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HRO and RE: A pragmatic perspective



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ABSTRACT

This special issue invites to a debate to elaborate on differences and similarities between the perspectives of High Reliability Organisation (HRO) and Resilience Engineering (RE). Such a debate may be conducted along both essentialistic and pragmatic lines, and we suggest that the latter approach is potentially more interesting and fruitful than the first. We use the technique of feeding off controversies and expand on what might at first look merely like a polemic disagreement, a question of wording, namely the definition of safety as a dynamic non-event. This elaboration is used as a projector onto a canvas where a number of distinguishing themes between HRO and RE are outlined more clearly; symmetry, normativity, addressee and origin are keywords that show how HRO and RE are different, and why they cannot simply be combined into one grand theory of everything. Other concrete results from these investigations include a review of applications of HRO and RE in health research, an elaboration of the distinction between Safety I and Safety II, and a nuancing of how we may understand and study successful operations. We suggest a research agenda that combines the scopes and methods of HRO and RE, possibly in combination with other theoretical approaches. We also call for a more lively discussion on central themes of HRO and RE, not for fighting over definitions and proving who is right, but with the aim of producing knowledge that makes a difference regardless of theoretical stance.

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1. Introduction

High Reliability Organisations (HRO) (La Porte, 1996; La Porte and Consolini, 1991; Weick, 1987; Weick and Roberts, 1993; Weick and Sutcliffe, 2007) and Resilience Engineering (RE) (Hollnagel et al., 2013, 2008, 2011, 2006; Nemeth et al., 2009) have co-existed for more than a decade. Together with the Normal Accident Theory (NAT) (Perrow, 1984), they represent three of the more influential approaches to safety and accidents during the last three decades.¹ Both HRO and RE can be said to be a counterweight to NAT, in more than one sense. While NAT is particularly occupied with sociotechnical structures² and also can be said to be pessimistic with respect to the possibility of managing high-risk,

complex organisations successfully in the long run, HRO and RE pay more attention to the social conditions and the organisations' strategies and abilities to cope with complexity. Although not unambiguously, there is a tendency to think of HRO and RE as less pessimistic than NAT about the possibility of successfully managing high-risk, complex organisations.

The relation between HRO and RE has been one of co-existence at arm's length without any fundamental controversies between them,³ but also without much explicit cooperation and cross-fertilisation. Not strange, then, that the call for papers to this special issue is marked by a subtle hesitation and uncertainty: Are HRO and RE really different? Do we need both? And the question lurking in the background: Do we really need a special issue on this?

Through this paper we will argue that the answers to those three questions are all 'yes', but the answer must not be detached from our pragmatic interpretation of the questions. Pragmatists as we are, we believe that both HRO and RE will continue their work independently of any conclusions in this issue, but still, the special issue is important since it explicitly addresses a hesitation that has permeated a significant proportion of the community of safety

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¹ There are many ways to categorise and present safety science approaches, illustrated by e.g. Hollnagel (2004), Rosness et al. (2010) and Le Coze (2013).

² A widespread misreading of Perrow is that he is only occupied with technological structures, not social (see e.g. Hopkins, 2001). However, Perrow is also concerned with the organisational level, clearly expressed in Perrow (1983).

³ But as we shall see soon, there are controversies in spe that we may draw upon.

researchers and practitioners for a long time. It therefore represents a golden opportunity to establish a more fruitful dialogue, and facilitate further progress for each of them, and cross-fertilisation between them.

The main objective of this paper is to explore the differences that make a difference between HRO and RE. We do this by presenting a pragmatic perspective on HRO, RE and the debate. Inspired by Science and Technology Studies (Latour, 1987, 2005; Latour and Woolgar, 1986), we consider controversies as a good point of departure to describe how different research strands account for safety. Consciously exploiting – by feeding off rather than trying to reconcile – controversies is a fruitful strategy to clarify and raise awareness of foundational epistemological aspects of HRO and RE respectively. This method is operationalised into the very concrete question of what safety really is to HRO and RE in terms of dynamic non-events and dynamic events respectively, and how this perspective reflects their approaches and methods. In accordance with our pragmatic approach, we will explore applications of HRO and RE as they have travelled into the domain of health research.

Before we proceed, however, let us put the HRO-RE debate in context by briefly recapitulating the older and somewhat faded-out NAT-HRO debate. This is useful because this was a debate with much clearer dividing lines from the beginning, and yet it faded out in a deadlock (Rijpma, 1997, 2003) maintained by the essentialistic question of who was right and who was wrong. We believe there might be something to learn from that.

1.1. Recapitulating the NAT-HRO debate

From the mid 80ies and during the two following decades, the debate between the two approaches of Normal Accident Theory (NAT) (Perrow, 1984) and High Reliability Organisations (HRO) (La Porte, 1996; La Porte and Consolini, 1991; Weick, 1987; Weick and Roberts, 1993; Weick and Sutcliffe, 2007) was a central point of reference and almost an obligatory passage point for those interested in organisational safety theory. The two main axes of arguments in the debate can be summarised as

- (1) Is it possible or not to maintain control over organisations with tight couplings and high interactive complexity? In brief, the answer was 'no' according to NAT, and 'yes' according to HRO.
- (2) Are the approaches of NAT and HRO complimentary and compatible, or are they mutually exclusive and incompatible? Some (e.g. La Porte, 1994; La Porte and Rochlin, 1994) argued for compatibility,⁴ while others (e.g. Sagan, 1993) argued for incompatibility.

This debate, whose appearance and temperament have declined during the years, is useful to have in mind when invigorating a debate that has been smouldering for some years now, ever since Resilience Engineering (RE) (Hollnagel et al., 2006)⁵ consolidated as a theory and was brought into the discourse of organisational safety. From an essentialistic perspective the debate may be seen to fade out in a deadlock.⁶ However, from a pragmatic perspective,

the debate may be viewed as productive. It inspired Sagan's (1993) careful scrutiny of the operations of the U.S. nuclear forces during the Cuba crisis. The empirical contributions of this study to our understanding of organisations remain significant, whether or not one agrees with Sagan's interpretation of NAT and HRO and with the feasibility of pitting NAT and HRO against each other in an empirical study. Another important contribution that emerged from the field of tension between NAT and HRO is Snook's (2000) analysis of the accidental shooting down of U.S. Black Hawk helicopters over Northern Iran and his model of practical drift. Yet another example is Weick's (1990) argument, based on an analysis of the Tenerife air disaster, that the NAT key concepts "interactive complexity" and "tight coupling" could fruitfully be viewed as dynamic and situation-dependent. Weick and the so-called Michigan school emphasise the role of sensemaking in dealing with critical situations and thus complement the early HRO studies with an emphasis on team cognition and team properties.

The HRO-RE debate is in many respects commensurable to the NAT-HRO debate, and we can draw on experiences from the NAT-HRO debate to shape the HRO-RE debate and actually let it become a resource rather than merely a frustrating disagreement. Both HRO and RE investigate and account for the preconditions and work practices that are necessary to manage complex or intractable systems. And – perhaps because the dividing lines for this theme are not as sharp as for the NAT-HRO debate – the second theme gets even more imperative; hence this special issue: are RE and HRO complimentary, and perhaps not even different in essence, and do we in that case need both?

1.2. NAT and RE

The dividing lines between NAT and RE have not been discussed in a similar manner as those between NAT and HRO. NAT and RE have in common a sociotechnical and systemic perspective on their study objects, rather than an organisational perspective. An interesting point of departure for a potential debate, however, could be the way complexity is treated in NAT and RE respectively. While NAT primarily treats complexity as an ontological entity referring to sociotechnical structures, RE speaks of (in)tractability, and treats this as an epistemological aspect (Hollnagel, 2008a).⁷ Tractability does thus not refer to sociotechnical structures as such, but to the degree that the functional relations within sociotechnical systems are understandable to the organisations (Hollnagel, 2012a). Particularly for essentialistic elaborations, it is important to be clear about such differences in perspectives and terminology (for further elaboration on epistemological and ontological issues in relation to the sociotechnical systems that are portrayed by different approaches in safety science, see also Haavik, 2014a; Le Coze, 2013, 2019).

