

Understanding the ecological validity of relying practice as a basis for risk identification

T. Anderson

Blue Stream Consulting Ltd, East Lodge, Edenhall, Penrith, Cumbria, UK, CA11 8SX

tom.anderson@bluestreamconsulting.co.uk

+44 (0)1768 881030

J. S. Busby (corresponding author)

Department of Management Science, Lancaster University, Lancaster, UK, LA1 4YX

j.s.busby@lancaster.ac.uk

+44 (0)1524 594447

M. Rouncefield

School of Computing and Communications, Lancaster University, Lancaster, UK, LA1 4YW

m.rouncefield@lancaster.ac.uk

+44 (0)1524 10257

Abstract

Understanding the reliability of hazardous organizations and their protective systems is central to understanding the risk they produce. Work on ‘high reliability organization’ has done much to illuminate the conditions in which social organization becomes reliable in highly demanding conditions. But risk depends just as much on how relying entities do their relying as it does on the reliability of the entities they rely on. Patterns of relying are often opaque in sociotechnical systems, and processes of relying and being relied on are mutually influencing in complex ways, so the relationship between relying and risk may not be at all obvious. This study was an attempt to study

relying as a social practice, in particular analysing how it had ecological validity in a social organization – how practice was responsive to the conditions in which it took place. This involved observational fieldwork and inductive, qualitative analysis on an offshore oil and gas production platform that was nearing the end of its design life and undergoing refurbishment. The analysis produced four main categories of ecological validity: responsiveness to formal organization, responsiveness to situational contingency, responsiveness to information asymmetry and responsiveness to socio-materiality. This ecological validity of relying practice should be a primary focus of risk identification, assessing how relying can become mismatched to reliability in certain ways, both when relying practice is responsive to circumstances and when it is not.

200 character summary

Practices of relying become as important as measures of reliability in determining risk in socio-technical systems: analysing how such practices are adapted should be central to risk identification.

Keywords

High reliability organization, relying practice, risk identification

Acknowledgements

Many thanks are due to the anonymous reviewers of an earlier version of this article for their considerable insights and guidance. Thanks are also due to the organization in which the fieldwork took place for the extensive access they granted for the work.

1 INTRODUCTION

Our main understanding of how complex organizations manage the risk of large-scale physical dangers inherent in their production technologies comes from work on High Reliability Organization (HRO) (La Porte & Consolini, 1991; La Porte, 1996). This has revealed much about how social organization controls both the physical danger and the vulnerabilities of social organization itself. Although the term ‘reliability’ suggests a concentration on outcome measures of performance and function, HROs have distinctive processes as well as reliable outcomes (Weick et al., 1999). And much of what explains these processes is about appropriate and inappropriate ways of relying. But this has broadly gone unrecognized in the literature, which continues to concentrate on reliability: on success in being relied on, not on the nature of relying. The aim of this article is to make relying the focus of analysis, to suggest that being reliable unavoidably means doing a great deal of relying, and to argue that a central element of risk analysis should be analysing the ecological validity of relying practice: how relying responds to the conditions in which it is practised, and how this creates risk when relying somehow becomes mismatched to reliability. The aim is not to somehow eliminate such risk but to ensure that the acceptance of risk incurred in the practice of relying is informed. It is connected to Haimen’s (2009) emphasis on understanding a system’s state in order to then analyze its response to hazard: we need to understand practices of relying in order to understand the risk created by unreliability.

This is consistent with the view that reliability is relational (Busby & Iszatt-White, 2014). It is not so much a specific property of a relied-on object as a quality of the relationship between a relied-on object and a relying subject. It is also motivated by the observation that relying subjects and how they rely matter, not just in defining what is required of the relied-on object but also in shaping the relied-on object’s capacity to be relied on. Notorious examples include the way in which the space shuttle programme was imperilled, and failed, in the *Challenger* and *Columbia* disasters. The programme was relied on by its stakeholders funding it and using it to carry payloads as though it were a routine production operation, capable of predictable performance and cost, when in reality it

was still an experimental undertaking in terms of the technology it used and the conditions in which it was being deployed (Vaughan, 1997; Starbuck & Milliken, 1988). Vaughan (1997) suggested that an important line of analysis of *Challenger* involved expectations in NASA's organizational environment and its administrators' responses to such expectations. Starbuck and Milliken's (1988) analysis pointed to processes of fine tuning in which repeated experience of success led to an increasingly optimistic and less sceptical relying on the programme over time.

Our study is based on fieldwork on an offshore oil and gas production installation. Such installations are revealing settings not only because they involve a large-scale physical hazard of fire, explosion and structural collapse, but also because they typically involve a workforce that is often mostly itinerant or self-employed, and because they require the close collaboration of multiple organizations within a small physical space. In such settings, relying is a complicated and intense process, with hundreds of lives at stake, as evidenced by the 167 people killed on Piper Alpha (Cullen, 1990). Increasingly, these installations are physically aged, commonly reaching the end of their design lives and in a state of partial disrepair. And they are organizationally aged, having been sold on from one firm to another, often more than once, generally from larger, better-resourced to smaller and less well-resourced firms. Their reliability, both in physical and social processes, therefore comes strongly into question, and the ways of relying on them become especially important in determining risk.

The outcome of the fieldwork was a qualitative understanding of how relying practice exhibits ecological validity. We define this as a responsiveness to the conditions in which relying takes place. Practice is ecologically valid to the extent that its nature is consistent with these conditions, that it is adapted to the pressures that these conditions express, and that it can be explained at least partly by how these conditions will influence the way people behave. This is justified further in Section 3, but the principle arises from the idea that social practice generally is based on an 'ecological model' in which behavior is primarily a response to conditions (Gherardi, 2015), and that practical tasks are accomplished when practice follows rules that have 'ecological rationality' (Goldstein & Gigerenzer, 2002): that fit prevailing conditions. The fieldwork indicates that this

ecological validity involves relying practice that is responsive to formal organization, to situational contingency, to information asymmetry, and to socio-materiality – conditions that are explained and illustrated by the findings in Section 4. This analysis provides a basis for a risk identification procedure that searches for ways in which the ecological validity of relying practice becomes pathological, somehow producing a mismatch between relying and reliability: for example, through its unintended consequences, or because it is undermined over time as conditions change. Our intended contribution is therefore to draw attention to the significance of relying practice in the way organizations manage risk, and to show how it can provide an organizing principle for risk analyses that need to deal with the way risk arises from breakdowns in organization. In the remainder of the article, we briefly indicate how this study is located in relation to the high reliability organization literature, describe our methods of fieldwork and analysis, summarize the findings and then discuss their use in risk identification.

2 THE BACKGROUND IN HIGH RELIABILITY ORGANIZATION

It has long been recognised that there are organizations in which reliability is essential to their acceptance in a broader society, given the risks that they create. Nuclear power stations (La Porte & Thomas, 1995; Bourrier, 1996), nuclear-powered aircraft carriers (Rochlin et al., 1987) and nuclear-armed submarines (Bierly & Spender, 1995), for example, all have such a capacity for large scale physical harm that they must emphasize reliability over efficiency and productivity (Roberts, 1990). Offshore installations share crucial characteristics with some of these classical high reliability organizations. They are intrinsically vulnerable to large scale physical hazards such as fire and explosion, as exemplified in the Macondo incident in the Gulf of Mexico (CSB, 2014), and structural failure and capsizing, as seen in the Alexander Kielland disaster that killed 123 (Almar-Naess et al., 1984). They use relatively complex technologies in limited physical spaces, often in tightly coupled processes (Perrow, 1984). They employ workforces whose members must rely on one another in

circumstances that can be experienced as oppressive and unstable (Collinson, 1999). Yet, although there have been catastrophic failures, these have been rare given the scale of the industry and its operations. So we would expect to find these organizations drawing on resources similar to those of HROs. This includes protective redundancy, in both technical and social systems (for example Roberts, 1990; Rochlin et al., 1987; Schulman 1993). It includes an emphasis on learning from simulated rather than concrete experience (Weick, 1987), on the continuous search for improvement (La Porte, 1996), and on the avoidance of blame (La Porte, 1996; Grabowski & Roberts, 1997). It includes behaviors that exhibit ‘heedful inter-relating’ (Weick and Roberts, 1993), ‘collective mindfulness’, (Weick et al., 1999), and ‘extraordinarily dense’ patterns of cooperative behavior (La Porte, 1996). It also includes cultures of reliability (Weick, 1987) and flexible, expert-centred authority structures (Roberts et al., 1994; La Porte & Consolini, 1991; La Porte, 1996; Bigley & Roberts, 2001).

