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DATA ANALYTICS

TRANSFORMING DATA INTO KNOWLEDGE

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SUMMARY

Data Analytics covers the collection and analysis of structured and unstructured data from a variety of different sources. Different methods make it possible to process a large number of data much faster than the human brain. The fields of application for data analytics in healthcare are many covering areas within diagnostics, prevention and treatment. The Danish healthcare sector is one of the most profoundly digitised in the world and thus generates a lot of data thus providing a hugely advantageous starting point for carrying out data analytics on a larger scale. There are however also barriers for data analytics in healthcare. Since these are of both ethical, technical and legal kind, companies with an interest in developing services and solutions based on data analytics should focus on doing to in strong collaboration with clinicians and with an architecture build for transparency and with a high degree of security.

DEFINITION OF DATA ANALYTICS

For this report data analytics is defined as the process of examining raw data using analytical and logical reasoning to draw conclusions about the information they contain. Data analytics can be used on all sorts of data both structured and unstructured, for example on numbers, texts and images. It can be used to handle vast amounts of data as well as data from a number of different sources that could be very time-consuming or even impossible for human beings to analyse.

Analysis of healthcare data has been used to improve care delivery and to prevent hospitalization. Data analytics hold the potential to take previous advancements to a whole new level. We have seen the first glimpses of it when it comes to image recognition and decision support. But we are just starting to scratch the surface, both in terms of future potential within the field of advanced predictive measures, personalized medicine, behavioural pattern analysis, but also in terms of possible negative consequences such as automated erroneous decisions carried out based on data analytics forcing a potential distrust and public resistance toward adopting the technology.

WHAT IS DATA ANALYTICS

Data analytics applies data mining tools to generate qualified datasets based on many different data sources containing semi structured and unstructured data. Or in the words of Niall McDonagh from Microsoft:

> *"At Microsoft we really define Data Analytics as the process where we take data, structured and unstructured data, and turn that into timely, relevant and actionable information. We see Data Analytics more as a continuum … a continuum moving from historic to predictive and causative to prescriptive."*
> (McDonagh, 2017, 06:40)

In other words data analytics is taking various bits of data, information from different sources and different types of information breaking it into separate components that can be linked and combined and thereby provide new information and useful insights that would otherwise not have been available. Hospitals are already generating a lot of different types of data for citizen care, medicine admirations, operations etc. and all these data can be used to improve the quality in the healthcare sector through big data analytics.

The development of healthcare technologies has increased significantly over the last couple of years, which means that the healthcare sector is going to face a major transformation in the years to come. As a result of digitalisation the amount of data generated in the healthcare sector is expected to double every 8 months (Mandag Morgen & Danske Regioner, 2017). Thus making the potential for data analytics in the future even more promising than it is today.

WHY IS DATA ANALYTICS RELEVANT?

> *"The demographic changes will definitely change the way we can afford to do our healthcare so we need to employ some new methods to get an insight into people's health at an earlier stage"*

says Karen Andersen-Ranberg, Clinical Professor at University of Southern Denmark and Odense University Hospital (Andersen-Ranberg, 2018). Her expertise is epidemiology and geriatrics and she has been the head of several ground-breaking projects investigating the use of data analytics in healthcare. Her concern for the future of healthcare is based on solid evidence:

> *"the demographic change means that we will have a lot more older people. We know that older people now live a longer than their parents' generation; we know also that they survive with their diseases instead of dying earlier from them as they used to do before. So we will have a major proportion of the older generation that will have to attend the healthcare systems."*

In other words: we are facing a burning platform and something must change in order to preserve the level of healthcare that the Danish population has come to expect. Data analytics could be part of that change and part of the answer to how we will provide healthcare in the future.

Hal Wolf agrees:

> *"So we are fundamentally facing a challenge. I don't think we are at a crisis state yet but it could very well be, within the next five or ten years, both monetarily because the amount of money available and being produced by citizens at a GDP level, to take care of repentance, the number of patients that will be living longer with chronic diseases, because they are living longer, along with other habits that have existed during their lifetime."*(Wolf, 2018).

By analysing health data researchers and doctors can use the patterns of data to gain a whole new level of insight into the citizen's health and thereby markedly improve predictions on how a particular type of treatment will affect the citizen. Data analytics can also be used to target preventive efforts and thus reduce the effects of illness and hospital admissions, it can help prevent malpractice because the doctors have more information available and it can help reduce side effects from medicine. In addition, data analytics is relevant to the development of personalized medicine as well as being the obvious solution for carrying out routine tasks (such as text and image analysis, literature search etc.) faster and more efficient than humans thus freeing resources.

Niall McDonagh adds:

"So in terms of the opportunity for the use of data analytics for healthcare in Europe and the US – firstly I would say that from our view data analytics has always been the core in the delivery of healthcare – from diagnostics to treatment. What is different now is that there are new data sources, for example genomic data and data from personal devices and also new analytic techniques such as machine learning or artificial intelligence that enables us to derive insight that we could not derive before. There is also a new computing paradigm, called cloud computing, that enables us to apply these analytics techniques to huge data-sets in a very cost-efficient and timely manner that was not even possible five years ago. So these elements are already changing the nature of healthcare, i.e. how we diagnose illnesses, prepare for treatment and the type of treatment that we provide. An example would be the rise of personalized treatment for cancer based on genomic analysis" (McDonagh, 2017).

HOW IS DATA ANALYTICS DONE?