2. A pragmatic perspective

What are HRO and RE? The question may seem banal, but in reality it may be answered in many different ways, and the answer produces crucial conditions for how the further treatment of the HRO-RE debate takes shape. To keep it simple and narrow it down to two approaches, HRO, RE and the relation between them can be approached *essentialistically* or *pragmatically*. An essentialist stance would be based on an ontological and epistemological standpoint that everything has an essence that can be described and understood. It would involve a quest to define the unique properties and the *nature* of the two schools of thought. A pragmatic stance would be more oriented towards highlighting the practical applica-

⁴ This complementarity involves the view that Normal Accidents do exist and that the conditions that Perrow describes are true, but they should happen more often than we see in reality. Hence, normal accidents that don't occur provide a context for HRO to develop, and some blank spots for HRO to fill in.

⁵ 2006 – or even 2003 with Woods (2003) – as a starting point of RE makes sense in terms of when the publications referring explicitly to 'Resilience Engineering' started to emerge, but as Le Coze (2019) nicely reviews, the development of RE can be traced all the way back to the Three Mile Island accident in 1979.

⁶ One reason for this could be that the debaters are actually not discussing the same types of organisations. Leveson et al. (2009) notes that Perrow's argument that redundancy may actually increase the risk of an accident is referring to complex, tightly coupled systems, while HROs examples of redundancy protecting against accidents actually are referring to loosely coupled systems.

⁷ See also Haavik (2013: 51, 57) for more explicit explanation of the epistemological view.

tions of the two. It would involve emphasising how HRO and RE are used in different circumstances, with different purposes, and with different results.

In essentialistic terms, HRO is a perspective and approach that describes characteristics of organisations with high complexity and tight couplings that experience extraordinarily few accidents, despite the assumption that such systems – according to NAT (Perrow, 1984) – cannot be satisfactorily controlled in the long run. Two characteristic features of such organisations are their organisational redundancy in terms of overlapping work tasks and competencies, and their ability to reconfigure spontaneously from clearly defined command lines to a more decentralised, informal decision structure in demanding situations or crises (La Porte and Consolini, 1991). Another characteristic is summed up by the five elements of mindfulness (Weick et al., 1999); preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience and deference to expertise. In similar essentialistic terms, RE is a theory that explains the mechanisms of both failures and successes in terms of variability and functional resonance, and that particularly encourages studies of normal operations. ‘Safety II’ is a frequently used reference for the safety perspective of RE, the advice being that we should “move from ensuring that ‘as few things as possible go wrong’ to ensuring that ‘as many things as possible go right’” (Hollnagel et al., 2015: 4).

The relation between HRO and RE so far has been characterised by mutual respect and an unspoken division of labour, so there has actually not been much debate at all. To the degree that there has been a real debate and confrontation, it has largely been confined to the claim that HRO and RE are essentially the same (Hopkins, 2014). When key figures from HRO and RE appear on the stage together (such as in Hollnagel et al., 2013), the tone is more one of fraternisation than of challenge. Sympathetic as this is, there is obviously both a desire and a need for more interaction and also critical debate between the two, in which respect this special issue is indeed very welcome.

Now, changing the perspective from essentialistic to pragmatic, let us ask again: What are HRO and RE? From a pragmatic perspective, HRO and RE are actor-networks that produce a series of things; they foster professional identities and communities of science and research practice, they produce research, theory and models that may be translated into organisational guidelines and practices, they contribute to the discourse of safety as an entity and a scientific field, they produce dividing lines within these discourses, and they foster both fraternisation and controversies across disciplinary territories.⁸ With this pragmatic perspective on HRO and RE as a point of departure, we will show how we can use these constructs actively to explore new terrains of safety science and gain some new perspectives and insights that may be exploited both by HRO and RE, and by the safety science community as a whole.

3. Feeding off controversies

There is one striking difference between the NAT-HRO debate and the present HRO-RE debate: whereas the NAT-HRO debate revolved around clearly articulated disagreements, the opposite may be said to be the case of the HRO-RE debate – the articulated disagreements are few and the dividing lines are unclear. Still, the two communities seem to keep on living and practicing more or less in parallel. Instead of asking why, which could easily invoke essentialistic discussions and a possible stalemate, such as the one experienced in the NAT-HRO debate, we will go straight to the question of how to proceed from here: should we attempt to

merge or reconcile HRO and RE, or is it better to proceed at a cooperative distance? We shall here argue for proceeding at a cooperative distance, indicate how this may be operationalised, and illustrate the value of this approach by an example.

Bruno Latour, a philosopher of science and technology, is an indefatigable investigator of science, sociotechnical systems and the manufacturing of knowledge. Two central features of his *modus operandi* are (1) to study science in the making (Latour, 1987; Latour and Woolgar, 1986) and (2) to feed off controversies (Latour, 2005). Studying science (or sociotechnical systems, machines, organisations, theories, politics, etc.) in the making means to study subjects while they are still in the making and when it is still possible to identify all the heterogeneous elements and processes that go into their fabrication. At later stages the subjects become objects, and studying ready-made objects is much more difficult, since at that stage the process of fabrication tends to be black-boxed and impossible to trace. To feed off controversies implies not to take for granted, *a priori*, what agencies the objects of investigation are made out of, but rather to use that uncertainty as a resource for further, meticulous exploration. Controversies represent occasions where choices are made and directions are changed, and whichever direction is chosen it could have been different – and that would have made a difference. In retrospect, after the controversies have been settled, these occasions are often difficult to identify and it is not easy to see how it could have been different – not to say: it is not easy to *make* it different after it has been settled and stabilised.

With the HRO-RE debate clearly still in the making, and the controversies still not having been settled, we are in a position not only to make good sense of the debate, identify the actors and what interests are at stake; we are actually in a position to reflexively shape the debate and attempt to direct it where we think it should be heading. However, as authors of this paper, we are in a different position from that of Latour when he studied science in the making. We are insiders in the safety science community. As insiders, we may black-box or take for granted aspects of the research activity that an inquisitive outsider might choose to scrutinise. We have also found it challenging to maintain a consistently pragmatic perspective. This may reflect the way in which we, as researchers, are socialised to approach scientific controversies within our own field in an essentialistic manner.

In the NAT-HRO debate, one main disagreement was as follows: according to NAT, systems with tight couplings should be managed by centralised control, while interactively complex systems require a decentralised control. Systems that are both tightly coupled and interactively complex could therefore in the long run not be sufficiently controlled. According to HRO, however, organisations are able to reconfigure in times of high activity or crisis, so that they can provide either centralised or decentralised control, respectively, when the conditions call for it. As a consequence, the disagreement is very clear: while NAT states that systems that are both tightly coupled and interactively complex are inherently unsafe and should consequently be avoided, HRO states that such systems may be controlled by organisations with the right capabilities (redundant/re-configurable/mindful).

Now, what are the controversies that are central to the HRO-RE debate? As we have already indicated, there are actually no clearly articulated disagreements. And those being suggested by one of the parties have a tendency to be embraced by the other party, claiming that they mean the same thing! Proactivity, resilience and adaptation – all these are organisational characteristics that belong as much to HRO as to RE. But we should not necessarily look only for those big disagreements. The dividing lines between different research strands have a tendency to appear clear and uncompromising in retrospect, when each tradition has been consolidated and research practices have reinforced the dividing lines.

⁸ Bergström et al. (2015) adopt a similar perspective.

Since both HRO and RE, and particularly RE, are relatively young research traditions, we need to be more sensitive to identify the lines of discussion that make a difference and that may constitute good grindstones for both sides. And we may need to follow the advice of Latour to feed off those controversies in order to make them useful for our purpose.

In the following we will identify and feed off a candidate for controversy, and see if what it produces is of value to the HRO-RE debate, and to the field of safety science.