In more recent work, there has been a growing recognition that avoiding failure is just as important in a variety of other settings in which it is less dramatic but equally troubling: in railroad operations (Roth et al., 2006) for instance, in hydroelectric power generation (Milosevic et al., 2016), and notably in healthcare (Blatt et al., 2006; Roberts et al., 2005; Kaplan, 2003; Hales & Chakravorty, 2016). This has led to theorizing about other important qualities of collective activity that these organizations relied on – qualities such as giving voice to relevant observers (Blatt et al., 2006), shared awareness of developing situations (Roth et al., 2006), and more recently the emotional ambivalence that keeps minds open (Vogus et al., 2014). And work on virtual organizations has pointed to the difficulties of achieving high reliability when it is impossible to develop the ‘fabric of trust’ characteristic of HROs in which members are socialized in common processes and engage with each other face to face (Grabowski & Roberts, 2019).

The focus of this work on reliability, however – on explaining how people, organizations and institutions are made reliable – draws attention away from how other people, other organizations and other institutions rely on them. The literature offers important and acute observations on properties like collective mindfulness (Weick et al., 1999), but not on the way others rely on collectively mindful

groups, nor on the way such groups themselves rely on their own collective mindfulness and the capacities that support it. In even the most detailed and nuanced studies – such as LeBaron et al’s (2016) investigation of handoffs in a healthcare organization – the stress is on the processes producing reliability and safety. Yet it seems inevitable that these processes will be conditioned by how people or organizations are relying on them. Handoff routines in hospitals would not look the same if they were relied on simply for speed and not safety, or the safety of staff more than the safety of patients. And these processes must be doing a great deal of relying themselves – relying on human capacities for recall and discrimination, on social institutions that clarify human duties, on technologies that facilitate sensing and communication, and on the capacities of natural language. Bourrier (2011) has argued that HROs rely on ‘invisible webs of teams, decisions, technologies, infrastructures, and yet we know almost nothing about [their] daily operations.’ This is suggesting that HROs rely as much as they are relied on, and that relying is extensive and complex. It is this relying that is the focus of this study, and our research question is: what is the nature of the relying that goes on in hazardous organizations and how can this inform processes of organizational risk identification?

3 METHODS FOR INVESTIGATING RELYING

3.1 Practice as an analytical principle

The basic assumption underlying the study is that relying within social organizations is ultimately about practice: about ways of acting that become normal, practised and habitual (Reckwitz, 2002), growing out of the logic of the task in hand, efficient from the standpoint of those engaged in them, and gaining legitimacy through unremarkable repetition (Snook, 2000: 183). Even when relying is deliberated, calculated and somehow optimised, the ways that people deliberate and calculate are themselves social practices. And even when relying appears to be rule-based or proceduralised the way that people follow rules and procedures are themselves social practices. Our premise is that relying therefore always grounds out in social practice of some kind, and that it is the appropriateness

or inappropriateness of this relying practice to the reliability of what it relies on that ultimately affects risk.

Adopting the practice principle involves a commitment to the idea that actions are most directly explained and identified by the practices in which they arise, not by the goals and intentions of individuals (Schatzki, 1997). And it regards individuals as less central to the analysis, as ‘carrying’ practice (Reckwitz, 2002), and exercising ‘practical rationality’ (Sandberg & Tsoukas, 2011), rather than being the central entities whose dispositions explain what goes on. Although there is no unified theory of practice (Corradi et al., 2010), the aspect of recursiveness is a key quality. People do what they do in an organizational setting because for them it is a continuation of some normality, refined over time in the process of being practised but always referring back to a precedent of some essential kind, whatever the novelty of the circumstances.

3.2 The chosen setting

The fieldwork was carried out on an offshore oil and gas production platform as it was undergoing two major activities: the extensive upgrade for an additional 750 tonne module to be attached to the existing structure, and the annual ‘shutdown’ or ‘turnaround’ in which large scale maintenance took place. Offshore installations – and their relative isolated-ness, compactness and sheer danger – have been illuminating settings for organizational fieldwork in the past (Collinson, 1999). Since the Piper Alpha disaster (Cullen, 1990), which led to major change in the legal and regulatory structure of the offshore hydrocarbons industry, and since Collinson’s (1999) study, conditions have made relying practice even more problematic. Now 85% of individuals on an installation, on average, are contractors, not employees of the organization legally responsible for operating the installation, and some 50% of installations in the region in question are beyond their engineering design lives (HSE, 2014). There is extensive decommissioning activity going on, frequent change of ownership – typically towards newer and smaller owners – and extreme pressure on costs of production as the price of oil fluctuates and reserves become depleted.

The fieldworker and first author had extensive working experience in the industry, in the construction yards in which installations were built, and subsequently in the commissioning of new plant and facilities. He also worked as an inspector, so had first-hand experience not only of offshore construction and operations but also of the processes of degradation and failure to which they are subjected. These qualifications become important for identifying practices that were otherwise ‘hidden, tacit and often linguistically inexpressible’ (Corradi et al., 2010). As in Schakel et al.’s (2016) recent study, the dual role of the one of the authors is what made possible the focus on practice and the combining of ‘inquiry from the inside’ and ‘inquiry from the outside’ (Evered & Louis, 1981; Schakel et al., 2016).

3.3 Fieldwork and data collection

A commitment to studying practice strongly indicates an ethnographic analysis in a ‘perspicuous setting’ (Garfinkel & Wieder, 1992: 184) that can make the practice and what leads up to it readily observable, and can provide the kind of ‘ground level’ understanding (Lom, 2016) that helps reveal how practices are shaped by the specific conditions in which they occur. Observations were made on the helicopter flights out to the installation, general working life on the installation, and operations onshore that involved direct dealings with the installation. Much of the observation was of physical and social interaction during work, but there was also observation of 40 formal meetings and 40 unstructured interviews at various locations on the platform, with informants at all levels of seniority. The interviews were intended as ways of gaining discursive insights into the physical and social processes observed during the ethnography, which generally was intended to be a ‘deep engagement in the field, observing or working with practitioners as they go about their work’ (Feldman & Orlikowski, 2011). Data were collected in the form of hand-written observations and sketches of physical layouts and conditions. Where permitted, audio recordings, photographs and short video recordings were also taken.

