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Resilient Health Care: A Determinant Framework for Understanding Variation in Everyday Work and Designing Sustainable Digital Health Systems

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Abstract. This chapter presents an overview of Resilient Health Care (RHC), introducing two aspects of RHC that are important for designing sustainable digital health systems and for considering implementation outcomes: (1) understanding how normal variation in everyday work can affect implementation of digital health interventions, and (2) the role of information systems in coping with unexpected events. The importance of considering how variation in everyday work can lead to wanted and unwanted outcomes when designing information systems is illustrated through a case study of implementation of a telehealth intervention. We examine how normal variation in everyday work can lead to both safety and error, and discuss how consideration of system resilience when designing and implementing health informatics applications can contribute to improving safety for patients in the future. How health information systems can assist organisations in coping with the unexpected is illustrated through a second case study, of a thunderstorm asthma event in Melbourne, Australia. We briefly present the thunderstorm asthma case, and discuss the role of healthcare informatics in preparing for future unexpected events affecting population health.

Keywords. Resilient Health Care, Patient Safety, Complex Adaptive System, Safety-I, Safety-II

Learning objectives

After reading this chapter the reader will:

1. Understand the background to Resilient Health Care (RHC) and its historical antecedents.
2. Appreciate the main currents and selected underlying concepts in the field, including Safety-I and Safety-II; and Work-as-Imagined and Work-as-Done.
3. Apply knowledge about RHC to current research-based or practice-based problems in health informatics.
4. Analyse health informatics problems in a frame that offers a more positive vision of how safe, effective care can be delivered in complex, dynamic health settings.
5. Consider normal variation in everyday work when designing or implementing health informatics systems.

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1. The scope of Resilient Health Care

When designing and implementing new digital health systems, the safety of those systems for clinicians and the patients in their care must be a core consideration. Resilient Health Care (RHC) is a relatively new approach to safety, albeit with long antecedents to resilience engineering, that shifts from understanding safety as the absence of accidents or incidents, to thinking of safety as a system where as many things as possible go well. Measuring what goes wrong has been an attractive concept for organisations in the past: there are typically few things to count, and resources can usually be brought to bear to tackle problems that have been shown to result in significant harm. Traditional approaches to safety are reactive rather than proactive; examples include regulation,[1] protocols and checklists,[2-5] Root Cause Analyses[6] and judicial inquiries to investigate patient deaths.[7] Errors after they occur are identified and rectified, and processes are put in place in an attempt to prevent future occurrences. This approach is not effective, however, where the route to error is different on each occasion, and where fixes for previous errors can contribute to new paths to failure. In contrast, RHC asks us to understand how the systems requiring action actually work, to identify what goes right and comprehend why things routinely go well, and to proactively manage variability in the workplace. This newer way of thinking is necessary for the whole gamut of systems behaviour. It is especially apposite for improving safety in complex adaptive systems such as healthcare, and has been driven by failure to improve the safety of patient care by traditional means, despite more than two decades of effort.[8]

A complex adaptive system is one with multiple interacting and interdependent parts that change continuously and dynamically in response to environment or conditions.[9] In healthcare, these components consist primarily of humans, such as clinicians, patients and their families, aided by affordances such as technological artefacts and equipment. Human performance is inherently variable; regardless of their experience and ability, for example, the performance of an individual clinician will vary depending on the problem, time of day, and so on. Furthermore, clinicians work in small, medium and large ad hoc teams, and must interact with a range of other healthcare professionals whose performance is also varying. When the variability associated with patients and their illness or injury is also taken into account, the result is a complex and unpredictable system. Due to the complex and dynamic nature of the interactions of components, outcomes from a complex adaptive system can be unexpected and unable to be attributed to specific inputs—this is what is known as *emergent* behaviour. In addition, the system's history plays a part in determining where things are now; this is called 'path dependence'.[10]

As RHC grew from the field of resilience engineering, it borrowed from resilience engineering theory, which conceptualises how normal variation in task performance in socio-technical systems can lead to both wanted and unwanted outcomes. This guides research into how variation in human performance of everyday work processes contributes to both failure (i.e. unwanted outcome or 'error') and success (i.e. wanted outcome). The theory is grounded in system thinking and complexity science, and in understanding how systems typically cope successfully with unwanted outcomes (or events) that are unexpected. Resilience engineering originated in 2005, at a gathering of influential industrial safety scholars led by Erik Hollnagel, David Woods and Nancy Leveson,[10] and emerged from the work of Crawford Holling on ecological systems[11] and Charles Perrow on normal accidents.[12] The application of resilience engineering principles to healthcare can be traced to a meeting in 2012 of resilience engineering and healthcare safety experts led by Hollnagel, Jeffrey Braithwaite and Robert Wears and has since grown to involve a large and increasingly influential group, the Resilience Health Care Network (https://resilienthealthcare.net).[13] In the field of RHC, resilience is defined as the ability of the health care system (a clinic, a ward, a hospital, a country) to adjust its functioning prior to, during, or following events (changes, disturbances, and opportunities), and thereby sustain required operations under both expected and unexpected conditions.[14]