One of the methods for data analytics is called data mining. The basic concept of data mining is to sort through large data sets in order to identify trends, patterns and relationships. An example of how data mining can be used within healthcare is predictive analysis which seeks to predict future events such as hospital readmissions by identifying and acting upon trends, patterns and relationships that may be linked to readmissions. AI (artificial intelligence) is the method of data analytics currently most talked of and which currently holds some of the biggest potentials.

AI uses algorithms to decode large amounts of unstructured data (big data) such as images and texts in a short period of time, much faster than a human. The operative word is unstructured since big data analysis enables studies to be carried out on data from a number of different and very varied sources such as social media, images, medical records etc. - data which in the past were extremely difficult to combine.

Deep learning is a form of AI attempting to simulate the neocortex's large array of neurons in an artificial "neural network" i.e. creating an artificial brain, so to speak. In order to emulate the human brain an artificial network consisting of layers of interconnected "neurons" is set up. When used for say, image recognition, each layer analyses the image and communicates its conclusions to the layer above until finally reaching the top layer which forms the final conclusion. Particularly within image analysis and recognition, deep learning is expected to have a huge impact on healthcare.

Data visualization also plays an important role in predictive analytics and machine learning as the advanced predictive analytics or machine learning algorithms' outputs need to be visualized in order to monitor results and ensure that the models are performing as intended.

Kevin Dean explains some of the current uses of Data Analytics:

> *"Where we are looking at patterns of behaviour which are changing over a period of days or weeks and compare them with data from for instance people with similar diseases. Perhaps you are going to the toilet more often in the middle of the night. What are the implications of that? If you are a man it could be that you have prostate problems if you are a woman it could be that you've got an infection of some sort. That kind of minute-to-minute, second-to-second Data Analytics functions have been around for a while but they are becoming much more common"*
> (Dean, 2018).

DATA ANALYTICS IN DANISH HEALTHCARE SECTOR

TODAY

In Denmark every citizen can be identified by a unique number (social security number also called CPR in Danish). Furthermore there are a number of national electronic databases containing healthcare data on for example cancer, use of medication, side-effects, deaths and births just to name a few. The unique number allows for cross references between the many national databases. This puts Denmark in a unique position when it comes to carrying out data analytics on healthcare. Furthermore Danish hospitals are at the forefront of implementing and using IT (Jest, 2018).

Denmark has a comprehensive public health care system divided into several different sectors – primary care provided by the GP, secondary care provided by the hospitals, social care provided by the municipalities as well as a number of privately practising specialist doctors, dental care, physiotherapist etc. All of which collect data on the citizens they come into contact with and all obligated to report to national databases.

The Danish Health Data Agency provides access to health data in the national databases for citizen, healthcare professionals and others with an interest in healthcare data. The data are anonymised and therefore available to the public. The agency is currently working on a health data programme in order to provide an even better healthcare through a better use of data ("Sundhedsdataprogrammet", u.å.-b). The health data agency is also responsible for a national service platform for healthcare data which enables the use of national registry's and services to support the citizen's individual treatment and care (Sundhedsdatastyrelsen, u.å.-a). This national platform also supports the use and integration of data from home monitoring and patient reported outcome (PRO) data and alongside the national registries for storing healthcare data, is an important part of the Danish IT-infrastructure for healthcare data at national level.

Data analytics has been attempted in a number of different projects in Denmark already with varying degrees of success. Some of the positive stories can be seen in the selected cases in this report and some of the negative can be read in the papers, such as the attempt to use the IBM Watson technology in oncology at the largest Danish hospital. Some of the critics from the doctors include that the AI has trouble in reading the patient journals, does not generate new knowledge, has errors in a third of the conclusions and there is no third party or peer reviews to qualify the work that is done (MedWatch, 2017).

However, you also see positive examples of the use of different forms of computer analytics in the healthcare sector today. Karen Andersen-Ranberg says:

"You see it in two ways – you see it both administratively, where we follow our patients and can see the development in health care use. How large a number of patients do we treat? How many beds are in use?, and how many days our patients stay in the hospital and that sort of thing. And that's one part. But also in research, where we have the possibility of gaining new knowledge for the benefit of the patient/ the individual, by using, very often, societal data or healthcare data, and perhaps even in combination."
(Andersen-Ranberg, 2018).

John Christiansen, Head of the local Nursing association, says:

"We are used to count the drops and know how many drops were in a ml when administering the medicine. Today a computer handles this and that makes us close to using robots to help manage the medicine. This makes the patient more independent from us, and at the same time making sure that you have the expertise at hand."
(Christiansen, 2017).

EXPECTATIONS FOR DATA ANALYTICS IN 2025

Without a doubt Big Data, AI and machine learning holds a vast potential for providing significant improvements for the benefit of society and citizens. Due to the number of data already collected and the advancement of IT in hospitals today, Denmark has the potential to gain a real advantage when it comes to data analytics. However data analytics is an unproven technology and its degree of complexity requires thorough testing and investigating. Although we can expect to see some real advantages and results from the use of data analytics in 2025 we cannot expect to have realised its full potential until sometime further in the future. When it comes to applying data analytics to research, desk studies and logistics however, the potential may be expected to be realised in the near future since the data is already available and ready to be tested. In these cases it is merely a question of programming the right algorithms and start training them.

In January of 2018 the Danish Minister for Education and Research, Søren Pind, announced that there are starting six new educations in the field of Big Data in the Danish Universities and an extra economic boost of 30,4 mio DKK is given to the country's eight universities.