3.1. Safety as a dynamic non-event vs safety as a dynamic event

A central argument in RE is the argument of symmetry that one should learn not only from failures, but also from successes. Actually RE claims that there is *more* to learn from successes than from failures: “Even if the probability of failure is as high as 10^{-4} , there are still 9999 successes for every failure, hence a much better basis for learning” (Hollnagel, 2009: 83). This perspective of learning from things that go right and not only from that which goes wrong, has in recent years been associated with a splitting up of safety into Safety I (primarily occupied with that which goes wrong) and Safety II (occupied also with that which goes right) (Hollnagel, 2014). Still, when faced with the Safety II perspective, which can be said to be one of the main arguments of RE, proponents of HRO will typically say that this is nothing different from what is claimed by HRO: “Preoccupation with failure may seem antithetical to the spirit of Safety-II. But not so if we consider safety as a dynamic ‘non-event’” (Sutcliffe and Weick, 2013: 152). No controversy there, in other words. However, if we pursue this theme further, we see that the condition Sutcliffe and Weick point out for embracing Safety II, is that safety is seen as a *dynamic non-event*. Safety, or originally reliability, defined as a dynamic non-event is a perspective that was introduced by Weick (1987) and has been used widely since, almost without becoming subject to controversy at all. However, although he describes the definition as clever, Hollnagel (2014) finds it more reasonable to refer to safety as a *dynamic event*.⁹ How can he do so when there seems to be such agreement otherwise? Is this a difference that makes a difference, or is it merely a different way of phrasing it?

We will pursue and feed off this controversy to see if it can add value to the HRO-RE debate. We know a bit more about the meaning of safety as a dynamic non-event, since this definition has been circulating in the safety literature for quite a while. According to Weick, safety is dynamic in the sense that “it is an ongoing condition in which problems are momentarily under control due to compensating changes in components” (Weick, 1987: 118). Further, “safety is a non-event because successful outcomes rarely call attention to themselves. In other words, because safe outcomes are constant, there is nothing to pay attention to” (Sutcliffe and Weick, 2013: 152).

Hollnagel's doubt about the adequacy of Weick's definition is linked to the problem of counting:

“Although the definition of safety as a dynamic non-event is very clever, it introduces the small problem of how to count or even notice or detect a non-event. A non-event is by definition something that does not happen or that has not happened.” [Hollnagel, 2014: 6]

There is a way of overcoming this counting problem, he continues, since we may

“(…) turn the tables, by defining safety as a dynamic event. The event is now that an activity succeeds or goes well (…) The non-event consequently becomes the situation when this does

not happen, i.e. when things go wrong. We can count the non-events, i.e., the non-successes or failures, just as we have usually done. But we can now also count the events, the number of things that go right, at least if we make an effort.”

[Hollnagel, 2014: 9]

At first, what Hollnagel does here may seem as nothing more than a rhetorical trick. How else could it be explained that by turning the tables and calling successes events instead of non-events, and failures non-events instead of events, both events and non-events are suddenly countable? However, that would be an essentialistic and ahistoric reading. If we keep in mind our pragmatic perspective, viewing HRO and RE more as communities of science and research practice than as models explaining behaviour and outcomes and providing the ultimate formulae for safety, we may read Hollnagel's re-definition of safety as a dynamic event as an expression of different visions – literally – *different ways of seeing* associated with the traditions of HRO and RE. Now our feeding off of the minor controversy starts paying off, as it is translated into questions of the visible, the invisible and the practice of seeing.

3.2. Visible, invisible and the culture of seeing

Are dynamic non-events invisible because they do not exist, or because they do not call anyone's attention? Although the term *non-event* would suggest the former, we may deduce from Weick's (1987) elaborations, and his definition of *dynamic*, that he is also referring to the latter. And when Hollnagel makes his own twist on the definition of safety as an event, not a non-event, it is to underscore the value of paying attention to things that go right – events – by looking at normal operations (where these events are so numerous). And here we are approaching a central question, one that ties the threads together and brings us right to the heart of the controversy: *Do HRO and RE see the same? Do they look for the same?*

When one speaks of invisibility, it is crucial to be precise about *invisibility for whom?* Vision and seeing refer to a cultural practice. Goodwin (1994) has demonstrated this through his elaboration of *professional vision*. And when Suchman (1995: 56) quotes Wellman and writes about invisible work that “How people work is one of the best kept secrets in America”, she articulates the observation that in organisations, work practices are often invisible to others than those who perform them. Managers and designers of instruments, for example, may not be well aware of the shape and rationale for situated practices. Those actually *performing* the work, be they Suchman's secretaries¹⁰ or the professionals on aircraft carriers portrayed in the HRO literature (Rochlin et al., 1987; Weick and Roberts, 1993), know very well what they are doing. And with respect to what researchers are aware of and see – including HRO and RE researchers – there is much wisdom in the simple phrase *what-you-look-for-is-what-you-find* (WYLFIFY) (Hollnagel, 2008b).

There is a large body of literature from different research traditions such as Workplace Studies (Goodwin, 1994; Goodwin and Goodwin, 1996; Heath and Luff, 1992; Star and Strauss, 1999; Suchman, 1993, 1996), Distributed Cognition (Hutchins, 1995a,b) and Science and Technology Studies (Latour, 1987; Law, 2000) that have specialised in understanding mundane work practices that usually do not grab the attention of many others than those performing them and those who address them in their research (see Engeström and Middleton, 1996 to understand how closely related these research strands really are to each other). What these

⁹ See also Haavik (2013: 7–8).

¹⁰ For those interested in etymology, *secretary* is indeed a telling label for work that is invisible for those who profit from it.

studies – in the following denoted *Work Studies* for short – have in common is that they provide insightful analyses of situated work and the adaptability and flexibility that characterise it, although this is not reflected in formal procedures, prescriptions or presentations of the same work and hence often goes unnoticed by others than those who perform it (Star and Strauss, 1999; Suchman, 1995). Many of these studies address high-risk environments (e.g. Heath and Luff, 1992 on London underground line control rooms; Hutchins, 1995b on aircraft pilots; Suchman, 1993 on airline ground operations), but still they have not been well incorporated into the classical body of safety science literature. Although we do not often come across these references reading the RE literature (but see for example Nemeth et al., 2004a; Woods and Hollnagel, 2006), the relationship in terms of orientation between Work Studies and RE – with its emphasis on *work as done* – seem obvious and strong, and it is pregnant with a potential to enrich both RE and safety science as a field. More explicit communication with Work Studies could perhaps provide a more solid foundation for RE, and at the same time add nuances to the contrast with HRO. While also HRO indeed has a substantial empirical and ethnographic tradition, of which the early studies of air traffic control and naval air operations at sea (La Porte and Consolini, 1991) serve as good examples, the glasses of HRO are more suitable for accounting for structural and formal aspects of organisations than the RE glasses – which are particularly suitable for capturing situated work. This can be explained by reference to the different academic fields that HRO and RE grew out of (see below).¹¹

What Sutcliffe and Weick call ‘non-events’, Hollnagel calls ‘events’. In Work Studies, these are referred to as – ‘work’! Sometimes we come across the term ‘articulation work’ – “work that gets things back ‘on track’ in the face of the unexpected, and modifies action to accommodate unanticipated contingencies” (Star and Strauss, 1999: 10) which is a particular kind of work that in HRO corresponds to preoccupation with failure, timely adjustments and reconfiguration, and in RE is addressed as phenomena labelled ‘adaptation’, ‘variability’ and ‘work as done’.

The cunning with the definition of safety as a dynamic non-event is that the references ‘dynamic’ and ‘non-event’, although forming a combination of an adjective and a noun that together make up the definition of safety, have different referents. While *dynamic* refers to the work processes (timely human adjustments), *non-event* refers to the outcome of those work processes (no accident). When Hollnagel turns the tables and alters the definition, he is *essentially* not doing much more than playing with words. But our pragmatic perspective helps us here, because we know how essentialistic definitions and differences may lead us astray from the main objective. Although the definition of safety as a dynamic event also strictly speaking refers to both process and outcome at the same time, reading this through RE lenses brings to mind RE’s preoccupation with the *work process*, such as the focus on variability, adaptations, resonance, efficiency-thoroughness trade-offs and the like, rather than the result. That is not to say that HRO is not preoccupied with variability and adaptation; they are. The work of Roe and Schulman emphasises the role of reliability professionals in making real-time decisions to adapt to variability in load and generation within the California electricity system (Roe and Schulman, 2008).¹² But again, there are different connotations to variability and adaptation in HRO and RE, and where HRO is normative, RE is not. Adaptations in HRO are closely (but not exclusively)

associated with error (see Pettersen and Schulman, 2019 for a more nuanced elaboration), and is linked to the *need* for an organisation to adjust itself under varying conditions. In RE there is little talk of error. In RE it is an empirical observation that variability occurs, that it is perceived as necessary by operators, and that simultaneous variability and adaptations in many different functions may lead to resonance – in other words they are phenomena that are fundamental elements in successful operations as well as adverse events. It is this symmetry that has been referred to when RE calls for studying normal operations – that is operations where the outcome is not given. HRO, on the other hand, is grounded in an asymmetric philosophy: Some organisations perform extraordinary well under extreme conditions, and we should learn what it is that they do to succeed and use this knowledge to build similar capacities in other organisations.

