The Adaptive Organisation: Progress in understanding adaptation in safety management

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SUMMARY

In the last 20 years, new theories, ideas, and disciplines of safety have emerged to address the evolving nature of safety management in complex sociotechnical systems. The literature increasingly recognises the importance of adaptation; whereby the people in the system use their skills and experiences to make continuous, real-time demand compensations to ensure safety through trade-offs, self-organisation, informal practices and strategies. This paper presents the results of an investigation into the nature of adaptation and the emerging understanding of the role it plays with reference to the safety of UK air traffic control.

KEYWORDS

Safety Management, Adaptation, Air Traffic Control

Introduction

A feature of complex sociotechnical systems, such as air traffic control and many other domains that manage safety goals, is the highly influential role of human operators in creating safety in such systems. A key idea in recent developments in safety science is the study of this influence and how humans act in ways to dampen the variability inherent in complex systems. These actions prevent and contain emergent effects that can cascade in unpredictable ways to potentially degrade system performance and safety. This capability: to appreciate the context of the system and the changing demands placed upon it in day-to-day operations and to respond with proportionate and appropriate actions that maintain system performance, is termed adaptation and the features that promote it within the system as adaptive capacity. The term adaptation captures a multitude of ideas including the ability to self-organise, reconcile conflicting demands, re-evaluate priorities and innovate to cope with a changing context, the tacit acceptance of broken rules and stretched boundaries to achieve safe performance, the continuous, real-time compensations through trade-offs, informal practices and strategies (Foster et al., 2019; Hale & Borys, 2013; Holling, 1973; Reiman et al., 2015). Furthermore, and of particular relevance, is the ubiquity and normality of adaptation that, whilst recognised and possibly tacitly acknowledged, is generally 'hidden in plain sight'. Advances in safety science point towards a different approach to safety management which focusses on successfully harnessing the adaptations present within complex socio-technical systems (Dekker, 2003; Dekker & Pitzer, 2016; Rasmussen, 1997).

This paper provides a high-level review of progress towards understanding adaptation as a source of safety in complex sociotechnical systems. It reports on the results of an ongoing grounded programme of research in this emerging area of human factors (HF) and safety research. The goal is to support safety practitioners in understanding these developments and provide practical guidance on how these ideas can be integrated into the safety management systems of organisations charged

with managing the safety of complex industrial endeavours. This programme has successfully characterised the factors of adaptation, tested these with case studies from UK air traffic control and outlined a framework of HF methods that supports enquiry into adaptation. We also report the results of an ongoing critical appraisal into the nature of predicting adaptation and a potential approach with broad industrial and cross-domain applicability. The following sections review the progress towards each of these goals with reference to case studies from UK air traffic control. Future research directions that build on these findings are then outlined.

Defining Adaptation

In order to avoid a narrow domain focus or limit a review to the language aligned to a single school of thought, a literature review was conducted built on the premise that adaptation may be described using a variety of subtly similar terms. This review (Foster et al., 2019) used an expansive and iterative approach that attempted to build a list of inclusion terms characterising the core premise of adaptation in relation to the safety of complex sociotechnical systems. This compound search query was then used with logical operators and a similar set of iteratively identified exclusion terms in the SCOPUS database to build a core set of papers for review from a variety of industrial domains and theoretical stand-points. A smaller set of highly relevant papers was identified through a detailed title and abstract review. These were then investigated using a grounded theory approach and an open iterative coding technique to identify the core concepts, theories, methods, findings, results and recommendations that emerged from the text (Wolfswinkel et al., 2013).

This review (Foster et al., 2019) identified nine key factors that relate to: the use of experience; the strategies and informal practices of normal work; how knowledge is acquired; the unpredictability of complex systems, emergence and incomplete understanding; trade-offs and compromises; skills needed to adapt; violations and deviations from governance and practice; improvisations and creativity; and the procedures and rules that govern work. These factors appear to describe how adaptation operates and is related to safety in complex sociotechnical systems.