3.4 Analysis procedure

The analysis was based on selecting several specific ‘sites of practice’ at which to investigate specific relying practices. This provides a basic sampling founded on the principle that ‘A perspicuous setting makes available... material disclosures of practices of local production and natural accountability’ (Garfinkel & Wieder, 1992). The chosen sites of practice (SoPs) were those that appeared to make relying especially observable and explicable, and they included not just physical environments but also particular tasks, systems and roles. The following sites were selected for analysis:

- *The non-destructive testing (NDT) of over-board pipework.* Over the lifetime of an installation the pipework is subject to extreme levels of degradation both from the substances it carries and the salt-water environment it occupies, as well as movement and deterioration in supporting structure. For an organization to rely on such pipework, especially towards the end of an installation’s design life, it must regularly test its integrity. Some of the pipework is over-board, and hard to reach physically, so testing involves extensive relying between NDT technicians and rope access technicians (RATs) in order to test a given length of pipework.
- *The permit-to-work (PTW) system.* This was an administrative system that required a group intending to perform physical activity to document precautionary actions and gain approval before starting work. It was the primary means of coordinating and controlling the many dangerous, conflicting activities in a complex system in a highly confined space. Deficiencies in PTW systems have a particular significance in this industry, as a breakdown of the PTW system was centrally implicated in the Piper Alpha disaster.
- *Habitats for protected, isolated work.* These were a set of specially-demarcated zones for hazardous work, typically enclosed in temporary physical barriers with various forms of signage. Although temporary, and regularly adapted to suit the work being performed within them, they were subject to formal classifications and rules. Habitats also created particular roles for individuals and required extensive negotiations with others performing work in overlapping or contiguous spaces.
- *The office of Offshore Installation Manager, or OIM.* The OIM was responsible in law and in practice for all operations and safety on the installation. The office was an important nexus for the

coordination of onshore and offshore operations, and the managerial processes that surrounded the physical work on the installation. Perhaps the most important of these was the prioritization of maintenance and renewal tasks. The fixed constraint on the number of people on board the installation meant there was a substantial backlog of several thousands of hours of work, often safety relevant, at any time. Working out what had to have priority, and at what point continued operation was too dangerous, was a central focus of practice for an OIM.

- *Inbound helicopter flights.* Staff travelled to the installation by helicopter. Helicopter flights had a chequered history, and shortly before the time of writing a helicopter crashed on returning from the Statoil Gullfaks installation, killing all 13 people on board. There were many aspects of helicopter operations that went unobserved in the fieldwork. But the experience of the passengers was revealing, and the site of a number of relying practices. These included relying on certification systems to determine the passengers' medical status and emergency training, relying on passengers to possess and correctly wear survival suits, and to check each other's survival suits. And it included relying on passengers to report to the flight crew signs of failure in the aircraft itself.
- *Supply vessel unloading.* Materiel of any bulk had to be delivered to the installation by sea, and the movements of supply vessels close to the installation, and their unloading, was often hazardous. Collisions between supply vessels and installations were regular and in the worst case could be catastrophic: such a collision led to the loss of the Mumbai High North Oil and Gas Platform and 22 lives. The supply vessels were owned and operated by a different firm, and staff on the installation rarely met the tug masters and could not physically see them. So they relied on one another in physically closely coupled, real-time activity with very little social engagement.

The aim of the analysis was to understand identifiable relying practices in terms of how they were responsive or adapted to their ecologies – their 'ecological validity'. The notion of a practice's ecology follows Gherardi's (2015) principle of the 'ecological model' that lies behind theories of practice. 'Ecology' is metaphorical – coming from Haeckel's original notion of ecology as a

relationship between some animal and its environment – but theories of practice see practice by its nature in the same way: being the way it is in order to fit the conditions in which it takes place, including other practices. Analysing ecological validity also follows the idea of the ‘ecological rationality’ of the heuristics used by people successfully performing practical tasks (Goldstein and Gigerenzer, 2002): a heuristic is ecologically rational to the extent that it exploits whatever features there are in the environment to guide behavior. The term ‘ecological validity’ is found in the ecological psychology literature, usually with reference to the natural-ness of simulations and the data they produce (Araujo et al., 2007) – but the key aspect is some kind of match with a prevailing environment, and Araujo et al (2007) refer back to Brunswik’s (1956) usage of ecological validity as the validity of some perceived cue as indicating a true state of the environment. Our approach to looking for the ecological conditions that relying practice responds to is also motivated by Douglas’s (1987, 57) observation that conventions, however self-enforcing, are unlikely to persist unless they are ‘grounded in reason and nature’, and by the observation that ways of sensemaking about risks and risk controls are adaptations of some kind to a prevailing environment (Busby & Collins, 2015).

The analysis therefore involved examining how relying practices responded to their ecologies, and then inductively identifying the principal categories that this responsiveness or ecological validity fell into, via a thematic analysis (Boyatzis, 1998). This process produced four such categories, each category representing responsiveness to a certain aspect of the conditions in which relying was being practiced: 1) responsiveness to the formal organizational qualities of situations, 2) responsiveness to the information asymmetry they involved, 3) responsiveness to their contingent nature and 4) responsiveness to their socio-materiality. These categories emerged from repeated readings of the data and a process of constant comparison (Glaser, 2002) – that is, a repeated attempt to fit new observations to existing categories, to generate new ones where needed, to ensure they could be strongly contrasted, and to assess existing observations against new categories. The procedure is inevitably subjective, and the categories do not partition the data: the same relying practice may well exhibit a responsiveness to more than one aspect of the prevailing conditions. So the aim is not to produce a taxonomy of practices but to categorize the possibly multiple influences that shape them.

By involving repeated readings of the data, the aim of the procedure is to produce a categorisation that has an appropriate balance of economy and informativeness, and comprehensively accounts for the data. But this takes the pragmatist position that such a categorisation is not unique – and that there is not one privileged account of events (Wicks & Freeman, 1998). In the next section we describe the findings under these four main categories and attempt to show how these provide a useful basis for explaining relying practice.

4 HOW RELYING WAS PRACTISED AND HOW PRACTICE WAS ECOLOGICALLY VALID

4.1 How relying practice was responsive to the experience of formal organization

The first main category was responsiveness to formal social organization. Most obviously, practices of relying followed the formal division of labour. In the non-destructive testing (NDT) SoP, there was a relying on an NDT technician to test safety-critical pipework, and the NDT technician in turn relied on a team of rope access technicians (RAT) to place the probes on pipes running outside the main structure. Rope access technicians relied on equipment – their ropes, karabiners and fall arrestors – and relatedly on a formal system of certifying such equipment. This certification system in turn relied on processes of inspection, on the capacities of those carrying it out, and so on. Division of labour is often clearly aimed at improving reliability, since activities like using ropes to get access to outboard pipework are made more reliable by giving them to specialists, and activities like testing ropes are made more reliable by giving them to testing organizations, and so on. But this division of labour also deepens the relying network, creating more relying – and thus more opportunities for relying that is somehow at risk.

Correspondingly, much of the relying also arose from ways of organizing safety, in which new relying on protective devices and structures was practised to protect more basic relying. For example, the fieldworker notes described how

‘...all overboard work parties include a team member who stays within the confines of the platform. This member is trusted to maintain a constant watchful eye on those working on, or beyond the edge of the platform and maintain radio contact with the platform control room and with the platform’s Standby Vessel that sits some 500m distant. His role [requires] that he wears a high-visibility, hard hat over-cover, and red tabard with ‘Standby Man’ identification.’

To protect the relying on the rope access team, there was a relying on a ‘standby man’, which in turn produced relying on the standby vessel and all its functions and facilities (and its own relying), on radios (and all they rely on) and even on the standby man’s dress that communicates his or her function to others. Relying thus proliferated, through the reiterated division of labour and the reiterated addition of protection, although for any given practice of relying there was a backstop object or set of objects which it was simply the practice to rely on, without further concern. When a rope access technician relied on a rope, all the processes and materials on which the rope relied (for example quality assurance processes during its manufacture) were collapsed, for the technician, into that rope. Where this backstop lay defined the practice. In reality it was also the practice for rope access workers to inspect their own ropes before they used them, even though they appeared to be entitled to rely on the certification – so there was a natural scepticism in relying practice.

Ways of organizing work commonly produced relying practice that was bidirectional: it was hard to identify any formal, organizational transaction in which performance of a service did not rely in some way on the client. In the permit-to-work (PTW) SoP, the supervisors of particular tasks (the ‘performing authority’ or PA) took a completed permit application to a production supervisor (an ‘area authority’ or AA) for verification. They thus relied on the AA for the AA’s knowledge of potentially contiguous activity to ensure the planned work was going to be safe. But the AA relied on the PA’s description of the work being correct and comprehensive, and the whole package of mutual relying was best seen as a single practice. As the following extract shows, this reciprocity of relying materialised in an unfolding, sequential interaction as mutual relying is realised, responded to and exploited:

AA: That's a Habitat modification, you'll need to put in a rescue plan...

