong, Hui, 2017). Besides that, Doctors from Stanford University had used Augmented Reality to stimulate a risky surgery before the actual surgery, helping them to diagnose and avoid potential threats, allowing them to have a higher success rate during the actual surgery.

6. Public Reaction

Healthcare has been a sector that has been relatively untouched. Many patients still express their discomfort if all of their health choices are to be decided by artificial intelligence. (Kwok, 2019). This problem will be discussed later in section (b) of this written report.

b. Identification of Challenges

Challenge 1: Lack of human element

One of the biggest concerns that was raised in our discussion with Mr Kwok from the Tsao Foundation was the potential lack of human touch. He said that it was vital in many situations. The mood of many elderly would improve if there was a nurse, or even better, a family member with him or her when recovering from a disease or accident. Many of the elderly would feel down, when they were left on a bed themselves, and no one to talk and touch. Also, Dr Wee from the O&G care clinic had also commented on how many of the pregnant mums would feel comforted when he touched their abdomens and spoke to the babies. It gave them the peace of mind. The human touch would soothe pain from many patients (Stanford, 2006). The reasons behind this are highly complicated. It may be due to the inbuilt nature of humans, where close interactions with someone from the same species would mentally help them. In this situation, it would be near-impossible to solve these problems, and humans would still be required in the healthcare industry. However, the results of the research may be also due to our long-term habits, many formed when we are young. An example would be how our parents would hold and touch us when we are young, to soothe us, and to calm us. Thus, in the long run, it results in our brain associating the human touch with comfort (Fletcher, 2017). This would be an easier problem to address, however, not much easier.

Unfortunately, despite the manpower requirements in the healthcare industry, the Singapore workforce is facing a manpower crunch. A report showed how the aging population had resulted in the higher demand for manpower. This is due to the higher demand of long-term care, instead of the acute treatment, which is how the majority of cases are being treated now (Kwee, 2009). Coupled along with the workforce, which is being predicted to shrink to only half of the population by 2050, there is an imminent shortage of workers in the healthcare industry (Siau, 2017).

Challenge 2: Online healthcare data's vulnerability to hacking

Observation

One of the major concerns raised in our discussion with Mr Kwok in Tsao Foundation was that many elderly, which make up a large proportion of patients, are ill-informed about the potential threats of using AI in healthcare. (Kwok, 2019) Our online survey also indicates that although most of the respondents claim that they are willing to provide clinical data to Healthcare AI which in turn, can give them personalised healthcare (77.1% of them rated the linear scale of 7 and above, as shown in Figure 1), most of the respondents are also *concerned about* the leakage of clinical data that they provide for

healthcare providers. (72.2% of them rated the linear scale of 7 and above, as shown in Figure 2) Besides that, in the SingHealth data breach case where Ler Teck Siang aided his boyfriend to illegally access the HIV Registry, it is revealed that *level of cyber security of relevant personnel in healthcare institutions* is conspicuously lacking (Khalic, 2019). This deteriorates online healthcare data’s vulnerability to cyber attack. Besides that, healthcare is a high-risk sector for *corruption*. Best estimates are that between 10% and 25% of global spend on public procurement of health is lost through corruption. Even professional physicians may choose to sell their patients’ clinical data for monetary interests. (Jain, Nundy, 2014). On top of that, clinical data is *an especially sought-after commodity in dark web*, the reason being is that in addition to medical history, clinical data contains a lot of sensitive information such as an individual’s social security number, their date of birth and their parents’ date of birth, all of which could be leveraged to answer security questions, apply for other identity documents or other malignant purposes. (Soaring Eagle, 2018)

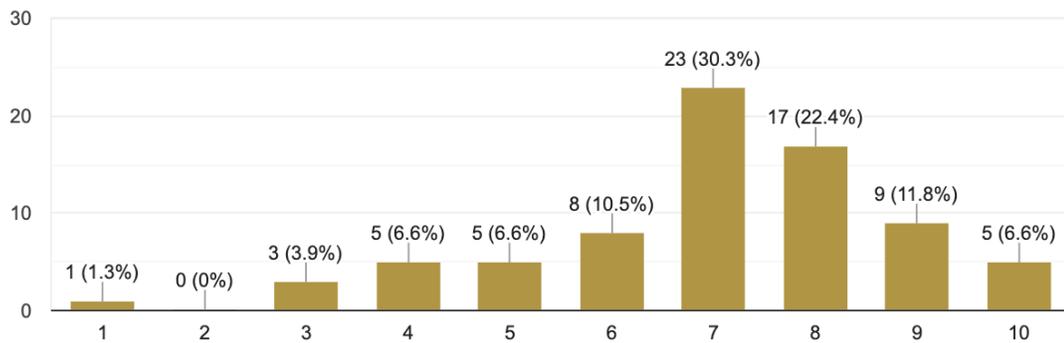


Figure 3: Public willingness on providing their clinical data to healthcare AI, which in turn gives them personalised healthcare plans. (With 1 being “not willing at all”, 10 being “extremely willing”.) N=76

