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The investigation of weak signals for safety and to aid task success in healthcare

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The Investigation of Weak Signals for Safety and to Aid Task Success in Healthcare

by

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Doctoral Thesis

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Abstract

Due to the complexity of the healthcare system and the nature of healthcare work, the paradigms of resilience engineering, high reliability organisations and Safety-II can offer this setting novel means of improving safety by promoting proactive safety. These paradigms advocate and promote a system's ability to succeed under varying conditions. One means of adjusting performance to ensure success of a task, is anticipating, identifying and responding to weak signals indicating changes in the system. These signals may provide an opportunity for proactiveness and resilience by identifying problems that threaten safety and allow for a more efficient and timely response. Despite accident reports, including those on healthcare disasters, increasingly stating weak signals were present prior to adverse events, research exploring weak signals and the role they may play in safety, especially in healthcare, is limited. This research aimed to address the following research question: *What are the weak signals in healthcare that may identify that a task or process may not be completed successfully?*

To address this question, this research aimed to provide the theoretical basis and approach to guide research into weak signals that are present in healthcare work systems. By adopting a qualitative explorative approach, the forms and sources of weak signals in healthcare were established, the underlying detection and interpretation mechanism were explored, and the potential applications examined. This was achieved through addressing several objectives that spanned four case studies. The objectives included developing a definition, framework and analysis approach to guide weak signal research in different healthcare contexts; depicting the work systems for the different healthcare contexts in which weak signals were explored and identifying the practical implications and different elements of weak signals that may support improvement work in the healthcare environment.

The definition and preliminary framework were developed through the collation of relevant literature on weak signals and information processing and macro-cognition theories. Weak signals in this research were defined as 'information that provide an indication of upcoming or emerging events that may have significant implications, whereby the information provided is often imprecise, ambiguous and incomplete, which requires active identification and processing'. The purpose of the framework was to provide a structure for the identification and analysis of weak signals in the healthcare context. This framework was tested in a first case study on patient handling, that consisted of two focus groups with experts in patient

handling. Based on these results and additional literature the framework was further refined and expanded. The second and third case studies focused on testing and applying the framework to two different healthcare contexts, one a specific process and the other a syndrome-specific context.

Case Study 2 explored the work system and weak signals for the hospital discharge process for patients that still require additional healthcare input from community healthcare staff. This case study applied a mixed methods approach utilising five different data sources. These consisted of five observation sessions, three focus groups held with hospital staff involved in the discharge process, six focus groups and ten interviews held with community healthcare staff involved in the discharge process, as well as the analysis of 348 reported incidents and one Ombudsman report associated with the discharge process. This case study yielded a large number of weak signal examples (a total of 435), that could be categorised into 46 category types based on the source. This case study assisted in expanding the weak signals in healthcare framework to include key behavioural elements associated with the identification, interpretation and prediction mechanisms underlying weak signals.

Case Study 3 explored the work system and weak signals for the identification and treatment of sepsis, using the third version of the weak signals in healthcare framework. In this case study, two Ombudsman reports and a total of 99 survivor and tribute stories were analysed, to identify the examples, structural and behavioural elements of weak signals. A key addition to the framework as a result of this case study was 'rationalisations', that are indicative of underlying behavioural elements of the framework.

Case Study 4 explored the application of the fourth and final version of the weak signals in healthcare framework and analysis approach to a different healthcare theme. In this case study, the presence of weak signals in the organisational failings of the Mid Staffordshire NHS Foundation Trust were explored. This application analysed the independent and public inquiry reports to identify the precursory weak signals and their rationalizations that occurred during this event.

The main contributions of this research were a conceptual structure for the knowledge on weak signals, the means of applying this theory, as well as knowledge on weak signals that present in specific healthcare contexts. The framework has several key applications, namely, to provide a structured approach to investigating weak signals in healthcare and to support use of weak signals on an individual level, through other system applications and for design of intervention or improvement projects.

Statement of Originality

The author (Eva-Maria Carman) is solely responsible for the work submitted in this thesis.

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This statement certifies that neither the submission nor the original work contained therein has been submitted for an award of this or any other degree awarding body.

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Publications

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Conference Publications

- Burford, E.-M., Fray, M., and Waterson, P. (2016). Unpacking Safety-II in action: Weak Signals of Potential Error in Patient Handling Tasks. In P. Waterson, R. Sims, & E.-M. Hubbard (Eds.). Contemporary Ergonomics and Human Factors 2016, Proceedings to the Conference on Ergonomics & Human Factors 2016. Daventry, UK, 19 – 21 April 2016. CIEHF, UK (p. 140–145).
- Burford, E-M., Fray, M., and Waterson, P. (2016). Stopping incidents in their tracks: Identifying weak signals for error prevention in healthcare. In the Proceedings of the Conference Healthcare Systems Ergonomics and Patient Safety: Healthcare and Society: new challenges, new opportunities, HEPS 2016. Toulouse, France, 5 - 7 October 2016. (p.61 – 167).
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- Carman, E., Fray, M., and Waterson, P. (2017). Weak Signals in Healthcare: A Case Study on Community-Based Patient Discharge. Doctorial Consortium of the 13th International Conference on Naturalistic Decision Making, Bath, UK, 19 June 2017 (p. 314 – 321).
- Carman, E., Fray, M., and Waterson, P. (2017). Sepsis: A Work Systems Analysis of 30 Survivor and Tribute Stories. The 12th International Symposium on Human Factors in Organizational Design and Management, Banff, Canada, 31 July – 4 August 2017 (p. 102 – 108).
- Carman, E., Fray, M., and Waterson, P. (2017). Development of a Framework for the Analysis of Weak Signals within a Healthcare Environment. The 12th International

Symposium on Human Factors in Organizational Design and Management, Banff, Canada, 31 July – 4 August 2017 (p. 265 – 271).