He states:

"The technological development is giving business brand new opportunities to change their productions and develop new products matching the consumers of tomorrow. Danish companies should have a head start and place themselves in the front of fields of new technologies such as artificial intelligence and big data. By

strengthening our research Denmark has a golden opportunity to be in the forefront and this will bring us well into the future" (Uddannelses- og Forskningsministeriet, 2017).

And with the health data programme initiated by the health data agency the path is set for Denmark to fully unleash the potential of data analytics in 2025.

Kevin Dean says:

> *"For me there are two large pots of Data Analytics we need to look at. There are things that give immediate feedback and decisions can be made upon probably second to second, minute to minute, perhaps hour to hour and then there are long term analysis of large amounts of data which is often done in bulk and where you can spend time looking at pattern analysis across multiple datasets in much greater quantities."* (Dean, 2018).

Studies of long term analysis as mentioned by Kevin Dean has already been carried out and shown great potential, for example within the field of predictive analysis. At least one example and a set-up for applying data analytics on exciting data and using it for predictive analysis have already been tested. Others are soon to follow. The key to success is identifying which data to analyse and how to gain access to them. The next step will be combing these data with other data generated by the citizens themselves for example via their use of smart home solutions, wearables or social media. The use of personalised medicine can also be expected to take off over the next couple of years and here data analytics can also be expected to play an important part.

Jonas Moll, CEO and Assistant Professor, says:

> *"….we can look up all the times you have been admitted to the hospital what kind of procedures that were carried out on you, your blood tests, your diagnosis and your prescribed medication so we have a wealth of knowledge."* And he continues: *"So I think the future of Data Analytics it will not so much be in new methods or algorithms, but mostly in combination of data sources. So we will see predictions and an ability to take care of people in another way by combining information that we right now have no way of combining"* (Moll, 2018).

CHALLENGES FOR
DATA ANALYTICS

The overall challenges for data analytics consist of challenges regarding access to data and the quality of data, ensuring enough talent and gearing the organizations, securing data and modelling quality, cross-sector and cross-country collaboration, adhering to legislative demands and ensuring continuous trust in the public and amongst healthcare professionals (SAS Institute, 2016). Data analytics will require new levels of education and it is important that the programmers developing the solutions understand the clinical needs and processes they are to support (or change). In order to ensure data is used in the most profitable way cross sector and cross country collaboration is necessary.

As Erik Jylling, Director of the Danish Regions, explains:

> *"And there is a growing realization within authorities and the public as well, which we of course have to take into consideration when we are sharing personal data and healthcare data, but there is an increasing acceptance that we have the ability to share data across sectors to support patients in the best way."*
> (Jylling, 2018).

And Karen Andersen-Ranberg supports him and elaborates on why cross country collaboration is valuable as well:

> *"Regarding the organization of the Danish healthcare sector I definitely believe that in the future we can make more out of using and transferring data between each other; meaning between the different health care sectors. So I think the way of trying to merge, functionally, the two sectors, primary and secondary, in terms of using the same data set would be of great value ... Internationally, or in Europe, which I know best, EuroStat collects national data from all the different countries. And this is very valuable for us to understand the differences between the countries. This is important because we, as Danes, live in one region in Europe, but still we can be different from our neighbouring country. A good example is Sweden which like Denmark has the same social structures, the same rules of game by having tax-funded healthcare and educational systems, but still Swedes lives 2-3 years longer than the Danes, and that we know from vital statistics. So that kind of data can be used to search for explanations why we have such a huge difference in survival. What are the Swedes performing better than we? What are the differences? What explains the differences in health?" (Andersen-Ranberg, 2018)*

In May 2018 the new person directive from EU (GDPR) will enter into force in Denmark. The purpose of the directive is to strengthen citizens' fundamental rights when it comes to data, privacy and digitalization – but also

to simplify rules for companies and thereby facilitate growth. Some of the more noteworthy changes enforced by the directive are the possibilities of issuing fines amounting to up to 4% of a company's annual turnover. Particularly the new obligations on such matters as data subject consent, data anonymization, data mining/automated processing, is likely to have a significant impact. When it comes to consent it must be explicit and the citizen must be clearly informed of the precise and defined purpose of data collection. However many solutions based on data analytics are not precise and defined. On the contrary, they are exploring as you look for patterns in data and use the results to ask new questions. Thus the regulation on data security and privacy will be huge a challenge in terms of achieving the full potential of data analysis. In fact according to the EU directive the citizen has the right not to be subjected to automated decision making without consent. The potentials and risks of AI, machine learning and particularly automated profiling is being discussed quite heavily as the bill is being debated by members of parliament. Since it has not yet been passed we cannot say exactly how the wording of the GDPR, General Data Protection Regulation, will turn out in Denmark.

If data has been fully anonymized then there is no requirement for consent when it comes to data analytics. But data must be fully anonymized. Pseudonymization of data is not sufficient. The difference is that pseudonymized data is depersonalized, which means that it cannot be directly linked to an individual. However, by providing additional information, data can be linked to a specific person again. When data is fully anonymized linkage to a specific person is impossible. In order to be able to handle this challenge it requires companies to have experts on anonymization employed as well as a clear and transparent set-up for their collection of data and implementing privacy be design in their solutions is also a very wise move.