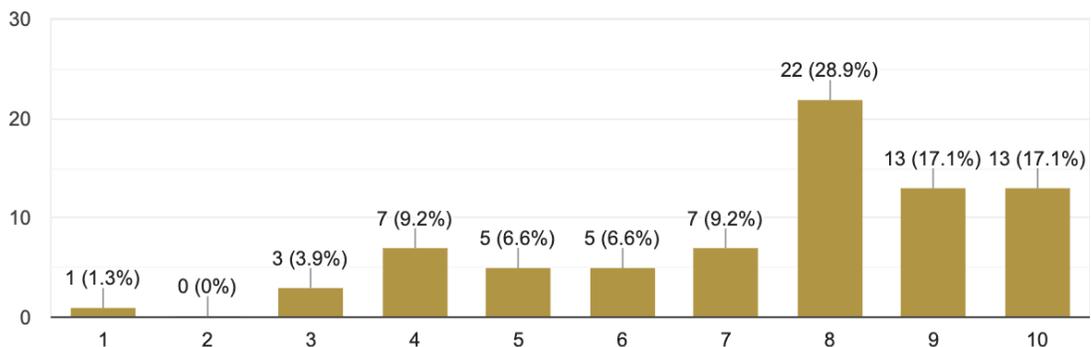


Figure 4: The extent to which the public is concerned about the leakage of their clinical data. (With 1 being “not concerned at all”, 10 being “extremely concerned”.) N=76

Reason why this could be a problem

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Singapore is particularly vulnerable to cyber attacks, the reasons are as follows: first, Singapore society would be highly connected and digitalised by the year 2030. Lots of sensitive data reside in Singapore's servers as it is a business, financial and healthcare hub, making it a high-value target for cyber threat-actors. (Cyber Security Agency Singapore, 2018) To fully achieve integration of AI in healthcare, a prerequisite is that there needs to be *a sea of clinical data* without which machine learning cannot function. Given that healthcare data is a desirable commodity with which malignant purposes can be achieved, malicious attacks to the healthcare system could be conducted to expose or exfiltrate healthcare data, to the dark web in worst case scenario. Such attacks are made easy by the prevalence of corruption and cronyism, and lack of adequate awareness of cybersecurity of relevant personnel in the healthcare sector. This may lead to two major problems. First, patients like elderly who are ill-informed about the threats of the integration of AI would be subject to the stolen or exfiltration of their valuable healthcare data and thus their privacy and well-being is at stake. Second, informed patients may frown upon the notion of providing exhaustive healthcare data to healthcare providers, and as a result, medical AI and the hypothetical "Personalised Treatment" may not function well.

Research

In a report issued by a committee designated to examine the 2017 cyberattack, which caused the clinical data of 1.5 million patients to be exposed, it is noted that staff at IHiS (The Integrated Health Information Systems Private Limited) responsible for administering and operating the Singhealth Sunrise Clinical Manager (SCM) database did not have adequate levels of cybersecurity awareness, training and resources to appreciate the security implications of their findings and to respond effectively to the attack. Certain IHiS staff holding key roles in IT security incident response and reporting failed to take appropriate, effective or timely action, resulting in missed opportunities to prevent the stealing and exfiltrating of data in the attack. A number of vulnerabilities, weaknesses and misconfigurations in the SingHealth network and SCM system - many of which could have been remedied before the attack - contributed to the attacker's success in obtaining and exfiltrating the data. (The Committee of Inquiry, 2019) Back in 2015, the massive hack of 10 million complete electronic medical records from companies such as Anthem, Premera Blue Cross and Excellus Health Plan served to jump-start the medical record market on the dark web. In 2016, complete medical records (known as "fullz" among dark web traders) were sold for around \$100 each, all paid for with cryptocurrencies such as Bitcoin. In the last few years, the price of a "fullz" electronic medical record has dropped significantly. According to CNBC, while a Social Security

number can be purchased on the dark Web for around \$15, medical records fetch at least \$60 per record because of that additional information, such as addresses, phone numbers and employment history. While there have been numerous additional hacks in the last few years, few people have kept abreast of this growing trend. It is estimated that the rate of medical record theft has increased by ten or twenty times over the last several years. (Soaring Eagle, 2018)

Challenge 3: Who would be held to account?

The assignment of responsibility should AI-caused medical malpractice occur is opaque. Insufficient tort liability doctrines might result in violation of patients' due rights, interests and reimbursements.

Background

AI is employed more and more widely in the healthcare industry, with a recent report showing that 86% of provider organizations, technology vendors, and life science companies use some form of AI. The rest 14% claim that they will do so by the year 2020. (Tata Consultancy Services, 2018)

As AI is employed more and more widely in healthcare, the problem of medical malpractice inevitably arises: after all, healthcare-related cognitive technology is still at its infancy and it cannot achieve 100% accuracy. For example, when both the A.I. was asked to sort the images in cardiology, the algorithm achieved an accuracy of 92 percent. (Tata Consultancy Services, 2018). Of course it is higher than a physician, but once medical malpractice occurs, the assignment of responsibility is much more opaque as long as artificial intelligence is involved. At this point of time we need to resort to tort liability doctrines, but are existing doctrines enough to address such issues?

Imagine this scenario: after AI is integrated into healthcare and utilised by doctors to perform diagnosis and unfortunately, the prescription caused severe adverse impacts and induced serious medical malpractice. In the past, there was only the physician to blame but now, with the integration of AI in healthcare, various stakeholders are involved.

Why current tort liability doctrines are not adequate for AI-caused injury

Physicians: Current tort liability framework requires physicians to compensate patients for injuries for which the physician is responsible. (Furrow, Greaney, Johnson, Jost,

Schwartz, 2018) However, it is unclear whether physicians will be able to assess the reliability of diagnosis derived from AI because AI operates as an opaque black box. Even if it were possible for a technically literate doctor to inspect the process, many AI algorithms are unavailable for review (Hart, 2017), as they are treated as protected proprietary information. Furthermore, the data used to train the algorithms is similarly publicly unavailable for privacy reasons. In that case, it hardly makes sense that a doctor should be held responsible for AI-induced medical malpractice.

