PREPARING TO BE UNPREPARED: TRAINING FOR RESILIENCE

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Abstract

Training methods for operators working under high pressure and in dynamic, unpredictable settings could benefit from a focus on resilience. In such settings, formal training often focuses on procedural conformity to train for particular scenarios, but resilient performance taps into a wider experience base and often more tacit skills. In this paper, we formulate a research agenda to develop useful theoretical insights about training for resilience. Our discussion follows recent developments on organizational routines, which suggest that sources of inertia and conformity, such as strict procedural training, can also enable operators' resourcefulness. Drawing from our diverse research experiences, we discuss the training needs for 1) developing or attenuating techniques for flexible procedural use, grounded in a rich qualitative understanding of practical experience; 2) the possibility to train skills that are more broadly applicable than specific training scenarios through simulation training methods; and 3) the development of training programs based on knowledge of "work-as-done" through Agent Based Modelling and Simulation methodologies and behavioral theories.

1 INTRODUCTION

Practical knowledge and experience are increasingly regarded as crucial facets of operational resilience (Weick & Sutcliffe, 2011). Resilience matters in conditions where operators work under high pressure in dynamic and unpredictable settings, facing major consequences if something goes wrong. Operators working in such conditions build knowledge and experience by learning in formal training, participating in communities of practice, and internalizing lessons from on-the-job performance. Knowledge and experience thus gained, often tacitly, can make operators resourceful and enable them to act adequately in surprising and ambiguous situations.

Formal training provides important building blocks to operate resiliently, but does not necessarily ensure management of unexpected events when instructions are only about following procedures. Procedures are useful guidelines in ambiguous, complex situations when operators know when, how, and why to deviate. This raises questions about what training for resilience would look like. What type of training could access and stimulate experiential learning and informally acquired knowledge? For what kind of situations could or should operational personnel be prepared to deviate—emergencies, routine situations, or both? Could or should formal training simulate the real world better?

In this paper, we formulate a research agenda to develop useful theoretical and methodological insights about training for resilience. To this end we first identify and elaborate on the challenges that exist in training for resilience. We draw from our diverse research experiences to outline topics of interests, methodological challenges, and contributions with the potential to quickly update current training practices. Consistent with organizational routines literature (e.g. Grote, Weichbrodt, Günter, Zala-Mezö & Künzle, 2009), we find that training can stimulate conformity, which helps to establish predictability and reliability, but conformity does not necessarily contribute to resilience. Training for resilience taps into, acknowledges and supports the variability of routine performance. Managing variability better may require training a different skill set than those associated with creating conformity to procedures. Furthermore, to establish how training of resilient skills translates to its practical application, we may need to develop alternative methodologies that can capture the variable nature of operational work as done.

Our discussion on resilience training challenges is guided by three, interrelated questions. First, we develop a theoretical perspective on flexible versus robust procedures. How can operators be guided to know when to deviate from normal procedure? Second, we review the training of broadly applicable skills that allow for coping with unexpected and untrained scenarios. Can general problem-solving skills provide a useful baseline to adapt to unexpected events? Third, we discuss ways to develop training programs based on knowledge of "work-as-done". How can knowledge about everyday challenges and adaptive performance inform training scenarios? We conclude our paper with a broad research agenda that can address these questions in relation to one another.

2 RESILIENCE CHALLENGES

2.1 Flexible vs robust procedures

Organizational rigidity and inertia are often seen as obstacles to the adaptive behaviors required for resilient performance (Weick & Sutcliffe, 2011). Normative management policies that focus on controlling behaviors, such as by enforcing compliance with procedures, are effective in limited degrees, because while some situations require robust procedures, others require flexibility (Hale & Borys, 2013). Recent developments in organizational sciences however suggest that commonly acknowledged sources of inertia and rigidity, such as robust procedures, may also function as sources for improvisational resourcefulness (Levental & Rerup, 2006).

Organizational routines are a useful unit of analysis to understand how deviating can be normal without endangering, but rather sustaining the continuity of an operation (Pentland & Feldman, 2005). Organizational routines conceptually represent the common sense-understanding of organizational continuity through repetition and habit, while also acknowledging that every single performance of a routine varies with respect to the one before. Furthermore, complex routine dynamics can be found in the shifting ways in which organizations standardize their routines, attempt to create conformity in routine performance, or leave more to professional discretion. This insight could be translated as designing additional, flexible procedures to handle non-normal situations. Alternatively, organizations could acknowledge the flexibility of existing procedures and train operators to motivate deviations and exercise professional discretion.

