Rethinking the improvisation of digital health technology: A niche construction perspective

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Abstract

The COVID-19 pandemic has sent shock waves through healthcare organisations and catalysed an impromptu digital shift, creating a demand for telemedicine and other digital health technologies. Under such conditions, improvisation, adaptation, and innovation emerge as core dimensions to an organisation's capacity to generate a response to crisis. This paper integrates a process perspective on the radical improvisation of a digital health technology and investigates how the radical improvisation of a digital health technology emerges and develops during a health crisis. Through a combination of supporting case evidence and literature, a multi-phase conceptual process model anchored in the crisis management cycle and illustrating the radical improvisation of digital health technology is developed and proposed. We conclude with discussion on the long-term implications of radical improvisation and crisis learning, with possible theoretical explanation using niche construction theory, and providing suggestions for future information systems and crisis management research.

Keywords: *digital health technology, radical improvisation, crisis response, COVID-19*

The COVID-19 pandemic has been a critical shock that has threatened healthcare organisations on a global scale resulting in unstable operational environments plagued with stress and uncertainty. While organisations ordinarily have predefined crisis management routines, protocols, and procedures, there are rare instances where the nature of crisis creates circumstances that render planned strategies inadequate. Such has been the effect of COVID-19, and it has catalysed an impromptu digital shift (Whitelaw et al., 2020). We see health organisations deviating from set protocols and procedure, radically improvising, and leveraging digital technologies at their disposal to respond to the uncertainty created by the pandemic (Levallet & Chan, 2018; O'Leary, 2020; Wickramasinghe & Seitz, 2021). The term 'radical improvisation' indicates an improvisation where emergent, unplanned strategy is implemented during crisis (Gkeredakis et al., 2021; Vera & Crossan, 2005). Consider how health organisations are using mobile applications to locate and provide information about people infected with COVID-19. In most instances these have been systems that were specifically designed for this purpose at the onset of the pandemic. However, in some cases, these have been systems that were already in use in the health network, underutilised but finally proving highly relevant due to the emergence of a specific nature of crisis (O'Leary, 2020). The latter are an example of radical improvisations in health organisations.

Effectively, the process of improvisation facilitates an organisation in the optimization of available resources to generate a response to crisis. Improvised use of digital technologies is a valid and viable alternative in the formulation of reliable process for response efforts where planned strategy is rendered irrelevant. However, while technology serves a necessary purpose the process is not so straightforward (Suarez & Montes, 2019; Vendelø, 2009). There is a need to understand these 'improvised technologies' – how they work, how and why they were chosen, and what are the implications of their use? Consequently, the use of technology in COVID-19 response efforts has become a major area of research for information systems (IS) and crisis management researchers (Aman et al., 2012; O'Leary, 2020; Pan et al., 2012; Stieglitz et al., 2018). Crisis management and

IS literature is rich in studies where ICT plays a supportive role to improvisation and crisis response (Stieglitz et al., 2018; Ting et al., 2020) . A common genre of studies are application areas where ICT supports typical roles such as communication and coordination, where the use of ICT is already standardised and widely used (Fischer et al., 2016). There are also studies that focus on specialised technological solutions that are designed for implementation in crisis response (Adrot & Robey, 2008; Granåsen et al., 2019; Jefferson, 2006). This is an 'incremental improvisation' where an organisation makes updates or changes during a crisis that are aligned to the standard operating procedures (Aman et al., 2012). However, in recent years the contribution of digital technologies to improvisation and crisis response has shifted from what was a 'supportive' to a centralised role that emphasizes a more 'radical improvisation.' This type of improvisation is consistent with the formulation and implementation of emergent, unplanned strategy which we have observed during the COVID-19 crisis, and it is far less commonly studied, yet it must be addressed (Vera & Crossan, 2005). Limited studies focus on ICT that is designed for an established use within an organisation but swiftly repurposed as a part of crisis response efforts. This research gap results in a lack of understanding of the conditions under which the radical improvisation of ICT emerges and develops.

The ongoing COVID-19 crisis illuminates this shift towards the radical improvisation of digital technologies in several sectors and makes it possible for scholars to learn about radical improvisation of digital technologies. It enables an exploration of the notable triggers that give rise to the radically improvised use of technologies in response efforts to a health crisis. This paper is based on a qualitative study that explores the repurposing and customisation of a digital health technology for use in COVID-19 patient monitoring. The study presents the unique opportunity to analyse the leveraging of an existing digital health technology in real time. The empirical case study also gives unique insight into improvised actions taken in a health organisation as it adapts to challenges and constraints created by COVID-19. This paper assumes a process-oriented approach and initiates a quest for a deepened understanding of the radical improvisation of digital health technologies in crisis conditions. The work contributes to crisis management and IS literature by capturing the process dynamics and proposing a conceptual process model for the radical improvisation of ICTs based on empirical findings and literature analysis. Therefore, the question to be answered is: How does the radical improvisation of digital health technologies emerge and develop during a health crisis?

The methodological approach of the paper is an explorative case study incorporating related literature analyses. The rest of the paper is organised as follows. The Previous Studies section follows and summarises a literature analysis on selected related works which serve a basis for the conceptual discussions later in the paper. The Case Description is next and is followed by the Methodology. A description of study findings and the discussion of findings follow in that order. The Conclusion and Limitations section concludes the paper.

Literature Background

This section focuses on two interrelated research streams, firstly detailing how digital health technologies have been progressively explored, accepted, and applied in healthcare service delivery in recent years. The first analysis is based on highly cited publications related to digital health technology in the information systems research stream and other relevant domains. It reveals the current discourse and deployments of telemedicine in healthcare service delivery. Secondly, an analysis on the capacities and functions that the use of such technology's avails to a healthcare organisation during a crisis. The second analysis centralises the COVID-19 pandemic as the crisis context and is based on a set of literature focusing on the use of digital health technologies in COVID-19 crisis response efforts. The aim is to uncover how digital health technologies create opportunities for radical improvisation in crisis response efforts and overall crisis management strategy.

Digital technologies are known to facilitate connectivity and innovation and oftentimes, the introduction of a single innovation stream may yield countless further innovations of organisational value (Agarwal et al., 2010; Gkeredakis et al., 2021; Jha et al., 2016; Wang, 2021). The potential benefit and eventual use of technology solutions in the monitoring of chronic diseases is a natural progression in the use of technologies such as sensors, wearables, and mobile applications to solve societal problems (Bardhan et al., 2020; Payton et al., 2011). ICT play an enabling role in healthcare. Commonly referred to as digital health technology/telemedicine/telecare emerged in response to operational challenges (ageing populations, increased service demand, and limited staff resources) faced by the healthcare sector. For the purposes of this paper, we define telemedicine as "the application of computer

and communications technologies to support healthcare provided to patients at remote locations" (Aanestad et al., 2019; Austin & Boxerman, 1997; Bower et al., 2011). The systems are designed to allow remote data exchange between patients and clinicians using various interactive data communication mediums e.g., cloud computing, biomedical sensors, artificial intelligence (Shah et al., 2016).