RHC is identified with two complementary approaches to safety – Safety-I and Safety-II. Neither approach is superior, however one approach might work better than the other depending on the complexity and predictability of the situation. Safety-I is an approach that is effective for minimising error in linear systems, where the interaction between components is well characterised, resulting in well-defined and predictable outcomes. Linear systems can range from simple to complicated, but the system outcome can always be predicted with a high degree of certainty provided we know the system inputs. In linear systems, the boundaries are usually fixed or able to be clearly defined, which means that local problems can be addressed independently of the larger system, and solutions can be generalised.

The best examples of linear systems are systems with primarily technological components, such as the computerised aspects of a digital heath system, or an anaesthetic machine. For an anaesthetic machine we understand how each of the electronic and mechanical parts are connected and operate so that the machine can function, and we can often predict accurately the mean time between failure for these sub-components. For a linear system, process-oriented controls such as standardisation of manufacture and operation provide effective safety measures, and barriers to error propagation across such a system can be applied effectively.

Once we add a sociological component, such as normal human behaviour, into the system, it becomes more complex, and Safety-I solutions become less effective. In contrast, Safety-II is an approach that is suited to a complex system. Rather than focusing on failures, Safety-II thinking tries to understand how human performance nearly always goes well and leverages that information to improve the number of things that go right. In a complex system, boundaries can be porous, and there is significant interaction between local context and the larger system. Rather than adding system controls or barriers, which is difficult to do when boundaries are not well-defined, a Safety-II approach will try to simplify the system and rely on the adaptability of the humans in the system to adjust their performance in response to changing system demands.

To apply RHC principles in the workplace to improve the number of things that go right, we need to understand 'Work-as-Done', or how clinicians make continuous small and large adjustments during their daily work, to satisfy the changing needs of patient care. In complex systems, 'Work-as-Done' is usually different to Work-as-Imagined' by those who administer healthcare and who develop the rules and procedures that clinicians must follow. This can result in different assumptions across hospitals of how tasks are accomplished, and can make implementation of new processes and procedures difficult and, sometimes, unsafe for patients. A digital health system that is designed without in-depth knowledge of how everyday work is accomplished may not be usable by clinicians, and result in clinician frustration and workarounds.

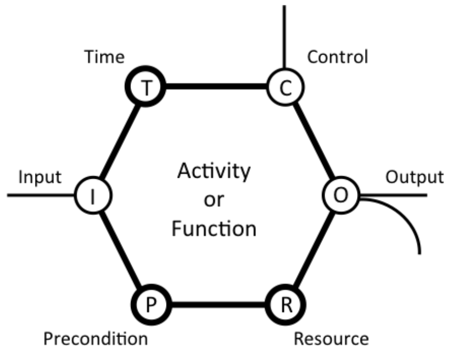
In terms of implementation science, RHC can be considered a *determinant framework*[15] that helps us to design and implement successful interventions through understanding healthcare professionals and the system in which they work. The tools of RHC, while still in early stages of development, have potential to complement other determinant frameworks such as computational simulation modelling (e.g. system dynamic modeling,[16-18] discrete event modelling[19, 20] and agent based modelling[21, 22]). This chapter presents two aspects of RHC applicable to interventions in health informatics: understanding how normal variation in everyday work can affect design and implementation of sustainable digital health systems, and designing information systems to cope with unexpected events.

