Implementation considerations in a Complex Adaptive System

An analysis of salient factors for the scaling and spread of new e-health interventions, a case of Northern Sweden

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Executive summary

This report is provides guidance for research teams who are currently planning or are in the midst of implementing an e-health intervention in rural communities. It describes the important factors which need to be considered when scaling-up a pilot project from one context to another, and demonstrates what a successful project needs to maximize the probability that it will achieve the desired level of spread within the healthcare system.

This report can be used as a reference for people who wish to implement a novel intervention into a new environment. Ideally it will be used in the early stages of intervention design to help researchers understand how a complex adaptive system functions and why navigating one is important for the outcome of their intervention.

To begin, the report covers some basic terminology used when discussing complex adaptive systems and highlights the importance of working with these ideas moving forward. Next, in-depth discussions about sense-making, leverage points, self-organization, and agent-based modelling provide evidence of the complexity of implementation. Finally, the principle of antifragility is discussed, as well as a tangible example of an intervention which has been designed with antifragility in mind. Finally, the conclusion summarizes the key findings of the report, offers future directions, and identifies some of the limitations.

Acknowledgements

This report was prepared for the Centre for Rural Medicine in Storuman, Sweden, as part of the Free Range international student exchange program. We would like to thank Professor Dean Carson of Charles Darwin University for his support in this program. We would also like to thank the many people at the Centre for Rural Medicine, Andreas Lundqvist, Peter Berggren, Thomas Molen, Anna-Karin Hurtig, and Roland Gustafsson. Lastly, we would like to acknowledge the communities themselves, which have allowed us to work in their midst and to gain from their lived experience.

Introduction

In the past several decades, there has been a greater emphasis put on the movement of theory to practice. This initiative has largely arisen due to the vast amount of academic interventions implemented and research papers published but are never ‘scaled-up’ into the broader system (Bégin, Eggertson, & Macdonald, 2009). This problem is especially prevalent in the healthcare systems of many developed nations. To help understand the important factors that need to be considered when scaling up a pilot project, a branch of science known as *implementation science* has risen to prominence. Implementation science draws heavily on *complexity thinking* and the analysis of *complex adaptive systems* (CAS), known as *complexity science*.

Every healthcare system operating today can be defined as a complex adaptive system. **Complex adaptive systems** possess characteristics such as irreducible complexity, non-linearity, unpredictable consequences, and high levels of interdependency (Rickles, Hawe, & Shiell, 2007). As such, implementing a new initiative into complex adaptive systems is unlike interventions into reducible, linear systems; and, the outcomes may be unpredictable and cascading. For project planners, the distinction between linear, predictable interventions and those that are complex, can provide new methods for evaluation and additional insights into how projects may (or may not) progress.

Irreducible complexity is the idea that an outcome cannot be traced back to a single factor retrospectively. For example, if a team decides to implement a tele-dermatology initiative in a rural community that ultimately fails, it is very hard to identify one specific cause for the failure, and adjust the model for future iterations. Feedback loops (both positive and negative), multiple moving parts, and the volatility of human interactions are just few of numerous factors which combine to make the investigation of a failed project extremely difficult. Most methods of evaluation and monitoring are developed with linearity in mind, and thus will be inappropriate.

Non-linearity is the idea that a change in one part of the system does not lead to an equal change in another part of the system. A small change to a system could lead to drastic changes in outcome, while similarly a system overhaul could yield small or non-existent changes. Non-linearity is a feature of health systems, as complex adaptive systems are greater than the sum of their parts. In a typical hospital for example, many different services (oncology, dermatology, cardiology, etc.) and groups of professionals (physicians, nurses, paramedics, allied health) work together to create the healthcare system as we know it. Any one of these groups would not exist in isolation and create a similar system; they each work with the other groups to collectively produce a rich and diverse system.