There is growing emphasis on the identification of alternative, non-traditional approaches to patient management and healthcare delivery through telemedicine is classified as 'store-and-forward' or real-time or remote monitoring. In store-and-forward, the technology is integrated for the capturing, pre-storage, and transmission of digital images and clinical information. In real-time, the clinical data and information is captured through a synchronised, interactive process between the patient and clinician such as video consultations. In remote monitoring, the patient vitals are monitored from remote distances with the aid of specialised medical equipment such as sensor technologies for the diagnosis, treatment, and prevention of disease and injury (Burke & Weill, 2018). Common trends in application include remote patient care, electronic health records, and smart medical devices, and automated decision support (Qiu et al., 2020).

As with any innovation initiative, there are factors (drivers and inhibitors) affecting the adoption of such systems. These may be technological e.g., a lack of appropriate infrastructure or data integration, regulatory e.g., Physician and equipment licensing , institutional e.g., lack of management support or individual e.g., privacy and security concerns (Yeow & Goh, 2015). Several systematic reviews argue that telemedicine provides affordable, punctual, and convenient treatment pathways (Bardhan et al., 2020; Ross et al., 2016). While the systems harness forward-thinking, technological progressions, they also generate high volumes of new real-time data types, that dictate new data management and usage protocols (Grisot et al., 2019) and introduce new avenues of risk, threat, and vulnerability (Qiu et al., 2020). So far, IS research examines multiple concepts related to digital health technologies with a balanced focus on the favourable and non-favourable effects experienced as a result of the use of telemedicine (Ellimoottil et al., 2018). However, the emergence of the COVID-19 pandemic has forced a shift in the healthcare delivery systems and accelerated digital health solutions implementations. We have witnessed the rapid implementation of infection control and monitoring measures, adapted to standard operating procedures. While telemedicine solutions prior to the pandemic were considered optional extras to clinical management pathways they have taken centre stage (Sun & Wang, 2021). Through the implementation of reactive crisis management strategies, telemedicine and other eHealth solutions are now considered a necessity. The use of digital technology in this way, to cope with crisis conditions is relatively new, and not fully explored theoretically. Research towards developing practical and refined pandemic crisis management processes, models and frameworks in the health sector is emergent and timeous (Hattenbach et al., 2020). The next subsection focuses on the application of digital health technologies in COVID-19 response efforts.

Emergent Responses to COVID-19 through Digital Health Technology

It is not possible to discuss the role of digital technologies in the response to COVID-19 without briefly discussing the crisis management cycle. Crisis management refers to administrative approaches that are used to address crisis situations through preparation and planning. Traditionally, these are outlined through predictive scenarios and examination of potential weaknesses in organisations in anticipation of future disruption (Quarantelli, 1988). In crisis management theory, the crisis management cycle comprises of six stages – risk assessment, prevention, preparedness, response, recovery, and learning. In light of this cycle, it is visible that following a crisis, an organisation may emerge in an improved or worsened state or direction (Pursiainen, 2017). When responding to crisis or disruption, organisations can either revert to a known state and, recover normal operations or capitalise on the opportunity presented by change and introduce solutions that extend beyond mere improvisation and adaptation (Manyena et al., 2011; Russpatrick et al., 2021; Walker et al., 2004). This thinking contrasts with disaster studies, where crisis recovery is characterised by efforts to return to known, stable state (Sakurai & Chughtai, 2020; Sakurai & Kokuryo, 2014). Thus, organisations, when supported by a flexible infrastructure, can maintain their operational capabilities as they adapt and respond to challenges posed by various disruptions and threats (Boh, 2020; Haque et al., 2014; Hartvigsen et al., 2007).

The COVID-19 pandemic is a crisis that has proven to be beyond the capacity of the planned management structures and processes in most health organisations

(Magutshwa & Radianti, 2022). While there were crisis response strategies in place for epidemics such as influenza, that include rapid, systematized response to mitigate infection rates, and maintain steady operations. However, COVID-19 has presented novel constraints and challenges not considered in existing policies and strategy and as a result, forced organisations to implement reactive crisis management strategies. In the information systems discipline, COVID-19 is characterised as an unprecedented existential threat, which brought out the best of society. A related discourse emerged that focuses on how health systems needed to be redesigned/reimagined to accommodate a more proactive response pattern as opposed to the traditional reactive approach (Rai, 2020). The COVID-19 pandemic is widely acknowledged as having been transformative, challenging individuals, organisations, and countries to revise health service models, and what they consider innovation.

Digital health solutions have emerged as viable approaches to various aspects of healthcare delivery (contact tracing, smart medical devices, and wearables) and response to COVID-19 induced challenges and constraints. Health technologies have been implemented across various phases of the crisis management cycle with varied impact and outcomes in health organisations. The development and implementation of such solutions has been rapid and fast-paced, with limited research in some instances and it has created avenues of research aimed at understanding these operational adjustments and adaptations (Djalante et al., 2020; Gkeredakis et al., 2021). These accelerated innovation processes have facilitated human resource allocation, and strategic decision-making process in health organisations. Due to the critical nature of work, the health sector is known to be a conservative and highly restrictive operational environment, with strict regulations governing policy strategy, and operations at all levels. Innovation changes in this sector are known to take extended periods of time – months or years in some cases. The pandemic has challenged this stance, and in some cases "removed barriers to experimentation and acceleration in the health-tech sphere" and there has been a marked increase in experimental use of telemedicine solutions for in and out-patient monitoring in hospitals (Oborn et al., 2021) . Naturally, the availability of highly reconfigurable and accessible digital platforms has been pivotal in these response efforts, but it has also meant a shift in organisational practices , and development of new skills to accommodate these digital work environments (Floetgen et al., 2021). This inclusion of complex institutional dynamics highlights how the crisis response efforts using digital technologies may also generate tensions due to the interruption or change in organisational practices as swift changes are put into effect (Orlikowski & Scott, 2021).

The literature reviewed in this section highlights the novelty and dynamism that the COVID-19 crisis has introduced to the health sector and illuminates research gaps and areas of contribution for this study. This study has the potential to build on extant crisis management theory through the analysis of how crisis creates conditions for experimentation and enables the innovation and improvisation processes in health organisations. This investigation of the use of digital technology during a crisis will also contribute to information systems literature by providing insight into the technology development process, highlighting dependencies that use of these technologies creates and the novel forms of risk that this entails.

Theoretical Background: Niche Construction Theory

Niche Construction Theory (NCT) is historically a branch of evolutionary biology that emphasizes the capacity of organisms to influence and modify their environment and inadvertently influence the evolution of other species due to pursuant environmental changes. These processes of environmental selection and adaptation/ modification are referred to as niche construction (Lewontin, 1982; Odling-Smee, 1988). In NCT, niche construction is an evolutionary process, where the environment is modified based on the selection pressures experienced by organisms. So fundamentally, the change and evolution process unfold according to natural selection and niche construction. Adaptations are products of both selection and niche construction processes. While it is originally associated with the biological sciences, NCT has also been incorporated into ecology and the human sciences and used in the formulation of evolutionary frameworks in those research streams (Laland et al., 2007; Odling-Smee et al., 2013). Effectively, a two-way process exists between humans and environment – the human may alter the environment in response to a 'problem' and said solution leads to new 'problems' in the changing environment, which emerge because of the prior niche construction. Thus, niche construction theory provides useful conceptual tools and theoretical insights for integrating technological evolutions (Luksha,

2008). Humans modify their environments through technological innovation, routines, and processes. NCT is also applied as a theoretical lens in studies pertaining to complex technological systems. Interesting parallels are drawn between biology and technology as NCT is applied in studies that investigate the design of technological modules through natural selection or a redesign for current use. The rapid emergence of a new niche is characterised by "technological continuity and functional discontinuity" (Andriani & Cohen, 2013). Niche construction processes are thus seen as pervasive in evolution of technologies. However, the challenge remains, how to conceptualise the leap from modification/ adaptation to design for unanticipated use.