One application of the organizational routines perspective is to design organizational routines with its inherent flexibility in mind (Grote et al., 2009). A good example is a recent study to create flexible procedures for flight crews. Modern flight crews operate in an environment with multiple detailed procedures to cover abnormal events. Complex and unexpected events without a clear procedure or systems solution are rare, and may thus present a challenge to the crew in knowing how to assess the situation and decide on a course of action. In a recent simulator study of flight crew's ability to respond to unexpected events, a procedure was developed that would assist crews in responding to events with situations where no single procedure was applicable and thus required a certain amount of problem solving and decision making (Field, Rankin, Mohrmann, Boland & Woltjer, 2017). The procedure offers a set of high-level strategies on the topics of problem solving, decision making, leadership and communication for responding to an event where there is no single and clear procedure. The procedure further has three focus areas: managing time criticality, managing (un)certainty, and to plan for contingencies and changes.

Another, similar approach, could be to acknowledge that existing procedures are to some degree flexible. Training then implies offering a range of high-level techniques—many of which are already being taught—to enact procedures in improvisational action trajectories. In aviation, pilots for example learn that the immediate response to a sudden disturbance is 'aviate, navigate, communicate'. These techniques help diagnose and structure an ambiguous situation and are often informally included in training, relying more on pilots' personal career experience. In an interview study (Passenier, de Bakker, Groenewegen, Wolbers & Catz, 2016), for example, a Dutch pilot explained what 'pro-active improvisation' by referring to a risk management technique used in German airlines. Improvisational action trajectories can refer to a broad range of situations and include any alteration of normal, routine, or prescribed techniques to conduct the operation, such as by creative reordering of steps, mixing procedures or techniques, or cropping checklists to suit the circumstances. Training operators to handle the array of robust to flexible procedures, prompts the following questions:

- How can high level procedures or techniques be defined?
- What kind of skills do operators need to apply procedures in ambiguous settings?
- How can organizations make the most of individual differences of learners?

- How can the organizational (training) culture facilitate flexible uses of procedures?

By investigating these questions, training can begin to tap into the experiential knowledge base of operators and link these with the development of skills that contribute to resilient performance.

2.2 Training general problem skills

The key to success in coping with unexpected events in many industries today still lies with the decision-making, supervisory control, or manual control skills of (teams of) individuals. Still, most current training programs – for example in aviation – mostly focus on pre-defined skills and context-specific scenarios where trainees know what to expect. The focus is on anticipating and mitigating variations, faults and failures at a system level and flight crews have little exposure to truly unexpected events (Advani, Schroeder & Burks, 2010; Casner, Geven, & Williams, 2013). Recent experiments on aerodynamic stall recovery training have shown that pilots confronted with abnormal events in the context of a well-known training scenario quickly recognised and carried out the appropriate responses (Casner et al., 2013). However, when presented with similar events but with different timing and in a different context, they failed to recognise and recall the appropriate response (Casner et al., 2013; Schroeder et al., 2014), implying that responses learned and practiced during current airline training may not be generalizable to more naturalistic settings. Creating such truly naturalistic settings, with realistic surprise, in training programs (and thus *repeatedly*) is impractical, if not impossible (Advani et al, 2010). Possible solutions, such as scenario-based training, require instructors that are highly skilled at deception of their trainees and unacceptably increase required training times and thus costs. Therefore, the skills to deal with the unexpected and to “be prepared to be unprepared” in cockpit operations are today largely left to mature through experience.

With persisting incidents and accidents involving unexpected events, aviation authorities, airlines, and pilots themselves have all questioned the effectiveness of this current approach to training for the unexpected. For example, a recent interview study has investigated pilots’ experiences with the re-framing process of coping with unexpected events in the cockpit (Rankin et al., 2016; Rankin, Woltjer, Field, & Woods, 2013). The results show difficulties that pilots have in re-framing following a surprising event, including the identification of subtle cues and managing uncertainties regarding automated systems, coping with multiple goals, tasks, narrow time frames, and identifying an appropriate action. The findings of the study suggest that the underlying training issue to cope with surprise is to understand and support the complex socio-cognitive process (Chow, Christoffersen & Woods, 2000) by which pilot’s frame and re-frame data based on their knowledge and available cues or triggers. These findings are further supported in recent study of common causes on automation surprises (de Boer & Dekker, 2017), demonstrating that the most common reason for surprise is an incorrect understanding for the automated systems. In this view, training should focus on the process by which pilots search for data, identify relevant cues, manage uncertainties, make trade-offs, re-frame, and decide on a course of action. This can be compared to current training programs focused on e.g., specific competencies or specific known problems (Klein, Woods, Klein, & Perry, 2016).