Whenever a new intervention is placed into a complex adaptive system, the implementation team must be cognizant of unforeseen consequences. No matter the level of due diligence done by the research team prior to implementation (interviews, site visits, census analysis) there are always consequences which could not have been predicted (Braithwaite et al., 2017). This is due in large part to the factors already discussed above. Therefore, throughout the implementation process, researchers must diligently monitor their intervention, and try to gather the appropriate data related to the intervention as holistically as possible. This holistic evaluation will yield better identification of so called *leverage points* within the complex adaptive system which can then be targeted to change outcomes.

Key Aspects of Complex Adaptive Systems

Leverage Points

Leverage points are a key element of complex adaptive system that need to be understood when considering system implementation from this perspective. Leverage points typically exist where one part of the system overlaps with another; say a group of nurses interacting with paramedics, or patients with care providers. Donella Meadows outlined 12 leverage points which can be found and exploited within a complex adaptive system (Meadows, 1999), and outlined the importance of understanding why working with these leverage points will yield better results than naively attempting to monitor smaller parts of individual systems. On this list of points of influence to change system outcomes, among other things, are items such as 'rules of the system', 'gain of driving positive feedback loops' and 'the power to transcend paradigms'. If a researcher can correctly look at their system and identify one of these 12 points, they may be able to influence the outcome of the system in a desired direction.

An example of leverage points can be seen in a paper by Lanham et. al. This example traces antiretroviral drug regimens in West Africa to combat HIV, where adherence was very poor. Practitioners found that a high proportion of patients wouldn't come to the clinics regularly or would be lost to follow up (Lanham et al., 2013). In seeking interventions to address low adherence, researchers identified a leverage point to increase the rate of drug regimen adherence, which was the communication between nurse and patient. Most patients had access to some sort of cellular phone, and so the researchers implemented a simple short-message service system (SMS) that would contact patients about keeping with their regimens. Patients then could respond with either a 'yes', indicating everything was going well, or a 'no', indicating there was a problem with the drug program, and they required assistance. Results showed that 98% of patients in the experimental arm of the investigation said they wanted the program to continue (Lanham et al., 2013). This is a great example of researchers identifying a leverage point, and using it to benefit their patient group.

In a Virtual Health Room (VHR) context, potential leverage points may exist when the patients use these rooms, when patients communicate with other patients, and when decision-makers evaluate the rooms success (to be expanded later). It is important therefore to monitor the points at which different groups come together in the usage of these rooms, and careful analysis must be done to understand what type of intervention could push the rooms one way or another. For example, the SMS service implemented in West Africa could be used for the rooms instead; if people wanted to know when the rooms would be open, but do not want to spend the time driving and waiting, an SMS system could be set up where they could message a toll-free number to ascertain whether the room is free.

Sense-making: Bridging the gap between what is 'done' and what should be done

The West Africa example raises another issue that researchers must be aware of when they begin to implement things into a new context; that is the issue of **sense-making** (Braithwaite et al., 2017). Sense-making generally refers to the gap between how things are done, versus how things are professed to be done. For example, in an emergency department triage the protocol may be to page the emergency physician regarding an urgent case. But, in reality it could be much easier for the nurse or paramedic to walk through the emergency department and speak to him or her face to face. The official protocol in this case would hinder efficient care. Sense-making is important to understand, because if an intervention is designed for how the protocols are laid out, it could risk rapid decline and failure as that is not how work is *accomplished* in that context.

At its root, sensemaking the process through which people assign meaning to experience.(Lich, Ginexi, Osgood, & Mabry, 2013) Because sensemaking is a social activity, interdependencies affect sensemaking. Interdependencies which are trusting, attentive to new ideas, and mindful of differences between ideas are more likely to result in effective sensemaking than interdependencies that lack these qualities. Facilitating effective sensemaking can help people understand interventions. Sensemaking can also help people understand a SUS intervention as it unfolds. These real-time insights may be crucial for effective implementation. One important aspect of sensemaking is its connection to action.(Lich et al., 2013) Effective sensemaking is more likely to lead to productive action than ineffective sensemaking. Ex: complication rates in low v high mortality rate hospitals were the same, but complications were faster seen and diagnosed in low mortality rate hospitals. This ‘failure to rescue’ can be seen as ineffective sensemaking.