The theory explains how humans acquire knowledge during niche construction through embedded informational processes that influence and shape future decisions through learning and development at distinct levels, i.e., individual, team, organisational. This inherited and learnt information is instrumental to and underpins niche construction. Learning and development are quite significant and further guide the niche construction process. For instance, a technological solution may be introduced into a health organisation to improve overall service delivery but create new constraints for patients and medical personnel such as poor patient experience. Humans may then respond to this novel constraint on multiple levels of the organisation. At individual level, through offering capacity training to all patients and staff, and at organisational level through further technological evolution, by incorporating patient-centred design principles (Klecun, 2016) that optimise patient experience. From this example it is evident that niche-constructing traits go beyond ordinary adaptation and influence future decisions in a manner that shapes the overall evolutionary dynamic and pathway of a technology. The possibility of a bifocal lens of the evolution of technology and the environment makes NCT ideal for the study of human innovations and complex systems. Distinctions can be easily drawn between two aspects of niche construction—environment alteration and subsequent evolution in response to a constructed environment (Andriani et al., 2020; Andriani & Cohen, 2013).

The operational environment factor could not be more important in a study focusing on the use of digital technologies in response efforts to a health crisis. The rapid development and deployment of digital technologies experienced during the pandemic has rendered what were ordinarily stable health organisations environments as now 'unstable' (Fischer & Baskerville, 2022; Rodon & Silva, 2015). This calls for novel approaches that will provide deepened insight into the required triggers and processes. This paper selects the Niche Construction perspective on this basis and argues that by highlighting the operational environment ramifications of changes that crises bring about in health organisations we may reveal and understand future evolution pathways in the use of digital technologies in health organisations (Magutshwa & Radianti, 2022). It is possible to view and analyse the radical improvisation process as an adaptation/ modification following a negative environmental selection (COVID-19). NCT further helps link crisis response efforts to longer term technology evolutionary changes, and potentially leading to a deeper understanding of how digital technologies change over time. The next section is a case description that details the empirical context of the study.

Research Gap and Potential Contributions

Although COVID-19 presents with novel constraints that demand a rethinking of existing core practices and goals for many health organisations, it is also likely to require changes on a broader scale, i.e., organisational transformations that are not necessarily linked to COVID-19. The use of digital technologies in pandemic response efforts would have had impact on multiple levels the technical components must be matched to suitable organisational capacities and social functionalities. Crisis provides a unique opportunity to review mitigation plans, refocus priorities, and reimagine strategy to similar challenges. Digital technologies emerged as prominent components of service delivery solutions deployed in critical services such as health, finance, and energy. The shift from physical to digital modalities creates fundamental changes in social interactions, organizational routines, and practices. With most organizations and societies resolute not to be 'fooled twice,' we observe the integration of lessons learnt during the crisis into novel routines and practice. Literature published prior to 2020 does not account for an exogenous shock like COVID-19 and literature published following the pandemic does not account for the sociotechnical arrangements required when using digital technologies. Further, only a few papers explore how the emergency measures taken could potentially impact the decision making and evolution pathways of the digital technologies in the long term. Majority of the papers present a high-level abstraction on the use of ICT

supported solutions during the crisis but do not explain how decisions being taken in the short term could shape or influence the future. While the focus of prevalent IS research on technological and organisational capabilities is insightful, it tends to hinder the use of evolutionary frameworks in the understanding of phenomena. This paper applies an evolutionary framework to go beyond the use of the solution and its capabilities to consider the theoretical implications that provide insight into how the short-term crisis efforts could influence future use of digital technology in the health sector. This is a new way of thinking that not only considers adaptations but also the possibility of exaptation. NCT, although used in other social science, economics, and management disciplines has seldom been taken up in the IS discipline. The use of this theory to explain both the crisis response actions and the follow up reactions to the changes positions this study well to contribute to crisis management and digital health technology literature in IS.

Case Description

The Norwegian health Directorate for eHealth provides support to Norwegian municipalities to implement welfare technology through the National Welfare technology program. The program was established in 2013 to promote innovation initiatives in health and social welfare services in municipalities. The aim of the program is to fully integrate welfare technology into the health service by 2021, thereby improving service quality, and saving on time and costs. The Fundi region (pseudonym) in Norway has a project team affiliated to the National Welfare Technology program and have run multiple 'digital home follow-up' projects in different municipalities. They target patients that are chronically ill (e.g., heart disease) or suffering mental disorders. The region has three established telemedicine centres (TMS centres) in the municipal health services.

The service allows elderly, chronically ill patients a degree of independence while they continue to receive an acceptable level of care. The patient vitals are monitored remotely by qualified health personnel using a selection of biosensors and real-time follow up through messaging, video, or telephonic calls (see Fig. 1). When the patient makes a reading, input data is transmitted through a Wi-Fi connection to a cloud-based server for processing by clinicians located at a monitoring station. Medical personnel then provide advice and feedback to the patient based on this data. When the COVID-19 pandemic came to Norway, the Fundi region anticipated strain on the health service. An assessment of the suitability of this digital solution used in the welfare technology program for COVID-19 patient monitoring was conducted and the decision to repurpose 'digital-follow-up' for COVID-19 patient monitoring was made. The design and development of the digital-follow-up system had been a collaborative effort. It involved Org-X, a health technology vending company responsible for the technical development of the solution and its digital platform. They also included various clinicians with specialisation and expertise in the relevant, common comorbidities such as hypertension, diabetes, heart disease, and chronic obstructive pulmonary disease (COPD). They provided input in the design of algorithms and ensuring the solution was in alignment to existing clinical practise. The basis for the decision to use digital-follow-up was experience with COPD patient monitoring, a different pulmonary disease and so this was viewed as a 'further development' of the original system.

Consistent with the process and practice followed in the initial solution design, the Fundi region assigned the digital-follow-up project team and the relevant, pre-existing collaborators to design and develop the COVID-19 module. Fig. 2 provides an overview of the different collaborators involved in the design, development, and implementation of the COVID-19