4. Applications of HRO and RE in health research

From their original empirical fields of enquiry, both HRO and RE have travelled into a wide range of empirical fields. The health field has experienced considerable interest among safety researchers in the later years. In keeping with our pragmatic approach, we shall review briefly how HRO and RE have implemented and developed their perspectives in this field. The aim is to demonstrate that HRO and RE do not in general provide contradictory answers to the question of how safety is achieved, but they produce and cultivate different (although overlapping) discourses of safety, and provide new knowledge within those discourses.

4.1. HRO

Health care organisations are not prominent in the earliest studies of HROs – possibly because no health care organisations were found to exhibit unambiguous high reliability characteristics (Roberts and Rousseau, 1989). From around year 2000, two waves of applied HRO research in the health sector seem to emerge in the literature. The first wave is mainly concerned with organisational design and structure, e.g. redundancy, decentralisation of decision authority, distribution of knowledge and capacity for spontaneous reconfiguration of the organisational structure (e.g. Carroll and Rudolph, 2006; Gaba, 2000; Madsen et al., 2006; Tamuz and Harrison, 2006). Authors in this tradition refer extensively to the classical empirical HRO studies performed by the Berkeley group. Gaba (2000) and Tamuz and Harrison (2006) also drew on Normal Accident Theory as a complementary perspective. These authors primarily used HRO theory as an analytic or diagnostic tool, to characterise health service organisations and the ways they deal with patient safety. However, their ultimate goal was to transform hospitals into HROs, or at least to approach some of the characteristics of HROs (Tamuz and Harrison, 2006: 1655). This strand of research also provided reflections on the dilemmas and challenges involved in transforming hospitals into HROs (Carroll and Rudolph, 2006; Madsen et al., 2006). For instance, Madsen et al. (2006) analysed a specific attempt at organisational redesign in a paediatric intensive care unit by broadening the decision authority of bedside nurses and at the same time increasing their competence. The mortality rates decreased during this redesign and the unit had extremely low turnover rates for nurses and therapists. However, it took vigilant efforts from the unit leaders to buffer this fragile new organisational design from the rest of the organisation, and in the end, the unit reverted to its previous *modus operandi*. Madsen et al. pointed out that the early HRO studies addressed organisations with “natural” buffers against outside pressures, such as aircraft carriers, nuclear submarines and nuclear power plants. It might take prolonged and vigilant efforts to build and maintain an HRO within a less protected environment.

¹¹ We do not mean to say that HRO accounts for formal aspects while RE accounts for informal, we point to the fact that different scientific disciplines have different perspectives and strengths, and that this influences what one looks for and what one sees. But of course, nobody keeps strictly within their own theoretical disciplines, so in practice these borders are blurry.

¹² See below for further discussion of Roe and Schulman’s study.

More recently, HRO research in the health sector turned increasingly towards cultural aspects of organisations (e.g. Sutcliffe, 2011; Vogus et al., 2010). Authors in this tradition frequently refer to the notion of ‘organisational mindfulness’ (Weick and Sutcliffe, 2001; Weick et al., 1999). A study by Pronovost et al. (2006), for instance, launched a comprehensive framework to improve culture in intensive care units. The framework includes several organisational levels, from top management to front-end staff. As the focus is on culture, the study is preoccupied with contextual factors that can exert lasting influences over organisational behaviour. It is also worth noting that this and other applications of HRO concepts are normative, as they aim at the identification and implementation of measurable reliability interventions. The ambition to identify “what works” is both an inheritance from the HRO tradition, but is also an approach with strong roots within evidence-based medicine. Methodologically, this ambition led to stronger reliance on quantitative and experimental approaches, in contrast to the qualitative and observational approaches that prevailed in the early HRO studies. However, Tolk et al. (2015) found that empirical research on high reliability cultures in health care was geared towards developing better survey instruments rather than developing interventions and tracking changes over time to understand if changing the organisational culture also changes organisational reliability.

This second wave of applied HRO research may be viewed as an adaptation to the organisational and economic constraints in the health sector. The sector is not protected from outside pressures and the scope for modifying structures or building extensive organisational redundancy may be limited. Accordingly, Vogus et al. (2010) emphasised the extent to which safety culture interventions may also lead to improved efficiency or faster implementation of new technologies. The second wave may also be seen as an approximation to the RE tradition. A symbolic token of this approximation is the contribution of Sutcliffe & Weick to the first anthology on *Resilient Health Care* (Hollnagel et al., 2013).

The impact of HRO in health care also includes organisational development. In 2009, the Joint Commission, a non-profit accreditation agency, launched the Joint Commission Center for Transforming Health Care. This initiative explicitly aimed at transforming health care into a high-reliability industry, and may have contributed to the second wave of applied HRO research in health care (Tolk et al., 2015).

4.2. RE

The attempts to transform health care organisations into HROs have been questioned by Nemeth and Cook (2007) and others with the argument that health care is characterised by high variability, diversity, partition between workers and managers, and production pressure – in other words that a hospital is not an aircraft carrier. Consequently, Nemeth and Cook advocated a focus on resilience rather than reliability.

Resilience is a term with many connotations, and resilience is also an important topic in the HRO literature.¹³ The elaborations on Safety I and Safety II in Hollnagel et al. (2015) and Hollnagel (2013) contribute to articulating central aspects of resilience and how it may be obtained through methodological reasoning. The advice to study *work as actually done*, through studying *everyday work*, and to focus on *things that go right*¹⁴ can be traced back to

the early days of RE (Hollnagel et al., 2006). Looking at recent publications on resilience in health care, the main ideas are still there, but vocabulary and theory have developed so that it is possible to approach the ideas from more angles and pursue them with different methods. Thus, RE has gained footing and relevance in health research and practice, reflected in two recent books on resilient health care (Hollnagel et al., 2013; Wears et al., 2015).

Many of the contributions of RE to health care can be characterised by a focus on everyday practices of practitioners, such as nurses and surgeons (Debono and Braithwaite, 2015; Nyssen and Blavier, 2013; Pariès et al., 2013). That does not mean, however, that RE focuses on individuals and not organisations. The lack of reference to organisational structure and organisational culture in the RE literature, and the presence in the HRO literature, may give the impression RE is little interested in *organisations*, while HRO takes organisations more seriously. This looks different, however, when considering Braithwaite and Plumb's (2015) way of writing about organisations. Inspired by actor-network theory they portray organisations as *networks*, leading attention primarily to *mundane actions*, and only subsidiary to *formal arrangements*. While this may be misunderstood as being more occupied with the lower levels of the organisation and less with the leadership level,¹⁵ Braithwaite and Plum are quite clear that this is not the case:

“The discrete surgeon, or anaesthetist or nurse, although important, is not the optimal focus of attention in safety studies. Resilience resides in and emerges from collective not individual activities.”

[Braithwaite and Plumb, 2015: 127]

Our reading of the insistence on studying work as done in health research does not point towards a stance in RE that formal structures are not important, but the view that

“[d]etailed studies using network approaches can uncover hidden social structures and unfolding practices which have more relevance for how work actually gets done than any policy, guideline, procedure or formal organisational chart.”

[Braithwaite and Plumb, 2015: 127]

In general, HRO and RE health research mirror some of the characteristic differences that we see in the broader field of safety research. While RE focuses on functional dependencies in local everyday work, and explore the opportunities of exploiting variability, HRO researchers are more sensitive to producing safety through building more lasting organisational cultures and structures. We also find a higher degree of normativity in HRO than in RE. While the former keeps adding to the list of desirable organisational characteristics and *modi operandi*, RE focuses more on understanding the trade-offs and adaptations necessary in everyday operations, and to organise for that. In that sense, HRO seems to support scaling and benchmarking more than RE does. Finally, we suggest that one way of thinking of the differences between, and strengths of, HRO and RE respectively is that HRO studies how organisations work, while RE studies how ‘work works’. They study the same empirical phenomena, but they represent different cultures of seeing – one particularly tuned for organisations and organisational constraints, and the other particularly tuned for sociotechnical systems, the same and different entities at the same time – they see and describe different kinds of events.