Niall McDonagh, Microsoft adds to the subject:

> *"As regards to the barriers concerns about data privacy are an obvious barrier and it is perfectly valid that healthcare services should tightly control what third parties can do with data. Microsoft welcomes the introduction of legislation and regulations to protect privacy and we commit to comply with it. While privacy concerns and lagging legislation might slow adoption we believe that society will adopt these technologies because they have the power to significantly improve health outcomes"*
> (McDonagh, 2017).

When it comes to scientific studies the obligations, when it comes to consent – amongst others – are more lenient than when data is used as part of daily operations. Karen Andersen-Ranberg explains the needs for scientific studies:

"The challenges for using data analytics in the future are if we get more restrictions on using the data that would be a problem. For example if we should have the informed consent from each individual to run some register analysis that would really hamper the results because we know that people just by default say "No, we do not want to be part of it", because they do not know what they are talking about, so to better be safe than sorry they just say no. I think there is a general fear in the society that we have to much "Big Brother" watching you so that is why people are afraid of "What are you going to do with my data?", "Are you going to sell them?". And people are right about asking these questions, but they should know more about how we use the data, because we do not have their identity, it is pseudo-anonymized data and we do not have access to the key data that can directly identify an individual. And I do not think that people really understand this. But public opinion could very well add to the restrictions on the use of data, which would hamper our work. And perhaps also take some of the fun out of doing research" (Andersen-Ranberg, 2018).

Jonas Moll agrees with her on the barrier:

"Today we are prohibited to combine those kinds of information as a standard company so you can only do it if you are doing research. So either you are in a research project engaging with a university or hospital or you do the work as a researcher. I have not seen a solution to this yet. In my opinion I think that we should acknowledge that there is so much data being produced about us that it is not so much a question of whether or not to engage in producing data because there is no way back, but we need to figure out a way to meaningfully handle it. I think we should, for the sake of generations coming after us, let go of the data and spend a lot of time figuring out how to deal with it privacy wise. So we need to put some money in to how we tackle these problems systematically" (Moll, 2018).

One possible answer could be to carry out more scientific studies in order to identify and test relevant sources of data and possibilities for anonymizing the data used for analysis when implementing the solution. Further collaborations with hospitals, municipalities, universities and private companies could very well turn out to produce new and innovative solutions the trying combination that is data analytics and privacy legislation.

Another challenge that might hamper the uptake and implementation of solutions based on data analytics is the commercial aspect and business models proposed by some companies today. In Denmark there is a core principle in the Danish healthcare system of easy and equal access to healt-

hcare. It is one of the cornerstones of healthcare in Denmark and detailed in the legislation as well (Retsinformation.dk, u.å., §2). If for example – large tech companies – make their solutions available solely based on commercial terms thus leaving the less resourceful citizens behind this would be in opposition to the core principle of easy and equal access (Mandag Morgen, 2017). Such a business model would deny the public healthcare system (hospitals, GP's etc.) the possibility to utilize these solutions, because it would be illegal for them. This would also mean that the potential marked for these solutions would be quite small since the public sector would not be part of it. It is therefore important for companies developing solutions based on data analytics to ensure that they are not basing their product on a business model in conflict with this principle. Karen Andersen-Ranberg gives an example of poor resources in terms of infrastructure and network connectivity:

> *"Another barrier for us to use digital data collection is if we do not have a proper mobile network out there that can support the transmission of data from the individual to us. This will affect those living in an area with a poor mobile network, which usually is synonymous with remote or rural areas where we have relatively more older people living, which also typically are those with a lower socio-economic background. And those are also the ones who need us more because they are more ill and have more health problems. Definitely barriers are that we do not have the underlying logistic support for all the things we want to do with the new technological devices."* (Andersen-Ranberg, 2018).

VALUES AND RISKS OF DATA ANALYTICS

VALUES FOR CITIZENS

EARLY DETECTION

Data analytics can help ensure a better and more effective treatment for citizens who come into contact with the healthcare sector. As described by Karen Andersen-Ranberg:

> *"To the citizens the value would definitely be that we could monitor by surveilling them at the individual level and monitor and follow a disease progress and maybe intervene earlier so that they can avoid some adverse health outcomes, for example an acute hospitalization, which is always something quite strenuous for the older individual"* (Andersen-Ranberg, 2018).

ACCESS TO INFORMATION

Through data analytics, citizens can have access to new and more differentiated information regarding their own behaviour and health, which can support their individual empowerment and ability to take care of themselves. This might also mean new tasks for the professionals as John Christiansen says:

> *"It will be part of our profession to be able to guide the patients in making choices on the basis of accessible information, and in reality all this knowledge can make it difficult to navigate and I see us playing a new role here"* (Christiansen, 2017).

RISKS FOR CITIZENS

BREACH OF SECURITY

Since more data is being collected and used as part for the healthcare system the risk of breach of security is also increased. Karen Andersen-Ranberg explains:

> *"When it comes to the risks of course there is a risk of being surveilled; people do not like to be surveilled all the time, so it is always a kind of weighing out the benefits and the risks of it. So we need to have a dialogue with the individual about doing what we do. Also it can end up in the wrong hands and be misused by other commercial interests, for example, at the individual level. That is really something that we are all very much concerned about and we have to make sure that we have some safety guards that can avoid this unfortunate situation to happen. We need to reassure people that data cannot be shared with someone with commercial interests"* (Andersen-Ranberg, 2018).