Agents and their influence

To understand how work (used in this context as including anything that the implementation hopes to influence) is *accomplished* compared to how the protocols *dictate* work should be accomplished, it is usually most beneficial to interview agents within the system. **Agents** here refer to individuals who work and interact everyday with one another, and are the single most influential factors on the outcomes that the system produces. Agents can have their own relationships not defined by their job title or other status, and can have different beneficial or negative effects (such as being a *bridge* or a *gate-keeper* respectively (Brainard & Hunter, 2016).

To understand how an agent works to accomplish everyday tasks within the system, they must first feel comfortable sharing how they work. This is not a trivial point. Perhaps some of the work they do does not follow a specific protocol, which could lead to discipline from a superior. Regardless of how their work gets accomplished, hopefully the safety of the patient is never put in jeopardy. It is one thing to use heuristics or shortcuts to circumnavigate a tedious task; but quite another to purposefully put a patient at risk for your own convenience. Getting an agent to sit down and talk and be totally open about how things are done is difficult, and requires fostering a trusting relationship. This process can be expediated by locating a **bridge**: a type of agent which has a high degree of influence within the system and can provide opportunities for interactions between agents who may otherwise be siloed from each other.

Champions on the other hand are individuals that are usually easier to identify than bridges, and if they are suitably approached can be invaluable for the implementation of your intervention. In Slussfors, the example was given of an elderly woman who discovered that she had type 2 diabetes from using the VHR. Since that moment, she became a very vocal champion within the community for the continued use and upkeep of the VHR, and probably shifted the opinion of the community towards a more positive outlook. Having someone like that as a champion can prove invaluable moving forward when it comes to talking to policy makers or decision makers for future expansions and implementation.

However, the nature of evidence-based medicine means that it would also be beneficial to have a champion within the medical or policy-making community; someone who is trusted by other medical professionals and decision-makers. Finding a champion in both the patient population and provider population is a dream case, and rarely plays out the same in reality.

Bridging agents allow for dialogue between groups that may or may not have much communication in the past (Brainard & Hunter, 2016). Relevant to eHealth implementation, in traditional medical models the IT department and the primary care providers had little reason to intermingle. In todays healthcare models, the importance of having an open line of communication between these two groups is becoming more and more evident. Agents can be reluctant to accept change, and appropriate tension for change must exist in order for certain populations to begin to look for alternative options. These options are even slower to come to fruition if the agents involved are siloed off from one another. As such, in the context of the VHR implementation, it is important to maintain open communications from both a care perspective and an IT perspective and encourage collaboration from these agents. This collaboration at a grass-roots level is what helps inform other levels of structure and can give rise to insightful innovations. This is a result of the *self-organizational* nature of agents within a complex adaptive system.

Self organization is another key attribute of complex adaptive systems (Alami et al., 2017; Brainard & Hunter, 2016). It is commonly defined as the agent-based movement or alignment with other agents of similar characteristics, whether characteristics defined by the hospital that the agents work in (such as nurses self-organizing with other nurses, or ICU staff self-organizing within the ICU) or other characteristics which are held by a broader population (religious affiliations, recreational interests, etc.). When agents encounter other agents within the complex adaptive system, they tend to form rich relationships with one another, which then inform the structure of the organization in higher levels. Already we have seen how the interactions between triage staff informs the structure of the triage system overall. Likewise, interactions with the support staff and users of the VHR will create the structure of the VHRs moving forward.

The adage ‘build it and they will come’ naively assumes that the decision-makers ‘in charge’ know what the people want. It also operates on the assumption that people do not know that they need a certain intervention until they are provided with it. Perhaps that may be the reason many e-health initiatives fail to reach broader implementation; people assume that the general public will use a technology simply because it exists where before there was no service. The work of my colleague Matthew Bishop is important here. Dr. Bishop defined the communities readiness for an e-health initiative by using the *replace, enhance,* or *introduce* model. The initiative must be either replacing a previous service (such as a district nurse), enhancing an already existing model of service (such as a cottage hospital) or introducing a new service altogether (such as tele-dermatology).