PA: Why is that...because the Habitat is open...?

AA (*checking paper copies of Habitat location drawings*): '...it's nothing to do with the Habitat, it's because it's a restricted access...'

PA: 'I haven't put that in the routine...'

AA: '...I'll add that for you now (*Typing*) ...Transfer rescue plan...EMD...ERC...229...'

(*Phone call interrupts the AA*)

AA (*pointing to a platform location*): 'So, just remember the riggers are working up there.'

A lot of relying appeared to take place through ad hoc interaction like this, in the context of formal procedures but not determined by formal procedures.

Another way in which relying practice responded to formal organization by migration away from formality was evident in the OIM's practice around Safety Critical Elements (SCEs): physical parts of the installation that received particular scrutiny from the regulator. Often SCEs became inoperative, in which case Operational Risk Assessments (ORAs) had to be used to assert in some formal sense that operations could still continue. ORAs provided a rule-based way to break rules. The OIM had a formal duty to record ORAs, and to limit their timescales, yet in practice prioritizing and monitoring them became very informal. As an OIM explained, 'When you have ORAs, it's a bit like being an air traffic controller and some of the green dots disappear from the radar screen. The aeroplanes are still there, but you just can't see where they are, or how they're flying in respect to the other dots on the screen'. So even the rule-based way to break rules ultimately relied on the OIM's informal capacities for maintaining attention on all the 'green dots'. Relying practice was intended to be formal and rule-based; it had migrated to a still-formal system that provided some flexibility; but eventually it had become an informal system that referred to formal elements but was not bound by them. This is similar to Vaughan's (1996) analysis of normalized deviance at NASA. What happened to NASA is instructive about the risks created by this migration, and makes the point that formal procedures do not dictate behavior: it is the practice through which people rely, or do not rely, on formal procedures that determine behavior.

The formal, organizational context was also important in explaining why relying practice was sometimes intentionally made difficult for the members. In the permit-to-work SoP, the authorizer was relied on to identify any clashes between a proposed piece of work and other work already authorized. Relying on a central individual to do this was an important way of achieving this coordination. But it had the side-effect of creating a bottleneck, meaning that applicants could face a long wait before being able to negotiate, let alone obtain, a permit. The beneficial result, however, was that people preparing applications took this preparation more seriously. They did not want to be told to go back and prepare an application again. In this way, practice exploited formal organizational controls to shape behavior: to avoid slipshod, lazy relying on the permit-to-work system.

4.2 How relying practice was responsive to information asymmetry

The second main category was of responsiveness to information asymmetry – an almost inevitable condition in relying relationships. So often there was relying on objects not only to constrain behavior or otherwise make some task safe but also to convey information. In the PTW SoP, there was a practice of posting a permit to work physically at the workplace, which advertised the nature and location of this work to others who needed to know. Relying on the permit was not just for a primary, substantive function of authorizing an activity but also for the informative function of telling people about the nature of the activity and telling them it was legitimate.

Relying on something or someone in an informative as well as a substantive way in turn meant relying on communication practices. For example, the NDT technician described earlier wore a ‘green hat’, whose green-ness was as important as its hardness. Green hats were worn by all who had less than three trips on the platform, informing others that the technician could be relied on to assess pipework integrity but not to have local knowledge of platform conditions, layout and practice. The green hat was both an instruction to others to be sceptical when relying on such technicians, and a communication to the technicians wearing them that they should rely on others for local knowledge. At the same time, this communication itself then came to be relied on, and was obviously at risk when novices, because they were novices, did not appreciate the practices that surrounded these

communications. The key point is that these communication practices both supported other practices of relying, and were relying practices in their own right.

In the helicopter flight SoP, passengers on embarkation were briefed by the helicopter co-pilot about weather conditions and flying time, and were asked to contact the pilot or co-pilot if they noticed anything out of the ordinary during the flight, for example, unusual smells or fluid leaks. In this sense passengers were recruited into the system of concern to help make it reliable, becoming sensors for the flight crew. It is an important step for an organization to accept that its clients can and should become part of what makes it reliable, that they can be an important source of information about discrepant conditions. But clients relied on this way need to be informed they are relied on. There was an asymmetry both in the sense that passengers could know more about certain conditions than flight crew, and in the sense that the flight crew knew more about the fact that passengers could know more about these conditions. Relying practice had to respond to this second-order information asymmetry.

Another observation made on the helicopter flight SoP was the way each passenger, wearing a survival suit, relied on a colleague to check the suit's integrity, ensuring zips were fully closed and sealed, and lifejacket fastenings made secure. The act of checking the other's equipment was done in an exaggerated way, the checker making the inspection task accountably obvious in the act of demonstrably touching and pulling on straps. It was the gestures as much as any language that performed the communication. It would be easier to report you had checked someone else's survival suit by simply saying 'all checked'. But this does not have the same authenticity as exaggerated physical actions. As Kohn (2008, 40) puts it, 'The conundrum of language is that an animal clever enough to speak seems too clever to be believed'. Although language may be capable of transmitting much more complex information than simple signals, language is also used to deceive and evade. Practices of relying that respond to the information asymmetry that relying involves reflect this, sometimes avoiding rather than relying on language to resolve this asymmetry.

4.3 How relying practice was responsive to situational contingency

We quoted a fragment of dialogue, above, around the permit-to-work SoP, in which the practice of negotiating a permit-to-work was one of following procedural rules but also one of performing corrections, amendments and collateral actions, and handling disruptions. The practice was to combine formulaic behavior with a response to the contingency both of what the practice was directed to (obtaining a permit) and of what turned out to be the conditions of practicing (the interruption by a telephone call). By unfolding in time (Bourdieu, 1990, p.91) the practice could be a sequential response to what was specific about the circumstances at the time. The responsiveness of practice to contingency is a quality found in probably all practice-based studies (for a recent example see Whitford & Zirpoli, 2014). And the important point is that dealing with contingency is part of the practice, not a suspension of it.

In the Offshore Installation Manager SoP, one of the most obvious relying practices was the way the OIM relied on a variety of means and criteria for assessing whether to continue operations in the face of emerging hazards. For example, for hydrocarbon releases – leaks of flammable, explosive fluids – there was a formal rule on which the OIM was officially expected to rely: releases were to be acted on if they ‘exceeded 3 kg/h or 20% of the Lower Explosive Limit at 50cm’. Yet the practice was for OIMs to rely on a variety of more observable criteria, such as counting the number of drops of oil leaking per minute, the quantity of oil collected in an open bucket in a 24-hour period, or (for gas leaks) how much bubbling was occurring around a leaking fitting. OIMs also then relied on a highly contingent view of current circumstances to determine whether a leak could be tolerated. On ageing and degraded installations, leaks were commonplace and the OIM had to have a considerable tolerance for leaks if such installations were to remain in operation. Installations faced large maintenance backlogs, and even the simple step of replacing a valve stem seal could require the expensive shutdown of an installation’s production. The practice of relying was thus one of appreciating the specific situation being faced in the moment, using under-specified but observable measures, not to follow rules.

There was also extensive contingency in the supply vessel unloading SoP. Workers on the platform relied on demarcated laydown zones to know where they were likely to encounter large

moving loads, but congestion meant that large loads were often set down in any available space, requiring a relying on crane operators, banksmen and load-handlers for additional vigilance. But in all conditions, as one of the deck crew expressed it,

‘things could change in a split second. Your surroundings, you know... So you’re looking for changes... like we’ve got a crane operator, he sees things from the sky... He’ll see more changes... than what we do on the decks. So he’s our bird in the sky type of thing. So if he sees a change, he stops it. So, you know, we rely on a second set of eyes...’.