INEQUALITIES IN HEALTHCARE

The ethical aspects of data analytics may also be regarded as a risk for citizens because if data analytic solutions are being developed and implemented solely from a commercial perspective the less resourceful groups of society may not be able to take advantage of them. They may lack the funds to invest in the necessary technology or the company developing the solution may exclude them from access because of lack of financial potential. If this were to happen further inequalities in the public health and thereby for low income and groups and citizens with low resources would follow.

DATA FAULTS

Faults in data sets or algorithms pose an immediate threat to patients. A small error in the data or methods can lead to maltreatment of the citizen which may result in a deterioration of health or even death.

VALUES FOR THE HEALTHCARE PERSONNEL

ACCESS TO INFORMATION

When more data is being collected and made available to the healthcare personnel they will have a better foundation for providing treatment and medical guidance to the citizens. Data analytics will be able to provide healthcare personnel with tools to support decision making, predictive medication etc.

EFFECTIVE TREATMENT

Access to tools to support decision making, predictive analysis and personalised medicine will assist the healthcare personnel in being able to provide a more efficient treatment for the citizens and thereby supporting a higher degree of job satisfaction. Karen Andersen-Ranberg elaborates:

> *"To healthcare personnel I think the value is definitely that they would be more alerted on an individual by seeing the data coming in and seeing that something has changed, so they would optimize the use of data analytics for the good purpose of treating this patient or citizen a little better."* (Andersen-Ranberg, 2018).

REDUCE ROUTINE TASKS

Data analytics can be used to carry out or support routine tasks thus allowing for more efficient utilization of resources. This can help ensure a higher degree of job satisfaction as well.

RISKS FOR THE HEALTHCARE PERSONNEL

POSSIBLE REDUNDANCY

Data analytics will require a new set of skills from healthcare personnel and some may fear to be made redundant as a result of implementing solutions based on data analytics. Data analytics require healthcare personnel to be willing and able to use insights from data as well as requiring a change from traditional practices. This may lead to change of working methods that may be difficult for some healthcare personnel.

LOSS OF CONTROL AND ABILITY PERFORM QUALITY ASSURANCE

Lack of skills may also result in incorrect use of technologies which can harm the citizen and lead to demotivation of health personals. Furthermore, due to the complexity of data analytics will also be difficult – sometimes even impossible – for the healthcare personnel to access if the data analytics based solution they are using is not providing correct results due to for example errors in the algorithms. The healthcare personnel thus risks carrying out malpractice or adverse events due to no fault of their own and without being able to prevent it. This loss of control may prove unacceptable to many healthcare personnel – particularly doctors.

VALUES FOR THE HEALTHCARE SECTOR

IMPROVED QUALITY OF CARE

More information is available to the citizens and healthcare personnel. Data analytics help structure the data and gain new knowledge from it thus helping to provide more efficient treatment to the citizens and improve quality analysis.

PREDICTIVE ANALYSIS

Predictive analysis can support the healthcare sector in a number of ways. It's possible to predict hospital readmissions through data from home monitoring devices, which improve the quality and cost of health services. Home monitoring systems also promise to provide better care for citizens and help solving resource challenges, such as limited human and financial resources.

REDUCE ROUTINE TASKS

As stated by Professor Uffe Kock Wiil *"Machines can outperform humans in carefully selected and very limited domains"* (Kock-Wiil, 2017). Data analytics can be used to carry out or support routine tasks thus allowing for more efficient utilization of resources.

BETTER CITIZEN EXPERIENCE

Data analytics can also be a great help in hospital logistics. Unplanned events like citizens falling sick, lack of staffs, lab closures, and equipment failures can lead to unplanned delays especially in departments like OR. However, this is where AI algorithms can be helpful. Using machine learning techniques datasets over several months and years can be analysed to look for patterns that would be a great predictor of times and delays in hospitals. This information can then be used to improve logistics and thereby create better citizen experiences.

RISKS FOR THE HEALTHCARE SECTOR

POTENTIAL SETBACK FOR RESEARCH

One of the risks healthcare is experience is that people don't always know how and for what their data is used. This may lead to worry and refuse when they are asked to participate in clinical trials. Without clinical trials it can be difficult to test which impact medicine and treatments have on certain people with certain diseases. This can be a drawback for the development of healthcare.

LACKING DATA RELIABILITY AND QUALIFICATION

The hype that data analytics will improve healthcare is big, but however the reality is far more limited. One of the challenges to implementation of data analytics in healthcare is data reliability. There may be error and bias in electronic health data from human entry, and a system can also introduce bias into data collection and analysis. For example organizations with a weak technological infrastructure may not be able to collect all relevant data or may collect incorrect data if algorithms have flaws.

In addition, physicians who don't get sufficient instruction to the system or don't have the right skills to use it may also lead to bad reliability of data. Reliability of data is very important as physicians decide which treatment or medicine a citizen should have on the basis of data.

Hal Wolf recognizes the shift in culture and the need for different skill sets as an important issue:

> *"So it is important to recognise that this is a fundamental change when you begin to shift from cranial knowledge, what is in your head, to the use of external knowledge tools in order to supplement diagnosis or conversations that happen, whether it is at the patient level or at the clinical level, that is a cultural change" (Wolf, 2018).*

VALUE FOR SOCIETY AS A WHOLE

REDUCE NUMBER OF ADMISSIONS

Data analytics will enable us to transform the healthcare system completely because we will be able to carry out more targeted and earlier preventive actions which will reduce the need for hospital admissions considerably. We will also be able to detect serious illnesses earlier thus carrying out more effective treatment and reducing the time spent in hospital. The number of public registers containing healthcare data will be important tool in achieving this. All these together will improve the quality in citizen experience. Karen Andersen-Ranberg explains:

> *"Using data analytics could affect the way we organize the whole health care system especially the cooperation between the primary and secondary health care sectors because we share the same individuals, but we do not use the same systems to monitor them. If we somehow through the data analytics could see the benefit of using the same systems it would be very valuable both for the individual and for the society"* (Andersen-Ranberg, 2018).

