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Drifting into failure: theorising the dynamics of disaster incubation

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Ergonomic theory holds that accidents are preceded by periods of gradually increasing (but essentially unrecognised) risk, known originally in man-made disaster theory as the incubation period. This paper discusses the theorising of the dynamics of such accident incubation. It considers theoretical contributions – ranging from high-reliability to control theory to resilience engineering – for their ability to illuminate the driving forces behind a gradual shift in norms and erosion of safety margins, and for their ability to effectively track and represent such changes over time.

Keywords: accidents; incubation; disasters; drift into failure; resilience; control theory

Introduction

It is widely acknowledged in ergonomics science that accidents and disasters do not come out of the blue but are preceded by sometimes lengthy periods of gradually increasing (yet unrecognised) risk. Barry Turner referred to this as the incubation period (Turner 1978). During this period, it is believed that 'latent errors' and events accumulate which are culturally taken for granted or go unnoticed because of a collective failure of organisational intelligence (Pidgeon and O'Leary 2000). As such, the accumulation of these events can produce a gradual drift towards failure (Dekker 2011; Woods 2003). Intervening in, and preventing incubation has become a practical and theoretical preoccupation, for instance, driving work on safety cultures (Antonsen 2009; Guldenmund 2000), high-reliability organisations (LaPorte and Consolini 1991; Rochlin 1999; Rochlin, LaPorte, and Roberts 1987) and risk control and management (Hale, Guldenmund, and Goossens 2006; Rosness et al. 2004). The dynamics of disaster refer, for the purposes of this theoretical consideration, primarily to changes in organisational norms related to safety over time: changes in what is considered acceptable or even noticed as unacceptable (Vaughan 1996). In this paper, we consider contributions to theorising the dynamics of disaster incubation. In the literature, these dynamics have been linked to an erosion of safety constraints (Leveson 2011), to complexity and intransparency of bureaucratic organisations (Vaughan 1999), to limits on rationality and learning, and to pre-rational, unacknowledged pressures of production (Vaughan 2005) and to the inability of organisations to recover from disruptions (i.e. lack of resilience) (Hollnagel, Nemeth, and Dekker 2008).

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The incubation period

In 1966, a portion of a coal mine tip (unusable material) near Aberfan, South Wales, slid down into the village and engulfed its school killing144 people, including 116 children (Turner 1978). Investigating events leading up to the disaster, Barry Turner found that this period was characterised by events that went unnoticed or were disregarded because they were at odds with taken-for-granted beliefs about hazards and norms for their avoidance. Turner considered the managerial and administrative processes to be a promising target for understanding this discrepancy between a build-up of risk and the sustained belief that it is under control. For Turner, the space that gradually opened up between beliefs and growing risk was filled with human agency – perceptions, assessments, decisions, actions (Turner and Pidgeon 1997), and

> . . . rarely develops instantaneously. Instead, there is an accumulation over a period of time of a number of events which are at odds with the picture of the world and its hazards represented by existing norms and beliefs. Within this "incubation period" a chain of discrepant events, or several chains of discrepant events, develop and accumulate unnoticed. (72)

Thus for Turner, accidents were primarily a sociological phenomena. He shifted the focus from engineering and structures to social processes. He also suggested that failure needs to be understood over time, and over people and groups and organisations – many of which were ironically tasked with preventing the disaster in one way or another. Other researchers too, noted the relevance of social and psychological processes ahead of large-scale disasters. In the analysis of these events, not only has the inability to detect drift been considered, but also the surprise that is produced when boundaries or margins are exceeded. These shifts from within the systems operational space may significantly alter participants' understandings of their world and in some cases even produce movement beyond the system's safe boundary. It is believed that this is where system-wide failure occurs. For example, Stech applied this idea to the inability of Israeli intelligence to foresee the Yom Kippur war, even though all necessary data were available across the intelligence apparatus (Stech 1979). In his reflections on that war, Lanir used the term 'fundamental surprise' to capture the sudden revelation of the incompatibility of one's perception of the world (Lanir 1986).