The redundancy from a ‘second set of eyes’ echoes the earliest observations of high reliability organization studies (La Porte & Consolini, 1991) that organizations rely on multiple not single sources of observation in order to deal with unpredictable, rapidly unfolding events.

There is a clear connection between the contingency of relying practice and the literature on flexibility in routines (Feldman et al., 2016; Pentland et al., 2010; Pentland & Rueter, 1994). Yet the term ‘flexibility’, like ‘underspecification’ (Weick et al., 1999), is too passive to express the point that the practice is not just open to being done differently but that it evolves to incorporate ways of positively discovering and dealing with contingency. This is not a matter of what might be regarded as simple awareness. Goble et al’s (2018) recent analysis pointed to the natural antithesis between the kind of vigilance that involves searching for known conditions, and the kind needed for noticing relevant conditions that are *not* being searched for. This means that relying practice must deal with contingency by looking for and responding to well-specified conditions (like the relying on informal but well-specified leak criteria). But it must also deal with contingency by being intendedly open to unspecified indications of danger (like the relying on a crane operator as a ‘second set of eyes’). There is a similar connection to work on ‘improvisation’ in safety critical systems (for example Meshkati & Khashe, 2015; Trotter et al., 2014; Trotter et al., 2012). Such work typically sees operators’ capacities for improvisation as being needed when system designers cannot comprehensively foresee how emergencies arise (Meshkati & Khashe, 2015). Improvisation is therefore typically seen as a capacity to act in ways that are not designed, prescribed or habitual. But there is also a clear understanding that improvisations can deepen emergencies instead of resolving them (Trotter et al., 2012) – so the

relationship between improvisation and effectiveness is itself contingent. Relying practice that is fully adapted to contingency is adapted to the possibility that its adaptedness can be both protective and risky.

4.4 How relying practice was responsive to socio-materiality

Relying practice had to reflect the universally socio-material quality of the ecology – the way in which the materiality of work on the installation was both a creation of the social and a facilitator of it (Leonardi, 2012). In our study, the materiality of non-destructive testing equipment was an important part of the relationship between its designers and the technicians using it, for example. Each was engaged in mutual relying – the designers on the technicians for appropriate use in specific conditions, and the technicians on the designers for appropriate, general functionality. There was no direct engagement between designers and technicians in which the relying practice could be negotiated. But the way this practice operated through material objects allowed relying to be asynchronous in time and space, with the material embodying both technical functions related to ultrasonic testing (the generation and processing of ultrasonic signals), and social conventions related to what designers and technician were responsible for (the controls that designers provided for the technicians' use).

The 'habitats' SoP also involved a basic socio-materiality. In hazardous operations, segregation becomes a central objective, separating explosive materials from ignition sources, large moving masses from vulnerable structures, and people from many kinds of danger. Thus relying around 'habitats' was most obviously relying on physical separation: the material form of a habitat functioned as physical restraint. But it also functioned as social restraint, since the materiality of barriers and markings embodied and cued much social negotiation:

'If work areas involved the potential for dropped objects, for example, during scaffold erection or dismantling, barriers might cover a large area, and necessitate blocking off multiple access walkways. However, it was apparent that those marking out barrier areas gave consideration to others, trying both to facilitate the free-flow of foot traffic, and to

respect the working territories of others. When ... clashes did occur, resolution was often locally negotiated, with work parties deciding which task/group should have priority.'

The working-out of conflicts was part of the relying practice. Habitats also existed within a simple linguistic system, and relying on the material form of habitats also required relying on and through the language by which they were classified:

'Habitats had three main classifications: Level 1, for general protection against weather and providing protection for, and against, shot-blasting and paint activities, Level 2, capable of containing hot-work activities such as welding, and Level 3, a fully-enclosed, pressurised, forced-air containment suitable for hot-work in active, oil and gas producing environments.'

Relying on this language is not just relying on it as 'a system of signs and symbols but [as] a medium of practical activity' (Giddens, 1993: 163) – where in this case the practical activity was to keep certain people out of certain areas. Language was relied on to choose the appropriate kind of physical restraint, to tell others what kind of hazards the physical restraint surrounded and to confer legitimacy on it.

In the PTW SoP, much of the function of the socio-materiality was concerned with remembering. For example, in the following quote, an AA (area authority) described how he used plant layouts and on-screen documents as aide memoires:

'I do roughly try and remember the permits I've issued, but it's difficult when you've got 40 odd. So, this is just a back up for me just to reconfirm my... you know it's there so I might as well use it you know. The screen's there and it's just that crosscheck for myself before I issue certain permits... And also I keep in my mind any kind of incidents we've had over the last week while and it's just reinforcing them kind of things, you know what I mean? Like hoses today, there was mention about hoses based on two incidents we've had the last few days so, just kind of reinforcing and reminding them that that's what's required'.

This echoes Hutchins' (1995) observations on distributed cognition, in which representations are embodied in material media, and physical processes propagate representations across them. These representations are not just an external memory but part of cognitive performance. On an offshore

installation undergoing extensive refurbishment, the sheer complexity and constantly evolving nature of the physical system and its hazards meant that the actors within the system had to regularly update their models of the system's state. In such a setting, as in many others, a key step was to transform relying on human memory into relying on material entities like computer screens. But ultimately it was the practices that enfolded both human behavior and material entities that performed the necessary remembering: on-screen documents only provided memory when there were practices of using them as memory.

5 A DISCUSSION OF RELYING PRACTICE AND RISK IDENTIFICATION

5.1 Identifying risk as product of ecological validity in relying practice

Table I summarises the observations made in Section 4. It shows for each of the four main categories the observations made on the nature of relying practice and its ecological validity. It also suggests some potential risks of organizational failure or breakdown that these imply. Such risks arise in various ways from the issue of ecological validity: 1) some come from validity that is incomplete or inadequate – for example relying that is responsive to information asymmetry by being communicative, but which fails to recognize strangers to a system; 2) some come from validity that is vulnerable in some way – for example relying that is responsive to situational contingency by exploiting social redundancy, but then is threatened by removal of redundancy for the sake of efficiency seeking; and 3) some come from validity that has problematic and typically unintended consequences – for example relying that is responsive to the formal division of labour, but produces a diffusion of relying that undermines a sense of responsibility. In all such cases it is not the relying practice in isolation that creates risk, but its mismatch with the reliability that it is relying on.

-----Table I about here-----

The central point is that ecological validity provides an explanation of relying practice that then helps us predict the potential for this mismatch, and therefore for risk. The suggestion is that assessing and,

in particular, identifying risk in settings such as hazardous installations should incorporate broadly the same kind of process: it should look at the nature of relying practice and how this is responsive to its ecology; and it should then ask in what ways the ecological validity is incomplete, in what ways it is vulnerable, and in what ways it produces unintended consequences; and it should then ask in what ways this produces risk of organizational dysfunction through mismatched relying and reliability. The categories that emerged from the fieldwork offer a basic way of organizing this analysis, and the practices described in Section 4 provide examples of what is normal and what is typically adequate.

As a reviewer of a previous draft of this article pointed out, a central challenge in most settings is change – whether in conditions of operation or in knowledge about them. One of the categories developed in Section 4 was the responsiveness of practice to contingency. But this may not encompass large, long-term or unprecedented change. This means that threats to and from ecological validity just identified need to be assessed in the light of such change. In the context we studied, where there was extensive physical degradation, it becomes important to ask whether the validity of relying practices becomes suspect when degradation reaches a certain point. For example, the practice of relying on rope access technicians – a normal division of labour – becomes suspect when physical structures become dangerously fragile. All three types of risk indicated in the previous paragraph are really predicated on the possibility of change of some sort. And what essentially distinguishes ‘change’ from ‘contingency’ is what confounds or undermines any given relying practice.

