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Challenges of collaborative disruptive technologies

A case study on upscaling MPC applications in the healthcare domain

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Contents

1 Summary

Multi-Party Computation (hereafter: MPC) is an innovative solution to jointly analyse sensitive data without having to share it. This ensures that parties cannot see each other's data, but also that the end result cannot be traced back to individuals or companies and that data is not visible to the outside world.

However, the technology behind such an ICT application only covers part of the innovation. When a disruptive technological innovation[1] is implemented within an organisation, organisational issues are involved. When it concerns a disruptive technological innovation that is implemented in multiple organisations (i.e. *collaborative disruptive innovations*), other issues also play a role, and these are focused on collaborations between organisations during the implementation of such a disruptive technology. In addition, for emerging technologies[2], it is important to identify additional challenges, in particular ethical and legal ones.

This case study describes the organisational, ethical and legal issues involved in scaling up MPC applications. It is based on a qualitative use case study of the *Care for Data* use case[3], also known as *Privacy Preserving Analytics,* in the healthcare domain carried out within the Techruption programme[4] by TNO, CZ, CBS and Zuyderland hospital.. In this use case, MPC is applied in the healthcare domain with the aim of contributing to value-driven care. Value-based healthcare aims to maximise the medical care provided to a patient. The value of healthcare is measured in terms of patient results achieved per euro spent. Therefore, better care does not mean more care or more expensive care[5]. The case study consists of interviews with organisations involved in the use case, expert interviews and input from (internal) stakeholder meetings.

[1] Disruptive technological innovations concern the process whereby new technologies - often introduced by newcomers - develop into disruptive innovations that capture the market with new business models - often at the expense of established companies (Christensen, 1997; Christensen & Raynor, 2003). Creative start-ups want to develop disruptive innovations, while established companies fear being surprised by them (Geurts, 2017).

[2] Emerging technologies are new technologies whereby it is not clear at first glance whether they will develop further and how they can or will be applied (Martin, 1995). Such technologies are often still in the '*fuzzy front end',* characterised by significant uncertainty and ambiguity. It is clear that there is an evolutionary relationship (over time) between emerging technologies and potentially disruptive technologies (Li et al., 2017).

[3] https://www.tno.nl/en/tno-insights/articles/secure-data-sharing-in-healthcare-with-complete-privacy/

[4] https://www.techruption.org/

[5] Kaplan, R. S., & Porter, M. E. (2011). How to solve the cost crisis in health care. *Harvard Business Review*, *89*(9), 46-52.

The results of our analysis identify several specific challenges for organisations that want to jointly develop and implement collaborative disruptive technological innovations. In addition, we identify a number of challenges related to the emerging nature of disruptive ICT innovations.

2 Theoretical background

2.1 Disruptive technological innovations

In these times of rapid technological change, we are increasingly faced with disruptive innovations. This is the process by which new technologies - often introduced by newcomers - develop into disruptive innovations that capture the market with new business models[6]. Newcomers and start-ups often want to develop such disruptive innovations, while established companies are stuck with their existing business models[7]. Known challenges such as inertia, dependencies due to past investments and existing networks, and outdated or irrelevant knowledge base and business models play an important role in this respect[8,9,10]. Organisational changes also play a role, such as changing existing or creating new processes and procedures, or changing existing or creating new roles and functions and role shifts[11]. A new technology therefore only covers part of the innovation process.

2.2 Issues in scaling up collaborative disruptive ICT innovations

The technologies at the heart of this article - see box - result in two unique challenges for organisations dealing with disruptive technological innovations. Firstly, the organisations in this study are dealing with a disruptive technological innovation[1] that is developed and implemented by multiple organisations. This means that this is a technology that is applied across organisations. We therefore identify such disruptive innovations as *collaborative disruptive technological innovations*. We expect other organisational issues to play a role when it comes to such collaborative disruptions, which are aimed at collaborations between organisations, compared to 'traditional' disruptive technological innovations restricted to a single organisation.
Secondly, the organisations in this study deal with *emerging* ICT technologies[2]. When designing and scaling up a *new, emerging* ICT technology, it is particularly important