Two recent studies on role-improvisation in teams responding to a crisis situation (Lundberg & Rankin, 2014; Rankin, Dahlbäck, & Lundberg, 2013) further underline the necessity for direct attention to surprise, sensemaking, and (re-)framing in training. Crisis situations are often characterised by ambiguous and unplanned for events and the need for improvised roles can therefore be of great importance to successfully cope with a crisis. A study of crisis responders in operations following the Tsunami in 2004 and the Lebanon crisis in 2006 (Lundberg & Rankin, 2014) showed that role-improvisation is an important part of crisis response work to cope with dynamic and unpredictable environments. The participants in the study mentioned positive and negative aspects of using role flexibility such as: completing tasks despite a lack of resources, positive team-building effect and increased endurance of the team, decreased efficiency and increased workload due to unclear organisational structure and ineffective planning, increased burden for all team members as people in new roles require more guidance and, people may get stuck in temporary roles. A follow-up study with crisis responders was designed to create a dynamic and non-routine situation in which the participants would be forced to take on roles outside their field of competence (Rankin, Dahlbäck, & Lundberg, 2013). The results showed that improvising in the face of unexpected events is not an ad-hoc activity, but requires training and a strong organisation.

Thus, the importance of exposing trainees to sufficiently surprising, varied and naturalistic training scenarios, to ensure activation of the needed skills during training for a range of potential scenarios, is evident. However, the main challenge lies in how to achieve this without unacceptably increasing training times and costs.

Especially since most critical unexpected scenarios are thankfully rare in occurrence, increasing the duration and cost of training is simply not acceptable. In short, what is needed to ensure resilience at the individual human level, is time-efficient training that teaches broadly applicable − generalizable (Healy & Bourne, 2012) – skills that can be proven to transfer from a (limited) training program to untrained scenarios in the real world, which in our view requires addressing the following issues:

- How much variation and truly unexpected scenarios need to be incorporated in a training program to ensure sufficient resilience and an ability to cope with a sufficiently wide range of potential scenarios?
- How could training programs be re-defined to best facilitate training for unexpected scenarios, and with realistic surprise?
- How can advanced training techniques, such as "augmented (reality) training", help reduce training times, keep costs down, and provide trainees with more broadly applicable skills? Augmented training uses virtual training environments to actively emphasize critical task constraints and accelerate the development of an awareness of what information should guide problem solving. Especially in initial (*ab initio*) training (Healy & Bourne, 2012), augmented training has proven potential to reduce training times and instil generalizable skills that transfer to reality and scenarios different from those used for training (Healy & Bourne, 2012; Ravesteijn, Borst, Pool, van Paassen & Mulder, in prep).
- How can the effectiveness of updated training practices for increasing resilience at the system level be quantified and proven?

In our view, the answers to these questions will increase our understanding of how to actively train for the generalizable recognition, decision, and control skills that will increase resilience at the individual human level. Thereby, these answers will provide the insight needed to make structural improvements to current training programs and ensure trainees are better "prepared to be unprepared".

2.3 Develop training programs based on knowledge of "work-as-done"

Coping with complexity and uncertainty in socio-technical systems requires people to continuously adapt, "fill in the gaps" and find alternative solutions to complete tasks. Although informally recognised by many, the abilities to adapt are not well understood in organisations, leaving a gap of knowledge between "work-as-imagined" and "work-as-done" (Hollnagel, 2014). Knowledge about what enables and disables abilities to successfully adapt to unexpected events is rarely addressed in e.g., accident and incident investigations today, providing a potentially skewed baseline for interpreting actions leading to unsuccessful outcomes. This may further affect assumptions about what is required in terms of training. For example, in a study of crisis response teams (Lundberg & Rankin, 2014; Rankin, Dahlbäck & Lundberg, 2013) the fine balance between situations with successful and less successful outcome are demonstrated, showing how minor details may greatly affect the overall result. This result underlines the argument that successes and failures are closely related (Hollnagel, 2014), and problems that may occur if situations are analysed in hindsight, where the aim is to identify causes of a known outcome. By studying the complexity of everyday events "work-as-done" can inform training design by identifying the cognitive demands of operators in today's complex systems.

