Can weak-resilience-signals (WRS) reveal obstacles compromising (rail-)system resilience?

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Abstract

Analysis of accidents in socio-technical systems frequently reveals unnoticed obstacles, which have grown to become the main cause of incubation and surprise at failure (Dekker, 2011). Thus far, it has proven to be a challenge to identify those unnoticed obstacles upfront among the tremendous number of events occurring during normal operations. In this article, we describe the usage of weak resilience signals (WRS) (Siegel & Schraagen, 2014), at a rail control post, to reveal obstacles compromising the resilience state of the system. Resilience is defined as the ability of a complex socio-technical system to cope with unexpected and unforeseen disruptions (Hollnagel, Woods, & Leveson, 2006). The WRSs, developed and presented around three system boundaries: safety, performance and workload, are used to stimulate a state of mindfulness (Weick & Sutcliffe, 2007) revealing unnoticed obstacles. An observational study is proposed to verify exposure of obstacles and their impact on rail-system resilience. The WRS and its stimulus to rail traffic controllers are expected to contribute to a higher rail operation reliability.

Introduction

Accident analyses of socio-technical systems expose unnoticed disturbances which are a component in the process towards failure (Hall, 2003; Stanton & Walker, 2011). These disturbances are either not observed or ignored throughout the complex process of the system. This is not surprising since many disturbances occur continuously and do not evolve into an accident. Some disturbances are identified with a potential to evolve into an accident, but are ignored due to the culture of the organization (Vaughan, 1997, 2002). Weick and Sutcliffe (2007) propose high-reliability-organization principles influencing the culture of organizations to deal with the unexpected. They introduce the term 'mindfulness', split into the phases anticipation and containment, to work out the principles. The three principles of anticipation are: 1) preoccupation with failure; 2) reluctance to simplify; and 3) sensitivity to operations. The two additional principles of containment are: 4) commitment to resilience; and 5) deference to expertise. In previous research, we have developed weak-resilience-signals (WRS) to identify disturbances to the resilience state of a rail-system (Siegel & Schraagen, 2014). The WRSs are signals around the boundaries: safety, performance and workload, on a high aggregation level needing further analysis to understand the root causes. We described a method

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to measure workload WRS and applied it at a rail control post. Analysis of the workload WRS identified has revealed a disturbance which we call an obstacle. The obstacle identified influenced the resilience of the system. Our analysis showed that the obstacle attracted resources and attention, which may influence the spare capacity needed when a disruption occurs. Although the WRS measurement has a clear methodology, the obstacle identification has not and was a result of ad hoc analysis. This was sufficient to quantify a WRS, since it proved the ability of a WRS to reveal an obstacle, but left a gap concerning the methodology of obstacle identification. The aim of this article is to fill this gap by describing a process to reveal obstacles systematically using WRSs as the carrier of mindfulness.

Process to reveal obstacles with help of WRSs

The first principle of Mindfulness, defined by Weick & Sutcliffe (2007) as "a rich awareness of discriminatory detail", is preoccupation with failure. They suggest four questions to deal with this principle which will cause "actively searching for weak signals that the system is acting in unexpected ways" (Weick & Sutcliffe, 2007, p. 151):

> 1) What needs to go wrong?; 2) What could go wrong?; 3) How could things go wrong?; 4) What things have gone wrong?

The focus is here on "wrong", occurring repetitively in all questions, while a central concept of resilience is the focus on what goes right (Hollnagel, 2009). We suggest to seek beyond failure to enrich Mindfulness using weak-resilience-signals (WRSs).

The Mindfulness phase of anticipation is suitable to enrich with signals to anticipate on like the WRS, while the containment phase is about the way of acting and has no direct relation with signals. Therefore, we only adjust the three Mindfulness principles of anticipation, marked with underlined text, to focus on the WRS and are phrased as follows:

1. Preoccupation with *WRS in addition to* failure;
2. Reluctance to simplify *WRS interpretations*;
3. Sensitivity to operations *by being aware of WRS*.

The *preoccupations with WRS, in addition to failure*, can be achieved through after-shift-review discussion of a rail traffic control team guided by questions they have to answer. The team has to go through a process of analysing the WRS based upon the activities occurring throughout its shift. For doing that, they need *sensitivity to the operation* and keep in mind operational facts to be used at the review. During the review they *should not simplify the reasoning* of the WRS but stimulate each other for deep reasoning and search for underlying reasons and conditions causing the WRS beyond their own responsibility. Once rail traffic controllers have understood these conditions, they have to discuss whether they can reoccur as an obstacle to interfere with future operations. Finally, they have to discuss how they can anticipate these obstacles.

A set of after-shift-review questions will help the team to direct its discussion:

- Which conditions have made the WRS possible? Search deep and beyond your responsibility.
- Are (some of) these conditions obstacles that may reoccur?
- Which actions can be taken, on different levels of the system, to anticipate these obstacles?