[6] Christensen, C.M. (1997*). The innovator's dilemma: When new technologies cause great firms to fail*. Boston, MA: Harvard Business School Press.
[7] Geurts, A. (2017). *Firm Responses to Disruptive Innovations: Evidence from the music industry.* Dissertatie Rijksuniversiteit Groningen.
[8] Christensen, C.M., & Overdorf, M. (2000). Meeting the challenge of disruptive change. *Harvard Business Review*, 78(2): 67-75.
[9] Assink, M. (2006). Inhibitors of disruptive innovation capability: a conceptual model. *European Journal of Innovation Management*, 9(2): 215233.
[10] Geurts, A., Broekhuizen, T.L.J. & Dolfsma, W.A. (2017). Responses to disruptive innovations: results from the Dutch music industry. *Monthly journal for Accountancy and Business Economics*, 91 (3/4).
[11] https://www.berenschot.nl/expertise/diensten/blockchain/blockchain-toepassen/"

to embed the identification and evaluation of ethical interests in the innovation process[12]. Ethics refers to the discussion and reflection on morality. Morality is the whole set of views, decisions and actions by which people express what they think is good or decent[13,14]. Ethics can be described as a search for the right morality, and is by definition something to discuss[15]. Current legislation is based on the morality on which consensus has been reached. An example of this is *privacy legislation*. Because new technologies, such as MPC, address subjects that have not yet been addressed before, discussions around moral issues play an important role. This makes the implementation of emerging disruptive technological innovations challenging, because there is no consensus *(yet)* [16]. As a result, we expect ethical and legal issues to play a more important role when it comes to such emerging, disruptive technological innovations.

This article looks specifically at Multi-Party Computation (MPC) technology. MPC consists of cryptographic techniques that make it possible for parties to jointly rely on their data as if it were a shared database, while they cannot access each other's data with mathematical certainty. One of the underlying techniques is Paillier, a so-called *homomorphic encryption technique* that encrypts the data in such a way that it can be used for calculation purposes without having to decrypt the data. In this way, MPC replaces the functionality of a *trusted third party* (a trusted intermediary): the input data remains confidential, and yet the outcome of a calculation can be determined. Blockchain technology is a way to capture distributed information (e.g. transactions) across multiple organisations without being changed. As with MPC, Blockchain technology makes use of cryptography, and offers an opportunity to replace a traditional *trusted third party*. However, where MPC focuses on data confidentiality, Blockchain focuses on data integrity and non-repudiation: creating a common truth. In the use case central to this article, blockchain is used *in combination with* MPC to establish rules about what is and what is not allowed by means of a smart contract. For example, with the stipulation that parties cannot carry out random *queries* on each other's data - *queries* can only be carried out on the basis of consensus. An *audit trail* is also maintained on the blockchain, using meta data (information about which dataset, when, by which party was used in which *query*). This information is irrefutable and permanent.
These technologies are applied in the healthcare domain. The increasingly expensive healthcare sector with increasing staff shortages requires a different way of organising. By using MPC and Blockchain Technology to evaluate e-health applications, the intention is to deliver value-based healthcare.

[12] Dignum, V. (2019). *Responsible Artificial Intelligence: How to develop and use AI in a responsible way*. Springer International Publishing.
[13] Bolt, L. L. E., Verweij, M. F., & Delden, J. J. M. (2003). *Ethics in practice*. Publishing house Van Gorcum.
[14] Dubbink, D. W. (2015). Legally correct or morally correct? *Controllers Magazine*, 26-29.
[15] Santoni de Sio, F., & Van den Hoven, J. (2018). Meaningful human control over autonomous systems: A philosophical account. *Frontiers in Robotics and AI*, *5*, 15.
[16] Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology Analysis and Strategic Management*, 18(3–4), 285–298.

3 Methodology

To determine the challenges of disruptive collaborative technological innovations, a qualitative case study in the health sector is used focusing on the *Care for Data* use case. A qualitative approach has been chosen to accommodate the different interpretations and experiences of different stakeholders regarding the introduction of MPC technology in the healthcare domain[17].