Such a process of risk identification is not complex or technical, but requires a shift in focus from the reliability of the systems and components that are relied on to the socially organized practices in which relying occurs. Unreliable objects do not in themselves create risk in a wider system but do so jointly with relying subjects whose relying process is insufficiently careful, vigilant or sceptical. Correspondingly, reliable objects *do* create risk jointly with relying subjects engaged in inappropriate relying processes. Since reliability is defined with respect to some function that is provided to a relying subject, the contrast between relying and reliability is not a definitive one, ultimately, but one of emphasis. Sarwar et al’s (2018) recent analysis of resilience in offshore operations, for example, is based on modelling with Bayesian networks so naturally shows that

various capacities (such as absorptive capability) rely on sub-systems whose success or failure conditions the capacities that rely on them. This is important information for risk analysis, but we suggest that such an approach does not show the *way* in which relying takes place, particularly when it consists of human practice, nor does it bring out the ways in which this relying is ecologically valid or invalid. Understanding this relying practice is an important first step before trying to estimate failure probabilities and their conditioning events, so logically comes before the kind of analysis proposed by Sarwar et al (2018).

5.2 Making risk assessment more endogenous

The shift from an emphasis on the reliability of external entities to the relying practices of the entity at risk helps to endogenize the risk assessment process. The task of the risk manager is not so much to manage someone else's unreliability but to manage its own relying on them. There are various themes in risk studies that similarly endogenize the risk problem:

- Beck's (1992) reflexivity, and the observation that ways of managing risk themselves produce risk. This indicates that relying on our capacities to control risk is a key type of relying, but that often we appear blind to the other risks that this relying creates.
- Power's (2004) notion that creating risk managers creates reputational risk. This suggests that relying on risk managers is an important species of relying, but is vulnerable to the problem that risk managers' reputational risks may come to dominate the substantive risks they are managing.
- Luhmann's (1993) insight that risks – as opposed to dangers – arise by definition from decisions, not happenstance. This suggests that there is always a relying on decision processes that underlies any risk, and we that should be looking not to our vulnerabilities to external agents but to the weaknesses in the way we make decisions about such agents.
- Busby and Duckett's (2012) argument that risk responses are often responses to other people's risk responses. We rely heavily on the others that communicate risk to us and on the ways we then interpret communications from them. The issue is not just about the reliability of risk information sources but about the way we rely on these sources.

- Hutter and Power's (2005) observation that organizational encounters with risk are as much organizations' encounters with their own natures and limitations as they are encounters with the outside world. This reminds us that relying, as practice within an organization, is shaped by the nature and limitations of that organization, and should be analyzed as such.

All these themes point to the importance of examining practices of relying as much as reliability.

Analyzing risk as though it were endogenous also helps you understand where and how you accept risk (and whether the acceptance is responsible), and helps you recognize that your relying may need to change as circumstances change. Of course this is not to say that seeing risk as also coming from an external entity is somehow less useful. Some of the practices illustrate this: relying on a 'second set of eyes' rather than your own observation makes the risk of failing to see some hazard an exogenous risk, and an appropriate relying practice must respond to the way such a risk lies beyond the relier's influence. We are grateful to a reviewer of a previous draft of this article for pointing this out.

5.3 The practice principle and risk

The study is based on the assumption that what explains and accounts for how people rely is social practice. Relying by people is inherently social, not simply because people rely on other people but because their practices of relying on material entities are learned socially and follow social norms.

The findings of this study do not prove in some simplistic sense that practice explains relying, but show that describing and explaining relying is profitably accomplished by looking at practice.

Practice also supports the principle of inspecting ecological validity because practice is practised – it is repeatedly carried out.

Suchman (1987) observes that what are seen as 'background assumptions' are often not assumptions in anyone's head, offering the example that when we open a door we do not form a belief that the floor continues on the other side. We simply open the door in the way we know is normal practice. It is only in the act of accounting for actions subsequently that we might think about the continuity of floors. If our subsequent experience is that the continuity of a floor is at risk then the practice adapts, and incorporates some action involving checking the floor. As suggested earlier it is

change that makes the relying practice problematic: a change in the condition of a floor as it is experienced, for example, that undermines the ecological validity of the former practice. Once the poor condition of a floor persists, or at least the unpredictability of the floor, relying practice as the normal, justifiable way of going through doors is likely to adapt. So the sophistication of the relying practices described in Section 4 reflects the experience of what has needed doing – at a broad level, coping with and exploiting formal organization, recognizing the problem of information asymmetry, dealing with the contingency of situations, and attending to the socio-materiality of the environment. If asked, the people engaging in these practices would generally be able to explain the logic behind them. But that does not mean that they work through the logic and then carry out the action. They rely in the way they do because it is normal, conventional, appropriate or somehow proper for them to do so – in other words, because it is a practice. Since there is no unique, correct way of categorising types of ecological validity they would be very unlikely to explain the logic behind their practices according to the four categories we have developed, even when they are asked to give an explanation. But such categories nonetheless provide a third-person view of practice that becomes important in assessing risk.

The idea of looking at what is normal or precedented, as practice, also fits with Vaughan's (1996) observations of 'normalized deviance'. This captures the notion that what is deviant according to some formal standard may nonetheless become socially normal. Safety rules may be a formal standard, representing some kind of authoritative ideal, but conformance may not be a normal practice in a particular group in a particular situation. Normalized deviance is the practice of deviating from such standards, and has its own ecological validity – being responsive to organizational conditions like 'structural secrecy', and the need to make repeated decisions. A practice-based analysis similarly fits with Snook's (2000) idea of 'practical drift': a problematic adaptation that sets aside rules because, in benign conditions, ecological validity makes such rules superfluous. It is the change in the ecology – the transition into problematic conditions – that suddenly undermines this validity and makes the practice inappropriate and often dangerous. For similar reasons, the focus on practice and ecological validity fits Reason's (1997) model of organizations exchanging protection gains for

production gains. In all these models, the central issue is that practice is what explains people's actions, and ecological validity is what explains why practice ends up being a prime mover in producing risk. There is a variety of ways in which this happens, but practices of relying, the way they are shaped by the conditions in which they are practised, and their match with what is being relied on, seem to be common to all.

6 CONCLUSION

Our central argument is that risk analysis should attend to the practice of relying in social organizations. Having the property of reliability is the obvious concern when trying to understand risk in a particular system. But unreliable entities do not produce unacceptable levels of risk if relied on in sufficiently circumspect ways, and inappropriate relying produces unacceptable risk even if there is some reliable system being relied on. And, within systems being relied on, there are components whose relying on other components is instrumental in defining the systems' reliability. In social organization, specifically, relying is usefully regarded as a practice: as collective activity that is routine, habitual and conventional (not deliberated or calculatively optimal) yet also situated and contextual (not the product of general rules). The key quality of this practice is its ecological validity – its responsiveness to the circumstances in which it takes place. The empirical study we present is intended to show what relying practice looks like in a hazardous organization and how it can be explained by its responsiveness to the ecology in which it takes place. This logically leads to ways of identifying risk that are focused on how ecological validity can be inadequate, vulnerable or counter-productive in various ways. The result is a more endogenous focus during risk analysis, where entities at risk are seen as being at risk from their ways of relying as much as the unreliability of the entities they rely on. This should produce understandings of risk that are more holistic (Haimes, 2009) than those primarily informed by analysis of reliability alone.

Our intended contributions are therefore to:

- 1) Argue the case for making relying practice an important object of study.
- 2) Show how relying practice can be analyzed in a specific setting.
- 3) Propose that risk assessment in such a setting should focus on the analysis of its ecological validity and how this can produce risk.