The first question causes the team to think in terms of conditions, rather than obstacles. They should not simplify these conditions on their relative small span of control, but search beyond the responsibility of the individual and the team. When understanding the conditions, they can progress to the second question dealing with potential reoccurrence. Reoccurrence is an important attribute of an obstacle in addition to the ability to respond to the occurrence. This ability is the core of the third question, dealing with anticipation. Different levels of the system can anticipate. Anticipation is possible on the level of the individual and the team. In this case, the team can agree on future actions to take. However, some anticipatory action can only be taken on higher levels, like the whole Post, the national control centre, the company or even on the national political level.

To illustrate the above, we will take a workload WRS identified by Siegel and Schraagen (2014). This workload WRS presents a situation of a rail controller being occupied during the morning shift by continuous ad hoc shunting activities, rating his workload the whole morning much above the standard low workload. The standard low workload enables him to peak and react adequately when an unexpected disturbance occurs. The continuous ad hoc shunting activities may undermine his ability to react appropriately. A discussion of the team about this workload WRS, with help of the above review questions, can result in the following. The team identifies the condition that small train companies using the rail infrastructure are having difficulties to manage their equipment and react on the spot without planning shunting movements ahead. This situation is reoccurring and can be seen as an obstacle, since it occupies the spare capacity needed during calamities, causing a reduction in resilience. Anticipation on this obstacle is possible on different levels. The individual rail controller can either request his counter party to plan his activities ahead or refuse accepting the shunting order. The team can reorganise its activities to unload the specific rail controller to manage its capacity. The Post, being the management unit of the teams, can add resources to the team to bring the workload to the standard level or approach the local management of the train companies to search for a solution. This obstacle can also be dealt with on a national level, which goes beyond the direct influence of the team, but could be addressed by the Post management.

The proposed process needs to be verified and prove its ability to expose obstacles, compromising system resilience. In the next section, we describe the design of an observational study at a rail control post to verify the process in a socio-technical rail-system.

Observational study design at a rail control post

The main effect to verify the proposed process is its influence on the resilience state of the system. Hollnagel (2009) states that resilience implies four essential system

capabilities, also called the four cornerstones of resilience: anticipating, responding, monitoring, and learning. The proposed process of using WRSs at after-shift-review s aims to improve 1) the *learning* of team performance throughout their shift and 2) the *anticipation* on the obstacles identified. In that sense, the verification should focus on learning and anticipation to prove the influence on the system resilience. However, this does not imply the resilience compromise of the obstacles identified. Analysis of scenarios describing the obstacle occurrence, with help of all four cornerstones with emphasis on *responding* and *monitoring*, can indicate the resilience impact of the obstacle itself. Another aspect to verify is the influence of the WRS itself on the whole process. In other words, what would be the result of conducting an after-shift-review of the events, without presenting the WRSs? We will address these aspects in the study design after describing the setting at the rail control post, where the observation takes place.

The setting is a rail control post responsible for an area with rail stations split up into two main rail corridors: south-north, called corridor North, and west-east, called corridor East. Each of the corridors has workstations for rail controllers working in three shifts operating the control post 24 hours a day. Corridor North has 4 workstations, corridor East has 3 workstations, and one workstation at the post is used only during calamities and can be added to each corridor. At the Post, approximately 70 rail controllers are authorized to work at one, more, or all of the workstations. During a trial period of one week, the morning shift of corridor East will conduct an after-shift-review discussion for an hour. The first half hour will concentrate on the occurrences of the day and the second half hour on WRSs as described in the previous section. Corridor North and the other shifts will not conduct an review. The review will be led by a team-leader, who is not a rail-controller, and observed by a researcher. The researcher will take notes on the discussion and focus on the difference in the two half hours and on the reasoning trace of the obstacles. After the review, the researcher will interview each team member of corridor East, and of corridor North and of the next shift of corridor East as reference.

The researchers will seek for evidence through interviews on the hypothesis that: 1) the resilience of the morning shift of corridor East grows and 2) the resilience has grown due to the review discussion on WRSs. The first hypothesis will be tested by: 1) an observed growth of learning and anticipation plans and 2) identification of obstacle scenarios influencing the four cornerstones. The findings will be corroborated through interviews with the target and reference teams. The second hypothesis will be tested through the difference between the first and second half hour of the review as well as with interviews with the different teams.

Summary and discussion

We combine in this article two theories, high-reliability-organisations and weak resilience signals (WRS). High-reliability-organisations underpin their qualities with the assumption that first, it is possible to identify and anticipate potential failure scenarios, and second, it is possible to spot errors when they occur and identify a timely and appropriate course of action in real time to avert catastrophic consequences (Lekka, 2011). Weak resilience signals originate by obstacles which

compromise system resilience but lack a systematic organisational process identifying the obstacles and ensuring the anticipation to prevent their incubation (Siegel & Schraagen, 2014). The two theories seem complementary, where the first concentrates on the organisation and its processes, the second focuses on visualization of cues, which have not been spotted or cannot be seen. However, evidence is needed that in reality they will strengthen each other. We proposed an observational study in a rail operations control room where high-reliability-organisation principles are using weak resilience signals. The study will verify and challenge the hypothesis that weak-resilience-signals can reveal obstacles compromising rail-system resilience. A positive outcome is expected to contribute to a higher rail operation reliability.

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