Knowing how care-providers and patients themselves self organize, and being honest about the aim of the intervention in question (replace, enhance, introduce) will help the research team tailor an intervention for different contexts while maximizing the probability that the intervention will succeed. An example of self-organization can be pulled form Dr. Bishop’s work. In New Zealand, rural nurses met annually at a regional center to discuss the challenges and innovations of rural nursing. The downside of this convention was that rural hospitals had to essentially close from 2 days while their staff was away. To combat this, the health authority in New Zealand introduced a tele-conference which lasted the entire day, which allowed the hospitals to remain open and still gave rural nurses to share their expertise with each other. The reality of the situation was that the nurses quite enjoyed going to the regional center for the conference, as it was a change to make new connections, go out to dinner, and bolster their professional circles. The attendance for the tele-conferences were dismal compared to the 'bricks and mortar' convention, and as a result the health authority had an officially sanctioned rural nursing convention bi-annually, with smaller tele-conferences throughout the year.

Antifragility: How to become comfortable with volatility

The above example combines aspects of a complex adaptive system outlined above: self-organization, sense-making, irreducible complexity, and holistic evaluation to name a few. It also highlights how easily good intentions within a CAS can be misconstrued to create poor outcomes. A common theme within CASs in unpredictability and volatility, which can contribute to the failure of pilot projects. So how can a project be designed so that it takes account of the inherent volatility within a CAS and not only deals with it, but actually benefits from it? The principle that e-health initiatives should strive for is known as 'antifragility'(Taleb, 2012). Antifragility is the antonym of fragility. While a fragile system breaks or loses its interventional integrity when there is an increase in volatility, an antifragile system gains stability with more unpredictability. A resilient or robust system performs the same whether there is volatility or not within an environment; volatility has no impact on the overall outcome of a robust system.

So what does it look like to be tangibly antifragile? A starting example is the human genome. Any one human is fragile, they don't especially like being subject to disease, famine, or natural disaster. With each pathogen or funny looking mushroom encountered by the individual human however, the human genome gets stronger. It *likes* volatility. Although the black plague in the middle ages wiped out a majority of Europe's population, the people that survived developed an immunity, and the genome was stronger because of it. This reliance on volatility means that the genome is antifragile.

A slightly more relevant example is the VHR is Slussfors. Firstly, the VHR was placed in a school that had some empty space. This is important for two reasons; the first being that by placing the VHR in a trusting and respected environment such as the local school, people that may have had some reservations about technology and healthcare tacitly understand that a room with unforeseen dangers wouldn't be placed in a vulnerable environment such as a school. Therefore, in the early stage of implementation where volatility can be the most harmful, the preconceptions of what is and is not acceptable in a school will help the VHR, not hurt it. In towns where there is relatively little infrastructure, building new infrastructure could be counter-productive, as it adds to the feeling of foreignness which may already be present when dealing with technology and healthcare. Finding a space that was used for something trusted in the past (a school, an old post office, a café) is both less costly and better situated in patients mindsets than building something new.

Another element of anti-fragility within the Slussfors VHR is the presence of multiple functions. It is ostensibly a VHR, but the technology can be used (and is used) for other things as well, such as teacher training, health care training, or virtual meeting spaces. Ensuring that the VHR has built-in optionality for its use is key to ensuring that it becomes engrained within the community and people who use it for one thing will then feel more comfortable using it for something else (Taleb, 2012). Providing people with optionality is an important part of fostering antifragility of an intervention. If an intervention is designed and evaluated using rigid metrics, the chances that the intervention falls short of these metrics is higher than if the criteria for 'success' are more fluid and change based on the context of the environment surrounding the VHR.