3.1 Use Case: Care for Data

Deployment of technology in the healthcare domain can contribute to value-based healthcare[18], for example by relieving the burden on healthcare personnel or making business processes smarter. Value-based healthcare focuses on maximising the medical care provided to a patient. The value of care is measured in terms of patient outcomes per euro spent, so better care does not necessarily mean the provision of more care or more expensive care. Within this use case, an attempt is made to enable effectiveness analyses in healthcare in order to better determine which care (in this case e-coaches) are effective for which group of patients[19]. This information helps healthcare providers to determine when they can best use which instruments, and helps healthcare insurers to determine which care will or will not be reimbursed in which situations.

In order to perform these effectiveness analyses, it is important to bring together data from different parties and analyse it. Sharing and combining personal data risks the invasion of privacy and data leakage. In order to manage these risks, regulations, such as GDPR and the law governing the use of the Citizen Service Number (BSN), have been implemented in the healthcare sector. These regulations, but also the necessary administrative actions and safety procedures, mean that it is not scalable to have these effectiveness analyses carried out by a trusted third party.

[17] Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, 14: 532-550.
[18] Kaplan, R. S., & Porter, M. E. (2011). How to solve the cost crisis in health care. *Harvard Business Review*, *89*(9), 46-52.
[19] N.B. Effectiveness analyses of a specific intervention can therefore increase the value of the care provided.

Within the use case, four collaborating parties have therefore developed a scalable analysis method that enables data to be processed in line with privacy guidelines. The following conditions, formulated by the cooperating parties, have been taken into account:

1) parties are not allowed to view each other's data;
2) the outside world is not allowed to see the data;
3) the end result should not be traceable;
4) the outside world is not allowed to see the result of the analyses, and
5) parties may not perform random queries on each other's data.

The result is a cross-organisational ICT system, designed on the basis of a combination of MPC and Blockchain technology (for more explanation, see box).
This ICT system is deployed by using analyses with privacy-sensitive data to find out whether an e-coach, used for *inflammatory bowel diseases* (*IBD)*, has an effect on the number of patient visits to the specialist. Inflammatory bowel disease is a useful case, because this target group has fairly intensive and regular contact with their healthcare providers due to the rather spontaneous course of the disease. The use case involves Zuyderland hospital (a healthcare provider), CZ (a healthcare insurer), CBS (the Dutch Central Agency for Statistics) and TNO (Dutch applied scientific research institute). The healthcare provider has data on 1) the number of visits to a specialist, and 2) which patient uses the e-coach or not. The healthcare insurer has data on healthcare declarations and the data-carrying organisation provides data on socio-economic status.[20] TNO is the technology supervisor within the use case, and supports and supplies knowledge in setting up and configuring the ICT system.

3.2 Data sources and data analysis

This article is based on the analysis of various data sources. Firstly, archive material was used around the case (Care for Data). This was supplemented by four interviews with each of the four organisations involved in the use case. The questions during the interviews focused on the role of the organisations, their ambitions within the use case, and the role of stakeholders. In addition, specific questions were asked about the influence of MPC technologies on existing processes and procedures, the emergence of new processes and procedures, the role within the organisation and the impact of MPC on the organisation and working methods. We also looked at the structural embedding of MPC within the organisation, and the changes needed to achieve this. Finally, questions were asked about the ethical and legal issues and

[20] Note: so far no real data has been used in the testing of the innovation in this use case – the data has been simulated to resemble real data.

difficulties encountered by the organisation, and the impact of MPC on decision-making processes.

In addition to the interviews with stakeholders, two expert interviews were held and the material was supplemented with input provided during internal stakeholder sessions. During these stakeholder sessions - or '*requirement sessions*' - stakeholders from the different organisations were present. In these sessions, requirements to be met by the MPC application were discussed together with internal stakeholders, such as the legal and technological aspects as well as the requirements that the form of collaboration around the pilot should meet. The different data sources were analysed to identify common challenges.