There are some obvious limitations to the study. The concentration on relying as social practice naturally emphasizes the organizational rather than the technical, engineered parts of what is a complex socio-technical system. But it would be misleading to suggest that risk somehow arises more from the social than the technical. And, although the fieldwork took place over a period of two years, it was not longitudinal in the sense of observing the same setting in the same way over time, including the way in which relying practice might or might not have adapted to changing conditions, in both the long and short term. Recent work on practice, for example, studies the way members attempt to switch practices (Schakel et al., 2016), and the way practices change in response to changes in policy (Lom, 2016). As a study of a single organization it was also specific and idiosyncratic, reflecting the particular events, experiences and institutions of a small number of organizations in one industry, operating at one location. This detail helped to indicate what might be found in other organizations in other industries, but a study of practice is a recognition that people engaged in organized activity respond to the particular as much as they exhibit regularities of behavior and disposition. This naturally limits external validity – providing a prompt for investigation in other contexts but not a definitive explanation for all contexts. Finally, the study was entirely qualitative, so provides a basis for identifying risks but not prioritizing them or assessing their acceptability. It provides reference classes for a probabilistic analysis, but no more, and offers an exploratory early process before a more definitive quantitative analysis. Nonetheless, the study indicates that the practice of relying is a rich subject for analysis, providing a way of explaining a diversity of behavior and materiality, and indicating how ways of relying are important in understanding how organizations stay safe. This naturally forms a basis for identifying threats to the capacity of an organization to stay safe.

REFERENCES

- Almar-Naess, A, Haagenen, P.J., Lian, B., Moan, T. & Simonsen. T. (1984). Investigation of the Alexander L. Kielland failure—metallurgical and fracture analysis. *Journal of Energy Resources Technology*, *106*, 24-31.
- Araujo, D., Davids, K. & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioral setting: comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology*, *19*, 69-78.
- Beck, U. (1992). *Risk society: towards a new modernity*. London, UK: Sage.
- Bierly, P.E. & Spender, J.-C. (1995). Culture and High Reliability Organizations: the case of the nuclear submarine, *Journal of Management*, *21*, 639–656.
- Bigley, G.A. & Roberts, K.H. (2001). The incident command system: high reliability organizing for complex and volatile task environments. *Academy of Management Journal*, *44*, 1281-1300.
- Blatt, R., Christianson, M.K., Sutcliffe, K.M. & Rosenthal, M.M. (2006). A sensemaking lens on reliability. *Journal of Organizational Behavior*, *27*, 897-917.
- Bourdieu, P. (1990). *The logic of practice*. Stanford, CA: Stanford University Press.
- Bourrier, M. (1996). Organizing maintenance work at two American nuclear power plants, *Journal of Contingencies and Crisis Management*, *4*, 104–112.
- Boyatzis, R.E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.
- Brunswik, E. (1956). *Perception and the representative design of psychological experiments*, 2nd Ed., Berkeley, CA: University of California Press.
- Busby, J. & Iszatt-White, M. (2014). The relational aspect to high reliability organization. *Journal of Contingencies and Crisis Management*, *22*, 69-80.
- Busby, J.S. & Collins, A.M. (2015). Organizational sensemaking about risk controls: the case of offshore hydrocarbons production. *Risk Analysis*, *34*, 1738-1752.

- Busby, J.S. & Duckett, D. (2012): Social risk amplification as an attribution: the case of zoonotic disease outbreaks. *Journal of Risk Research*, 15, 1049-1074.
- Collinson, D.L. (1999). 'Surviving the rigs': safety and surveillance on North Sea oil installations. *Organization Studies*, 20, 579-600.
- Corradi, G., Gherardi, S. & Verzelloni, L. (2010). Through the practice lens: where is the bandwagon of practice-based studies leading? *Management Learning*, 41, 265-283.
- CSB (2014). *Investigation report volumes 1 – 4: Explosion and fire at the Macondo well*. US Chemical Safety and Hazard Investigation Board, June. Last accessed on 7th October 2016 at <http://www.csb.gov/macondo-blowout-and-explosion/>.
- Cullen, Lord (1990). *The public inquiry into the Piper Alpha disaster, volumes 1 and 2*. London, UK: Her Majesty's Stationery Office.
- Douglas, M. (1987). *How institutions think*. London, UK: Routledge and Kegan Paul.
- Evered, R. & Louis, M.R. (1981). Alternative perspectives in the organizational sciences: "Inquiry from the inside" and "inquiry from the outside". *Academy of Management Review*, 6, 385-395.
- Feldman, M.S. & Orlikowski, W.J. (2011). Theorizing practice and practicing theory. *Organization Science*, 22, 1240-1253.
- Feldman, M.S., Pentland, B.T., D'Adderio, L. & Lazaric, N. (2016). Beyond routines as things: introduction to the special issue on routine dynamics. *Organization Science*, 27, 505-513.
- Garfinkel, H. & Weider, L. (1992) Evidence for locally produced, naturally accountable phenomena of order, logic, reason, meaning, method, etc. In Watson G, and Seiler, R. (eds.), *Text in Context: Contributions to Ethnomethodology*, London, UK: Sage, pp.175-206.
- Gherardi, S. (2015). To start practice theorizing anew: the contribution of the concepts of agencement and formativeness. *Organization*, 23, 680-698.
- Glaser, B.G. (2002). Conceptualization: On theory and theorizing using grounded theory. *International Journal of Qualitative Methods*, 1, 23–38.
- Goble, R., Bier, V. & Renn, O. (2018). Two types of vigilance are essential to effective hazard management: maintaining both together is difficult. *Risk Analysis*, 38, 1795-1801.

- Goldstein, D. G. & Gigerenzer, G. (2002). Models of ecological rationality: The recognition heuristic. *Psychological Review*, *109*, 75-90.
- Grabowski, M. & Roberts, K. (1997). Risk mitigation in large-scale systems: lessons from high reliability organizations. *California Management Review*, *39*, 152-161.
- Grabowski, M. & Roberts, K.H. (2019). Reliability seeking virtual organizations: challenges for high reliability organizations and resilience engineering. *Safety Science*, *117*, 512-522.
- Haimes, Y.Y. (2009). On the complex definition of risk: a systems-based approach. *Risk Analysis*, *29*, 1647-1654.
- Hales, D.N. & Chakravorty, S.S. (2016). Creating high reliability organizations using mindfulness. *Journal of Business Research*, *69*, 2873-2881.
- Hollnagel, E. (1993). *Human reliability analysis: Context and control*. London, UK: Academic Press.
- HSE (2014). *Offshore oil & gas sector strategy 2014 to 2017*. Health and Safety Executive. Last downloaded on 1/16/20 at <https://www.hse.gov.uk/offshore/offshore-oil-and-gas.pdf>.
- Hutchins, E. (1995). How a cockpit remembers its speed. *Cognitive Science*, *19*, 265-288.
- Hutter, B. & Power, M.. (2005). Organizational encounters with risk: an introduction. In Hutter, B. & Power, M. (eds.), *Organizational encounters with risk*. Cambridge, UK: Cambridge University Press, pp. 1-32.
- Kaplan, H. (2003). Event reporting, mindfulness and the high reliability organization: is the glass half empty?’, *Vox Sanguinis*, *83*, Suppl. 1, 337–339.
- Kohn, M. (2008). *Trust: Self interest and the common good*. Oxford University Press (Oxford, UK).
- La Porte, T.R. (1996). High reliability organizations: unlikely, demanding and at risk. *Journal of Contingencies and Crisis Management*, *4*, 60-71.
- LeBaron, C., Christianson, M.K., Garrett, L. & Ilan, R. (2016). Coordinating flexible performance during everyday work: an ethnomethodological study of handoff routines. *Organization Science*, *27*, 514-534.
- La Porte, T.R. & Consolini, P.M. (1991). Working in practice but not in theory: theoretical challenges of ‘High Reliability Organizations’. *Journal of Public Administration Research and Theory*, *1*, 19-47.