Healthcare Organisations: The doctrine of respondeat superior places vicarious liability on employers for the negligent physicians (Allain, 2013). Alternatively, hospitals and other health care providers may be held separately negligent for failing to exercise due care in hiring, training, or supervising employees (Meera, Phanjoubam, Nabachandra, 2016). However, hospitals and other healthcare institutions which leverage AI face the same dilemma as physicians who use AI directly, as they too, cannot access the inner processing of the AI system.

Designers of the AI system: Manufacturers of prescription drugs and medical devices are liable for harm to persons caused by defects (Reuters, 2002) To truly develop AI in healthcare, a whole bunch of technologies need to be sufficiently developed simultaneously by different developers (Fung, 2016). Hence, it is difficult to pin down individuals responsible for particular features as the teams creating these AI can often number in the hundreds. Furthermore, even if it were reasonable to hold designers to account, doing so would likely dissuade many from entering the field, and therefore delay the many benefits of AI from being realized (Hart, 2017).

Given that there are no laws specially aimed at addressing AI-caused medical malpractices, we conclude that the legal system is not ready for the AI disruption in healthcare, and this judicial ambiguity may directly result in ambivalence in assigning responsibility should the use of AI causes medical malpractice.

Another major challenge is solving the liability issue with regard to AI in healthcare. The AI system may be opaque due to the high number of parties involved, and with the high amount of intellectual property, the truth may be slow and hard to find out. Judges can no longer hold one person responsible for any problems with healthcare, and may lead to a long and slow legal process. The loser becomes the patient and or his or her family, who may not be compensated fairly. So in this new age, the legal system must be able to keep up with the development in the healthcare sector.

Why would this be a problem

If the allocation of responsibility of medical malpractice caused by AI is ambiguous, no stakeholder would be held responsible and actually render compensation for the malpractice. In the light of this, patients will not get their due protection and reimbursement. As a result, no one would actually embrace the change, which will further deteriorate the public unwillingness towards the digitalisation in healthcare.

Challenge 4: Bias inherent within of AI algorithms

Due to the inherent bias of AI algorithm, it might display results that ignore racial sensitivity, discriminating those of a certain racial, gender, communal or ethnicity.

Background

Precision medicine research initiatives aim to use participants' electronic health records (EHRs) to obtain rich longitudinal data for large-scale precision medicine studies. Although EHRs vary widely in their inclusion and formatting of social and behavioral data, these data are essential to investigating genetic and social factors in health disparities. However, there are possible biases in collecting, using, and interpreting EHR-based social and behavioral data in precision medicine research and their consequences for health equity.

Currently, a number of large-scale cohort initiatives are collecting social and behavioral data for use in research. Thoughtful inquiry and expansive discourse on the limitations of EHR-derived social and behavioral data are necessary if precision medicine research initiatives are to avoid inadvertent harm. Considerations of the inclusion or exclusion from EHRs that can impact the rigor of precision medicine research and the bias that occur in the collection, collecting, utilisation and interpretation of social and behavioral data are all valid concerns. There will also be possible consequences of interpreting and using data gathered through biased collection methodologies. By considering all the possible outcomes, we would be able to better promote understandings of the data's limitations and help inform strategies to reduce the data's misapplication by researchers. "The bias in the collection and analysis of EHR-derived social and behavioral data is present throughout the research process, from the recording of data to the interpretation of results." (Brittany Hollister, 2018) Hence, decisions about which information to record in EHRs can lead to bias in the type of data available and affect the accuracy and

completeness of what is recorded. For example, health care professionals, who vary in the content and completeness of data they include in EHRs, could be influenced by discussions of social and behavioral health indicators with patients, possibly unconsciously biasing available social and behavioral data. Because of data recording inconsistencies, important social and behavioral data could be missing from EHRs.

Connections to AI

Hence, since AI is prejudiced against people of different racial and ethnic groups, this can cause people to feel insulted and lower their self-esteem because they are labelled. AI may also make undesirable and unreliable decisions solely based on a persons ethnicity, this hence causes a lack of credibility of the AI algorithm, posing a challenge.

A Possible Solution

Recognizing the importance of formally and systematically capturing social and behavioral measures, the National Academy of Medicine (NAM) (formerly the Institute of Medicine) recommended social environment measures' inclusion in EHRs. Specifically, the NAM recommends intentional collection of structured social environment data, which in turn would encourage standardization of such data across patients, thereby reducing the probability of undesired bias. The NAM also recommends that a plan be developed by the National Institutes of Health to expand the use of EHRs in research by including social and behavioral data. Recognition by the NAM of the need to incorporate social data in clinical care, together with the importance of these data in precision medicine research, is likely to accelerate inclusion of these data in EHRs.

Challenge 5: Possible monopoly of medical companies

Observation

With the huge market sector to be established with the new Artificial Intelligence, There pose to be significant risk where companies are able to establish big monopolies, like today's technology juggernauts. There may be a chance where a near-full monopoly is established, and the incumbent juggernauts will be anti-competitive and try to stamp out any competition. Situations like this have already happened, and one of the most prominent examples is the price of Insulin , a life-saving drug for diabetics. The patent of Insulin was sold for only \$1, yet in some countries like the United States, the cost in Insulin has increased to nearly \$300 a bottle, out of reach to many in the working class

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(Prasad, 2019). This has resulted in many patients rationing their insulin, sometimes having fatal consequences. How do we ever solve this problem while maintaining the free market, and not stifle medical innovations.