4 Findings

4.1 Organisational issues during disruptive technological innovations

4.1.1 Issues for collaborative disruptive technological innovations

An important finding of the *Care for Data* use case is that the incentives vary for the different organisations within the use case. One organisation would like to test the quality of a care innovation, another wants to take the technology fully into production for structural support in decision-making about reimbursements, and yet another wants to experiment with such a technology largely to be able to determine what this could mean for the future. Another difference between the organisations concerns the many varied procedures and formats that are used. When the technology is scaled up, these various incentives, intentions and formats can influence collaboration and coordination. For this reason, the role of governance and the role of standardisation are central themes.

4.1.1.1 Governance

Governance is therefore important in the joint commissioning of an MPC application. First, the governance of collaboration. Governance stands for the framework of decision-making and responsibility within an organisation, which ensures that the desired results are achieved. Governance is important when entering into a collaboration because it provides insight into how different parties think about the collaboration and the (behavioural) rules within the collaboration. Governance also helps to define the collaboration structures that enable agreement to be reached on joint activities.

In addition to the governance to enable joint decision-making on the cooperation, a joint ICT governance system should also be considered by the different parties: *IT governance*. IT governance is about online decision-making power, the power to enter data and give orders to the system, or how the parties are held responsible[21]. Data governance, which concerns who/which party is responsible for and is allowed to make decisions about the data that is used[22], is part of this.

[21] Weil, P., & Ross, J. (2004). IT Governance on One Page. *MIT Sloan Management Review. Retrieved April*, *21*, 2006.
[22] Khatri, V., & Brown, C. V. (2010). Designing data governance. *Communications of the ACM*, *53*(1), 148-152.

Finally, the use case shows that good IT governance and data governance is in line with corporate governance principles. As a result, ICT systems are in line with business objectives. However, the decentralised nature of MPC, which is implemented across organisations, makes it more difficult to align IT governance with organisational goals and strategies, because each organisation has its own goals and strategies and thus its own incentives to participate in the collaboration.

"Account must be taken of stakeholder interests of multiple organisations and the legal framework conditions of multiple domains, and IT governance should be consistent with the corporate governance of all participating organisations" - note

4.1.1.2 *Standardisation*

During the implementation of a collaborative disruptive technological innovation, different organisational procedures and formats arise. For example, all data from the participating organisations must be provided in the same file format. Also, integration of the MPC system with other systems within organisations is one of the common challenges when scaling up MPC solutions. Collecting data and entering it into an MPC system is now usually a manual process. To simplify the use of MPC, it could be integrated into existing (ICT) systems.

In order to achieve this, agreements need to be made. As the application scales up, and more organisations possibly participate in the collaboration, it is predicted that this will become increasingly difficult to achieve. It is therefore important that in the future, when putting an MPC-based application into production, the organisations themselves bear responsibility for their own data. Such agreements also make the commercialisation of MPC technology possible: so far there are a limited number of commercial parties offering MPC applications, including Partisia in Denmark and Roseman Labs in the Netherlands.[23] At the moment, MPC technology 'lives' mainly in the academic world.

"If working with MPC really gets off the ground, there's a world to be won." – Leon van de Weem, project manager Zuyderland

4.1.2 *Issues for emerging disruptive technological innovations*

There are a number of other factors that could complicate the scaling up of MPC applications. When taking the MPC application into production within the Care for Data case, the results show that a role shift is taking place within existing roles, and

[23] www.rosemanlabs.com

that new roles are also emerging within the participating organisations. For example, ICT staff must be trained to set up and maintain the system. For working with data and doing analyses, data scientists are needed.