- La Porte, T. R. & Thomas, C. W. (1995). Regulatory compliance and the ethos of quality enhancement: surprises in nuclear power plant operations. *Journal of Public Administration Research and Theory*, 5, 109–37.
- Leonardi, P. M. (2012). Materiality, sociomateriality, and socio-technical systems: What do these terms mean? How are they related? Do we need them? In P. M. Leonardi, B. A. Nardi, & J. Kallinikos (eds.), *Materiality and organizing: Social interaction in a technological world*, Oxford UK: Oxford University Press, pp. 25-48.
- Lom, S.E. (2016). Changing rules, changing practices: the direct and indirect effects of tight coupling in figure skating. *Organization Science*, 27, 36-52.
- Meshkati, N. & Khashe, Y. (2015). Operators' improvisation in complex technological systems: successfully tackling ambiguity, enhancing resiliency and the last resort to averting disasters. *Journal of Contingencies and Crisis Management*, 23, 90-96.
- Milosevic, I., Bass, A.E. & Combs, G.M. (2016). The paradox of knowledge creation in a high-reliability organization: a case study. *Journal of Management*, 44, 1174-1201.
- Nicolini, D. (2011). Practice as the site of knowing: insights from the field of telemedicine. *Organization Science*, 22, 602-620.
- Pentland, B.T., Haerem, T. & Hillison, D. (2010). Comparing organizational routines as recurrent patterns of action. *Organization Studies*, 31, 917-940.
- Pentland, B. T. & Rueter, H.H. (1994). Organizational routines as grammars of action. *Administrative Science Quarterly*, 39, 484-510.
- Perrow, C. (1984) *Normal accidents*. New York: Basic Books.
- Powell, J.H., Hammond, M., Chen, A. & Mustaffe, N. (2018). Human agency in disaster planning: a systems approach. *Risk Analysis*, 38, 1422-1443.
- Power, M. (2004). *The risk management of everything: Rethinking the politics of uncertainty*. Lond, UK: Demos.
- Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate.
- Reckwitz, A. (2002). Toward a theory of social practices: a development in culturalist theorizing.

European Journal of Social Theory, 5, 243-263.

Roberts, K.H. (1990). Some characteristics of one type of high reliability organization. *Organization Science*, 1, 160-176.

Roberts, K.H., Stout, S.K. & Halpern, J.J. (1994). Decision dynamics in two high reliability organizations. *Management Science*, 40, 614-624.

Roberts, K.H., Madsen, P., Desai, V. & Van Stralen, D. (2005). A case of the birth and death of a high reliability healthcare organization. *Quality and Safety in Health Care*, 14, 216–220.

Rochlin, G.I., La Porte, T.R. & Roberts, K.H. (1987). The self-designing high reliability organization: aircraft carrier operations at sea. *Naval War College Review*, 40, 76-90.

Roth, E.M., Multer, J. & Raslear, T. (2006). Shared situation awareness as a contributor to high reliability performance in railroad operations', *Organization Studies*, 27, 967–987.

Sandberg, J. & Tsoukas, H. (2011). Grasping the logic of practice: theorizing through practical rationality. *Academy of Management Review*, 36, 338-360.

Sarwar, A., Khan, F., Abimbola, M., & James, L. (2018). Resilience analysis of a remote offshore oil and gas facility for a potential hydrocarbon release. *Risk Analysis*, 38, 1601-1617.

Schakel, J.-K., van Fenema, P.C. & Faraj, S. (2016). Shots fired! Switching between practices in police work. *Organization Science*, 27, 391-410.

Schatzki, T.R. (1997). Practices and actions: A Wittgensteinian critique of Bourdieu and Giddens. *Philosophy of the Social Sciences*, 27, 283-308.

Schulman, P.R. (1993). The negotiated order of organizational reliability. *Administration and Society*, 25, 353-372.

Snook, S. A. (2000). *Friendly fire: The accidental shootdown of US Black Hawks over northern Iraq*. Princeton, NJ: Princeton University Press.

Starbuck, W.H. & Milliken, F.J. (1988). Challenger: fine-tuning the odds until something breaks. *Journal of Management Studies*, 25, 319-340.

Suchman, L.A. (1987). *Plans and situated actions*. Cambridge University Press (Cambridge, UK).

- Trotter, M.J., Salmon, P.M. & Lenné, M.G. (2014). Impromaps: applying Rasmussen's risk management framework to improvisation incidents. *Safety Science*, 64, 60-70.
- Trotter, M.J., Salmon, P.M. & Lenné, M.G. (2012). Improvisation: theory, measures and known influencing factors. *Theoretical Issues in Ergonomics Science*, 14, 475-498.
- Vaughan, D. (1996). *The Challenger launch decision*. Chicago, IL: University of Chicago Press.
- Vaughan, D. (1997). The trickle-down effect: policy decisions, risky work, and the "Challenger" tragedy. *California Management Review*, 39, 80-102.
- Vogus, T. J., Rothman, N.B., Sutcliffe, K.M., & Weick, K.E. (2014). The affective foundations of high-reliability organizing. *Journal of Organizational Behavior*, 35, 592-596.
- Weick, K.E. (1987). Organizational culture as a source of high reliability. *California Management Review*, 29, 112-127.
- Weick, K.E. & Roberts, K.H. (1993). Collective mind in organizations: heedful interrelating on flight decks. *Administrative Science Quarterly*, 38, 357-381.
- Weick, K.E., Sutcliffe, K.M. & Obstfeld, D. (1999). Organizing for high reliability: processes of collective mindfulness. *Research in Organizational Behavior*, 21, 81-123.
- Whitford, J. & Zirpoli, F. (2014). Pragmatism, practice, and the boundaries of organization. *Organization Science*, 25, 1823-1839.
- Wicks, A.C. & Freeman, R.E. (1998). Organization studies and the new pragmatism: positivism, anti-positivism, and the search for ethics. *Organization Science*, 9, 123-140.

Table I. Fieldwork observations on the ecological validity of relying practice and risks to it

<i>Category of responsiveness</i>	<i>Observations on relying practice</i>	<i>Example risks</i>	
Formal organization	Relying arises from increasing division of labour often intended to increase reliability	Diffusion of relying undermines sense of responsibility	
	Relying is typically bidirectional, mutual and interactional	Formalising relying procedure under-emphasises the need for interaction	
	Relying migrates away from formality under conditions of operation	Consequences of migrating away from informality are poorly understood	
	Relying recruits formal organization to engender an attitude of seriousness	Formal organization may be changed without appreciating how it contributes to practice	
Information asymmetry	Relying is on systems for advertising for potential need as well as enforcing for anticipated need	The value of advertising to support unknown information needs becomes forgotten	
	Relying is on signals of novice status to ensure novices receive and request local knowledge	Novices fail to appreciate the significance of such practices because they are novices	
	Relying is necessarily communicative when it is unusual for the relied-on party to be relied on	Communication about how a stranger is relied on may provide incomplete instruction	
	Relying is on as well as with communication practices	Strangers unaware of communication practices enter the system	
	Relying avoids language which can be used to deceive and evade	Non-linguistic relying is misinterpreted especially by strangers to the practice	
	Situational contingency	Relying involves corrections, collateral actions and handling disruptions to procedure and rules	Ad hoc modifications to practice are under-emphasised so driven out by efficiency seeking
		Relying on formal criteria relies on situational appreciation to know when to set them aside	Unprecedented situational novelty occurs and leads to inappropriate setting-aside
Relying is socially redundant in order to deal with unpredictable, rapidly unfolding events		Social redundancy is removed from systems as a result of efficiency seeking	
Relying evolves to discover not just react to contingency		Practices lag situations as they evolve so may not discover contingencies from recent changes	
Socio-materiality	Relying is asynchronous and this is achieved by socio-materiality	Material entities are changed without consideration for their coordinating role	
	Relying is on barriers for both physical separation and social restraint	Organizational changes undermine the restraint needed to avoid circumvention of barriers	
	Relying for social restraint involves local negotiation and working-out of conflicts	Local negotiation may be ignorant of global safety properties and permit unsafe actions	
	Relying is on materiality that cannot be separated from relying on language about it	Language is ambiguous to strangers or new members so materiality loses significance	
	Relying is on material environments and systems for memory	Designers under-estimate remembering function and re-design systems inappropriately	