There is, of course, a theoretical and practical problem with the analogy of drift from previous norms. Hindsight makes it possible to identify a growing gap and attribute it, as Turner did, to erroneous assumptions and misunderstandings, rigidities of human belief and perception, disregard of complaints or warning signals from outsiders and a reluctance to imagine worst outcomes. Additionally, Turner identified decoy phenomena, which describes distractions that consume resources away from the truly major hazards (Turner 1978). For example, at Aberfan, residents mistakenly believed that the danger from tips was associated with very fine waste, not coarse material. So 'despite the best intentions of all involved, the objective of safely operating technological systems could be subverted by some very familiar and "normal" processes of organizational life' (Pidgeon and O'Leary 2000, 16). Such 'subversion' occurs through usual organisational phenomena such as information not being fully appreciated, correctly assembled, or when it conflicts with prior understandings of risk. Turner noted that people were prone to discount, neglect or not take into discussion relevant information. Hopkins has called this poor decision-making or a failure to learn (Hopkins 2010). This reductionist focus on which parts or people went wrong has been sustained in, for example, high-reliability theory (Weick and Sutcliffe 2007):

> ...failure means that there was a lapse in detection. Someone somewhere didn't anticipate what and how things could go wrong. Something was not caught as soon as it could have been caught. (93)

It remains a challenge to illuminate why, to key decision makers, such things seemed right or unremarkable at the time. It is hard to explain deterioration, or the gradual progression in how wrong these assessments were – yet that is central to understanding incubation, or a drift towards an accident (Dekker 2011; Woods 2006a; Woods et al. 2010). One such attempt is of course the so-called Swiss Cheese model (Reason 2008), and has, like Turner, explained how things can go wrong on the basis of upstream deficiencies like inadequate supervision and ineffective leadership. It has confirmed the popular, if reductionist notion that things *go* wrong because things *are* wrong (deeper inside of the organisation or higher up). It does not really help illuminate processes of gradual formation and degradation (Dekker 2005), but rather shows the resulting image of an imperfect organisational form (layers of defence with holes in them). It cannot directly support thinking of organisational risk in dynamic, adaptive terms (Reason, Hollnagel, and Pariès 2006).

Continued belief in safe operations

Research on so-called high-reliability organisations (HROs) stretches across decades and diverse high-hazard complex domains (aviation, nuclear power, utility grid management, Navy). It has tried to dig deeper into organisations' beliefs in their own infallibility. The HRO paradigm suggests that accidents are incubated when the organisation's belief in continued safe operations is left to grow and solidify (Rochlin 1999). High-reliability theory has concluded (and counselled) that the past is not a good basis for a belief in future safety, and tapping into only a limited number of channels of information will render this belief narrow and unchallenged (LaPorte and Consolini 1991; Weick 1987). This can happen because of overconfidence in past results, suppressing of minority viewpoints and the giving of priority to acute performance expectations or production pressures (Dekker and Woods 2009). To guard against these drift-inducing impulses, HRO theorists suggest we stay curious, open-minded, complexly sensitised, inviting of doubt and ambivalent toward the past (Weick 1993). Thus practitioners in high-reliability organisations are described as sceptical, wary and suspicious of quiet periods. Success, after all, or the absence of symptoms of danger (Starbuck and Milliken 1988):

> ...breeds confidence and fantasy. When an organization succeeds, its managers usually attribute success to themselves or at least to their organization, rather than to luck. The organization's members grow more confident of their own abilities, of their manager's skills, and of their organization's existing programs and procedures. They trust the procedures to keep them apprised of developing problems, in the belief that these procedures focus on the most important events and ignore the least significant ones. (329–330)

Weick and colleagues echoed this two decades later (Weick and Sutcliffe 2007):

> Success narrows perceptions, changes attitudes, reinforces a single way of doing business, breeds overconfidence in the adequacy of current practices, and reduces the acceptance of opposing points of view. (52)

High-reliability theory suggests that it is this complexity of possible interpretations of events that allows organisations to anticipate and detect what might go wrong. An important part is understanding the gap is between how work is imagined and how work is done in practice (Dekker 2003), which requires leadership involvement. It includes managerial and supervisory visibility at the sharp end and interest in what goes on there beyond whether it complies with pre-understood notions of protocol and procedure (Dahl and Olsen 2013). Of course, even deference to expertise, a diversity of viewpoints (including dissenting ones) and a sensitivity to operations does not protect a system from failure (Hayes 2012). Despite an organisation's best intentions, a 'warning of an incomprehensible and unimaginable event cannot be seen, because it cannot be believed' (Perrow 1984, 23). This constrains people's rationality in decision-making settings: 'seeing what one believes and not seeing that for which one has no beliefs are central to sensemaking. Warnings of the unbelievable go unheeded' (Weick 1995, 87). To some extent, both high reliability and normal accidents theory are pessimistic about people's ability to pick up on the shifting of norms and erosion of margins – a conclusion Diane Vaughan also drew after her extensive analysis of the Space Shuttle Challenger launch decision (Vaughan 1996).