Figure 1
Remote Patient Monitoring Application

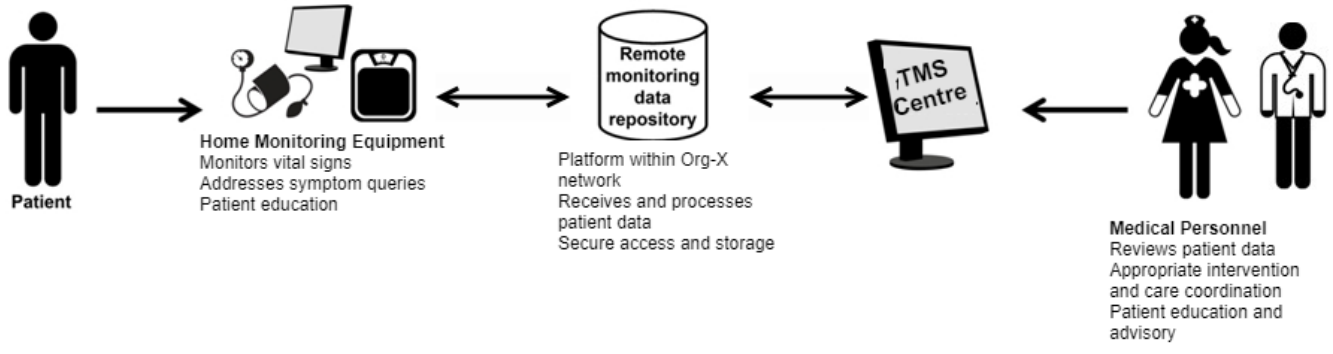
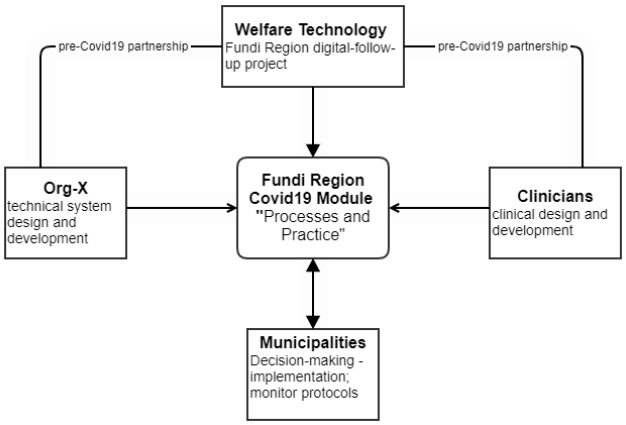


Figure 2
COVID-19 Module Design Collaborators Overview



module. The main innovation and development drivers for the project was the emergence of a destabilising health crisis. Healthcare professionals, crisis management, and technology development experts collaborated in delivering a service to a targeted segment of patients while educating themselves on a little-known disease. In a period of 2 – 3 weeks the new application was available for public use and would provide a buffer to the health service and potentially contribute significantly to crisis alleviation activities. The focus of this study is on the radical improvisation processes and practise implemented in the design, and development of this COVID-19 module. The following section is a description of the methodology used in this study.

Methodology

The research is designed as an exploratory case study. The intended outcome of the study is focused on unpacking the process of radical improvisation of a digital health technology and arriving at an adequate understanding of how this organisational response emerges and develops. A combination of qualitative research methods is used to address the main research objective.

Fig. 1 provides an overview of how the research was conducted. The activities and findings related to the literature analysis are outlined in the Literature Background section of this paper. The literature analysis serves to re-examine the nature and definitions of crisis management routines and improvisations as they exist in literature. The study covers how the project develops in relation to the technology development, tactics, and decision making with various stakeholders including the technology vendors, clinicians, and managerial personnel. Interview transcripts, and other secondary data - reports, and meeting minutes were compiled and coded using NViVo – a data management software used in organisation and structuring of qualitative data.

Data Collection

Consistent with process tracing research practice, the data gathering activities are characterized by repetitive cycles of asking participants how and why different responses and actions were taken. The study traces the actions followed by people belonging to the different collaborator groups described in Fig. 2, who were engaged in the repurposing of the remote patient monitoring solution. This ensures that all key perspectives of the organisations involved in the project were covered. Fieldwork is conducted primarily within the research and innovation project team of a municipality in Norway, but also includes various technology and healthcare professionals who collectively contributed and had responsibility for the project through its divergent phases.

The study had a first phase, in July 2020. This component of the study had a focus on understanding the COVID-19 module of the remote monitoring tool and its development. This phase also involved the analysis of a collection of documentation – reports, meeting minutes, and system documentation, and a live demonstration of the digital-follow-up tool and discussions with staff from Org-X, the technology vendor.

In this second phase, the specific focus was on the practicalities of the implementation of the monitoring tool. Ten interviews were conducted with eleven study participants (Table 1) in total, lasting approximately 22 hours in

Figure 3
Research Methodology

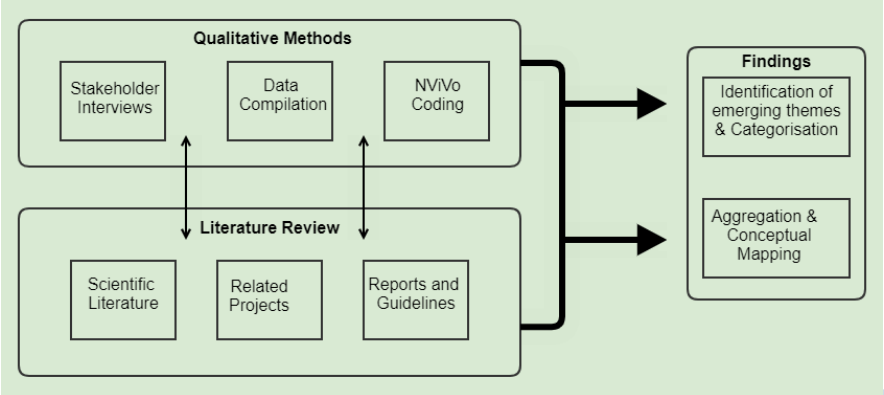


Table 1
Study Informant Profiles

	Position	Organization
Inf-1	Head of Digital and Enterprise Services	Org-X
Inf-2	Digital Solution Lead	Org-X
Inf-3	Head of Research & Medical Doctor	Municipality
Inf-4	National Welfare Technology Program Manager & ex Rescue Medic	Fundi Region
Inf-5	eHealth Research Innovation Manager	Municipality
Inf-6	eHealth Advisor	Fundi Regional Hospital
Inf-7	Nurse	Fundi Regional Hospital
Inf-8	Project Lead – Digital follow-up (Design) & ex Nurse	Fundi Region
Inf-9	General Practitioner	Municipality
Inf-10	Project Lead – Digital follow-up (Security)	Fundi Region
Inf-11	Welfare Technology Distribution Lead	Fundi Region

total. The participants interviewed for the study included the Project Lead for the National Welfare Technology Program, eHealth Research Innovation manager, Head of Research, medical doctors, nurses, crisis, and technology experts from the different stakeholder groups associated with the project. Table I details the study informants and their level of expertise.

Data Analysis

For analysis, (Gioia et al., 2013) provides a systematic presentation of the data analysis phase that enables the categorisation of interview data into first, second and third orders. Drawing inspiration from the Gioia methodology, the data analysis follows an interpretive stance and plays out in three iterative phases. These are identification of descriptive keywords and direct quotation of interview subjects in the first order; creation of a logical sequence of steps and process mapping in the second order; and finally, aggregation involving a conceptual mapping of the second order themes to existing literature and theory in the third order (Gioia et al., 2013).

The discussions focus specifically on the work done in the development of the COVID-19 module of the monitoring tool following people assigned in various stages of the project (Lapointe & Rivard, 2005). The first analytic phase consisted of organising all the data from the various sources in chronological order. Descriptive codes were then selected, paying attention to preserve the informant's keywords and statements. The data was coded according to specific dates, actions, meetings, and roles. This was because specific interactions among the actors were linked to specific processes or practice. In the second phase, the data coded and arranged in phase one was analysed to identify the connections and linkages, to reconstruct the various stages and key processes related to the COVID-19 module development. These would provide deepened understanding on how the Fundi region operated from one stage to the next. The stages and key processes comprised the second analytic phase codes, and they are used in a reconstruction of events through a logical sequencing, this is discussed further in the Discussion section of the paper. The third analytic phase the second phase codes are mapped to theoretical concepts identified in the literature that give further explanation and understanding to the order of events and actions taken. The outcomes of the data analysis are discussed in the following sections. Firstly, in the next section where the findings of the study are described, followed by the Discussion.