ACCESS TO INFORMATION AND MORE EMPOWERED PUBLIC

Data analytics can contribute to better information to the citizens about their health which can help empower them to improve it thus saving resources for society. Karen Andersen-Ranberg says:

> *"I think that those who would benefit the most are equally the health care system and the patients because of course the patients would benefit from being better tracked, better monitored, better treated and earlier treated, and that in the end this will also be a gain for the society, that pays for the health care through our tax funded welfare. For the companies of course it is an opportunity to make some good business which we as a society but also as individuals could benefit from given they find some new solutions that can be used for the good of the individual and not for harm"* (Andersen-Ranberg, 2018).

BETTER QUALITY OF CARE

In addition, automation of processes can contribute to increase efficiency in terms of using fewer resources, faster analysis and possibly reducing of adverse events which reduce deaths, complications and costs.

RISKS FOR SOCIETY AS A WHOLE

BREACH OF SECURITY AND LACK OF TRUST

One of the major challenges the society as whole is facing when it comes to data analytics is lack of trust when it comes to giving access to their data and lack of trust from the healthcare personnel who are to rely on the solutions based on data analytics. Insufficient understanding of the consequences of giving access to ones' data may also cause breach of security and/or lack of trust in solutions based on data analytics.

INEQUALITY OF CARE

There is also a risk that use of wearable and citizens who have access to more information will leave the most deprived citizens behind. It is often the more resourceful and well educated citizens who are able to make use of wearable and improve their health. Moreover, predictive data analytics that aims to improve public health through preventive initiatives will be more beneficial to those who are already socioeconomically advantaged and have the necessary resource to change their lifestyle – thus resulting in further stigmatising the citizens struggling with diseases related to unhealthy lifestyle such as for instance diabetes or COPD.

CASE:
COMPUTER-VISION FOR IN-HOME MEDICAL DIAGNOSIS AND MONITORING

Human facial image/video can convey information regarding to expression, mental condition, physiological parameters such as heart-rate and respiratory rate, and symptoms of disease. Thus, this thesis aims to contribute to the development of facial image-based diagnostic and monitoring systems for in-home patient or elderly by employing computer-vision methods.

Development of facial image-based diagnostic and monitoring systems using computer-vision methods imply a number of challenges to be addressed. Major challenges include setting up an appropriate network of sensors for facial data acquisition, pre-processing of facial image data, selecting the area of interest as a subset of captured data, extraction of appropriate features from the data, and employing effective machine learning methods to automatically detect clinically important factors from the captured data.

In this project, emphasis will be put on face extraction from video using a quality assessment, facial skin colour analysis, face alignment and facial feature tracking in video frames, expression and emotion recognition, and finally, developing clinically relevant systems using relevant facial information. The thesis proposes an improved method by using a new heartbeat footprint tracking approaches in the face. The thesis also introduces a novel way of analysing heartbeat traces in facial video to provide visible heartbeat peaks in the signal. The way to extract and utilize this biometric trait in person recognition and face spoofing detection is described in the project.

[Click for further reading on the case](#)

OPPORTUNITIES FOR COMPANIES

COMBINING DATA FROM DIFFERENT SOURCES

There is a vast potential for data analytics in healthcare, and one of the major opportunities is analysis of data collected from different types of sources e.g. Internet of Things, public data, home monitoring data, social media and etc. The amount of data continuously increases and by its high volume, variety and velocity, the potential for data analytics is therefore substantial. The key to accessing these data is adhering to legislation (particularly with regards to consent and the restrictions on carrying out data analytics/data mining as they will be stated in the bill when it is passed) and ensuring full transparency in how the data and the analysis is used. As described in the case example combing and analysing the right data comes with enormous possibilities. The challenge is identifying which data it is worthwhile combining. Further studies are needed in order to proceed here and companies can benefit from teaming up with researchers in joint projects looking further into the value of different data sources and how to combine them.

REDUCE ROUTINE TASKS AND IMPROVE JOB SATISFACTION

As mentioned earlier by Professor Uffe Kock Will: "Machines can out-perform humans in carefully selected and very limited domains" meaning that data analytics can be successfully applied to automation of selected workflows, e.g. in literature search, dermatological and radiological imaging (Kock-Wiil, 2017). Algorithms can be trained to detect abnormalities in radiology images while radiologist can rate its effectiveness and make the final decision. And there are probably a number of other routine tasks within healthcare which can be carried out or at least supported by AI. The key is to identify them. This is probably best achieved in interdisciplinary teams where healthcare personnel work together with technical experts.

PERSONALIZED MEDICINE

Furthermore, data analytics also holds great potential regarding personalized medicine. The goal of "personalized medicine" is to make use of data from citizen journals and genomics data to facilitate clinical decision making which is predictive, preventive and personalized. The potential for success in the field of personalized medicine is extremely high but as pharma in general the entry barriers to this marked are also extremely high. The most likely contesters to succeed here are therefore the companies already established within the pharma industry in collaboration with clinical researchers – for example in public-private collaborations.