Evaluation through a complexity science lens

Decision-makers with no vested interest in the outcome of a VHR may fail to see the importance of even small numbers of users. An example is where funding decisions are made from urban centers such as Umeå or Stockholm, where a VHR is not needed. If in a village with a population of 150, 25 people report using the VHR at least once throughout the year, that is over 16% of the population who utilise this service. Rural communities are already marginalized in regards to access to health and other services compared to their urban counterparts. By singling out low sample sizes as reason for scaling back the VHR program, policy-makers will effectively deny a community with already reduced access the help it needs to be put on par with urban inhabitants in a supposedly universal healthcare system.

Therefore, the evaluation of VHRs should be done with the small sample size of the community in mind, but also other factors that are salient to the context. This could mean changing the way things are evaluated as the rooms are rolled out in different communities. Things like population size, underlying disease burdens, and general hospital admission numbers should be gathered as completely as possibly and used when evaluating the VHR effectiveness in different communities (Gates, 2016). The marks of improvement in an urban center will be quite different than a rural one, and the argument could be made that even if a handful of patients observe better outcomes, this is sufficient given the realities of these communities.

So for the future rollout of other VHRs, a site could be selected that has some relevance in the community. This will increase the chances that the community will foster the VHR and a champion agent emerges, as they already tacitly understand its importance because of its location within a previously prominent building. The VHR should also provide optionality; with the possibilities of using it for many other things besides health. This will help it get through the early stages of implementation where volatility and unpredictability are the most dangerous to the long-term health of an intervention. Finally the evaluation of the VHR should be done holistically and on a case by case basis, with sensitivity to the fact that although outcomes may not be statistically significant because of small sample sizes, they are philosophically significant from the viewpoint of a marginalized community being pulled even with urban communities within a universal healthcare system.

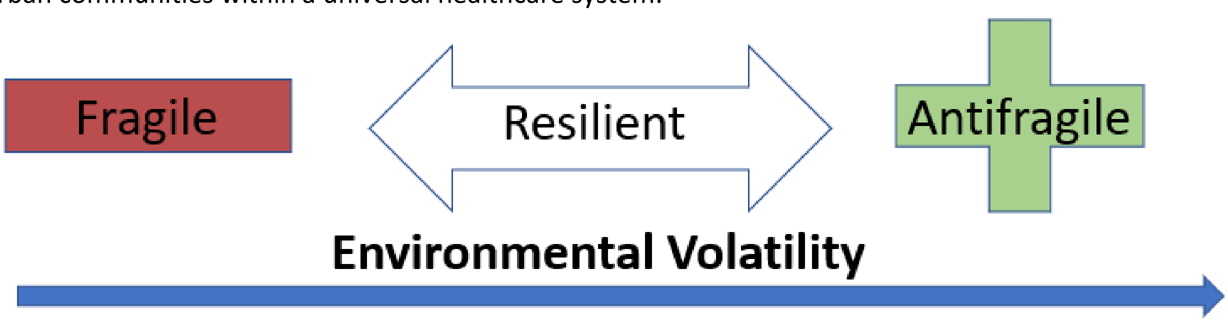

Figure 1: As environmental volatility increases, a fragile intervention loses stability, a resilient intervention retains its integrity, and an antifragile intervention gains stability from volatility.

Figure 1 shows the notion that as the environmental volatility of a given context increases, a fragile intervention will fail, while a resilient intervention will produce the same outcome regardless of volatility level. Indeed, an antifragile intervention will benefit from unpredictability and volatility. Antifragility is an intriguing guiding principle as it does not work against a complex adaptive system. Instead of trying to 'fix' the unpredictably that is inherent in healthcare systems, anti-fragile complex adaptive systems seek ways to work with and benefit from any unpredictability. In summary, table 1 highlights some defining characteristics of a fragile vs. antifragile intervention.