Link to AI

How are all of these is connected to Artificial Intelligence. Simply, the programming. Copyright laws nowadays are aimed at protecting one's individual rights, while allowing anyone to take inspiration from another person's work. However, as virtually all Artificial intelligence would be following a code and algorithms, these machines performing similar tasks may result in many similar codes. Companies may very well use this for their own corporate greed. They will accuse rivals with any remotely similarity of infringing their copyright, and use it in an attempt to establish a monopoly. If ever a monopoly is established, results may be catastrophic. These companies may make healthcare a privilege, and out of the hands of many people.

c. Deriving the Underlying Problem

As can be seen from our challenges, people are unfamiliar, and not willing to step out and utilise AI. Challenges 1 and 2 have both shown us that the masses are afraid of AI due to its vulnerabilities as well as because it is relatively unknown yet in this decade. Challenge 3 has shown us that people are unwilling to trust AI and its various utilities due to the fact that they feel that they would be held responsible in the case that anything goes wrong. Challenge 4 shows us how AI may be unreliable because of the way it is structured and the inevitability of prejudices in its system. Lastly, Challenge 5 brings us the fact that AI may be easily exploited and used wrongly in unwanted hands. All this scepticism and criticisms towards AI goes to show that people are still doubtful and are unaware of how AI works. If we could increase the public's acceptance and boost their confidence in regards to the benefits of the integration of AI into their lives, it could then be carried out much more smoothly. Hence, we surmised that our underlying problem was that the majority does not accept or trust AI due to its opaqueness and a lack of confidence towards it.

Underlying Problem

- **Given that the majority does not accept or trust AI due to its opaqueness, it appears that there will be a lack of acceptance and confidence in healthcare system (Condition Phrase).**
- **How might we increase public acceptance and confidence in AI healthcare (key verb phrase)**
- **so that AI integration would be smoother and better serve the public (purpose) in the years 2030 and beyond in Singapore?**

Justification of this group's underlying challenge

Observation

In our interview with a senior consultant in Tsao Foundation, a non-profit organisation which works to promote the longevity of the elderly, we are told that generally most of the senior citizens do not accept the use of artificial intelligence in healthcare.

Additionally, judging from the responses of our survey conducted online, the notion of

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having a doctor diagnosing patients' diseases or operating a surgeon on them is overwhelmingly rejected by people in all age brackets, with only 23.7% of the respondents claim that they have more trust in Artificial Intelligence than physical doctors in practising diagnosis on them (Figure 5) , and 21.1% claim that they have more trust in Artificial Intelligence than physical doctors in conducting an operation on them (Figure 6).

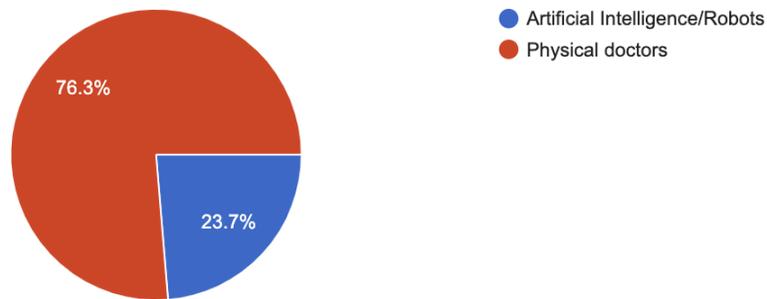


Figure 5: Percentage of people trusting physicians in making a medical prescription for them versus AI, with the red part indicating the percentage of people trusting physicians and blue part representing the percentage of people trusting AI. (N=76)

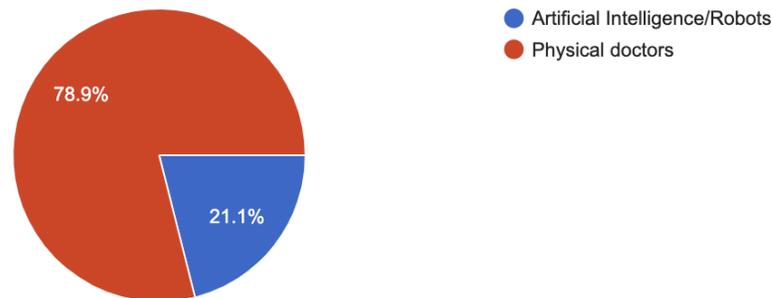


Figure 6: Percentage of people trusting physicians in conducting an operation on them versus AI, with the red part indicating the percentage of people trusting physicians and blue part representing the percentage of people trusting AI. (N=76)

Reason why this could be a problem

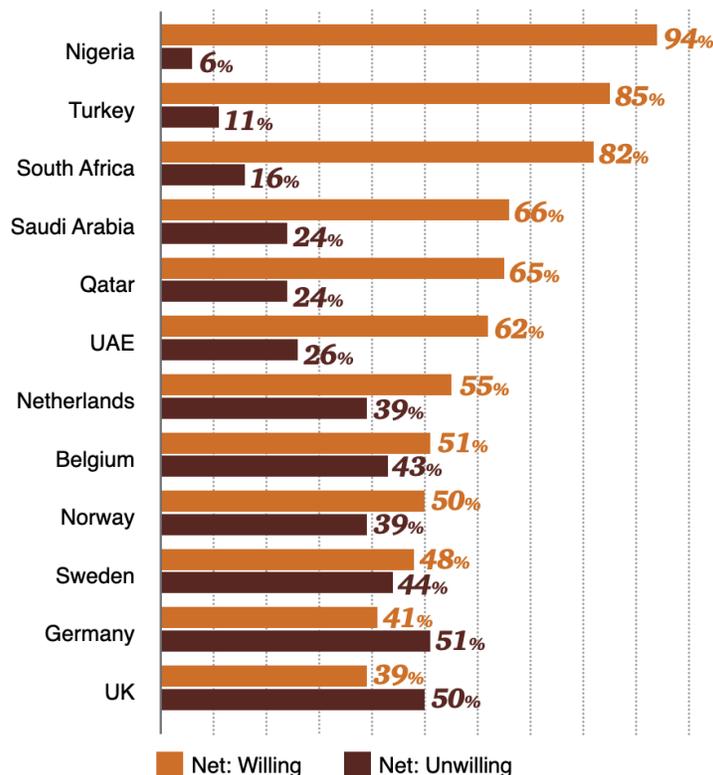
This could pose a problem for the application of AI in healthcare because the perception of having AI making decisions for humans is very new and a lot of people are skeptical about it. As a result, if people cannot embrace the shift towards automation in healthcare, they will resort to seeing physical doctors instead, although the AI doctors are already readily available. In the light of that, the deployment of AI in the healthcare sector would be rendered redundant. Hence, it is a great challenge for AI in the healthcare sector.