2. Applications of Resilient Health Care in health informatics

2.1. Identifying and understanding variability in everyday work

The importance of considering wanted and unwanted variation in everyday work when designing sustainable digital health systems is illustrated through a case study of the implementation of an Australia-wide video consultation and triage service supporting expecting parents and parents, families and carers of young children. Established in 2010, the telehealth service consists of a national helpline, video and website service sponsored by the Australian government. Telephone consultation and triage services are commonly used to deliver health advice worldwide. In Australia, availability of high-speed internet services in remote areas is driving a move from telephone to video telehealth services for healthcare providers; however, providers are unfamiliar with how to introduce and operate a video service. When designing a new system of work, it is important to take into consideration how day-to-day work is currently carried out, in order to improve uptake and reduce workarounds when the system is implemented.[23] A useful tool for understanding variation in everyday work, including how that variation in combination with multiple interacting activities can affect outcomes, is the Functional Resonance Analysis Method (FRAM).[24]

The FRAM supports modelling complex socio-technical systems and is developed by determining the activities or functions that make up a process, and how they are coupled. Depending on the problem to be solved or question to be answered, the process can be modelled broadly, or at a more detailed level. For example, if we wanted to model the processes involved in using an automatic teller machine (ATM), we might break the process broadly into activities of (1) insert card, (2) enter PIN, (3) enter withdrawal amount, and (4) take money and card. However, if we were interested in specific detail such as the usability of the ATM screen, we might expand step (3) to include additional steps for select savings account, check account balance, enter withdrawal amount, request receipt, and so on. The data for developing a FRAM model can be obtained through a number of methods, including ethnography, interviews, documented processes, and so on. Each function is then described in terms of six aspects (see Figure 1):



Input (I) is what the function acts on or changes
Output (O) is what emerges from the function
Precondition (P) is what must be satisfied before the function can begin
Resources (R) are materials/people needed to carry out the function
Control (C) is how the function is monitored or controlled
Time (T) is any time constraints that might affect the function

Figure 1. FRAM activity hexagon [25] .

A FRAM model is built using a software tool called the FRAM Model Visualiser (FMV).[25] The potential variability of each activity is annotated as the model is built, and can be defined in terms of source of variability (internal or external, type, likelihood), output with regard to time (too early, on time, too late, not at all), and output with regard to precision (possible but unlikely, typical, possible and likely). The resulting model can be interpreted to determine how variability present in each activity affects other activities, and how delays can propagate through the system. Such a model can help to predict unwanted variation when the new system is implemented.

In the telehealth service case, two levels of direct client support are provided: (1) Customer Support Officers (CSOs) provide standardised advice on common situations, such as planning for pregnancy, foods to avoid when pregnant, and breastfeeding, and (2) accredited counsellors provide psychological support and counselling. To illustrate where we found variability in Work-as-Done in our telehealth evaluation, Figure 2 is a FRAM model showing the portion of the work activity where calls are answered and dispositioned by the CSO (we have simplified the FRAM for ease of interpretation, and have not included Resource, Control or Time aspects in the figure). Calls answered and resolved by the CSO form a linear process, passing through steps 1 to 4 (shadowed steps). Variation is indicated in the model by the sine curve within the function (see steps 2 and 4). In this case, the time taken to chat with the client to establish the purpose of the call (2) can vary depending on the client, the purpose of the call, and the expertise of the CSO. The time taken to resolve the call (4) can also vary depending on the complexity of the problem raised by the client, and the amount of information that must be passed from CSO to client to resolve the issue. Once the CSO has resolved the problem (Step 4), they are then available to return to Step 1 to take the next call (CSO availability shown as a precondition).

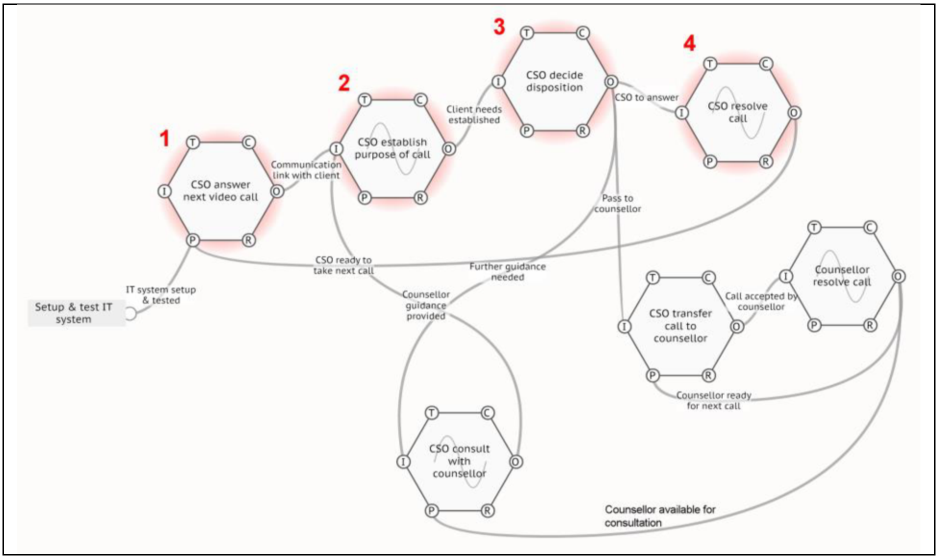


Figure 2. Resolving calls – CSO.