Results

This section focuses on describing the findings of this case study and provides details of the information provided by the study participants. It is a narrative approach with descriptions of the context, activities, and structures from the perspective of the interviewees. The section highlights the key emerging themes, observations, and outcomes of the study.

Perception of Threat Under Tentative Crisis Conditions

In Fundi region, some of the earliest reports of COVID-19 infections surfaced in February 2020 and impacted nursing homes where elderly patients live. The region was prompted to mobilise its crisis management protocols at a local level in line with National guidelines. Mobilisation of structures such as organisational crisis management routines, departure from known patterns of action, protocols and procedures, and role switching are evident. Informants recalls: "*We established a crisis organization that met on a regular basis, and let many persons work from home office, the head of the crisis management he very soon got an important role in how to run the organization.*" There are also invisible structures such as dynamic information and knowledge structures formed as specific knowledge and skills gaps related to COVID-19 were identified. The uncertainty of the possible disruption was also evident. One of the informants said, *"We were not prepared to cope with this kind of the contagious disease… There was a large focus*

on the hospital sector, and we could have an overload." Existing structures are fundamental in the early crisis response process, they provide harmonised execution within the rhythmic order set by the structures (Pan et al., 2012).

The fortification of the crisis management team with a wider selection of staff, with varied expertise was necessary and is seen as an early indicator of resource reallocation. Informants describe how they begin an idea development, solution-oriented process. The project lead recalled: "*I was thinking will we have, in the worst-case scenario thousands of patients with COVID-19 in isolation? … trying to put myself in a jam and ask what we then do? thinking that maybe we can just take that Welfare Technology Project and scale it."* The priority was the formulation of a solution, even if it leads to novel thoughts, activities, and organisational relationships. Members of the project team emphasize how their attention firmly shifted in this direction. *"How can we contribute to this situation that we're all in? How can we contribute to the safety of the patient?"* The primary concern was the need to shield the hospitals from floods of patients. However, there was also a need to ensure the expected standard of care. An informant said: "The *lack of PPE underscored the importance of providing online and digital follow up."*

Identification of Potential Mitigation and Fortification Actions

The 'digital follow up' approach would cater for other possibilities as well, such as the quarantine of teams/ shifts of health care workers following exposure, which could have rolling implications on available staffing resources. Remote patients follow up meant such personnel could still perform their duties even though confined to their homes. The main objective of this process within the context of the study was the scanning of the operational environment to identify avenues to solution and counter measures that could be introduced for COVID-19 patients. Informants said: *"we looked up on the opportunity to use these experiences following up patients with COPD, heart failure and diabetes, that it would be possible to develop an application for follow up of COVID-19 patients*". The changes were sourced from existing digital solutions within the health services operations. Speaking of the remote patient monitoring tool, an informant said*: "so naturally, of course, like we've already mentioned that the technology was already there."* However, the mere availability of a potential solution was not enough. Further considerations and consultations needed to be made concerning how to adapt the system infrastructure for use in COVID-19 patient monitoring. This prompted information gathering and planning activities on the disease. The presence of predefined organisational structures and partnerships with the local hospital and technology vendor are highlighted as key contributors to the hastened progression in this phase of the project. The need for the determination of relationships that exist within these structures and among stakeholders was also a necessary step.

Design and Continuous Refinement of Structures and Resources

Following the identification of organisational and technical adaptations crucial for crisis mitigation, this process focused on the development of a COVID-19 module for the approved digital follow-up tool. Multiple stakeholders comprising clinicians, technical, and administrative personnel were brought to the table and worked collaboratively over a two-week period to make the necessary changes to the existing remote monitoring solution. Informers recall: *"we had to figure out how can we make that adjustment and it be good and dynamic towards the patients, so they feel they're taken care of*." This collaborative, joint effort, involving human resources from multiple organisations is a demonstration of inter-organisational trust among the various collaborative decision-makers and stakeholders. Among the series of changes that was required, the first was an assessment of the existing distribution strategy. The service has previously been rolled out to patients using custom designed kits, but the decision to migrate the service to an application and a web interface was made. The application and web interface would be replacements for the tablet used in the previous monitoring regime. This adaptation meant a 'bring your own device (BYOD)' protocol was possible. This was ideal in the interest of scalability, prompted by a need for wider distribution numbers (to cater for the anticipated COVID-19 patient numbers), dynamism, and ease of access. Secondly, the development of the follow up algorithm that would be used in patient monitoring was required. Informants stressed: "*there was no algorithm to follow up people with COVID-19. And we didn't at that time have very many facts about what to predict or that algorithm.*"

The project team quickly realised it was beneficial to assume an iterative design and development approach. There was experience in monitoring Chronic Obstructive Pulmonary Disease (COPD) patients, but a new monitoring algorithm needed to be developed for the novel COVID-19. A group of medical doctors, including a pulmonary disease specialist was set up to participate

in the algorithm development. There was a clear need to monitor patients before, during, and beyond peak infection, for varied reasons. Concerning patients in the early phase of infection, the project leads shared: "*My hypothesis was if you don't know how they're doing (before hospital admission), you don't know how to prepare the (health) system. So do we prepare for forty patients in the healthcare system, or do we just prepare for five?"* Another team member shared about the value in end-stage/post-infection monitoring: "*it might also be of interest to follow up long term effects of COVID-19 for those who have only partly recovered, and not necessarily recovered completely.*" Such an approach enabled continuous refinement of the patient registration questionnaire and follow up algorithm as added information became available. It also meant there was added value, an opportunity to harvest data on the long-term patient recovery patterns from the disease.

Due to time limitation, and the impending crisis, the design and implementation were expected to happen in tandem. The project lead recalled: "*my project (approach) is just start stop and make improvements there and then do another one (pilot test) and go back and forth and optimize as we go forward. But that mindset is not a culture here, and they give good reasons for it sometimes.*" Typical testing protocols were not possible. Some of the test subjects used included, clinical staff that had contracted the disease, family members and close contacts of people involved in the system development. Interestingly, due to changes in user demographic (previous users were elderly) and roll out strategy (BYOD) there were far reaching security implications that needed to be considered. A lot of emphasis was placed on securing the application, the system would manage patient data and be susceptible to attack. It needed to be secured. Two rounds of risk assessment and penetration testing were conducted by an external service provider before the level of risk was deemed acceptable. Informants recall: "*My nightmare was a headline in the papers about a patient data leakage. Because we were going from an iPad tablet form working on 4g, where the risk is really low*".