Of further interest from the literature review was the finding that adaptation can be seen at the level of the individual in the improvisations and innovations in context that draw on the skills and previous experiences of the frontline (e.g., Macrae & Draycott, 2016) to the balancing of competing goals and task demands (e.g., Sperandio, 1971); at the level of the team in the breakdown of hierarchies, deference to expertise and sharing of knowledge (e.g., Reinartz, 1993; Ritz et al., 2015) and the coordinated performance and patterns of behaviours in teams (e.g., Crichton, 2005); and at the level of the organisation in the reallocation of resources (e.g., Cook & Rasmussen, 2005) in the discussion of the importance of culture (Reiman et al., 2015) and collective mindfulness (Weick & Putnam, 2006; Weick & Sutcliffe, 2015).

Exploring Adaptation

Human Factors and Ergonomics is founded on the use of structured methods to study systems, teams and individual performance (Salmon et al., 2017; Stanton et al., 2013). Safety practitioners wishing to explore adaptation and the complex interactions and emergent properties that exist between system constructs in complex sociotechnical systems, as defined in the previous section, need appropriate guidance on which methods will support them in this endeavour (Grant et al., 2018; Holman et al., 2020). To address this requirement, the second goal of this research programme, after defining adaptation, was to identify potential methods to help practitioners explore adaptation. The selected approach to survey the breadth of HF methods and identify a likely pool of potential methods was a Delphi survey. Delphi surveys are commonly used in problems where the goal is to "obtain the most reliable consensus of opinion of a group of experts" (Dalkey & Helmer, 1962, p. 1). This used an iterative series of sequentially issued surveys, known as 'rounds', with controlled feedback provided to the participants on the results from previous rounds, that aims

to distil the judgment of experts to gradually form a considered opinion or a consensus (Landeta, 2006; Powell, 2003; Skulmoski et al., 2007). For this survey a Schmidt ranking-type Delphi (Hasson et al., 2000; Schmidt, 1997) was used to develop a group consensus where the participants are asked to propose features of the domain that they believe are important. This list is consolidated and narrowed down through a subsequent round (or rounds). The participants are then asked to rank the consolidated subset of features to achieve a considered opinion in the final round.

A three-round Schmidt ranking Delphi survey of 13 HF and safety experts and practitioners from across industry and academia identified a soft consensus towards a small number of Human Factors methods (Foster et al., 2020a). However, and as hypothesised, no one method was identified as being the first choice for all nine of the adaptation factors, nor was there a consensus method that was applicable across all levels of the organisational hierarchy. Two methods Cognitive Work Analysis (CWA) (Vicente, 1999) and Critical Decision Method (CDM) (Klein et al., 1989) came close to achieving this goal. The survey concluded with a general consensus for: the CWA and CDM methods at the level of the individual (micro level); the use of a toolbox approach based around CWA and CDM supplemented with Systems Theory Accident Modelling and Process (STAMP) (Leveson, 2004), Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012) and Event Analysis of the Systemic Teamwork Framework (EAST) (Stanton et al., 2008) at the level of the team (meso level); and, the use of STAMP and FRAM, again in a toolbox approach, with Hierarchical Task Analysis (HTA) (Annett, 2004), EAST, Human Factors Analysis Classification System (HFACS) (Shappell & Wiegmann, 2000) and Ethnographic analysis at the level of the organisation (macro level).

Explaining Adaptation

The grounded theory approach to the understanding and definition of adaptation provided an initial literature-based exploration of the factors associated with adaptation in complex socio-technical systems. The application of case studies is a common approach in Human Factors research to understand the ability of a theoretical model to adequately represent real-world experiences.

Case Study: 9/11 Oceanic Turnback

To explore the initial validity of the adaptation factors, a case study exploring the implications on UK air traffic control of the closure of US airspace, as a result of the terrorist attacks on New York and Washington on the 11th September 2001, provided initial confidence in the utility of the adaptation factors and their accompanying descriptions. The adaptation factors, and the terms that described them, were shown to be practically applicable to make sense of the gathered data (reports, analysis, interviews) and provide useful insights into the nature of adaptation across the organisational, team and individual layers of the organisational hierarchy. For example, the uncertainty that existed in the operation; the informal strategies to increase the efficiency of checks on aircraft reroutes against the trajectories of other aircraft; the application of skills honed through training, competence assessment and practice; the improvisation and coping strategies across teams; and, how resources were stretched to focus on what was really important.