Figure 3 is the same FRAM model showing the portion of the work activity where calls are passed to the counsellor for resolution. It is easy to see from the Figure that including only one additional person in the process increases the complexity and resulting variation. In this process, the CSO takes the call from the client (1), establishes the purpose of the call (2) and decides whether it needs to be passed to a counsellor (3). Sometimes the CSO lacks sufficient expertise, or is uncertain about the correct disposition, so must consult with a counsellor (4) to obtain more information (5) and make the decision (6). The call can then be passed to the counsellor (7), who will resolve the client issue (8). Variation is evident in terms of the time for the CSO to establish the problem (2), in consultation with the counsellor if necessary (3, 4, 5); and for the counsellor to resolve the call with the client (8). We will also see interactions between functions that can exacerbate variability: for example, the counsellor must be available to give advice at step 4, and not on another call. Otherwise the CSO must either wait, or seek advice from another counsellor. We can see where workarounds might arise: if, for example, all counsellors are on other calls, the CSO may decide to proceed without advice, potentially leading to incorrect disposition. We can also see how the advice loop (steps 3-4-5-6) could consume CSO and counsellor time, leading to delays in providing advice by counsellors (8), and backup of new calls waiting for the CSO (1, precondition).

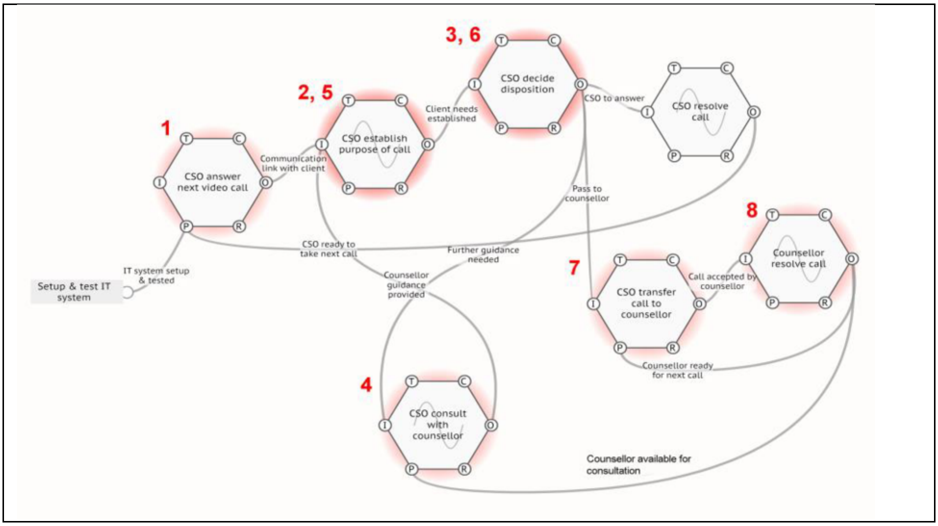


Figure 3. Resolving calls – counsellor.

2.2. Designing information systems to cope with unexpected events

How health informatics can enable systems to cope with the unexpected will be illustrated through a case study of a thunderstorm asthma event in Melbourne, Australia.[26] Over two days in November 2016, nearly 10,000 people presented at hospital Emergency Departments with breathing difficulties, and nine people died. The efficiency and effectiveness of locally embedded health information networks enabled emergency services to manage the unanticipated increase in ambulance calls and hospital presentations, however the crisis revealed deficiencies in command and control level information systems. A useful tool for proactive evaluation of resilience in response to unexpected events is the Resilience Assessment Grid (RAG).[27]

The RAG was derived by considering four essential capabilities of resilience (Figure 4): knowing what to do in response to unexpected occurrences and being capable of doing it (actual), knowing how to identify early that developing events might prove problematic (critical), knowing what to expect as events develop (potential), and learning from what has happened in the past (factual). The ability to respond includes taking unpredictability into account and adjusting responses to enable local experts to improvise. The ability to monitor includes tracking how things are being done well and understanding Work-as-Done. The ability to anticipate includes policy makers balancing prescriptive controls with local level discretion, improvisation and judgement. The ability to learn should be based on frequency and severity of what goes right.