Research

As Steve Leonard, Chief Executive of SGInnovate, a government-owned company that funds deep tech startups, claimed, social adoption is a bigger challenge than the technology. As he pointed out, the lack of trust in AI is visible from people’s negative perceptions of autonomous vehicles – made worse by the high-profile death of a woman by a driverless Tesla car in Arizona in March. Autonomous vehicles could transform urban mobility in countries as dense as Singapore, but innovation in this area would not “be worth much” if users are nervous of this technology.

David Howard, professor of health policy and management at the Rollins School of Public Health at Emory University, says doctors and the public are still skeptical about Watson Health, a deep-learning programme that is aimed at improving healthcare through the use of AI. (Walker, 2016)

A 2016 survey of 12 000 people across 12 European, Middle-Eastern, and African countries found that only 47% of respondents would be willing to have a “robot perform a minor, non-invasive surgery instead of a doctor,” with that number dropping to 37% for major, invasive surgeries. These findings indicate that a sizeable proportion of the public has uneasiness about medical AI (Figure 7). (pwc, 2017)



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Figure 7: Percentage of respondents willing to engage with AI and robotics for their healthcare needs. (Source: pwc, What doctor? Why AI and robotics will define New Health, 2017.)

If we observe the public acceptance percentage by country, we might find an interesting pattern: developed economies with entrenched healthcare systems – characterised by a high per capita health spend and a long legacy of universal healthcare coverage delivering good overall value – occupy the bottom half of the scale where respondents were less willing to rely on AI. With the rapid ageing of the Singaporean population, an increase of per capita health spend (which is already very high right now) is expected. Singapore's health expenditure per capita in 2016 is 2462 in US dollars, with that of the UK 2892. Additionally Singapore's health expenditure per capita is increasing more rapidly than the UK, making Singapore fall under the category where the public is unwilling to accept the integration of AI in healthcare. Hence, this group of researchers conclude that the Singapore society would less likely be receptive towards application of AI into healthcare, making this process a relatively tough one.

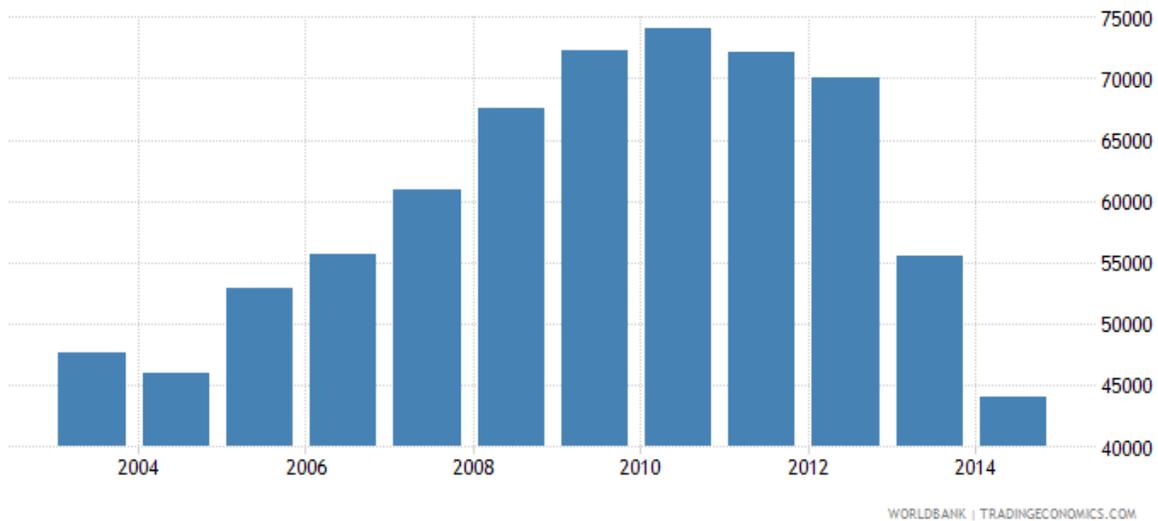


Figure 8: Singapore's health expenditure per capita from 2010 to 2016. (Source: Trading Economics)