Implementation & Post Crisis Adjustments and Development

Following the initial rush, COVID-19 patient numbers were not so high in the first wave (March – June 2020). The solution was not immediately deployed for use in the health services. The informants describe this period as a brief intermission, which allowed them an opportunity to take pause for reflection. The time allowed for extensive assessment of the system, with in depth consultation of experts. The project lead recalls: "I *had some discussions with some friends in a pretty big international network, some out of Italy and out of Asia, US region, to see how they are doing it, application user managers and designers, I needed to get some feedback*." Rather than simply being a summarization of past activity, the feedback informed a learning process at this stage that was used in further refinement of the system. The team demonstrated a keen sense of awareness and willingness to remain alert to the changing environment and the possibility of expansion. An imagination of the possibilities and additional services that the system could provide was also evident. In reference to the onset of the second wave of COVID-19 infections, one of the informants said: *"I thought about how it should have contributed, contributed to the security of several other patients than just COVID…we have seen now as this society is in a new lockdown, depression rises, loneliness rises, and suicide was so high. And I think if society was more mature, to just give this solution to anyone that just needed a health worker to be on the other side, then I think we would gain much more than we ever can anticipate."* Interestingly, the project team members are ready to consider the long-term integration and benefits that can be realised from a wider scope of usage for the system. There are unanticipated issues in the integration of the service into existing health systems and the general practitioner's (GPs) clinical practice. A mixed reaction to the solution is unsurprising, the health service is widely known to be 'conservative' and required to follow strict procedures and policies even in crisis. One interviewee stressed: "*work changes in routines are difficult to implement in the system. It is conservative… They know their existing routines. And they get insecure when it's new way of working.*" It is understandable that clinicians would be concerned about the extent to which the information furnished by the system could be trusted. In contrast, a GP that had been part of the development process and implemented the system in their practice was optimistic. He stated: "we *had to be quite strict, with those questions (algorithm), and they had to be in a way that was true with our clinical practice… it has to be a solution that is quite convenient into the main practice. It must not disturb the practice."* The project team's reflection activities emphasize the immediate revision of prior knowledge in the face of emergent trends, shaping and influencing an operational environment that responds to the trends. Collaboration, adaptation, innovation, novel thoughts, and rapid idea development

are highlighted as critical factors leading to the successful radical improvisation process.

Data Analysis

As mentioned in the Data Analysis section, the analysis is conducted in three phases as set out by Gioia (2013). This was an iterative process comprising multiple rounds of coding into the first and second orders. Fig.4 is a snapshot of the process, detailing the progression from data to theory, giving examples of how first order themes are subsequently linked to crisis management theory.

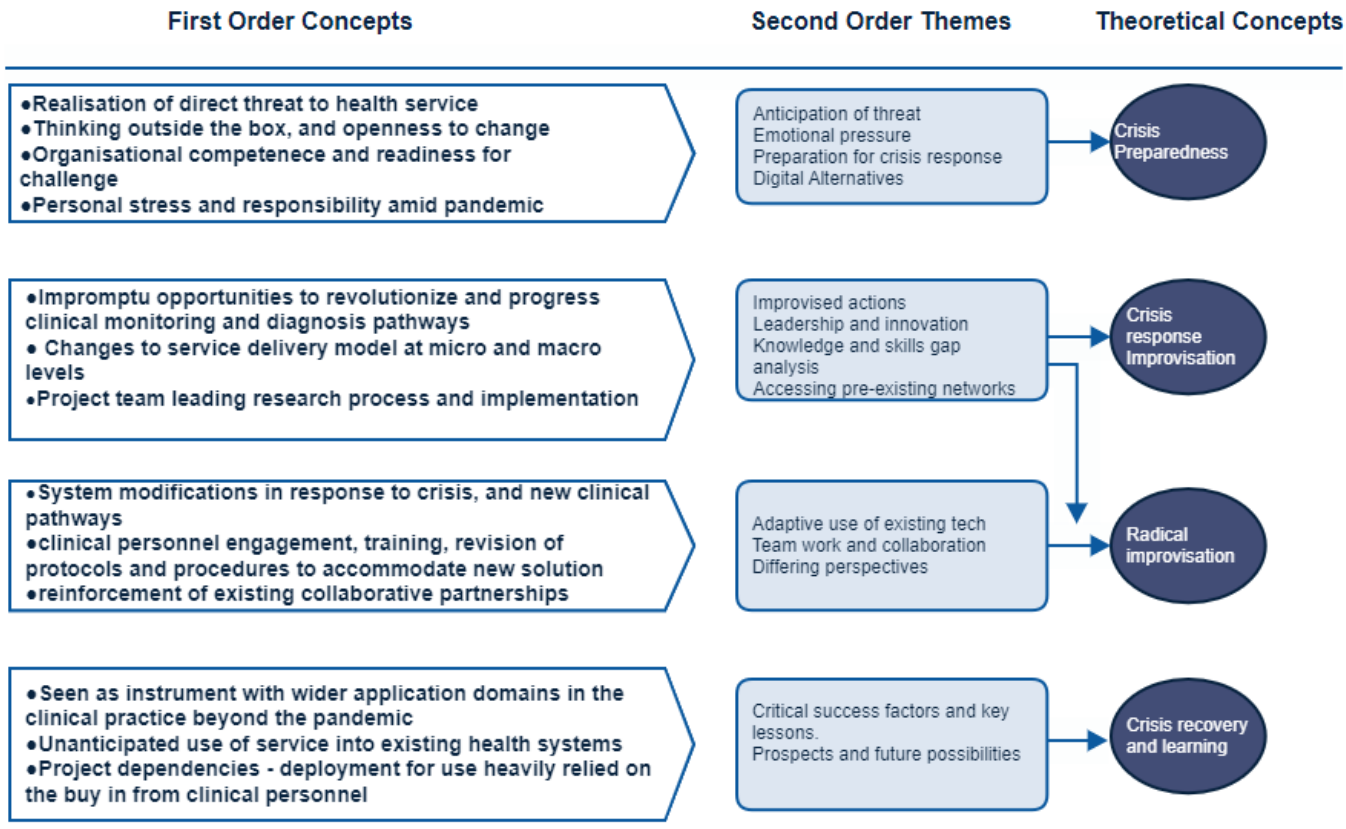
In the following section, a discussion of how radical improvisation of health technology occurs and logical insight into the subprocesses that structure it are proposed.

Discussion

The empirical case provides the opportunity to investigate how health technologies are included as resources and contribute to crisis response efforts in a health organisation. A key assumption in the analysis of the data is the consideration of radical improvisation as an innovation process of technological adaptation and optimization due to crisis (Weick, 2017). This approach makes it possible to factor in established practise, structures, routines, and resources that contribute to crisis response efforts (Suarez & Montes, 2019). The findings in the previous section described how the emergence of the COVID-19 pandemic led to the improvised use of digital-follow-up. A sequence of steps that reveal the radical improvisation of technology to be a process comprising various subprocesses is deduced. The sequence of these steps is illustrated in timeline format as seen in Fig. 5, overleaf.