Goal interactions and normalisation of deviance

A key ingredient suspected in any incubation period is the organisation's preoccupation with production and efficiency (Turner and Pidgeon 1997; Vaughan 1996; Woods 2003). Pressures to achieve production goals can be felt acutely, and the effect of operational or managerial decisions on the ability to achieve them can often be measured directly. But there is a feedback imbalance: The extent to which these decisions create pressure on safety margins (while obscuring chronic safety concerns) is not typically easy to see or quantify (Woods 2006b). Vaughan (1996) has traced in detail how pressures of production find their way into local decision settings and exercise an invisible, powerful influence on what practitioners see as rational at the time. Sociology refers to this as the *macro–micro connection* – which links macro-level forces operating on the entire organisation, and the micro-level cognitions and decisions of individual people within. However, this link is far from straightforward, and cannot just provide a roadmap or action list in any prescriptivist, managerial sense. A suggested starting point is to trace the organisation's diversity of goals and how they might conflict (Dörner 1989; Vaughan 1999; Woods et al. 2010), creating basic incompatibilities in what its members need to achieve. As Dörner observed (Dörner 1989), 'Contradictory goals are the rule, not the exception, in complex situations' (65). Some organisations pass goal conflicts on to individual practitioners quite openly, but many are never made explicit (Dekker 2005); left to emerge from multiple irreconcilable expectations from different levels and sources or from both subtle and tacit pressures and from management or customer reactions to past trade-offs (Woods et al. 2010).

Incompatible goals emerge from the organisation and its interaction with its environment. The managing of these conflicts is typically transferred to local operating units (the sharp-end), such as control rooms, patient wards, airline cockpits. The conflicts are negotiated and resolved in the form of countless daily decisions and trade-offs. These are decisions and trade-offs made by individual operators or crews vis-à-vis operational demands: external pressure becomes internalised: the macro becomes micro where global tension between efficiency and safety seeps into local decisions and trade-offs by individual people or groups – typically into what they see as normal, professional action (Dekker 2011; Woods and Cook 2002). When success is achieved, this either stays unnoticed, or practitioners might be celebrated and rewarded. When 'failure' is the result, then these same assumptions and statements are then compared to the implicit or explicit guidance and any gaps are offered as a causal explanation for system collapse.

Some might consider these trade-offs between production and protection to be amoral calculations by managers, engineers or operators (Goldman and Lewis 2009; Hopkins 2010; Woolfson and Beck 2004), but cost and efficiency are taken-for-granted goals in most professions committed to problem-solving under constraints (Petroski 1985; Wynne 1988). ‘Satisficing’ irreconcilable constraints and demands (which can mean doing more with less) can be part of a professional culture, co-determining what organisation members will see as rational. Vaughan, again, tried to develop a more nuanced and socially patterned vision of the incubation period (Vaughan 1996). The ‘normalization of deviance’ describes a process whereby a group’s construction of risk can persist even in the face of continued (and worsening) signals of potential danger. This can go on until something goes wrong, which (as Turner would have predicted) reveals the gap between the presence of risk and how it was believed to be under control (cf. Starbuck and Milliken 1988). Small departures from an earlier established norm are often not worth remarking or reporting on. Such incrementalism contributes to normalisation (Dekker 2011). It allows normalisation and rationalises it (Starbuck and Milliken 1988):

> Experience generates information that enables people to fine-tune their work: fine-tuning compensates for discovered problems and dangers, removes redundancy, eliminates unnecessary expense, and expands capacities. Experience often enables people to operate a sociotechnical system for much lower cost or to obtain much greater output than the initial design assumed. (333)

Actions that are interpreted as ‘bad decisions’ after an adverse event (like using unfamiliar or non-standard equipment) are, at the same time, actions that seemed reasonable – or people would not have taken them (Dekker 2002; Vicente 1999). This literature does not see wrongdoing, but rather tries to understand how people can see their actions as being right. Success can entail risk, of course: things almost always go right, repeatedly (Weick, Sutcliffe, and Obstfeld 1999). As alluded to earlier, success, or the absence of symptoms of danger, can help engender confidence in future results (Clarke and Perrow 1996; Starbuck and Milliken 1988). Contributing to this is what Vaughan called ‘structural secrecy’, the mix of bureaucracy and specialised knowledge that leads to people in one department or division lacking the expertise to understand the implications of the work in another (or even the work of their own specialists). Formalised information exchanges (e.g. meetings, PowerPoint presentations, memos) can worsen the problem: such efforts to communicate can ironically result in people knowing less (Vaughan 1996).