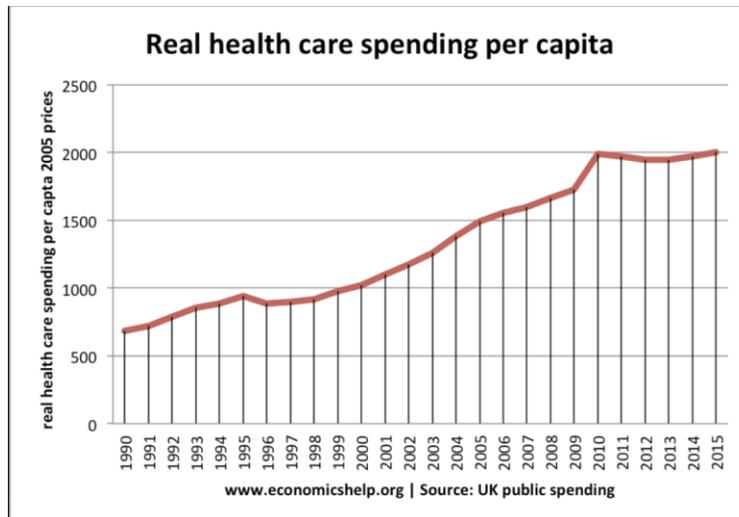


Figure 9: UK's health expenditure per capita from 1990 to 2015. Source: UK Public spending

d. Producing Solution Ideas

Solution 1: Conferring AI personhood

The first solution is to confer “personhood” on the artificially intelligent machine itself, viewing the machine as an independent “person” under the law. Viewing the machine itself as a person resolves agency questions, which are important for analysis of vicarious liability claims, as the machine will be viewed as the “principal” and no longer as an agent in a medical malfunction case, and in the scenario of a cyber attack exfiltrating the population’s clinical data. The machine, deemed a principal under this model of personhood, will have burdens and duties of its own and will then be sued directly for any negligence claims. In such instances, the AI system will be required to be insured (similar to how physicians possess medical malpractice insurance themselves) and such claims will be paid out from the insurance; the AI system will be deemed a quasi-judicial person and treated the “same as any other physician.” Funding for such insurance may come from users of the AI technology, physicians who utilised AI, health organisations who employed such physicians, and those who developed AI. In such a way, public trust and confidence would be boosted up as they know that there would be reimbursements and compensation in case of cyber attacks and medical malfunction.

Moreover, conferring AI personhood, and requiring insurance from all public sectors would give the general public the sense that people are actually putting in a lot of efforts to work for the security and reliability of such a system, including themselves. This sense of belonging would naturally translate into trust and confidence in AI systems, as they *themselves* are taking part in the process of making it better and safer.

Research

The act of insurance promotes fairness, as it extends beyond the technology's creators and encourages users of such technology to also bear some cost. (Vladeck, 2014) The AI system will be deemed a quasi-juridical person. AI system will be required to be insured and such claims will be paid out from the insurance. (Allain, 2013) In New Zealand, a river, which was considered the ancestor of New Zealanders, was conferred personhood. They have fought to find an approximation in law so that all others can understand that from our perspective treating the river as a living entity is the correct way to approach and protect it, as an indivisible whole, instead of the traditional model for the last 100 years of treating it from a perspective of ownership and management (Roy, 2017). Hence, by conferring an special object personhood, there would be a sense of reverence and respect amongst people, and naturally there would be more confidence and trust towards the application of AI in healthcare.

Solution 2: Improving general AI literacy of patients and physicians

Since, most physicians would be unfamiliar with AI, they would certainly pick up a thing or two just by listening to a sharing. Not only so, but they would also be more comfortable with using or incorporating it into their practises. (Siraj and Wan Ishak, 2008) In this case, physicians might be apprehensive to use the AI as while it can “learn from experience” by “looking” through millions of terabyte of data, it would never be the same as human instinct, which is what doctors have been used to for so long.

Currently, students know little to nothing about how technology works. And few of them appreciate that smart machines are reshaping the employment landscape and challenging social norms. Young people need to be prepared to engage in dialogue about technology that is shaping their future. Understanding how AI works, the data used to train systems, and the benefits and pitfalls of AI in specific domains is essential knowledge to be a participant in these discussions. The current students are the part of the generation that

will be replacing the workforce of Singapore by 2050, where there will be a smaller workforce to sustain the larger number of elderly. It is vital they have the know-how and acceptance of AI, so that they would be able to support the country's economy, even with less manpower. (Ark, Barriger, 2019)

Every physician in the future will have a MyAISkill account. Every time he takes part in activities learning about AI, he would get points added to his account. For example, attending a formal seminar spanning 2 days would give him 6 points. 100 points is needed for a physician to renew his practising license every year.

Solution 3: Government-led embracement of AI

Government embark to push AI into public hospital and increase the public's interaction with AI. Benefits of this initiative is that it allows the government to lead the industry in this new field, and it crosses the bold line between technological tools and Artificial Intelligence.

Right now, there is little AI innovation and testing, This is probably due to the doctor's fear of AI malfunctions, and them being liable. Doctors now are unwilling to take such a huge jump, when most of them are financially stable, and are unwilling to put their reputation at stake. The government can be the first to take the huge leap from technological tools to Artificial Intelligence. This had already happened in many parts of the world. Trump had just approved of more spending to spur AI Development (Vincent, 2019).The Singapore Government, with its rather large budget surplus (Lim, 2019) and high public trust, can devote enough monetary resources to ensure the safety of AI. With proven success, private companies and doctors may see the potential of this field, and invest more time and money it, thus leading to better results.

Solution 4: Strengthening algorithmic processing of healthcare AI to eliminate risks of cyber attack and reduce biases

This project's main focus is to boost public acceptance and confidence in healthcare AI. On the one hand we need to expose the public more to healthcare AI so AI will become more and more natural to them. On the other, given that most people do not have acceptance and confidence in healthcare, particularly due to lack of transparency and security, which

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is deteriorated by the SingHealth Data Breach, we need to improve the actual quality of AI healthcare to make sure that it is not easily hacked, the public's privacy is not violated when they use healthcare AI, and by eliminating biases in healthcare algorithms healthcare AI can diagnose more accurately. All of these can bolster up public acceptance and confidence.

Recognising that some patients are not willing to give their medicine records to healthcare AI for tailored healthcare plans out of security concern, we must first ensure the AI system is secure and protected from cyber attacks.