Fragile Projects	Antifragile Projects
Mandated from the top down	A result of the emergent properties of a complex system
Have rigid success criteria	Adapted and modified throughout the implementation cycle
Core components and peripheral components are distinct	Core components and peripheral components are indistinguishable
Designed 'by the book'; adhere to protocol	Designed 'by real-world needs'; may or may not adhere to protocol

Table 1: A selection of characteristics which separate fragile and antifragile e-health initiatives.

A final element an intervention needs to maximize antifragility and potential for scalability is that the core and peripheral components must be as *blended* as possible. In implementation science, it is generally agreed that the core components of the intervention are the parts of the intervention which are crucial to the interventions integrity. They usually cannot be changed with the intervention falling short of reaching its outcomes. The peripheral components of an intervention can be changed from context to context, allowing for the scale and spread of a pilot project.

An antifragile project ensures that its core and peripheral components are as blended as possible, maximizing the possibility it can be spread from context to context without losing its integrity. For example, a central goal of a rural VHR is to provide healthcare services to populations which are otherwise far removed from brick and mortar institutions. In order to achieve this, technology has been used to substitute a face-to-face consultation or meeting with a healthcare provider (Hurtig, 2018). Blending the core goal of improving healthcare access with the peripheral components of ensuring that technology works in multiple different contexts (to name one of the many peripheral components of the VHR project) will ensure that the VHRs have a high chance of succeeding moving forward.

Conclusion

In conclusion, research teams and health planners must be aware of several important aspects when working within a complex adaptive system framework: self-organization, bridging vs. gate-keeping agents, irreducible complexity, non-linearity, flexible success criteria, blending of core and peripheral intervention components, sense-making, and the guarantee of unforeseen consequences are all salient factors when introducing a new intervention into a community (such as a VHR).

In Sweden, Slussfors is a great example of using the factors mentioned above to help the intervention thrive (in this case, the VHR) instead of throttling it at its infancy. Bridging agents helped quell the initial uncertainty about technology and healthcare; blending of the core and peripheral intervention components meant that the VHR could be adapted into other communities of similar profile; optionality of the room ensured that even if it was not being used in a healthcare context, people would still find use in it, allowing for the possibility utilization for its original purpose in the future. Placing the VHR in a part of the community that has longevity with community members and is tacitly understood to be trusted helped to guard against the non-linearity and irreducible complexity of why things fail.

The idea of antifragility is to build an intervention which works with the many factors of complex adaptive systems that create such a barrier to scale up and spread of innovative healthcare interventions. The Slussfors VHR embodies many of the things required for an antifragile intervention, and has seen plans of expansion to 8 other communities in Northern Sweden. If antifragility really can aid in the design of pilot projects, these next few years should illuminate its potential as an important principle in intervention design and implementation science.

This leads to the biggest limitation of this report; which is the fact that this analysis is done retrospectively. Working within a system, it is very easy to look back and misattribute something to a factor which you deem to be the cause of an outcome, but in actuality has little to no effect whatsoever. The only way to truly evaluate antifragility is to conduct a prospective study in multiple contexts, with a diverse range of stakeholders and environments, to see if the tangible aspects of an antifragile project (optionality, guarding against non-linearity, and the blending of core and peripheral components) can really help to scale up and spread.

It is worth pointing out that making an intervention antifragile still does not guarantee its success. Many things in life are immune to prediction (Orrell, 2007), and the fates of e-health initiatives are no different. Ultimately it is about maximizing the probability a project will succeed while minimizing the probability the project will fail. Even so, drastic changes (loss of funding, loss of key agents, paradigm shifts) all serve to ensure that no one can be perfect in their predictions or their designs. An antifragile project is not necessarily a foolproof one; but rather one which is better served in the long run compared to its naively produced counterparts. Antifragile projects *could* have a better chance than their fragile or even robust counterparts at scaling up and spreading to broader levels of organization, but until a prospective study is undertaken nothing definitive regarding antifragility can be said.

If future research teams can ensure that their projects are designed with complexity science in mind from the outset, and also ensure that their projects are evaluated from a complexity science lens, there may be improvements in the ability to scale-up and spread e-health initiatives.

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