Influencing the decision-making environment

One site suggested for intervention is the information that people in an organisation use for decision making (Rasmussen and Svedung 2000). Studying and influencing information environments, how they are created, sustained and rationalised, and in turn how they help support and rationalise complex and risky decisions, can help illuminate the small incremental steps that mark an incubation period. This, in a sense, is where risk is ‘constructed’. Managing the information environment, of course, cannot be done through a-priori decisions about what is important: that simply displaces the problem. Rather, high-reliability theorists and others (Janis 1982) recommend decision makers to remain what Weick calls ‘complexly sensitized’: to situate decision making in an information environment full of inputs from different angles – and from below (Weick 1993). They encourage decision makers to defer to expertise and take minority opinion seriously

(Weick and Sutcliffe 2007). Yet potentially meaningful signals can remain weak or few in information-intense environments. And as the Columbia Accident Investigation Board reported, this can once again encourage a tendency to oversimplify, categorise, bulletise and thus exclude (CAIB 2003).

In addition, even with attention to information environments, decisions inside of them are pre-rationally influenced by forces such as production pressures, budget priorities and schedules, contractor workloads, employee qualifications and workforce levels. This co-determines and constrains what is possible and rational for decision makers at the time. Although the intention was, for instance, that NASA's flight safety evaluations be shielded from external pressures (essentially turning it into a closed system, as per the high-reliability recommendation), these pressures nonetheless affected data collection, trend analysis and anomaly reporting (Feldman 2004; Vaughan 1996). Indeed, the idea of a closed system is probably illusory: the boundaries between the world and any system are not only arbitrary, but the outside is 'folded into' the system of interest at many points of individual contact (Cilliers 1998; Dekker, Cilliers, and Hofmeyr 2011).

Control theory and resilience engineering

A family of ideas that approaches the incubation period from another angle is control theory. It traces adverse events from interactions among system components (Dekker et al. 2011; Leveson 2011). Safety or risk management is viewed as a control problem, and adverse events occur when failures, disruptions or interactions between components are not adequately managed; when safety constraints that should have applied to the design and operation of the technology have loosened, or perhaps become badly monitored, managed or controlled (Leveson 2002). While there is a (retrospective) normativism in this (e.g. 'adequate', or 'should have applied'), control theory tries to capture these normally imperfect processes, which involve people, societal and organisational structures, engineering activities, as well as physical parts (Green 2003). According to control theory, the operation of hazardous processes means maintaining many interrelated components in dynamic equilibrium (Hale et al. 2006). This means that control inputs, even if small, are continually necessary for the system to remain within certain boundaries and stay safe (Hollnagel 2006). This is accomplished through feedback loops of information and control. Adverse events are not the result of an initiating event or a root cause that triggers a linear series of events. Instead, they emerge from (normal) interactions between many system components (Leveson et al. 2003). One common reason for an eventual loss of control is that feedback loops and control inputs grow at odds with the problem or processes to be controlled. Concern with control processes (how they evolve, adapt and erode) should be at the heart of control theory as applied to organisational safety. The potential for failure builds, for example, when deviations from the system's original design assumptions become rationalised and accepted, nudging a system's operations closer to its boundaries (Rasmussen 1997). In control-theoretic terms, degradation of the safety-control structure over time can be due to asynchronous evolution, where one part of a system changes or deteriorates without the related necessary changes in other parts (Leveson 2011; Snook 2000). Changes to sub-systems (even if well-planned and executed) can have unpredicted effects on other parts of the system. Or, as Snook has shown in the case of a friendly fire incident in a complex foreign military operation, changes and the loosening of constraints that happen over time in a number of sub-systems can go unnoticed when the total system is loosely coupled. During sudden times (stochastic 'fits') when such coupling tightens, however, the mismatches show up and have consequences. How the sub-systems have grown at odds with each other becomes visible then, sometimes with catastrophic results (Snook 2000). The more complex a system (and, accordingly, the more complex its control structure), the more difficult it can become to predict the reverberations of changes throughout the rest of the system. Small changes somewhere in the system, or small variations in the initial state of a process, can lead to large consequences elsewhere (Dekker 2011). Control theory accepts that a system is more than the sum of its constituent elements (i.e. emergence): an organisation is seen as a set of constantly changing, adaptive processes or sub-systems focused on achieving their (and the overall organisation's) multiple goals while adapting around its multiple constraints (Leveson 2011). The commonly applied approach of making and enforcing rules is not an effective strategy for controlling either system or individual behaviour against the background of such complexity. Instead, this can be more effectively achieved by trying to make the boundaries of system performance explicit (in the information environment of the decision maker), and by helping people develop skills at coping with processes at those boundaries (Rasmussen 1997). Another strategy proposed by Rasmussen entails increasing the margin from normal operation to the safety boundary. This can be done (if all things are equal economically, of course, which they never are) by moving the safety boundary further out, or by moving operations further inward, away from a fixed safety boundary. In both cases, normal operations are moved further from the safety boundary, which offers greater margin of manoeuvrability. This, however, is only partially effective due to risk homeostasis or the tendency for a system to gravitate back to a certain level of risk acceptance, even after interventions to make it safer. In other words, if the boundary of safe operations is moved further away, then normal operations will likely follow not long after – under pressure, as they always are, from the normally and expected rationalised objectives of efficiency and less effort.