> *" Data scientists who must have a number of specific skills are deployed to carry out the analyses. The data scientists have to make considered choices about which data is needed for which analysis, and what kind of result is expected. The reason for this is that the Care for Data application does not allow an infinite number of queries to be carried out, as this entails the risk that results from analyses can be traced back to individuals. In addition, the data scientists analysing the results should be aware of the functioning of the MPC system and possible biases it entails" - note*

4.1.2.1 Trust

A number of potential encryption technologies that can be used in MPC applications still have a low technology readiness level. Because of this, as well as the changing and new roles within the organisations, trust is a challenge that is assigned an important role in MPC applications. A technically sound solution is a first step towards trust. Furthermore, it is important to explain in an easily understandable way what cryptographic technologies entail. MPC technology is also still little known or familiar in the social context. MPC technology is not yet subject to a '*reliability label*'. As a result, the reliability - or familiarity - of MPC applications cannot yet be demonstrated using standardised norms. Especially for the various stakeholders involved in this innovation process, these present potential challenges in the development of MPC technology. For the parties that now work with MPC, there is therefore an opportunity to make the technology more robust and create more familiarity and trust.

> *"You're dealing with patients first and foremost because yes, we also want to explain to the patient exactly what we're going to do and not that there's going to be any leaks that make him feel like we're peeking into his medical records." – Paul van Helvoort, innovation analyst CZ.*

4.1.2.2 Ethical issues

When designing and scaling up an emerging new technology, the identification and evaluation of ethical interests is not easy to embed in the process because new, emerging technologies - such as MPC technology – raise issues that had not previously been addressed. As a consequence, the ethical issues are not easy to

address because *no consensus* exists (yet). In addition, the results point to two specific challenges in the development of an ethical application of MPC technology: bias and human-in-the-loop.

Bias. The analysis of the data shows that one of the most important ethical issues focuses on the possible role of bias in the results. This bias can be caused by, for example, bias on the part of the researcher (in this case the data scientist), wrong selection of datasets and/or wrong cause-effect relationships. It turns out that precisely because MPC applications can be analysed more often with more and larger datasets, a possible bias is more difficult to recognise afterwards. So it is good to be aware of the risks as early as in the design process as possible. Awareness of a potential bias in the results, and how to deal with this, is important. In the Care for Data use case, for example, various moral considerations, including privacy, were taken into account. After all, the technology is designed to share data without violating privacy (i.e. *privacy by design*).

> *"It is difficult to explain to outsiders that a healthcare insurer is going to use data from a medical file. Try explaining the principle of sharing data without sharing." – Paul van Helvoort, innovation analyst CZ.*

A second moral consideration that was (implicitly) taken into account is where the responsibility lies when a choice is made on the basis of results with a bias. Two points of human control were therefore embedded within the use case. First with the data scientists performing the analysis. These data scientists determine which data is necessary/useful for an analysis and ensure that the analysis cannot be traced back to individuals. These data scientists are also expected to be aware of the creation of a bias in the analysis. Secondly, the healthcare provider is responsible for the care provided at all times. The healthcare provider is the person or entity who knows the patient and has an advisory role. The healthcare provider also has the choice of whether or not to rely on the results of research using MPC technology in individual cases.

Human-in-the-loop. Another ethical issue in emerging disruptive technological innovations is how to deal with responsibilities in automated decision-making. One way of embedding this responsibility that emerged in the case study is by ensuring that somewhere in the process of automated decision-making there is a person at the helm who is responsible for the choices that are made. This could be embedded in different ways, for example in the design process of the technology, or by having a person approve an automated decision. However, the extent to which MPC

applications could lead to automated decision-making is debatable. This is a technology that performs analyses on the basis of certain data. The possibilities for including data in these analyses are endless; from data about whether the patient uses an e-coach (hospital data), how much care the patient declares (health insurance data), socio-economic status and economic situation at that time to climate information and living environment. The more data that is added to an analysis, the less transparent it is, however, in terms of what the outcome is based on. This makes full automation of the decision-making process difficult.

4.1.2.3 Legal issues

Finally, in the innovation process and in the implementation of MPC applications, legal preconditions must be taken into account: it is precisely cross-sectoral cooperation that gives these preconditions added complexity because organisations have to deal with different laws in different jurisdictions. Compliance with privacy legislation, for example, is one of the challenges of working with MPC applications. Although many encryption technologies can ensure that the application meets the requirements of privacy legislation, processing sensitive data on a large scale is seen as a general risk because sensitive personal data is subject to additional security rules. For this reason, the experts recommend performing risk-based multi-factor compliance analyses[24] to ensure that data processing routines comply with the requirements of privacy laws.