¹³ See Pettersen and Schulman (2019) for a thorough elaboration of different types of resilience.

¹⁴ This advice contains both the symmetry argument (study not only that which goes wrong, but also that which goes right), and the non-normative perspective (adaptation of procedures should not necessarily be seen as non-compliance).

¹⁵ This may be a reason why an important task in RE now seems to also be to work explicitly with the leadership level to ensure organisational acknowledgement of, arranging for and – importantly – limits to the normal variability of *work as done* (e.g. Grøtan et al., 2015).

5. Some themes of distinction

We have chosen to take the debate about dynamic non-events (Hollnagel, 2014; Hollnagel et al., 2013) – which can be considered as a proxy-debate about Safety I/Safety II – as a point of departure, to feed off that controversy and use it as an instrument for providing content and direction to the HRO-RE debate. This phenomenon – whether one chooses to call it non-event or event – is central to safety science, it is intangible and concrete at the same time, and it can be used as an entry point to understand some of the more fundamental differences between HRO and RE. In accordance with our pragmatic approach, we have followed HRO and RE into a field of practice, and we have argued that HRO and RE tend to see and describe different, but not necessarily contradictory kinds of events.

In the following, this content and direction will be presented as a series of themes growing out from the preceding elaboration of the controversy, and at the same time as pointers towards presumptively fruitful arenas for discussion, disagreements and cross-fertilisation between the different approaches.

5.1. Asymmetry and symmetry

RE has consistently argued for studying not only failure, but also successes. That has been based on the arguments that (1) the mechanisms behind successful operations are the same as the mechanisms behind failures, namely performance variability and resonance (*symmetry*) and (2) there are far more successes than failures, and hence far more empirical material to learn from by studying and learning from successes than limiting safety science to learning from and preventing things from going wrong. HRO is also associated with successful operations, but in a different manner. HRO's argument for studying successful operations, which was the rationale and the background for HRO, was rather one of *asymmetry*¹⁶: they set out to study what it is that these particularly safe organisations do that distinguishes them from less successful organisations. Based on these studies, the HRO group came up with organisational characteristics that are distinctive for safe organisations. However the highly reliable organisations themselves “pay more attention to failures than success” (Weick, 2011: 24). So the asymmetry is somewhat double. Thus, we may say that the RE community has been more occupied with the *nature of work* and *sociotechnical systems*, being perhaps a bit modest in establishing causal relations to outcomes, while the HRO community has been more occupied with the nature of *organisations*, and with linking organisational characteristics causally to outcomes.

5.2. The exceptional versus the generic

The early HRO research may be presented as the story of an intriguing discovery. The researchers found organisations capable of extremely reliable performance under demanding conditions. Their main contribution was to theorise and report the discovery of this rare species. The subsequent applied research sought to make ordinary organisations more like HROs, i.e. to build properties associated with HROs in order to approach the reliability performance of HROs. These efforts met with organisational constraints, as illustrated by the study of Madsen et al. (2006) discussed above. Consequently, HRO researchers have developed a

sensitivity to the differences between organisations and operations, recognising that different kinds of HROs use different means to achieve reliable performance (Schulman, 1993).

RE has been more generic in its ambitions and orientation. A broad range of industries were studied from the outset, without a clear preference for organisations or systems displaying exceptional degrees of reliability or resilience (e.g. Hollnagel et al., 2006). Particularly complex and dynamic systems have received special attention, not because of their performance, but because of the challenges they pose to operators, organisations and resilience engineers. Generalisability of results and concepts has not been a great issue, although Hale and Heijer (2006) have argued from an “outsider” position that some systems (e.g. railways) achieve excellent safety records by means other than resilience. An interesting exception is Nemeth and Cook's (2007) argument that health care should strive for resilience rather than high reliability due to the constraints facing the organisations.

This is another example of HRO and RE seeing different things due to their different perspectives. It is conceivable that this distinction may erode in the future if HRO research is assimilated into consulting work and subjected to standardisation and the constraints of mass production. We shall argue that this complementarity between HRO and RE illustrates that we need both perspectives.

5.3. Limiting versus embracing variability

A conspicuous feature of many HROs is the reluctance of operators to enter uncharted territory (Schulman, 1993). Operators make complex systems tractable by restricting the system to states that are familiar and have been thoroughly analysed. They achieve predictability and coordination by limiting process variability, for instance by adhering strictly to procedures.

Inspired by Ashby's (1956) law of requisite variety, RE proponents have repeatedly promoted the opposite strategy, i.e. to increase diversity and process variability in order to match variability in inputs, demands and constraints (e.g. Dekker, 2011). Sheps and Cardiff (2013) thus argued that a clear distinction needs to be made between quality and safety in health care because the two rely on opposite strategies, i.e. limitation of variability and exploitation of variability respectively.

We shall argue that the two approaches to variability are more complementary than they may seem at first sight, and that this complementarity could give rise to research that is highly relevant to dilemmas faced by practitioners navigating the difficult path between loss of control and loss of resilience.

5.4. Normative/non-normative

HRO is more normative than RE. This is natural, taking HRO's asymmetric approach into account; the HRO research tradition is built on an argument that particularly successful operations have particular characteristics, and that other organisations can obtain a better safety record by adopting the same characteristics,¹⁷ a process that require comparison, scaling and benchmarking. RE, on the other hand, is more occupied with functions and their variability, and how they in combination may cause unintended, intractable couplings and consequences. The measure of safety for HRO is thus similar to their point of departure – the safety track record or the non-event – while the measure of safety for RE is rather the understanding of the nature of events, understood as the ability to make

¹⁶ Symmetry and asymmetry in everyday language often have positive and negative connotations. It is important to note that in the current context, such connotations are *not* relevant. The symmetry argument has nothing to do with harmony, and the asymmetric approach is well grounded in valid methodology.

¹⁷ The list of characteristics is not closed, however, and HRO encourages scholars to continue investigating more organisations to expand the horizon of high reliability (Bourrier, 2011).

sense of intractable systems (e.g. through FRAM¹⁸) and to adapt in an adaptive universe (Woods, 2015).

5.5. Addressee

It is our impression that HRO and RE appeal to different levels within organisations.¹⁹ This is not surprising, since HRO as a research tradition came out of political science, public administration, organisation theory and business schools,²⁰ and was followed up by scholars with background in organisation theory and organisation behaviour, while RE came more from the engineering, human machine interaction and human factors side. RE researchers have been particularly interested in the difference between work as imagined (prescribed) and work as actually done (practice), and have approached this in a pragmatic manner – interested in the rationale for this difference rather than seeing it as complacency. Organisational structure and organisational culture are seldom mentioned in the RE literature, while in HRO these are seen as factors that affect the collective organisational achievements and that should be designed and shaped deliberately. Perhaps for these reasons, RE may appear more comprehensible and intuitive for the operating environment who are concerned with operations (events), while the managerial level are more familiar with the abstract indicators of work and the results of work, particularly non-events, and how these can be used to inform the conscious shaping of organisational structures and cultures.

5.6. Origin and orientation

The appeal to different organisations described above is reflected in different orientations towards academic journals²¹; while HRO research is often published in organisational journals, RE research often finds its way into journals more oriented towards human factors and technology. This is of course also associated with HRO's and RE's relation to different academic disciplines. Many scholars writing within the HRO school have backgrounds in political science and organisational psychology, and many of the classical works have been published in journals such as the *Journal of Contingencies and Crisis Management* (La Porte, 1994, 1996; La Porte and Rochlin, 1994; Weick, 2011), *Journal of Public Administration Research and Theory* (La Porte and Consolini, 1991), *California Management Review* (Weick, 1987), *Research in Organisational Behaviour* (Weick et al., 1999) and *Administrative Science Quarterly* (Weick, 1993; Weick and Roberts, 1993). In the case of RE, central contributors have backgrounds in industrial psychology, systems engineering and human factors, and examples of popular journals and conferences for central contributors within RE have been *Safety Science* (Hollnagel, 2008c; Woods, 2009), *Cognition, Technology and Work* (Dekker and Hollnagel, 2004; Henriqson et al., 2011; Hollnagel, 2012a), *Theoretical Issues in Ergonomics Science* (Woods and Dekker, 2000), *IEEE Transactions on Systems Man and Cybernetics* (Nemeth et al., 2004a,b).

