**Development of a framework for the analysis of weak signals within a healthcare environment**

This item was submitted to Loughborough University's Institutional Repository by the/an author.


**Additional Information:**

- This is a conference paper.

**Metadata Record:** [https://dspace.lboro.ac.uk/2134/32212](https://dspace.lboro.ac.uk/2134/32212)

**Version:** Accepted for publication

**Publisher:** © Association of Canadian Ergonomists (ACE)

**Rights:** This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at: [https://creativecommons.org/licenses/by-nc-nd/4.0/](https://creativecommons.org/licenses/by-nc-nd/4.0/)

Please cite the published version.
DEVELOPMENT OF A FRAMEWORK FOR THE ANALYSIS OF WEAK SIGNALS WITHIN A HEALTHCARE ENVIRONMENT

Eva-Maria Carman
E.Burford@lboro.ac.uk

Mike Fray
Patrick Waterson
Human Factors in Complex Systems Research Group, Loughborough Design School, Loughborough University, Loughborough, UK

KEYWORDS
Weak signals, Healthcare, Patient Safety, Safety-II

SUMMATIVE STATEMENT
Weak signals provide an opportunity for pro-activeness that can assist in improving safety. Through a review of literature and evaluated with three different case studies, this study proposed a framework for the analysis of weak signals in the healthcare environment.

INTRODUCTION
Due to the complexity of the system (Carayon & Friesdorf, 2006) and dual nature of safety in healthcare research, both the staff's and the patients', this field will benefit from adopting not only the traditional definition of safety, whereby the number of adverse events are as low as possible but also the more recently developed definition of Safety-II, whereby the ability to succeed under varying conditions is promoted (Hollnagel, 2014). To adjust performance to ensure success of the task anticipating, identifying and responding to signals indicating changes in the system is required (Hollnagel, 2014). Signals are sensed information regarding emerging events (Ansoff & Mcdonnell, 1990), and include indicators or cues from the environment (Rasmussen, 1983) which require interpretation and sense-making (Weick, 1995). The strength of these signals can vary resulting in different requirements regarding interpretation and abilities of sense-making. Often these signals are weak and resultanty vague in nature (Ansoff & Mcdonnell, 1990). They need to be actively sought out and created by processing interrelated existing events, prior knowledge and future expectations in order to understand the information they provide (Macrae, 2014a).

Weak signals may provide an opportunity to achieve pro-activeness and promote effective risk management, in that through the continuous identification and addressing of problems that threaten safety (Macrae, 2014b) unexpected events may be addressed in a more cost-effective and timely manner (Vogus & Sutcliffe, 2007). Despite accident reports increasingly stating signals which indicate missed opportunities were present prior to adverse events, research exploring weak signals and the role they may play in safety, especially in healthcare, is limited. The aim of this research was to develop a conceptual framework for the investigation of weak signals in the healthcare environment and to explore the framework elements in three different healthcare case studies using qualitative methods.

METHODOLOGY
Through a review of literature on weak signals from the field of human factors, strategic management theory, systems ergonomics, natural decision making theory as well as literature on safety, a list of possible theories and models was compiled and a preliminary framework was developed. The framework aimed to provide a structure for identifying sources of signals, an understanding of how signals are manifested in the work environment and a process for the classification of these signals.
An explorative qualitative method was adopted to investigate aspects relating to weak signals within the healthcare environment due to the fuzzy nature of weak signals. Three different case studies in healthcare were used to test and evaluate the framework. The three case studies included cases from patient handling, patient discharge from acute care to community-based care and the treatment of sepsis. The patient handling case study consisted of 2 focus groups, the patient discharge case study consisted of 348 incident reports, 1 ombudsman report, and data collected from 9 focus groups, and the sepsis case study consisted of 2 ombudsman reports and 99 survivor and tribute stories.

The same focus group method was applied for the patient handling and patient discharge case studies. The focus groups consisted of a 45-minute session and focused on investigating the signals present when tasks go wrong and how task failure could be prevented. The questions used to guide the discussion in the focus groups were developed based on the literature on Safety-II (Hollnagel, 2014). Examples of the questions asked included: “What could go wrong with this task?”, “How do you know the task is going wrong?”, and “When you know it is going wrong, how do you correct yourself?”. The discussions of the focus groups were recorded using two audio recorders and one researcher recording field notes. The focus groups were transcribed and together with the field notes, Ombudsman reports, survivor and tribute stories, and the incident reports, were analysed using thematic analysis using QSR International’s NVivo 10 qualitative data analysis software.

Sample Characteristics
For the patient handling case study, 2 focus groups with a total of 17 participants were conducted. The mean age of the participants was 50.29 years (±8.64). The mean total number of years involved in patient care across the focus groups was 28.00 years (±10.59). The current positions held by the participants included manual handling advisors or managers, manual handling area leads, one head of manual handling and one director manual handling consultant.