What also needs to be taken into account when possibly putting an MPC application into production is that different techniques can be used when using MPC technology, all of which have to be legally tested separately. For example, when setting up the use case and testing the technological feasibility of the MPC application, a number of lawyers from the organisations involved were deployed to test the application against the GDPR, the conditions of the IT system and the form of collaboration. However, legislation was not been examined in depth by all parties.

> *"Within the use case, the GDPR, the Hospital Act, the Healthcare Insurance Act and the BSN Act must be taken into account in the first instance" - note*

However, the biggest legal challenge for the MPC application is the rapid development of the technology while no legislation is yet available on these technologies. The in-house lawyers have limited knowledge of the technology and

[24] Veeningen, M., Chatterjea, S., Horváth, A. Z., Spindler, G., Boersma, E., van der Spek, P., ... & Veugen, T. (2018, April). Enabling Analytics on Sensitive Medical Data with Secure Multi-Party Computation. In *MIE* (pp. 76-80).

are often unable to find their way in terms of jurisprudence in this field. The early involvement and guidance of a lawyer working in this field would be a solution to overcome legal challenges early on in the process.

"I need a lawyer who understands whether I may link two charts based on a hashed BSN. Someone who knows the jurisprudence." – Ted Stormen, IT architect CBS.

5 Discussion and Conclusion

When scaling up ICT innovations, organisations have to deal with all kinds of non-technological issues. MPC technology poses additional challenges compared to other ICT systems. MPC is pre-eminently applied in collaborations between organisations. As a result, there are additional issues on each aspect that need to be taken into account. For example, in addition to its own corporate governance, account must also be taken of the governance of the collaboration. IT governance must also be aligned with the corporate governance of the various organisations involved. Finally, the various organisations must comply with laws and regulations that apply to the sectors in which they operate.

In addition, the use of MPC applications is only recent and still relatively unknown to the general public. As a result, there are no standards against which an MPC application can be tested, and therefore there is not always trust among the internal and external stakeholders of organisations that want to start working with an MPC application. Also, the current laws and regulations are not yet geared to the use of MPC applications. The fact that the technology in this case is ahead of the legislation means that MPC applications are difficult to test against current legal frameworks. During the design process of an MPC application, it is advisable to have a lawyer with knowledge of both the technological field and the domain in which it is applied who can look at how and whether the application complies with applicable laws and regulations. Another way to overcome a key ethical objection around (automated) decision-making (based on biased data) is to keep human control in the application.

5.1 Limitations and future research

Despite the important results that have emerged from this use case, there are also some limitations that offer opportunities for future research. For example, the results documented in this article follow from a single use case, so more input can be obtained by expanding the dataset to other use cases. A more comprehensive dataset would also make it possible to carry out analyses between the experiences

and challenges of different organisations. A second limitation is that the investigated time horizon of the selected use case was relatively short, so it remains to be seen whether the respondents have a good overview of the entire impact on the topics discussed. A longitudinal study could provide more input on this. Finally, the interests of external stakeholders were considered differently. On the one hand, the patient is seen as an important stakeholder because healthcare ultimately revolves around the patient and data about the patient is used. On the other hand, it is stated that no traceable data is shared, and therefore the use of the technology does not directly affect the patient. Within the use case and in the set-up of the pilot phase, the patient is therefore not yet directly involved. In addition, the suppliers or producers of the care (in this case e-coach) were not included in the analysis, nor were the external supervisors, who check whether the organisations comply with set laws and regulations, taken into account. For follow-up research it is important to evaluate the influence of such external stakeholders.

Until now, MPC technology has been applied within a proof-of-concept environment in the Care for Data use case. This has led to interesting results regarding the specific challenges a disruptive technological innovation confronts when it 1) is deployed collaboratively in the market and 2) uses an emerging technology for which dominant design does not yet exist. Further research can further underpin the results. The organizations involved intend to bring the Care for Data innovation further, by validating the platform and involving additional partners in the healthcare domain.