AI algorithm developers should design the algorithm of healthcare AI cautiously to guarantee that malignant cyber attacks are infeasible or at least can be retroactively identified. Cyber attack simulations exercises are to be carried out. Only when simulative cyber hackers cannot penetrate the healthcare AI algorithms and access electronic health records, can these algorithms be passed, introduced to the market, and applied in healthcare Artificial Intelligence.

IHiS and public health institutions must develop and adopt an enhanced cybersecurity structure. The effectiveness of the current endpoint cybersecurity measures must be reviewed and enhanced. Perform regular checks on healthcare database system. Unusual activity in healthcare database should be immediately identified and broken off. Embed a sense of cybersecurity awareness in relevant personnel in healthcare institutions and physicians. They should be vigilant of cyber-attacks and cautious of patients' clinical data. Relevant personnel must be equipped with sufficient knowledge to recognise the signs of a cyber attack and; adequate skills to repair loopholes on sight and curb further development of cyber attacks; practice uprightness and integrity with patients' medical data.

Health information database companies must work closely with hospitals and governments to prevent the leakage and exfiltration of clinical data. Hospitals - roll out programmes to instil the importance of cybersecurity in nurses and doctors. Government - tighten regulations on the access to the clinical information database and stiffen penalties on those who breach the regulations.

Solution 5: Understanding the masses concerns through online forums

Through our research, we have found out the main problem is the lack of public acceptance and confidence in AI, and there are many reasons, such as privacy issues and lack of trust, or just general hesitation to try new things. Like future trends, we need to find a problem first to find a fix for it. Thus, really understanding the public's concerns could allow companies and the government to market and advertise the use of AI healthcare in better.

One such way this can be done is by having online forums where the public can comment and ask questions, and professionals in the related fields, such as doctors, government officials or experts in AI technology in this case, can answer questions pertaining to the topic. An example would be the use of Quora, which is an online forum, whose purpose is to allow people to gain and share knowledge. It is a platform to ask questions and connect with people who contribute unique insights and quality answers. One must have an account to ask or answer questions, people who give accurate answers are upvoted and deemed more credible. The Ministry of Health can work with Quora to allow all local experts in the fields pertaining to the use of AI in healthcare to answer questions that the public posts. They can also get a sign or symbol on their profile proving that they are certified experts. This will assure the masses that their concerns are addressed by professionals. According to Drs. Cavanaugh, who is an educational technologist, online forums can also be of use as they show the different opinions that the each individual of the public has.

This will be crucial as even now, fake news is easily being spread around, and people might not know how to distinguish it. One can only imagine how worse the spreading of fake news might get in the future. Thus the setting up of a reliable online forum would help to increase the public's trust in AI.

e. Selecting Criteria

1	Which solution is <i><u>the fastest</u></i> for the government/community to implement so that <i><u>public acceptance and confidence in healthcare AI</u></i> can be increased <i><u>as quickly as possible?</u></i>
2	Which solution has <i><u>the largest impact</u></i> such that <i><u>public acceptance and confidence in healthcare AI</u></i> can be increased <i><u>as much as possible?</u></i>
3	Which solution will be <i><u>the cheapest for the government to implement</u></i> so that a particular degree of increase in confidence and acceptance is obtained.
4	Which solution will be the <i><u>most imaginative way</u></i> for the government so that the solution can <i><u>appeal to the public most?</u></i>
5	Which solution will be the <i><u>most viable one that makes healthcare remain affordable</u></i> so that the public would be receptive to embrace the initiatives?

f. Applying Criteria

Solution	Fastest to implement	Largest impact	Least cost	Most imaginative	Most viable to keep healthcare affordable	Total score
AI Personhood	5	3	3	3	3	17
Improving AI literacy	4	5	4	2	4	19
Government-led AI	2	4	1	5	5	17
Strengthening AI algorithmic processing	2	2	2	4	1	11
Understanding the public's concerns through online forums.	1	1	5	1	2	10

g. Developing an Action Plan

Phase 1: Letting physicians harness the usage of Healthcare AI (2020-2030)

We, the Ministry of Health, will work together with the Singapore Medical Council, to improve the general AI literacy of physicians by educating them, so as to improve their understanding of AI, which will make them more comfortable with the integration of AI.

Every healthcare practitioner(includes nurses and doctors) in Singapore would be registered under the SMC and Singapore Nursing Board(SNB) , a statutory board under the Ministry of Health. The SMC and SNB will work together with the will require all doctors and nurses to have a MyAISkill account, which is an online account that they can use for various activities related to educating themselves on AI. This account will be established online in 2020, made into APP in 2022 and used by physicians islandwide by 2023. Using this account, the SMC can track those who actively learn new information about the use of AI in medicine. A point system will be created, in which if a physician is unable to attain the required number of points in a year, his license will be revoked, which will ensure that all doctors learn about AI actively and effectively.

Points will be awarded for learning about AI, for example, taking a 20-question quiz on the potential uses of AI in healthcare would award the doctor 1 point, while a more intensive programme, such as attending a formal seminar focused on AI spanning 2 days, would give them 6 points.

Phase 2: Dissemination of Vivid videos introducing Healthcare AI (2023-2024)

We, the Ministry of Health, will also work with the Ministry of Communications and Information (MCI), to disseminate short videos, introducing the information regarding the benefits of using AI and why citizens can trust it. We would work with MCI to disseminate these short videos on social media and television channels.

We would build up the positive image of healthcare AI, to make it seem approachable and eliminate the formidable image from sci-fi movies and novels where Artificial Intelligence is usually the “terminator” of mankind.