Resilience engineering

Systems are continually moving inside their safety envelopes between the various boundaries of safe operation. In resilience engineering, this dynamic process is considered normal and indicative of a performing system. It takes this premise as a source of organisational strength rather than weakness (Hollnagel et al. 2008; Hollnagel, Nemeth, and Dekker 2009). However, resilience in organisations is not only specifically about this dynamic normative process; it is more concerned about system-wide performance during times of non-normal states. That is, how does a system respond to challenges beyond this pre-designed ability (e.g. unanticipated perturbations)? Essentially, organisational resilience is about finding the political, practical and operational means to invest in safety even under pressures of scarcity and competition, because that may be when such investments are needed most. Organisational resilience is seen not as a property, but as a capability: A capability to recognise the boundaries of safe operations, and although abnormal operations may stress feedback mechanisms possibly even causing a loss of control, the resilient system will have the capability to steer back from them in a controlled manner before a system-wide collapse may occur. Resilience engineering also suggests that systems should have the capability to detect and recognise the phases of operation when the margins are skirted or crossed. Consequently, it tries to better understand how an organisation can monitor and keep track of its own adaptations (and how these bound the rationality of decision makers) to pressures of scarcity and competition, while dealing with imperfect knowledge and unruly technology.

How can an organisation become aware, and remain aware, of its models of risk and danger? Adaptive systems typically break down by one or all of the following mechanisms: (1) the exhausting of adaptive capabilities as an event continues to unfold (decompensation), (2) local rational decisions are made and while being locally adaptive are maladaptive on a global or larger scale (working at cross-purposes) or (3) despite the world changing around the system, previously successful strategies are continually employed because they have always been successful in the past (being stuck in outdated behaviours) (Hollnagel, Woods, and Leveson 2006). For resilience engineering, preventing the incubation of an accident requires a different kind of organisational monitoring and learning. One where we focus on higher order variables, adding a new level of intelligence, adopting a new language and new indicators (rather than measures) of resilience (Woods 2006a). In effort to be responsive to a system's proclivity towards failure, resilience engineering uses numerous indicators in a proactive fashion to probe a system's adaptive capacity before system-wide collapse results in disaster. By specifically examining system properties such as buffering capacity, flexibility, margin and tolerance, resilience engineers are able to better assess and design systems that can, despite the challenges offered, be more adaptive in a manner that is predictable and able to be adjusted as required. A significant challenge to the application of these indicators is the common but not frequently discussed issue in organisations: that of mis-calibration (another way of trying to understand Turner's 'cognitive failures' that mark an incubation period). The ability of organisational designers and leaders to realistically understand their abilities and those of their system is a significant hurdle that resilience engineering tries to overcome by the examination of these specific system properties.

Conclusion

Pressures of scarcity and competition, the intransparency and size of complex systems, the patterns of information that surround decision makers, and the incremental nature of their decisions over time, all enter into the incubation period of future accidents. Contributions since Turner's original identification of the period put less emphasis on the breakdowns or malfunctioning of individual components, and instead refocus on how the organisation is not adapting effectively to cope with the complexity of its own structure and operational environment (Woods 2003). The processes that normally help assure safety and generate organisational success (risk assessments, operational trade-offs) can also be responsible for organisational demise: failure incubates non-randomly, opportunistically alongside or on the back of the very structures and processes that are supposed to prevent it (Pidgeon and O'Leary 2000). Incubation happens through normal processes of reconciling differential pressures on an organisation (efficiency, capacity utilisation, safety) against a background of uncertain technology and imperfect knowledge. Incubation is about incremental, or small, seemingly insignificant steps eventually contributing to extraordinary unforeseen events. It is about the transformation of pressures of scarcity and competition into organisational and personal mandates, and about the normalisation of signals of danger so that organisational goals and supposedly normal assessments and decisions become aligned. This will remain the essential paradox for us to grapple with: organisations fail because they are successful. Organisations incubate accidents not because they are doing all kinds of things wrong, but because they are doing most things right. And what they measure, count, record, tabulate and learn, even inside of their own safety management system, regulatory approval, auditing systems or loss prevention systems, might suggest nothing to the contrary.

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