Theory and model development within the different research strands must be understood in relation to the history of their origins, academic traditions and publication practices. HRO and RE are dealing with different views on safety. From Science and Technology Studies (Latour, 1987; Latour and Woolgar, 1986) we know that HRO and RE are also actors on a stage where survival and

dominance depend as much on the ability to produce far-reaching social networks²² and alliances as on doing the most thorough and persuasive empirical studies and presenting the best theoretical evidences.

6. Looking ahead – is there fertile ground for innovative research in the borderlands between HRO and RE?

The discussion of the relationship between HRO and RE highlights several aspects related to the foundations of safety science. One is the relationship between failure and success. RE proponents make a case for studying everyday operations, that is, situations where things mostly go right. There is, however, a possible problem of induction (Chalmers, 1978) inherent in this approach. If we set out to study normal operations, the study will need to have some sort of demarcation of what aspects of normal operations are considered to be relevant to safety. Such criteria may come from past experiences where things have gone wrong in the sense that operations have led to negative consequences. Thus, it may be asked whether the study of safety-related success requires some sort of knowledge about the possible ways it could have become a failure. Without having some notion about what can go wrong, it is hard to have a conceptualisation of right. The epistemological discussion of the relationship between success and failure is an important discussion regardless of which definition and theory of safety one subscribes to.

The difficulties in seeing success without having a reference of failure is further complicated by the fact that there are many ways of failing, each of which has a different set of contributing causes, which only partly overlap. That means that there are many ways of succeeding which have to combine elements relating to each of the failure scenarios. Success against one set of scenarios may still permit failure against others, as the Deepwater Horizon case shows, with the senior management present to celebrate the success against occupational accidents just before the disastrous blow-out. A similar mismatch between different forms of success was also described in Hale's (1989) comparison of Dutch railways' exemplary performance in passenger safety and their dire performance on safety of track maintenance personnel.

Another obvious approach that could be explored in the interface between HRO and RE, is the combination of in-depth studies of work with an understanding of the organisational settings in which this work takes place. It is an assumption of HRO research that some organisational arrangements are conducive to success, but this link is not sufficiently understood. For instance, in high risk industries, resilience and adaptation usually take place within a context of highly regulated and rule-based management. The term "resilience in context" (RICO) has previously been used by Grøtan (2014) to denote the way resilient practices take place within a managerial and organisational context. The interplay between static properties and dynamic adaptations is familiar terrain for both HRO and RE researchers, but there is a potential for addressing this domain more explicitly, emancipated from commitments to HRO and RE, but with sensitivity for controversies and an aim to explore these to bring forward new knowledge. In many ways, the concept of resilience is a linguistic boundary object that makes communication across domains possible. Exploring such boundary objects can be a way of making safety science more cumulative and integrated as a scientific community.

When theories meet practice, we should be careful thinking about the areas of the theories' validity; as Schulman (1993) also

¹⁸ Functional Resonance Analysis Method (Hollnagel, 2012b).

¹⁹ This is not necessarily HRO's and RE's intention, but more the response from the organisations themselves. However, Grøtan (2013) has argued that RE should put greater effort into addressing the management level.

²⁰ And physics (Gene Rochlin).

²¹ The co-existence at arm's length has been reflected also in the journal/conference proceedings; Safety Science is an exception and an example of a common dissemination arena.

²² Examples of such initiatives facilitating interaction and communication are the Resilient Health Care Initiative (<http://www.resilienthealthcare.net>) and the San Bernardino HRO group (<http://high-reliability.org/san-bernardino-group>).

pinpoints, sensitivity to differences between different kinds of organisations and systems – and different levels within those – is crucial in order to produce well-grounded analyses. Theoretical accurateness could be strengthened if analyses are more explicit in their references to the generic and the particular respectively, and we believe there is a potential for both HRO and RE to contribute to defining each other's areas of validity. This could also contribute to developing and refining the classification of types of organisations and systems that has not been much challenged since Perrow (1984) introduced the interaction/coupling chart. This issue also has important practical aspects. Under what conditions is it feasible to build an HRO? When does a system reach a degree of complexity or a kind of dynamics that cannot be handled by efforts to build resilience? Such issues are particularly important if companies look for HRO or RE principles as a means to reduce the costs of safety or to stretch the organisation's capacity to meet extreme demands for flexibility or efficiency.

It is important to underline that some researchers have already contributed to the borderlands between HRO and RE. Roe and Schulman's (2008) work on High reliability management is one example. On the one hand their study of the California electricity grid is placed within an HRO tradition in the sense that they try to find the properties that can explain high reliability in tightly coupled and highly interactive systems (electricity infrastructures). On the other hand their study is centred on the role of control room operators and the way these operators make continuous adaptations in real time. This means that they describe and compare their case to different HRO properties, while at the same time describing successful adaptation on a micro level. Their work is thus both on an organisational and operational level.

The exploration of the borderlands between HRO and RE calls for research that is more 'box-breaking' than 'boxed in' in the sense of being able to transcend or bridge narrowly defined areas of study (Alvesson and Sandberg, 2014). That includes continuing expanding the repertoire to fold new theoretical and methodological resources into the field of safety science. One example of such initiatives can be found in the attempts to contribute to existing safety discourses by drawing on Science and Technology Studies (e.g. Braithwaite and Plumb, 2015; Haavik, 2013, 2014a,b, 2016, 2017; Le Coze, 2013, 2019).

7. Conclusion

As previous research within science studies has shown (e.g. Latour, 1999; Latour and Woolgar, 1986), the intellectual work and social function of new concepts must be understood in terms of the functions they perform for the communities of science and research practice. Purely essentialistic analyses of theories, models, mechanisms and definitions tend to miss out many important aspects of scientific fields and the work these fields do. The intellectual and practical driving forces of HRO and RE are not solely their distinctive views on the ontology of safety, but also the context they grow out from, the theoretical and research-practical alliances they form and the research portfolio they produce. Hence, the difference between HRO and RE lies not so much in the answers they give as in the questions they ask.

There are no approaches in safety science that capture into one theory or one model everything that explains why and how failures and successes are achieved. Neither HRO nor RE has that ambition. The ambition should be that safety science manages to produce and maintain different perspectives that may contribute to the collective task of continuously increasing the knowledge of how organisations and sociotechnical systems work, and how they work safely. But organisations and sociotechnical systems change, and the world they exist within changes, so the knowledge will never be complete.

We have used a subtle discussion of dynamic non-events as a leverage to explore how the relation between HRO and RE can be made more visible. By treating the discussion as a controversy, and by feeding off the controversy instead of trying to overcome it by essentialistic means, we have elaborated on some themes that may be useful to understand how HRO and RE relate to each other in terms of symmetry, normativity, addressees and academic associations. We do not suggest that this description is exhaustive or superior to any other descriptions. It should rather be seen as a pragmatic effort to use different perspectives constructively. This description can also be read as a suggestion of a *method* – that of feeding off controversies – for obtaining the same, so that we can have a fruitful debate, co-existence and cross-fertilisation between HRO and RE, avoiding the deadlock of the NAT-HRO debate. This paper may also be read as an example of employing such a method, and demonstrating the concrete outcomes that this approach may produce; we have produced a critical elaboration of the definition of safety as a dynamic non-event, an elaboration of the distinction between Safety I and Safety II, and a nuancing of how we may understand and study successful operations. The important thing here is that it is the difference and the co-existence between HRO and RE that makes these discussions possible. Still, without discussion and controversies HRO and RE do not do a good job of making each other relevant. We therefore call for a more lively discussion on central themes of HRO and RE, not for fighting over definitions and proving who is right, but with the aim of producing knowledge that makes a difference regardless of theoretical stance.