The data sources for the patient discharge case study consisted of 9 focus groups with a total of 53 participants, one Ombudsman report and 348 incident reports. The mean age of the participants in the focus groups was 40.89 years (±10.23). The mean total number of years involved in patient care across all nine focus groups was 15.50 years (±10.75). The current positions held by the participants in the focus groups included community, district and acute staff nurses, locality managers, physiotherapists and occupational therapists, discharge coordinators, ward managers, a hospital consultant and a team leader of a care home team. The report analysed was titled “A report of investigations into unsafe discharge from hospital” (2016) and included nine cases which illustrate problems with the discharge process. The incident reports analysed included all “Third Party Incidents” reported by adult integrated teams across three directorates in Nottinghamshire (UK) for the financial years 2014 – 2015 and 2015 – 2016.

The sepsis case study consisted of 99 survivor and tribute stories from the sepsis UK trust website and two Parliamentary and Health Service Ombudsman Reports. The 99 stories from the sepsis trust website analysed consisted of 55 survivor stories and 44 tribute stories. The reports analysed included the report “Time to act. Severe sepsis: Rapid diagnosis and treatment saves lives” (2013) and the report “An avoidable death of a three-year-old child from sepsis” (2014) which focused on one case. The “Time to Act” report was a clinical report that focused on ten cases in which the patients died of sepsis. The stories and reports analysed included cases that cover a wide age range from new-born babies to 90 years of age.
RESULTS
Framework
The preliminary framework drew upon research from numerous fields, including strategic management theory (Ansoff & Mcdonnell, 1990), systems ergonomics (Holden et al., 2013; Karsh et al., 2006), and the work on weak signals by Macrae (2014a), as well as the work on error by Reason (1991). The aim of the framework was to provide a structure for the analysis of weak signals in the context of the work, actions and events in the system in which they occur specific for the healthcare context and is depicted in Figure 1.

The work by Ansoff (1975) on weak signals in strategic management theory and the work by Macrae (2014a) on weak signals in aviation were used to provide the basic definition and premise for the conceptual framework. The left aspect of the framework included elements from the second version of the Systems Engineering Initiative for Patient Safety (SEIPS) model (Holden et al., 2013). The SEIPS 2.0 model was selected as it provides a framework for the analysis of processes and the relationship of various elements that occur in healthcare specifically (Carayon et al., 2006) and was selected to provide a structure for the identification of the sources of the signals. Furthermore, this model was selected as it provides a general multi-level model of a work system.

The forms of the signals have been described in the framework as either being internal or external. An external signal may also generate an internal signal, but the external source or signal that causes the experience of an internal signal may not always be present or known. The external signals include visual, haptic, verbal, auditory or olfactory cues. The internal signals include the experience of a “hunch”, “vibe” or a general sense of “something going wrong”. Signals can affect outcomes in that, as a result of fixation (Reason, 1991), no action may be taken or alternatively a recovery strategy is implemented which may either result in an appropriate or inappropriate outcome. By considering the source and type of information these signals provide, insight regarding the status of the system and areas of risk may be revealed (Macrae, 2014a).

Signals were identified in the three case studies and were grouped according to the elements in the sociotechnical work system, as described in the SEIPS 2.0 model, from
which they originated, the forms, either internal or external, and interpretation of the signals as well as the outcomes or actions that resulted due to these signals.

**Case Study 1 – Patient Handling**

From the two focus groups conducted with experts in patient handling, the signals that assisted in detecting that an error may occur were identified as originating from the work system elements of the “person(s)” and “tasks”. Examples of signals originating from “person(s)” included trained memory cues, individual checks, the patient’s physical state and feedback from the patient. Examples of signals originating from “task” in the system included heightened awareness due to an unfamiliar aspect or element of the task.

The forms or manifestations of the signals included either external (from the environment) or internal forms. The signals identified as internal consisted of trained memory cues, for example a rhyme to ensure all safety aspects of the task were completed, individual checks such as those developed through personal experience, being less task orientated and more situation aware, and questioning actions. The signals identified as external consisted of visual or sensory signals such as seeing or feeling that the brakes on the bed were not activated prior to the patient being transferred and feedback from the patient. In addition to these, participants also mentioned different sensory signals as well as feelings that could not be describe in more detail other than the experience of intuition. These forms included heightened awareness due to an unfamiliar aspect or element of the task, as well as visual or sensory signals.

**Case Study 2 – Patient Discharge**

The sources of the signals identified in the patient discharge case study included the following elements from the work system: “person(s)”, “tasks”, and “internal environment”. Examples of signals originating from “person(s)” in the system included the patient’s physical state and feedback from the patient and their family. Furthermore, the experience of the interaction with the patient’s family was also identified as a source. Examples of this included if the family was continuously contacting health services for support, as well as the behaviour of the families such as becoming intense or disengaged during interactions with community staff. Examples of signals originating from “tasks” included information contained in the patient documentation and key aspects of the patient history, for example the history regarding readmissions. Signals originating from the “internal environment” included the state of the patient’s home, which may indicate that the patient is not coping following the discharge from acute care.