We would make it seem more like a human being, although it may not necessarily talk like a human being, for we recognise the fact that humans tend to trust AI devices that look like human beings. (Subbaraman, 2013)

We would work with MCI to produce such videos by 2023 and they will be on air by 2024.

Phase 3: Letting the general public interact with AI more (2025-2030)

We will also improve the literacy of the public by providing them with additional opportunities to experience the use of AI personally and in real life, instead of just through advertisements or on social media.

We will work with the Smart Nation and Digital Government Office, which can provide research and implementation budget; we will also work with the Singapore Economic Development Board, which can provide AI technical know-how; moreover, we would work with local companies specialising in AI, such as SG innovate, which can help manufacture the hardware, like robotics.

This initiative will be tabled for Parliamentary discussion by 2025, with the first few healthcare AI being dispatched in community centres islandwide in 2027, and subsequent healthcare AI being dispatched later.

At the “AI Interaction Points”, Citizens can consult Healthcare AI on basic queries regarding their health, e.g. “What are the healthiest foods for me at this age?” This gives citizens a belief that Healthcare AI can actually work for the good of their health and give them personalised treatment - thus boosting up public’s familiarity with, and interest in healthcare AI.

h. Evaluation of the Action Plan's Feasibility

Phase 1: Letting physicians harness the usage of Healthcare AI (2020-2030)

This initiative precedes initial trust formation because only when the Healthcare AI system is made robust and reliable with AI-savvy physicians, can initial trust formation be smooth and meaningful (Montague, 2012) - by then, the videos can promulgate the robustness of Healthcare AI system, so the public will be more likely to trust Healthcare AI. This initiative will span a relatively long time to ensure healthcare AI system is kept robust and reliable.

Patients (passive users) are making decisions about the trustworthiness of technologies based on how the provider uses technology. If physicians harness AI very well and have confidence in AI, naturally patients will have confidence in AI too (Montague, 2012). Hence, we think that this initiative would be feasible and meaningful.

However, the biggest problem facing this initiative is that doctors worldwide are exceptionally busy, Singapore in particular, according to Dr. Wee Horng Yen in O&G Care Clinic, Singapore. It is also reported that a typical doctor in a busy hospital in Singapore would work from 8.00am to 6.00pm non-stop. (Doctor & Dentist, 2016). Hence, we would probably exert tremendous stress on doctors should they need to spend extra time to study expertise and technical know-how on healthcare AI.

Phase 2: Dissemination of Vivid videos introducing Healthcare AI (2023-2024)

This group of researchers think that this initiative is an effective way to boost up public confidence and trust in healthcare AI. With the masses receiving a constant flow of information pertaining to AI, they will be kept updated and be more conscious and willing to adhere to the technological change. This is also to prevent the crumbling of the “initial trust formation” because if the chain of information as well as initiatives stops being publicised, people may think that it is a one-off incident and disregard it.

Sci-fi books and movies have given AI a bad image — when the intelligence we create gets out of control. This image and perception will affect people's initial trust in AI. (Siau, 2018) However, when public organisations put in efforts to improve AI's image and integrate it into a specific culture through the form of videos, people's initial trust in AI will be boosted up.

This group of researchers believe that this initiative is feasible, given that in the past, when Singapore government was trying to put forward a new policy that would potentially influence the lives of millions, it often uses videos to disseminate its ideas and inform the public, and public reaction and acceptance turned out to be fairly well. For example, the Government has been using interesting videos to inform the elderly about the benefits of the Merdeka Generation Package. Hence, this group of researchers think that by disseminating videos and bringing AI into people's lives, public acceptance and trust would be effectively boosted up.

Phase 3: Letting the general public interact with AI more (2025-2030)

This group of researchers believe that this initiative would generally be effective and feasible because studies have found that when researchers survey the perception of new technologies across generations, they typically see resistance appear from people who are not users of technology. (M. Hengstler, E. Enkel, S. Duelli, April 2016) Thus, providing chances for potential users to try the new technology will promote higher initial trust. Also, to promote initial trust of healthcare AI, a critically important part is to let work systems help care providers by integrating technologies that they are able to use effectively in front of other users. (Montague, E., & Asan, O, 2012). When such an initiative is in place, those who were previously sceptical towards the application of AI into healthcare would see active users having fun interacting with healthcare, then they would also like to try out and normally, they accept and trust AI in heart.

However, the obstacle facing this initiative is that certain people, for example those who live in condominiums, private housing or those who dislike visiting community centres may not visit community centres regularly to interact with healthcare AI, so our objective, which is to improve AI literacy amongst the general public, is not met. However, this group of researchers believe that there is a way to resolve this issue. First, relevant organisations [Ministry of Health, Smart Nation and Digital Government Office] shall select places (including workplaces, community centres or schools) where the

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visitors flow rate is high, so more people can have opportunities to interact with AI products in these places; second, relevant organisations shall investigate the demographic around these places, as to how do they know about AI, so we can select places where people are not familiar with AI, so we can make this initiative more precise and effective; thirdly, staff at “AI interaction points” shall encourage those who have interacted with AI to share the experience with their friends, and recommend the opportunity to them. Staff at “AI interaction points” may also encourage users who find AI experience interesting to comment online. This would be effective because reviews from other users, whether online or in real life, will affect the initial trust level, encouraging others to follow suit. A positive review leads to great initial trust, depending on the trust on the person giving the review. (K. Sony , T, Shanka, and C, Marchegiani, 2012). In this manner, this group of researchers believe that this initiative would be an exhaustive approach to boosting up the public’s initial trust and confidence level towards AI integration in healthcare, which is further strengthened by the continuous trust development as discussed in Phase 1.

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