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References

- Alvesson, M., Sandberg, J., 2014. Habitat and habitus: boxed-in versus box-breaking research. *Org. Stud.* 35, 967–987.
- Ashby, W.R., 1956. *An Introduction to Cybernetics*. Chapman & Hall, London.
- Bergström, J., van Winsen, R., Henriqson, E., 2015. On the rationale of resilience in the domain of safety: a literature review. *Reliab. Eng. Syst. Saf.* 141, 131–141.
- Bourrier, M., 2011. The legacy of the high reliability organization project. *J. Contingencies Crisis Manage.* 19, 9–13.
- Braithwaite, J., Plumb, J., 2015. Exposing hidden aspects of resilience and brittleness in everyday clinical practices using network theories. In: Wears, R.L., Hollnagel, E., Braithwaite, J. (Eds.), *Resilient Health Care, The Resilience of Everyday Clinical Work*, vol. 2. Ashgate, Farnham, pp. 115–128.
- Carroll, J., Rudolph, J., 2006. Design of high reliability organizations in health care. *Qual. Saf. Health Care* 15, i4–i9.
- Chalmers, A.F., 1978. *What Is This Thing Called Science?* Open University Press, Milton Keynes.
- Debono, D., Braithwaite, J., 2015. Workarounds in nursing practice in acute care: a case of a health care arms race? In: Wears, R.L., Hollnagel, E., Braithwaite, J. (Eds.), *Resilient Health Care, The Resilience of Everyday Clinical Work*, vol. 2. Ashgate, Farnham, pp. 23–38.
- Dekker, S., 2011. *Drift into Failure: From Hunting Broken Components to Understanding Complex Systems*. Ashgate, Farnham.
- Dekker, S., Hollnagel, E., 2004. Human factors and folk models. *Cogn. Technol. Work* 6, 79–86.
- Engeström, Y., Middleton, D., 1996. *Cognition and Communication at Work*. Cambridge University Press, Cambridge, UK.
- Gaba, D.M., 2000. Structural and organizational issues in patient safety: a comparison of health care to other high-hazard industries. *Calif. Manage. Rev.* 43, 83–102.
- Goodwin, C., 1994. Professional vision. *Am. Anthropol.* 96, 606–633.
- Goodwin, C., Goodwin, M.H., 1996. Seeing as a situated activity: formulating planes. In: Engeström, Y., Middleton, D. (Eds.), *Cognition and Communication at Work*. Cambridge University Press, Cambridge, pp. 61–95.
- Grøtan, T., 2014. Hunting high and low for resilience: sensitization from the contextual shadows of compliance, safety, reliability and risk analysis: beyond the horizon. In: *Proceedings of the European Safety and Reliability Conference, ESREL 2013*. CRC Press, Amsterdam, the Netherlands, p. 327.