The external forms of the signals included sensory signals such as visual, auditory and olfactory cues. Visual cues included the patient not looking well, auditory cues included feedback from the patient and their family, and olfactory cues that provided an indication that possibly the patient was not coping with tasks related to activities of daily living. The internal forms of signals included cognitive signals, for example, awareness of a patient’s history and current health status. An additional cognitive signal included a mismatch between the patient’s expected state and their actual state. Similarly, to the patient handling case study, the signal generated by an unfamiliar aspect or element of the task that results in heightened awareness was also found in this case study.

Specifically, from the results of the focus groups, participants felt that the identification of these signals is a necessary component of their current work as they felt their work requires them to adapt the patient’s treatment plan accordingly so that a readmission would not occur. The outcomes, as a result of identifying signals described in most of the cases analysed in this case study, included action in order to prevent the patient being readmitted to acute care.
Case Study 3 – Sepsis

The work system elements of the SEIPS 2.0 model identified as being sources for signals in this case study included “person(s)”, “tool” and “task” elements. The person-related source identified included signals originating from the patient. The signals originating from the patient included the physiological indicators of sepsis (e.g. fever, vomiting, fast and shallow respiratory rate, elevated heart rate, rash, pain), behaviour-related (e.g. unusual response to illness) as well as unusual general behaviour (e.g. agitation, loss of appetite, not their “usual” self). Additional patient-related signals identified included patient history (e.g. immunosuppressed), and a change in the patient’s condition or rapid unexpected deterioration the patients’ health. Tool and task elements that were a source of signals relating to sepsis included the paediatric early warning score and the blood tests that may indicate sepsis even if the patient appears more health than they are.

The interpretation of these signals manifested themselves as “hunches” or “feeling something was wrong” to different persons in the system, these included the patient themselves, family members of the patients suffering from sepsis and the staff members treating them. In some cases, the patient identified and interpreted these signals and these would have been most likely in the form of a cognitive cue, in that the symptoms and severity experienced were unusual and not fitting the expected preliminary suspected diagnosis. In the majority of cases, the family identified and interpreted these signals. These included external forms such as visual cues (e.g. patient looked very unwell) and internal forms such as cognitive indicators. An example of cognitive indicators included identifying that the patient’s behaviour was very different and unique to other instances where they had been ill and possible registering the subtle indicators such a change in the patient’s awareness, mental state (e.g. slurring words) and consciousness. An additional example of the family interpreting signals included questioning the diagnosis when made by medical staff as they felt that the patient’s symptoms and behaviours did not align with the proposed diagnosis. In the examples of signals identified by staff, sepsis was not always immediately recognized but the seriousness of the situation was, which resulted in prompting action.

The outcomes initiated, as a result of identified signals, included the signals being rationalised away, the signals being misinterpreted so no action was taken, and seeking medical assistance. In many of the examples analysed the physiological signs and indicators of sepsis were attributed to other potential causes and rationalised away, for example “I am sure it is just flu, since it is flu season”.

DISCUSSION AND CONCLUSION

Weak signals may aid in rendering a system more resilient by improving the ability to succeed under varying conditions (Hollnagel, 2014) as they provide insight regarding the status of the system and areas of risk (Macrae, 2014a). As a result, weak signals may also provide a means for effective risk management (Macrae, 2014a). By identifying where these signals originate from and understanding how weak signals are identified and interpreted, possible changes to work structure and management could be developed to encourage signal identification for promoting patient safety. By identifying and interpreting signals as they arise, one may be able to detect unexpected or negative events earlier, which then could be addressed in a more timely manner. In healthcare, this could result in significant benefits particularly with regards to patient health.

The proposed framework provided a structure for the investigation and understanding of how weak signals are experienced within the healthcare environment. In all three case studies, sources were identified where these signals may originate from. The more systems spanned in the case studies, the more elements of the work system produced signals. Examples of the forms of signals as well as the types of outcomes that occur once signals have been identified were identified and collated across the three case studies.
Though the framework provided a structure for the investigation of weak signals, it is currently undergoing further evaluation and expansion to include theories and models that best assist in understanding how weak signals within the healthcare environment are identified and interpreted. Possible theories that will be evaluated in relation to weak signal identification and interpretation include the signal detection theory (Green and Swets, 1966), the concepts of situation awareness (Endsley, 1995), sensemaking (Weick, 1995), naturalistic decision making (Zsambok & Klein, 1997), emotional attunement (Benner, Tanner, & Chesla, 1996) and the skill-rule-knowledge model of behaviour (Rasmussen, 1983).

The proposed framework provides a preliminary basis for the investigation of signals and may assist in the development of a possible tool and means to incorporate signals in promoting patient safety and task success. Further investigations are required to identify additional elements that aid in task success as well as the factors that promote or inhibit signal identification.

REFERENCES