Case Study: The very Temporary Operating Instruction

The 9/11 case study highlighted examples of positive and constructive adaptations that exist within an organisation, its teams and individuals but which are only revealed when coping with complexity, uncertainty and adversity. However, adaptation exists in everyday work (Perry & Wears, 2012). A second case study (Foster et al., 2020b) explored the circumstances surrounding the unanticipated and maladaptive emergent effects of an apparently simple and minor procedural

change. This is a situation considered normal in most organisations that manage safety risks: the decision-making processes to address extant risks in the presence of uncertainty, complexity, safety culture, safety management processes and personal accountabilities. The addition of the phrase "standard pressure setting" at the end of controller instructions to aircraft climbing through the pressure transition level on low pressure days was expected to act as a reminder to pilots to change barometric pressure setting and avoid a risky phenomenon known as a "level bust" where a collision risk is created as aircraft fail to reach their intended level as expected.

For this case study, the first approach taken was a keyword-based ecological study of the available materials to make sense of the adaptive capacities present in the system and how adaptation was, or was not, considered within the development and introduction of the change. Two perspectives were taken, the individual level and the organisational level since both were involved. The adaptation factors were used to better understand and explain the many different facets of adaptation that were present, supporting safety, but not readily observable. The analysis showed the fundamental role of people in the system as an adaptive capability to cope with varying contextual demands and how they use their requisite variety to apply professional judgement and experience to use adaptive, targeted informal practices to address perceived risk (Ashby, 1956; Carvalho et al., 2009; Kirwan, 2001). The instruction unknowingly impaired these capacities by removing freedom and introducing overly prescriptive formality that had maladaptive effects.

To further develop these ideas and explore and validate the potential combination of the adaptation factors with the greater structure and rigour of HF methods, further explorations of the case study were conducted using the methods described in the Delphi Survey. This analysis applied, in turn, the nine methods identified from the survey (Foster et al., 2022). Each of the methods was found to provide a slightly different perspective on the circumstances of the introduction of the procedural change and the nature of adaptation. In a multi-faceted problem in a complex sociotechnical system it should be expected that multi-method approaches will be required to describe all perspectives. The case study also highlights the need to consider the broader systemic effects when considering interventions to address safety issues in complex sociotechnical systems. A framework for using the HF methods in series or parallel was proposed that supports proportionate use of practitioner experience and resources.

Case Study: COVID-19 Response

The COVID-19 pandemic caused an unprecedented and dramatic decline in air traffic worldwide, leading to a profound disruption in the global aviation industry. A further case study explored the extended COVID-19 incident response of UK ATC from late-2019 through to the autumn of 2021 as an example of macro, organisational adaptation (Foster et al., 2024). This case study applied CDM as the data gathering, analysis and synthesis approach using interviews with senior managers with direct experience of the decision-making to keep UK air traffic operating whilst balancing operational and health and safety risks. This case study used the standard probes for CDM (see for example Stanton et al., 2013) to explain the organisational response to the pandemic; yet, the finer details, the how, the understanding of the adaptive processes that gave rise to the enduring coherence of the organisation and the safety of its services in the face of the unprecedented challenges of the pandemic, was not necessarily articulated through the CDM-derived narrative and probe responses. If the adaptation factors can be considered to form the basis of a deductive theory of adaptation, then when these adaptation factors are applied to an iterative, re-reading of the source material, CDM-derived narrative and reflections on the COVID-19 organisational response, two contrasting, yet mutually balancing, themes emerge: 1) adaptive memory, and 2) adaptive innovation set in a context of complexity and unpredictability. These two ideas better illuminate some of the adaptive processes at work and are instructive in framing a discussion of the role of adaptation in the safety management of complex sociotechnical systems. A further step of

reappraising the analysis of the case study with STAMP, a further method identified by the Delphi and described in the methodology framework, is planned.