The RAG can be proactively applied by evaluating an organisation in terms of the four capabilities. This evaluation is usually completed as a series of probing questions that can be answered via a combination of interviews, focus groups, ethnography and audit or document review.

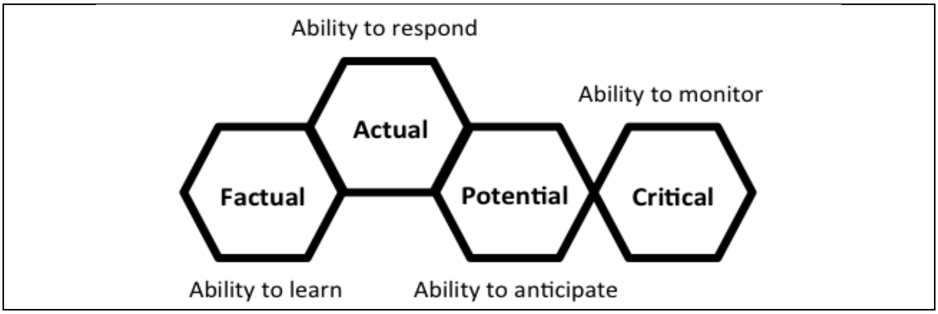


Figure 4. The four resilience potentials forming the RAG [27].

In terms of the thunderstorm asthma case, and guided by the RAG, we can examine what happened retrospectively in order to learn and develop information systems to improve the response of emergency services to future large scale unexpected events affecting population health. One of the difficulties faced by emergency services was that, at the time people were experiencing acute respiratory symptoms, information on the cause and extent of the problem was limited. Using the RAG framework, we can look at the successes and failures of information systems when challenged by the thunderstorm asthma event, as follows:

Actual: the ability to respond to the thunderstorm asthma event. Despite the rapid onset of events, the Emergency Services Telecommunications Authority (ESTA), Ambulance Victoria (AV) and Victorian hospitals responded quickly and increased the scale of their respective operations. The State Health Emergency Response Plan (SHERP) was not activated at an appropriate level, however, so processes to aggregate and share data were not available. In addition, neither ESTA nor AV formally activated their emergency escalation plans. The key decision-maker was the State Health and Medical Commander (DHHS). DHHS communicated with hospitals through mobile text messages, phone calls and emails to individuals such as hospital Chief Executive Officers; this resulted in inefficiency, and inconsistency of information provided to hospitals. In response, some hospitals contacted each other directly to obtain information.

Critical: the ability to monitor as thunderstorm asthma developed. When information is limited, it is vital to identify triggers for action. During the thunderstorm asthma event, there was a surge in demand for telecommunications, ambulance and hospital services. Monitoring of usage by the Emergency Services Telecommunications Authority (ESTA; see Figure 5), Ambulance Victoria (AV) and Victorian hospitals for future unexpected events may allow for a rapid surge in demand to act as a trigger to activate emergency response plans.

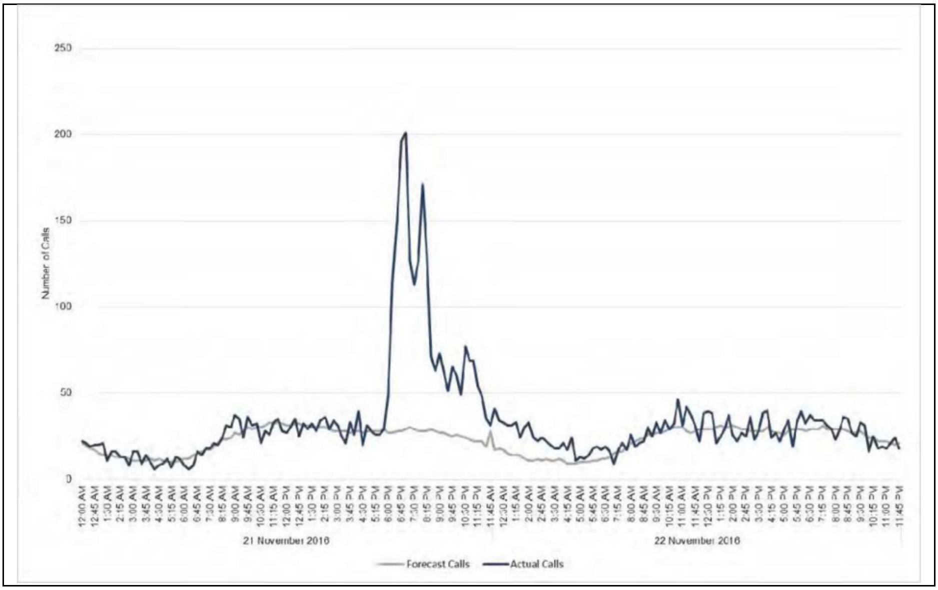


Figure 5. Emergency calls for ambulances presented to ESTA on 21-22 November [26].