The key steps and processes identified in Fig. 5 provide an overview of the organisation's operations as it transitioned from one phase of the project to the next. Nine milestones are identified in the project progression. The subprocesses identified were Perception and Mitigation of threat; Application Development and Continuous Refinement; and Implementation and Consultation-based Adjustments. These subprocesses were corroborated using crisis management and improvisation literature (Pan et al., 2012; Pearson & Clair, 1998; Suarez & Montes, 2019). This was to check that they were verified processes and steps in documented studies. A novelty was how the technology developers emphasized the need to 'rethink' the software

Figure 4
Snapshot of Analytical Process Following Gioia Methodology



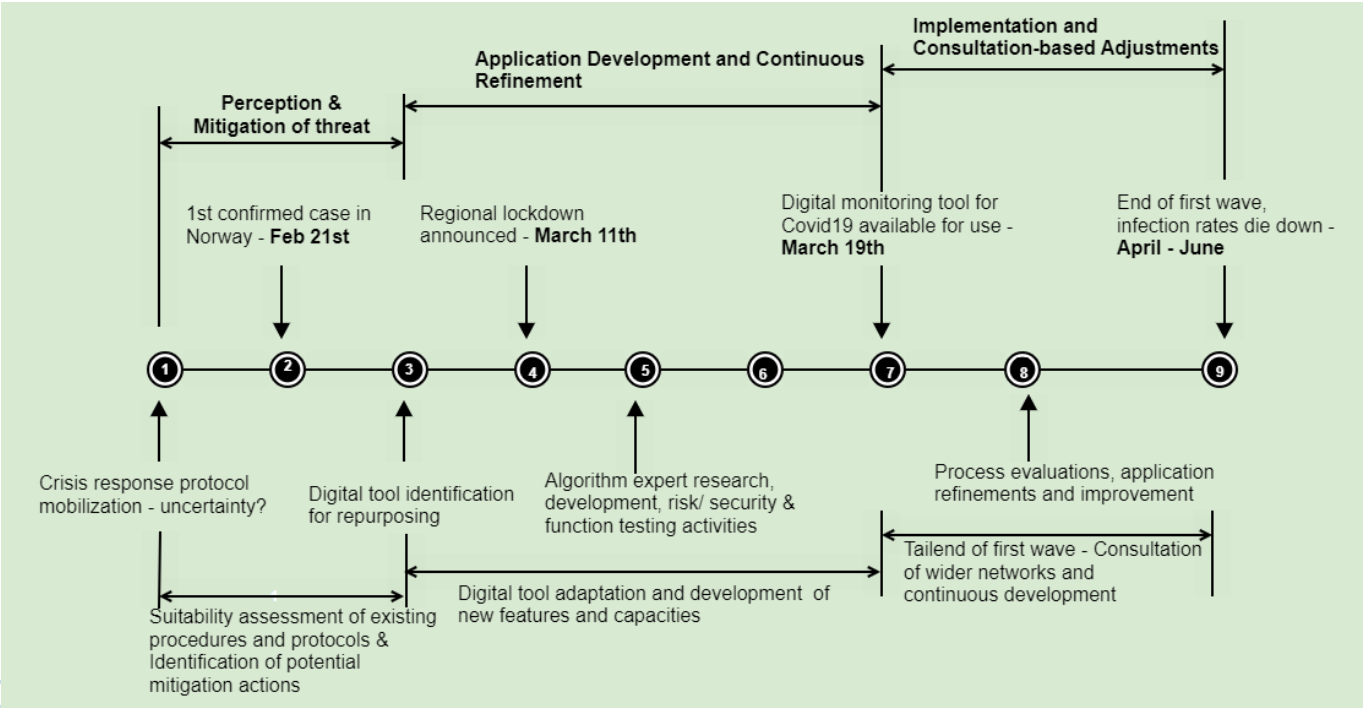
development procedure and make concessions, for instance- when Org-X undertakes to design the web user interface (a service they ordinarily do not provide at all) out of necessity. Therefore, additional scrutiny was applied to identify changes in pattern, enactment, and ordering of the known and novel processes (Suarez & Montes, 2019; Weick, 2017; Whitelaw et al., 2020).

The technical team's ability to respond to the rapidly evolving user requirements efficiently, and effectively while facing situational stress and time pressure is a demonstration of flexibility and agility. Based on the timeline and the processes and steps identified in Fig. 4, it is possible to logically arrange the identified subprocesses and steps and map them into a conceptual process model. A key observation in the data, is the participants emphasis on continuous learning – during and after the crisis highlighted in the Continuous Refinement, and the Consultation-based Adjustments subprocesses identified in Fig.4. Learning during the crisis is characterised by rapid intra-crisis learning and gradual inter-crisis learning. Intra-crisis learning aims to improve response as a single crisis unfolds while inter-crisis learning thrives to prepare and anticipate for probable future crises and improve general operations(Pursiainen, 2017). COVID-19 presents as an interesting scenario, as most countries experienced it in 'waves of infection', and in our analysis we characterise each wave as a new crisis cycle. The different learning points and scenarios experienced in the case are detailed in the table below. According to our interpretation, rapid intra-crisis learning is experienced during an active infection wave, and slow inter-crisis learning is enacted in between infections waves.

Table 2 provides insight into the practical implications on crisis triggered learning and is one of the novel contributions of the study. It is arranged in classifications that reflect the processes detailed in the Results section: illumination Knowledge building, Preventability, Management, Technical, and Decision-making aspects of learning. Knowledge Building describes matters related to skills gaps or capacity related necessities and the mitigatory actions taken to fill them now and in the future. Preventability and Anticipation describe the thinking concerning future pandemics and other disasters. Management/Coordination and decision-making focuses on the managerial implications while Infrastructure and Technical risk contemplates the technological elements and their handling. This is ideal, as it accounts for not only technical requirements of the digital technology, but the organisational and social system contributions.

Recall that the research question is: How does the radical improvisation of health technologies emerge and develop during a health crisis? The discussion so far provides an explanation for the emergence of radical improvisation providing a logical basis to determine the practical

Figure 5
A Logical Sequence of Key Steps and Processes



implications of the study. A theoretical conceptualisation will provide insight on how it develops.

Fig. 6 is a process model derived from the steps and subprocesses identified in Fig. 5. It highlights the relational aspect of radical improvisation subprocesses to the established structure and routines in the health organisation. This conceptual process model is novel because it factors in a combination of empirical evidence and literature to provide a coherent representation of the sub-processes that structure the radical improvisation of a health technology. As a convenient starting point and to illuminate the connection to the crisis management cycle, the processes in Fig. 6 are mapped against the first two phases of the crisis management life cycle – preparedness and response (Pearson & Clair, 1998; Pursiainen, 2017). Milestones 1-7 from Fig. 5 are classified under 'Preparedness' in the process model, and the remaining milestones classified as 'Response'.

Radical Improvisation begins in the preparation phase, both technical and organisational aspects are reflected. Resource and Policy fortification describes the early attempts made in the health organisation to reinforce and strengthen the system for shock from the pandemic. Resources reference human and digital elements that are assembled and reallocated to fortify existing structures. Mitigation and Capacity Building are necessitated by the information and skills gap created by the COVID-19 pandemic's novelty. Implementation and Refinement are the culmination of preparatory activities but are not closed ended subprocesses. All three subprocesses linked to Preparedness are connected by 'two-way' arrows to reflect the iterative nature of the processes, which also includes a learning loop. The learning loop in the Preparedness phase is representative of the inter-crisis learning activities, and steps taken to ensure reduced susceptibility to any future crisis. The Response phase comprises three subprocesses, the system is under implementation in the crisis Adapted/ Modified protocol and the radically improvised technology must be evaluated. Interestingly, the long-term applicability of the system and possibility of integration into legacy systems must be considered at the response phase as well. Another learning loop is reflected in this phase, representative of intra-crisis learning, however, as seen in the process model, both learning loops feed into

Figure 6
A Conceptual Process Model for Radical Improvisation of Digital Health Technology