Predicting Adaptation

To manage adaptation in safety-related complex sociotechnical systems requires approaches that support a predictive analysis of adaptation, or at least suggest the location of the mechanisms, that underpin the critical features of adaptation and adaptive capacity. Practitioners should work with people at the frontline who understand the work, perceive the signals, have the experience and know the strategies since they will have a key role in helping the practitioner in uncovering adaptation and adaptive capabilities. The goals for a predictive approach should be to present actionable information for design (Leveson, 2020) or normative guidance to inform a change and mitigate a risk.

Based on the practical results to date from the case studies, a CDM-like set of adaptation probes has been postulated that could support or supplement existing industrial hazard identification approaches. This set of probes has been built on a re-review of the original adaptation literature for keywords, terminology and thematic ideas that describe each of the factors. These terms have been collated and iteratively refined to form a set of open and neutrally-worded questions with accompanying keywords for each adaptation factor. It is believed that these probes and keywords could be used at the very earliest stages of a preliminary hazard identification step to situate the participants, extend the scope of discussion to consider possible issues with the change such as from adaptation and to adaptive capacities and inform a future hazard analysis step using whatever approach is in use in the organisation.

This question set is currently being tested with a series of focus groups, workshops and interviews with subject matter experts, controllers, risk assessment experts and practitioners to explore the value of this approach as a complement to NATS existing safety management processes.

Future Directions: Managing Adaptation

A key element to a discussion of adaptation and its role in safety management is the need for and promotion of structure to work whilst also encouraging innovation, exploration and learning. Interesting avenues for this research include the biological, evolutionary motifs inherent in the discussion of adaptation to suggest a safety management model for adaptation and adaptive capacity.

Firstly, research suggests that populations (systems/organisations) can only survive if they ‘test’ sufficiently many, sufficiently novel strategies (Bedau, 1997). The system needs a capacity for adaptive ‘innovation’ because of the context of uncertainty in the system. Innovation is required to come up with new ideas, improvements and generate adaptations at the individual, team and organisational level to, in a biological context, increase survivability (Langton, 1990; Waldrop, 1992). Terms such as the vibrancy of the organisation, the culture of ideas, a learning culture and requisite imagination all encompass this idea of creativity in organisations. Similarly, systems need a way to test these innovative strategies in a safe way. This testing implies a trade-off – the system could use its energies to maintain the status quo, or it could expend some energy in testing whether the innovation confers an advantage. In Rasmussen terms, does the innovation move the operating point away from a boundary? Does the innovation improve the fitness of the system/organisation? Similarly, violations of the rules reflect another form of testing: a true break from prior experience and existing rulesets to generate large leaps forward. Yet how is this learning to be achieved in realistic settings in safety-critical domains?

Secondly, populations (systems/organisations) can only adapt to a given environment or context if the strategies that prove beneficial can persist. The population/organism/system/organisation needs a capacity for adaptive memory. The experiences of the individual, the memory to understand the cues and signals and on-the-job learning are relevant to this discussion alongside, a culture of passing on acquired knowledge to colleagues and their ability to be receptive to this information. The analogy continues in the ability of the organisation to encode supportive adaptations in the strategies and informal practices of current work and the rules and procedures of work to form part of the organisational memory (the 'what works and the why it works'). Successful adaptation in an organisational context would appear to require that these competing demands (adaptive innovation and adaptive memory, flexibility and certainty) are suitably balanced. Too much innovation could result in unconstrained and random strategies with little coherence in the conduct of work. Similarly, too little innovation might imply an organisation getting stuck in arbitrary strategies, locally optimised minima with little resilient capability for the unexpected. These ideas suggest future directions for research into the management of adaptation in highly regulated and safety-related industries.

Summary

This paper has summarised a programme of work to support safety practitioners in understanding, explaining, exploring, predicting and managing adaptation and has highlighted future directions on the safety management principles that could be adopted by organisations to identify, harness, protect and develop the adaptive capabilities that keep complex sociotechnical systems safe.

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