PREDICTIVE ANALYSIS AND TARGETED PREVENTION

The use of data analytics for targeted and earlier preventive actions which will reduce the need for hospital admissions considerably and it will also

enable us to carry out earlier preventive actions.

Microsoft has identified some concrete possibilities for Data Analytics in Denmark:

> *"…in a recent innovation workshop we identified short term potential in Denmark for analytics to help in areas such as bone fractures, in predicting what blood tests specific persons will need in a range of population health scenarios. You know the countries where leveraging analytics in a range of clinical decision support scenarios – an example would be using artificial intelligence to support radiologists map tumors, prepare patients for treatment. We are using analytics in the detection and prevention of hospital infections, the analysis of how the patient pack impacts the admission rates, in remote screening and monitoring. More broadly we see advanced analytics in medical images, genomic analysis for precision medicine and analytics and data from monitoring devices for patients with chronical diseases will all grow exponentially."* (McDonagh, 2017).

BARRIERS FOR COMPANIES

DATA LEGISLATION

There are several challenges in healthcare when it comes to use of data analytics. One of them is the new EU-legislation (GDPR) regarding data privacy being debated and passed as this report is being written. The overall considerations section contains an overview of this, the two main barriers when it comes to legislation is handling consent and the restrictions on carrying out data analytics/data mining.

STAFF CAPABILITIES AND ORGANISATION CULTURE

Another challenge to implement solutions based on data analytics in healthcare is that healthcare personnel may be reluctant to change their routines due to fear of being made redundant. It is also clear that the healthcare sector will require more or some other skills from the healthcare personnel in order for them to successfully work with solutions based on data analytics.

SHORTAGE OF QUALIFIED EMPLOYEES

As AI finds its way into more and more areas, the demand for technical skills and talents are growing. This is a big challenge as there is a significant shortage of programmers, data scientists, IT specialist and cyber security experts, among others. Furthermore, the optimal effect of data analytics also requires organization that work targeted with AI and other data analytics methods which demands investments in each organization (Mandag Morgen & Danske Regioner, 2017).

NOT LIVING UP TO THE HYPE

The expectations of data analytics are staggeringly high and certainly can be described as constituting hype, thus facing the inevitable risk of not living up to its expectations. It is therefore important to bear in mind that the techniques currently explored within the field of data analytics are just that – at an exploratory state. It is also important to bear in mind that data analytics can't come close to human intelligence as it can calculate anything but understands nothing. Data analytics needs human inputs to learn and improve and it needs vast sets of data to train on as well. For example, an algorithm that detects cancer in the brain by analysing MRI will be trained on thousands of pictures to recognize a pattern. But what if the algorithm doesn't recognize the cancer because it looks a little different from the pictures it has been through? Or what if there is a small error in the algorithm causing it to only recognise certain types of cancer images but not all? How do we ensure the solutions developed are trustworthy?

CONSIDERATIONS FOR COMPANIES

The considerations given to the field of data analytics mainly fall within the field of ethical considerations, access to data and technical skills, trust and breach of security and of course legislative considerations.

ETHICAL

The ethical considerations pertains to the possible violation of the principle of free and equal access to healthcare (as described in an earlier section of this report) if data analytics is being developed and implemented by private companies and based solely on commercial terms. Another ethical aspect is that data analytics is so complex that both citizens and healthcare personnel can find it impossible to understand what the consequences of giving access to data or assessing the correctness of the results of the analysis carried out.

NEGATIVE EFFECTS OF PREDICTIVE ANALYSIS

Jonas Moll shares an example: "When we talk about ethics and AI I think a great example is a year old where some computer scientists, I think at the University of Copenhagen, the proved that for public schools you can predict what pupils will fail the final exam – and the computer scientist made this as a tool for teachers to know what students they should attend more to but in reality when they tried it out it showed that teachers would then conclude that "OK, they are gone anyway so I won't waste my time on those students". So I think that is a brilliant example of how prediction can become quite an ethical problem or how you should consider how your application will be used." (Moll, 2018).

RESPECT THE INDIVIDUAL AND THEIR DATA

Niall McDonagh describes Microsoft' considerations in regards to ethics:

> *"So the first ethical principle from Microsoft is that it is the customer's data. Our customers are obviously the health service and they control the data on behalf of their customers who are of course the patients. Our business model involves selling technology to enable our customers to derive value from their data. However we do not leverage that data in any way to generate a return. In fact we want to limit our access to the data to those instances where access is required to address a technical issue. We even provide the ability for our customers, again the health providers, to control our access in those instances. We do not just say that but we commit to it contractually. A second principle is that we do not see the role of advanced analytics to replace the clinician but to assist the clinician. Our product development in the AI space is focused on analytics that can assist the clinician in better decisions or in saving time."* (McDonagh, 2017).

YOU DO NOT NEED TO ACCESS THE STAIRWAY TO DATA HEAVEN

As mentioned in previous sections in this report access to data is crucial and attempts are already in the making as to increasing the availability of the data gathered in national databases. It is however important not to take the approach of getting access to all data - "see what we can find", as Uffe describes it (Kock-Wiil, 2017). It is important to work on data analytics in interdisciplinary teams with both healthcare personnel and technical experts present – and perhaps also including patients' representatives' organisations. The right combination of people is a prerequisite for identifying the right innovative combinations of data on which data analytics will add value.