- Grøtan, T.O., 2013. To rule, or not to rule is not the question (for organizing change towards resilience in an integrated world). In: The 5th Resilience Engineering Symposium, Soesterberg, Netherlands.
- Grøtan, T.O., van der Vorm, J., Macchi, L., 2015. Training for Operational Resilience Capabilities (TORC): 1st Concept Elaboration. SINTEF Technology and Society, Trondheim.
- Haavik, T.K., 2013. New Tools, Old Tasks: Safety Implications of New Technologies and Work Processes for Integrated Operations in the Petroleum Industry. Ashgate, Farnham, UK.
- Haavik, T.K., 2014a. On the ontology of safety. *Saf. Sci.* 67, 37–43.
- Haavik, T.K., 2014b. Sensework. *J. Comput. Support. Coop. Work* 23, 269–298.
- Haavik, T.K., 2016. Keep your coats on: augmented reality and sensework in surgery and surgical telemedicine. *Cogn. Technol. Work* 18, 175–191.
- Haavik, T.K., 2017. Remoteness and sensework in harsh environments. *Saf. Sci.* 95, 150–158.
- Hale, A., 1989. Safety of railway personnel: an outsider's view. In: Paper to the International Jubilee Congress of the Dutch Railways, 28–30 June, Amsterdam. Delft University of Technology: Safety Science Group.
- Hale, A., Heijer, T., 2006. Is resilience really necessary? The case of railways. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), *Resilience Engineering: Concepts and Precepts*. Ashgate, Aldershot, pp. 125–148.
- Heath, C., Luff, P., 1992. Collaboration and control: crisis management and multimedia technology in London Underground Line Control Rooms. *Comput. Support. Coop. Work* 1, 24–48.
- Henriqson, E., van Winsen, R., Saurin, T.A., Dekker, S.W., 2011. How a cockpit calculates its speeds and why errors while doing this are so hard to detect. *Cogn. Technol. Work* 13, 217–231.
- Hollnagel, E., 2004. Barriers and Accident Prevention. Ashgate, Aldershot.
- Hollnagel, E., 2008a. From protection to resilience: changing views on how to achieve safety. In: *Proceedings of the 8th International Symposium of the Australian Aviation Psychology Association*.
- Hollnagel, E., 2008b. Investigations as an impediment to learning. In: Hollnagel, E., Nemeth, C., Dekker, S. (Eds.), *Resilience Engineering Perspectives, Remaining Sensitive to the Possibility of Failure*, vol. 1. Ashgate, Farnham.
- Hollnagel, E., 2008c. Risk + barriers = safety? *Saf. Sci.* 46, 221–229.
- Hollnagel, E., 2009. The ETOO Principle: Efficiency-Thoroughness Trade-Off – Why Things That Go Right Sometimes Go Wrong. Ashgate, Aldershot, UK.
- Hollnagel, E., 2012a. Coping with complexity: past, present and future. *Cogn. Technol. Work* 14, 199–205.
- Hollnagel, E., 2012b. FRAM: The Functional Resonance Analysis Method: Modelling Complex Socio-Technical Systems. Ashgate, Farnham.
- Hollnagel, E., 2013. Making health care resilient: from safety-I to safety-II. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), *Resilient Health Care*. Ashgate, Farnham, pp. 3–17.
- Hollnagel, E., 2014. Safety-I and Safety-II: The Past and Future of Safety Management. Ashgate, Farnham, Surrey, England.
- Hollnagel, E., Braithwaite, J., Wears, R., 2013. *Resilient Health Care*. Ashgate, London.
- Hollnagel, E., Nemeth, C., Dekker, S., 2008. *Resilience Engineering Perspectives: Remaining Sensitive to the Possibility of Failure*. Ashgate, Aldershot, UK.
- Hollnagel, E., Périès, J., Woods, D.D., Wreathall, J., 2011. *Resilience Engineering in Practice: A Guidebook*. Ashgate, Farnham.
- Hollnagel, E., Wears, R., Braithwaite, J., 2015. From safety-I to safety-II: a white paper. Published simultaneously by the University of Southern Denmark, University of Florida, USA, and Macquarie University, Australia, The Resilient Health Care Net.
- Hollnagel, E., Woods, D.D., Leveson, N., 2006. *Resilience Engineering: Concepts and Precepts*. Ashgate, Aldershot, UK.
- Hopkins, A., 2001. Was Three Mile Island a 'Normal Accident'? *J. Contingencies Crisis Manage.* 9, 65–72.
- Hopkins, A., 2014. Issues in safety science. *Saf. Sci.* 67, 6–14.
- Hutchins, E., 1995a. *Cognition in the Wild*. MIT Press, Cambridge, MA.
- Hutchins, E., 1995b. How a cockpit remembers its speeds. *Cogn. Sci.* 19, 265–288.
- La Porte, T.R., 1994. A Strawman speaks up: comments on the limits of safety. *J. Contingencies Crisis Manage.* 2, 207–211.
- La Porte, T.R., 1996. High reliability organizations: unlikely, demanding and at risk. *J. Contingencies Crisis Manage.* 4, 60–71.
- La Porte, T.R., Consolini, P.M., 1991. Working in practice but not in theory: theoretical challenges of high reliability organizations. *J. Public Admin. Res. Theory* 1, 19–47.
- La Porte, T.R., Rochlin, G., 1994. A rejoinder to Perrow. *J. Contingencies Crisis Manage.* 2, 221–227.
- Latour, B., 1987. *Science in Action: How to Follow Scientists and Engineers through Society*. Open University Press, Milton Keynes, UK.
- Latour, B., 1999. *Pandora's Hope: Essays on the Reality of Science Studies*. Harvard University Press, Cambridge, MA.
- Latour, B., 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford University Press, Oxford, UK.
- Latour, B., Woolgar, S., 1986. *Laboratory Life: The Construction of Scientific Facts*, New ed. Princeton University Press, Princeton, NJ, USA.
- Law, J., 2000. *Ladbroke Grove, Or How to Think about Failing Systems*. Centre for Science Studies, Lancaster University, Lancaster.
- Le Coze, J.C., 2013. New models for new times. An anti-dualist move. *Saf. Sci.* 59, 200–218.
- Le Coze, J.C., 2019. Vive la diversité! High Reliability Organisation (HRO) and Resilience Engineering (RE). *Saf. Sci.* 117, 469–478.
- Leveson, N., Dulac, N., Marais, K., Carroll, J., 2009. Moving beyond normal accidents and high reliability organizations: a systems approach to safety in complex systems. *Org. Stud.* 30, 227–249.
- Madsen, P., Desai, V., Roberts, K., Wong, D., 2006. Mitigating hazards through continuing design: the birth and evolution of a pediatric intensive care unit. *Org. Sci.* 17, 239–248.
- Nemeth, C., Cook, R., 2007. Reliability versus resilience: what does healthcare need? In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. SAGE Publications, pp. 621–625.
- Nemeth, C., Hollnagel, E., Dekker, S., 2009. *Resilience Engineering Perspectives: Preparation and Restoration*. Ashgate, Aldershot, UK.
- Nemeth, C.P., Cook, R.L., O'Connor, M., Klock, P.A., 2004a. Using cognitive artifacts to understand distributed cognition. *IEEE Trans. Syst. Man Cybern. A: Syst. Hum.* 34, 726–735.
- Nemeth, C.P., Cook, R.L., Woods, D.D., 2004b. The messy details: insights from the study of technical work in healthcare. *IEEE Trans. Syst. Man Cybern. A: Syst. Hum.* 34, 689–692.
- Nyssen, A.-S., Blavier, A., 2013. Investigating expertise, flexibility and resilience in socio-technical environments: a case study in robotic surgery. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), *Resilient Health Care*. Ashgate, Farnham, pp. 77–96.
- Pariès, J., Lot, N., Rome, F., Tassaux, D., 2013. Resilience in intensive care units: the HUG case. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), *Resilient Health Care*. Ashgate, Farnham, pp. 77–96.
- Perrow, C., 1983. The organizational context of human factors engineering. *Adm. Sci. Q.* 521–541.
- Perrow, C., 1984. *Normal Accidents: Living With High-Risk Technologies*. Princeton University Press, Princeton, NJ.
- Pettersen, K.A., Schulman, P.R., 2019. Drift, adaptation, resilience and reliability: toward an empirical clarification. *Saf. Sci.* 117, 460–468.
- Pronovost, P.J., Berenholtz, S.M., Goeschel, C.A., Needham, D.M., Sexton, J.B., Thompson, D.A., Lubomski, L.H., Marsteller, J.A., Makary, M.A., Hunt, E., 2006. Creating high reliability in health care organizations. *Health Serv. Res.* 41, 1599–1617.
- Rijpmma, J.A., 1997. Complexity, tight-coupling and reliability: connecting normal accidents theory and high reliability theory. *J. Contingencies Crisis Manage.* 5, 15–23.
- Rijpmma, J.A., 2003. From deadlock to dead end: the normal accidents-high reliability debate revisited. *J. Contingencies Crisis Manage.* 11, 37–45.
- Roberts, K.H., Rousseau, D.M., 1989. Research in nearly failure-free, high-reliability organizations: having the bubble. *IEEE Trans. Eng. Manage.* 36, 132–139.
- Rochlin, G.L., La Porte, T.R., Roberts, K.H., 1987. The self-designing high-reliability organization: aircraft carrier flight operations at sea. *Naval War Coll. Rev.* 40, 76.
- Roe, E., Schulman, P.R., 2008. *High Reliability Management: Operating on the Edge*. Stanford University Press, Stanford, Calif.
- Rosness, R., Grøtan, T.O., Guttormsen, G., Herrera, I.A., Steiro, T., Størseth, F., Timmannsvik, R.K., Wæro, I., 2010. *Organisational Accidents and Resilient Organisations: Six Perspectives. Revision 2*. SINTEF Technology and Society, Trondheim.
- Sagan, S.D., 1993. *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons*. Princeton University Press, Princeton, NJ.
- Schulman, P.R., 1993. The analysis of high reliability organizations: a comparative framework. In: Roberts, K. (Ed.), *New Challenges to Understanding Organizations*. MacMillan, New York, pp. 33–54.
- Sheps, S., Cardiff, K., 2013. Looking at success versus looking at failure: Is quality safety? Is safety quality? In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), *Resilient Health Care*. Ashgate, Farnham, pp. 49–56.
- Snook, A., 2000. *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks Over Northern Iraq*. Princeton University Press, Princeton.
- Star, S.L., Strauss, A., 1999. Layers of silence, arenas of voice: the ecology of visible and invisible work. *Comput. Support. Coop. Work* 8, 9–30.
- Suchman, L., 1993. Centers of coordination: a case and some themes. In: Resnick, L. B. (Ed.), *Discourse, Tools, and Reasoning: Essays on Situated Cognition*. Springer, Berlin, pp. 41–62.
- Suchman, L., 1995. Making work visible. *Commun. ACM* 38, 56–64.
- Suchman, L., 1996. Supporting articulation work. In: Kling, R. (Ed.), *Computerization and Controversy: Value Conflicts and Social Choices*. Academic Press, San Diego, CA, USA, pp. 407–423.
- Sutcliffe, K.M., 2011. High reliability organizations (HROs). *Best Pract. Res. Clin. Anaesthesiol.* 25, 133–144.
- Sutcliffe, K.M., Weick, K.E., 2013. Mindful organizing and resilient health care. In: Hollnagel, E., Braithwaite, J., Wears, R. (Eds.), *Resilient Health Care*. Ashgate, London.
- Tamuz, M., Harrison, M.I., 2006. Improving patient safety in hospitals: contributions of high-reliability theory and normal accident theory. *Health Serv. Res.* 41, 1654–1676.
- Tolk, J.N., Cantu, J., Beruvides, M., 2015. High reliability organization research: a literature review for health care. *Eng. Manage. J.* 27, 218–237.
- Vogus, T.J., Sutcliffe, K.M., Weick, K.E., 2010. Doing no harm: enabling, enacting, and elaborating a culture of safety in health care. *Acad. Manage. Perspect.* 24, 60–77.
- Wears, R.L., Hollnagel, E., Braithwaite, J., 2015. *Resilient health care. The Resilience of Everyday Clinical Work*, vol. 2. Ashgate Publishing Ltd.
- Weick, K.E., 1987. Organizational culture as a source of high reliability. *Calif. Manage. Rev.* 29, 112–128.

- Weick, K.E., 1990. The vulnerable system: an analysis of the Tenerife air disaster. *J. Manage.* 16, 571–593.
- Weick, K.E., 1993. The collapse of sensemaking in organizations: The Mann Gulch disaster. *Adm. Sci. Q.* 38, 628–652.
- Weick, K.E., 2011. Organizing for transient reliability: the production of dynamic non-events. *J. Contingencies Crisis Manage.* 19, 21–27.
- Weick, K.E., Roberts, K.H., 1993. Collective mind in organizations: heedful interrelating on flight decks. *Adm. Sci. Q.* 38, 357–381.
- Weick, K.E., Sutcliffe, K.M., 2001. *Managing the Unexpected: Assuring High Performance in an Age of Complexity*. Jossey-Bass, San Francisco, CA, USA.
- Weick, K.E., Sutcliffe, K.M., 2007. *Managing the Unexpected: Resilient Performance in an Age of Uncertainty*. Jossey-Bass, San Francisco, CA, USA.
- Weick, K.E., Sutcliffe, K.M., Obstfeld, D., 1999. Organizing for high reliability: processes of collective mindfulness. *Res. Org. Behav.* 21, 81–123.
- Woods, D., 2003. *Creating Foresight: How Resilience Engineering Can Transform NASA's Approach to Risky Decision Making*. Institute for Ergonomics, The Ohio State University, Washington, DC.
- Woods, D., 2009. Escaping failures of foresight. *Saf. Sci.* 47, 498–501.
- Woods, D.D., 2015. Four concepts for resilience and the implications for the future of resilience engineering. *Reliab. Eng. Syst. Saf.* 141, 5–9.
- Woods, D., Dekker, S., 2000. Anticipating the effects of technological change: a new era of dynamics for human factors. *Theor. Issues Ergon. Sci.* 1, 272–282.
- Woods, D., Hollnagel, E., 2006. *Joint Cognitive Systems: Patterns in Cognitive Systems Engineering*. Taylor & Francis/CRC Press, Boca Raton, FL.