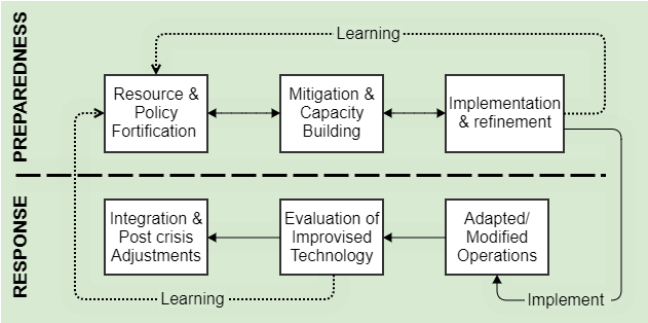


Table 2
Intra-Crisis and Inter-Crisis Learning Outcomes

	Rapid intra-crisis learning	Slow inter-crisis learning
Knowledge Building	• Capacity building to facilitate digital solution development. • Shift towards and heightened interest in digital technology supported solutions. • Digital solution design documentation. • Personnel training for nurses etc.	• Improved attitudes to digital technology and increased usage. • Change in risk perception, more trial-and-error based learning. • Continuous iterative learning and development strategies.
Preventability & Anticipation (future pandemics or other disasters)	• Notable waning 'alertness' as the pandemic went on longer. • Use of first wave of pandemic as a fire drill exercise.	• Planning for expected health care worker shortages in the next 20 – 30 years. • Digital solution use by mobile health care workers, mental health patients etc.
Management	• Presence of trust and enabling preconditions for successful improvisation. • Openness to 'outsider' innovation, using a less incremental and more radical approach.	• Creating incentives for the development of business models for technology deployment in the health sector. • Developing an affordable health care model. • Long term planning for project-based learning.
Infrastructure & Technical Risk Analysis	• Changing patient demographic, possibly a good and terrible thing. • Robust security testing. • Patient autonomy and increased independence.	• Integration of user experience focused design, and systems integration. • Heightened security models that consider the social aspects of the modern health systems.
Coordination and decision-making	• Mindfulness – harmonisation of all the moving parts that are required for the system to work. • Decentralised emergency decision making structures.	• Possibility to deepen partnerships and collaboration at various levels within the organisation. • Maintain the digital work format – proved efficient and effective.

overall resource and Policy Fortification processes. The subprocesses are in the response phase are linked by unidirectional arrows, with focus on organisational refinements and policy updates. The process model provides novel insight into the embedded subprocesses of the radical improvisation of digital health technologies. It gives insight into the technical and non-technical compositions and how they interact to generate adequate crisis response and influence future decision making and policy formulation. The next section focuses on discussing the theoretical implications of this study.

Radical Niche Construction: Crisis as Opportunity and Calamity

The traditional theoretical understanding of crisis and crisis management captures the calamity and challenges that the occurrence of crisis may create in an organization. However, this study has highlighted the possibility of opportunity arising from untoward conditions (Gkeredakis et al., 2021) and existing literature does not fully account for this possibility. The operational environment in this case if defined by the technical and non-technical constituents of the health organisation. The COVID-19 pandemic poses an undeniable existential threat to health organisations and prompts a 'natural selection' of the most efficient means of survival (Whitelaw et al., 2020). In this case, actors in health organisations (knowingly or otherwise) have made a series of decisions and taken actions that lead to the modification of the local operational environment (Laland et al., 2007). The observed adaptations in technology, health services protocols, and institutional logics in response efforts to the pandemic are a representation of the environmental modification that eventually opens the door to the possibility of deepened use of the technology. An example of such expansion is the decision to use the digital health technology to gather data on the novel virus, going beyond simple adaptation through the exaptation of previously unused secondary features (Magutshwa & Radianti, 2022). This observation is not only consistent with technology evolution but affirms niche construction literature by illuminating the growth spurt within the health organisation prompted by decisions and actions taken during a calamitous event. The COVID-19 crisis created an abundant 'demand' for digital alternatives, forcing the hand of an otherwise highly conservative health sector. Telemedicine and other digital health technologies have thrived during the pandemic, with improved attitudes to technology and increased appetite for health service models that are not centred on human contact. This is the construction of an operational-environment niche for digital health technologies. Radical improvisation, adaptation, and exapted innovations are crisis response processes that resulted in a pro-digital health technology trajectory that accelerates the technology evolution dynamics and yields the possibility of agile evolution pathways within health organisations (Fischer & Baskerville, 2022). This resonates with technological evolution that thrives on the availability of an assortment of radical innovative technologies that can be easily recombined and innovatively reconfigured (Odling-Smee et al., 2013).

The emergence of a new niche is often accompanied by the exploration of the form and process of radical improvisation is nuanced by the operational-environment niche carved by the COVID-19 pandemic. While the radical improvisations, technology adjustments, adaptations, and exaptation are slotted into pre-existing health organisation operations and prove useful steps in the short term, they also invent and construct the new operational-environment niche in the long term. This raises the possibility of health organisations and digital health technology growing and evolving in unanticipated directions. Participants in the study affirm this thinking when they describe a 'forced digitalization' that resulted in them making countless leaps and bounds in the wider adoption of the digital health technology. This notion alludes to radical niche construction theory, which states that "new technology markets cannot emerge and evolve without societal application of new technologies" (Andriani & Cohen, 2013). That adaptation, innovative processes, and exaptation explain the gradual progression of a niche from one into the next. This is evident in how the digital-follow-up solution is introduced to the health services system of the Fundi region as a welfare technology but swiftly changes due to a change in operational environment niche. Existing modules are co-opted for a new function through radical improvisations, adaptation and exapted innovations and while there is technological continuity, there is a functional discontinuity. The niche construction perspective emphasizes the opportunistic aspects of crisis environments and resolves the matter of the emergence of new technological capabilities in crisis situations (Cattani, 2008). It also highlights a new ideology on technological change and evolution. In this paper, we have contributed to crisis management and information systems literature by developing a conceptual process model that describes a crisis innovation process. Therefore, we introduce six embedded processes of radical improvisation. On a macro level we also propose

a novel theoretical interpretation of the development of digital health technology in crisis conditions that is based on a multilevel understanding of technological change through use of an evolution framework. The theoretical analysis investigates the role of crisis as a trigger of the niche construction process and highlights how recurrent innovative spurts can create avenues for future technological evolution. We map the structural and process sequences through which radical improvisation contributes to the development and emergence of a new niche. The use of NCT is novel and the proposed understanding of a co-constructed environment niche that blends parallel learning forms, including social, technical, and physical elements. The contributions of our paper provide deepened understanding of the evolutionary processes and functions of complex health organisations.

Conclusion and Limitations

The work in this paper has focused on the radical improvisation of ICT in crisis response, an under-developed area of research in crisis management and information systems literature. The empirical study clarifies how existing digital technologies in health organisations can be repurposed in times of crisis to meet changintg operational needs and generate a response to crisis. The main contribution of the paper is the Radical Improvisation of digital health technology process model which enhances the unidirectional type of incremental improvisation widely discussed in extant literature. It outlines a continuous, iterative radical improvisation process comprising interpretation, response, and learning from the operational environment to inform the parallel technology development process.

Despite this contribution, the findings must be considered within their limitations, and these are twofold. Firstly, this paper is based on a solitary case study conducted in the period July 2020 – January 2021, it is possible there have been further changes that are not within the scope of this study. Secondly, the findings focus on the processes outlining the development of a health technology and neglect to discuss the core attributes of the technology that facilitate the improvisation process. These are potential future research directions that other researchers may consider in future.

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