Potential: the ability to anticipate the severity of the asthma crisis. Despite a forecast for severe thunderstorms, there was no expectation of an impending emergency. Lack of situational awareness across the health system meant that, although clinicians suspected that the respiratory symptoms they were seeing were caused by thunderstorm asthma, there was no channel for sharing this information with DHHS. In addition, the traditional system for communicating public health concerns, whereby DHHS seeks to understand what is causing the problem in combination with its impact on the health system before issuing public information and warnings, was unsuited to a rapid-onset problem such as thunderstorm asthma.

Factual: the ability to learn from successes and mistakes when responding to the thunderstorm asthma event. Following the event, the state Inspector-General for Emergency Management was tasked by the state government to review the emergency response.[26] The review resulted in 16 comprehensive recommendations, of which 10 were related to improving data integration and/or information systems. Various organisations that were part of the response, including ESTA and AV, also reviewed and updated their emergency response plans. Finally, an interagency working group was established to share knowledge and improve procedures for detecting and anticipating the severity of future events.

3. Explanation of success or failure of health IT system

3.1. Identifying and understanding variability in everyday work

Using RHC principles enabled an understanding of Work-as-Done when delivering telehealth advice to new and prospective parents via video. The plan to use both CSOs and counsellors to deliver the service was abandoned, and a revised system design whereby CSOs continued to deliver their service over the telephone and only counsellors participated in the video service. This decision was made prior to implementation of the video service, as a direct result of the research findings.

While there are many process mapping tools that enable an understanding of work processes, FRAM is the only tool that enables variation in processes to be directly mapped. FRAM is therefore most useful for mapping processes that are non-linear, and that have many co-dependencies among tasks. A disadvantage of the method is that a FRAM can quickly become complicated and unwieldy, especially if the mapping is done at a level that is too granular for the problem at hand or if the boundaries of the system are not sufficiently constrained. Because FRAM involves mapping Work-as-Done, those who actually do the work must participate in its development; this may be a burden on resources for some organisations. Finally, while FRAM can be taught to novices such that they could produce basic models after one day of training, manipulation of the FMV software and useful interpretation of the results can be dependent on the skill and experience of the modeler.

3.2. Designing information systems to cope with unexpected events

Analysis of the thunderstorm asthma event revealed deficiencies in information systems that precluded a whole-of-system response to the emergency. In particular, information systems were found to be inadequate to support the ability to anticipate and the ability to respond. In terms of anticipation, a notification process should be developed that disseminates early information about an emerging incident to all relevant emergency management organisations. In terms of response, a centralised online system should be established to link all hospitals to ensure that they receive timely and relevant information on the medical implications of emerging events.

Using the RAG provides additional insight into the dynamic aspects of systems, particularly monitoring and anticipating, than that provided by more conventional investigation tools such as Root Cause Analysis. The RAG, however, is very dependent on the quality of the probing questions developed to assess each of the four capabilities of resilience. The questions must be designed for the specific case, and this may require specialist subject matter expertise. In addition, the combination of interviews, focus groups and ethnography required to elicit answers to the questions requires familiarity with qualitative research methods.

4. Discussion

The theory of RHC is relatively new, and tools such as FRAM and the RAG are still in their infancy. Despite this, we have learned that effective implementation in healthcare must consider that the system is dynamic, that behaviours are emergent and never wholly predictable, that causality is not knowable, and that validity of results will be limited by context. We know that local problems will impact, and will be impacted by, the larger system of which they form part, and that multiple interventions will interact, often in unpredictable ways.[9] Planning implementation and evaluation collaboratively with clinicians and patients will assist in understanding Work-as-Done and support the intervention so that it can be better matched to the needs of the workforce. Overall, RHC is showing great promise for implementation and sustainability of complex health service interventions, including digital health systems.

Teaching questions for reflection

1. What are the implications of RHC for design and sustainability of digital health systems?
2. When implementing a digital health system, how would you account for variation in everyday work?
3. What information system designs might work to improve communications during unexpected, rapid-onset, large-scale public health events?
4. How would you design large-scale information systems to incorporate the need to monitor, anticipate, respond and learn?

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