TRUST AND BREACH OF SECURITY

It is important to ensure trust from the citizens to give access to their data and from the healthcare personnel to base their decisions on data analytics. A high degree of security regarding the handling of data and full transparency as to which analyses are carried out is necessary.

As Peder Jest says:

> "It is about human beings. It is about respect for the human life. And it is what the single person would like or would not like. So there are a lot of ethical problems. There are also the security problems, again technology security it is a huge barrier. You know the Danish people they deliver their data everywhere. They don't care. But as a system, Danish system, or healthcare system, it is very important that you can keep your data and that your data is secure. So that is a huge barrier too, I think."(Jest, 2018).

LEGISLATIVE

Legislation should of course always be adhered to but in the case of data analytics it is particularly important since data privacy has a lot of political focus – particularly from the EU.

ADVICE FOR COMPANIES

COLLABORATE WITH THE RIGHT EXPERTS

In order to fully utilize the vast potential held by using data analytics for healthcare, the companies developing such solutions need to collaborate with experts from disciplines beyond computer science and engineering as well.

COLLABORATE WITH HEALTHCARE EXPERTS/USERS

It is equally important that the solutions support the healthcare professionals or patients in their daily work routines. As Peder Jest describes it:

> *"It is not good when the patients or the healthcare professionals should use the system while they are in the situation – it should be automatically picked up all this data. And I expect that will be possible very soon… So we have to be much more aware of the new types of mobile technology than we are today"* (Jest, 2018).

John Christiansen agrees and adds:

> *"…if systems are so complex that we need so much instruction to use them, maybe we are not the ones needing training but maybe the systems are not intuitive enough. The same goes for the citizens – if there needs to be a manual for the system then maybe it has not been designed correctly."* (Christiansen, 2017).

EXPERTS ON ANONYMIZATION ARE NEEDED

Due to the nature of the GDPR it is important for companies wanting to work with data analytics that they employ experts on anonymization and perhaps also collaborate with legal experts who can assess whether the data collected can be used for the purpose the company desires. Being able to anonymize data is key to being able to work with them and train algorithms on them as required in order to success with data analytics.

BUILD TRUST BY ENSURING SECURITY

Trust is a key issue in successful implementation and utilization of data analytics for healthcare. Healthcare data is extremely sensitive and the development and use of data is essential for both the development and the use of data analytics. Even the slightest hint of any lapses in the security of data could be fatal. It is therefore vital to ensure that proper control systems are implemented, constantly updated and sound governance processes regarding their use are in place. Full transparency regarding these controls and how they are carried out is likewise of great importance. Furthermore the legislation covering this area is complex and varies a great deal between Europe and the US. The implications of not adhering to the legislation can be significant – not only of a financial nature but also

in terms of loss of trust and thereby loss of the access to data in the future. It is therefore important to work closely with legal experts who can help ensure the full legality of the solutions developed as well as with communication experts who can ensure transparency is actually achieved. Involving the healthcare personnel and the citizens/public health organisations is likewise important.

FOCUS ON TRANSPARENCY

Transparency is important in order to ensure and keep the trust necessary to get access to data. In order to achieve this proper control systems must be implemented, constantly updated and sound governance processes regarding their use is also a must. As supported by Uffe Kock Wiil: "We need to avoid black-box approaches." (Kock-Wiil, 2017).

INTEROPERABILITY

Facilitation of data sharing between organisations holding data and organisations looking to use data is paramount for the success of data analytics. It is vital to ensure that exchanges are secure and mutually beneficial. As Niall McDonagh from Microsoft explains:

> *"So our advice to companies or other organizations considering developing analytics based applications for healthcare is to build solutions that are really grounded in interoperability, in open standards and with an architectural design for both privacy and security in the cloud. Extensibility, scalability and open governance will define adoption of artificial intelligence based solutions in the future. Think about possible and viable new business models for health data analytics that will serve the local and regional eco-system, provide benefits for citizens but also ensure the timeless values of privacy and security"* (McDonagh, 2017).

CASE:
IDENTIFICATION OF PATIENTS AT RISK AND PATIENTS IN NEED

Identifying patients who unexpectedly deteriorate during their admission to the emergency department challenges hospitals worldwide. In Danish emergency departments, 10 patients unexpectedly deteriorate every day – resulting in heart/respiratory failures, ICU transfer, or in-hospital death.

In this project, the aim is to develop and evaluate a new monitoring platform that utilize existing streams of clinical data from patient monitors to strengthen the situational awareness of clinicians – thus helping them spot risk patients in due time.

Building such a platform successfully requires close collaboration with subject matter experts and clinicians who would utilize the system on a daily basis. Fortunately, a strong alliance with the management and staff at Fælles Akutmodtagelsen (Emergency Room), Odense University Hospital, has enabled the project to design a prototype of a novel monitoring system. In the work, the system aggregates vital sign readings from the department's Philips monitors, and couples these streams of small data with clinical logistics systems information to provide clinicians with an overview that build upon their existing scoring systems and mental models.

The prototype has been validated in a feasibility study with very positive results, and is currently being elaborated upon to prepare it for a large scale effect evaluation. This will be conducted as a cluster randomized trial in 2018 at the emergency departments of Odense University Hospital and Hospital of South Western Jutland in Esbjerg. The study will be evaluated in terms of clinical, technical, and economical outcomes.

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