Computational social simulation studies based on formal models is a way to investigate "work-as-done" in the context of various operations. Existing formal and computational models of operations in critical infrastructures, particularly in transport and logistics, are predominantly based on the operations research (OR) modelling paradigm (Jensen & Bard, 2003). One of the central challenges in OR-based models and approaches is related to calculating global optima and equilibria states of simplified mathematical representations of operations. Such representations are often based on formal procedures and have limited flexibility. It has been shown that applying such an approach to complex sociotechnical systems, which are in fact complex dynamic co-evolving systems, has a number of issues (Helbing, 2012; Mitleton-Kelly, 2013). Such systems are characterized by the behavior far from equilibria, highly non-linear dynamics, and continuous co-adaptation of different system actors and components. Classical optimization approaches are not necessarily appropriate to such systems, as their state space and, consequently, equilibria and optima are constantly changing.

To address this challenge, more dynamic, adaptive, and agile approaches are needed. As was identified previously (see e.g., Ouyang, 2014, and Mitleton-Kelly, 2013), agent-based modelling and simulation (ABMS) and complex networks paradigms appear to be the most promising to address issues of formal and computational modelling and analysis of complex co-evolving sociotechnical systems. In particular, in previous studies using ABMS it was explored how safety culture emerges from everyday operations, organizational processes, and structures at an air navigation service provider (Sharpanskykh and Stroeve, 2011) and at an aircraft maintenance organization (Passenier, Mols, Bím & Sharpanskykh, 2016). Safety culture was characterized by a set of indicators, dynamic patterns, and trends that emerged from local dynamics and diverse interaction properties of organizational actors and the environment.

A particular focus of the ABMS paradigm is on studying emergence. Often the challenge of understanding emergence takes the form of establishing relations between the local dynamics of agents and global or systemic emergent phenomena. Another example in which this challenge was considered is a recent study of compliance with safety regulations at an airline ground service organization (Sharpanskykh and Haest, 2016). In this study a formal agent-based model was proposed, which explored the role of motivation for (lack of) compliance at the individual, team, and organizational levels. The model was able to reproduce and predict behavioural patterns related to compliance of the platform employees emerging at the organization under study.

One of the central questions that arise in the process of agent-based modelling of sociotechnical systems is how to use and incorporate rich conceptual theoretical basis from behavioral sciences in formal models of multiagent systems. Many of evidences and theories from behavioral sciences are fragmented, informal, high level and sensitive to a specific context. Furthermore, theories may be based on conflicting or inconsistent principles or philosophical viewpoints. This makes integration of different theories in rich sociotechnical system models problematic. We argue that a new generation of modelling techniques to better understand "work-as-done" needs to be developed, taking into account the following issues:

- how could both quantitative and qualitative knowledge of different levels of abstraction from behavioral sciences be used in agent-based modelling and analysis?
- How could ABMS analysis of complex, subtle variation in performance of routine (i.e. repetitive) action patterns distinguish which 'weak signals' (Weick & Sutcliffe, 2011) indicate failure and require active problem solving, and which ones can be ignored?
- How do organizational training routines—e.g. recurrent training cycles—interact with operational routines, such as flying from A to B, responding to an emergency, etc.?

Answering these questions could further our understanding as well as provide more adequate formal models for resilience than currently available. ABMS-based research strategy could also prove to offer good synergy with evidence-based training developments such as in the aviation industry. The ABMS methodology could help articulate a convincing, formal basis for advanced resilience training policies that deviate from the existing training regulations or conventions that might lag behind on these advanced insights.

3 RESEARCH AGENDA

In this paper, we addressed training needs of operators working under high pressure in dynamic and unpredictable settings, where formal training could prepare operators better for resilient performance. We therefore raised questions about what training for resilience would look like. In the table below, we summarize this research agenda organized by questions about operational variability, the skills needed to handle variability, and methodological development needed to assert these training needs.

Table 1. *Research agenda to train for resilience*

Procedural flexibility	Widely applicable skills	Building on work-as-done
How can operators be guided to deviate from procedures?	How much variability is needed in training secnarios?	How do training routines interact with operational routines?
What kind of skills do operators need to improvise well?	What skills could be generalisable across real work settings?	Which emergent dynamics require problem solving?
How can high-level procedures or techniques be defined?	How can generalised skill training effects be proven?	How can ABMS research use behavioural theories relevant to operator resilience?

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