- Carman, E.-M., Fray, M., & Waterson, P. (2018). Weak Signals in Healthcare: The Case Study of the Mid-Staffordshire NHS Foundation Trust. Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018), Florence, Italy, 26 – 30 August 2018 (p. 691–700).

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- Carman, E., Fray, M., and Waterson, P. 2017. *Weak Signals in Healthcare: A Case study on Community-Based Patient Discharge.* Poster session at the 13th International conference on Naturalistic Decision Making, Bath, UK, 19 June 2017.
- Wooldridge, A. R., Hoonakker, P., Gurses A. P., Carman, E., Waterson, P. and Sesto, M. 2017. *Panel: Designing and Managing Healthcare Transitions.* The 12th International Symposium on Human Factors in Organizational Design and Management, Banff, Canada, 31 July – 4 August 2017. (p. 538 – 542).
- Carman, E., Fray, M., and Waterson, P. 2018. *Safety-II in Healthcare: A systems analysis of sepsis survivor and tribute stories.* International Workshop on Safety-II in Practice, Cardiff, UK, 14 – 15 June 2018.

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Presentations for the NHS

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Abbreviations

A&E	Accident and emergency department
CARE	Concepts of Applying Resilience Engineering
ED	Emergency Department
GP	General practitioner
HCC	Health Care Commision
HFE	Human Factors and Ergonomics
HEPS	Healthcare Systems Ergonomics and Patient Safety
HRO	High Reliability Organisations
IOM	Institute of Medicine
IV	Intravenous
LASCAD	London Ambulance Service Computer-Aided Dispatch
NDM	Naturalistic Decision Making
NEWS	National Early Warning Score
NCEPOD	National Confidential Enquiry into Patient Outcome and Death
QI	Quality Improvement
SIRS	Systematic Inflammatory Response Syndrome
SRK model	Skill-Rule-Knowledge model
SSC	Surviving Sepsis Campaign

Chapter 1: Introduction

1.1 Background

1.1.1 The Relevance and Importance of Patient Safety

Healthcare has a mandate to do no harm, but increasing evidence shows that harm frequently occurs during healthcare delivery (Vogus, Sutcliffe, & Weick, 2010). In comparison to other high-risk environments, both the probability and consequence of adverse events in healthcare is relatively large (Hofoss & Deilkås, 2008). As a result, healthcare can be considered a high-risk environment in terms of safety (Bagnara, Parlangeli, & Tartaglia, 2010; Colla, Bracken, Kinney, & Weeks, 2005). Until about 2000, the prevalence of patient safety incidents was under-recognised, and the concept was under-researched (Donaldson, 2002). In 2000, two milestone reports, one from the United Kingdom ('*An Organisation with a Memory*') and one from the USA ('*To Err is Human: Building a Safer Health System*'), highlighted the prevalence of patient safety incidents and the need for change (Donaldson, 2002).

The Institute of Medicine's (IOM) report '*To Err is Human: Building a Safer Health System*' (Kohn, Corrigan, & Donaldson, 2000) raised awareness regarding medical errors and patient safety not only in the USA but also internationally (Yoder-Wise, 2013). A key finding in this report was that medical errors occurred more frequently than researchers had initially thought; moreover, most were preventable and systemic in nature (Kohn et al., 2000; Yoder-Wise, 2013). Addressing the concerns highlighted in the report, the IOM released a subsequent report in 2001, '*Crossing the Quality Chasm: A New Health System for the 21st Century*' (Institute of Medicine Committee on Quality of Health Care in America, 2001), which proposed four specific strategies to improve healthcare systems (Mahn-DiNicola, 2004). The strategies targeted different levels, including patient experiences; caregiving microsystems; organisations that house and support caregiving microsystems; and legal, financial and educational environments (Berwick, 2002). Furthermore, the report proposed that instead of representing an individual responsibility, safety should preferably be considered a system property (Berwick, 2002). The initial IOM report (Kohn et al., 2000) set out the aim of a 50 per cent reduction in errors within 5 years, but as of 2016, this goal had not yet been achieved (Palatnik, 2016). To date, the overall impact of patient safety strategies has been

underwhelming (Chassin & Loeb, 2013; Leveson, Samost, Dekker, Finkelstein, & Raman, 2016). This suggests that despite the availability of strategies designed to improve patient safety, this undertaking is far more complicated than initially thought.

The report published in the United Kingdom in 2000, titled '*An Organisation with a Memory*' (Department of Health, 2000), described similar results. This document highlighted the scale, nature and cost of serious failures within the NHS, revealing that even though the reported numbers of adverse events that cause harm to patients were not a comprehensive representation, these have been estimated in excess of 850,000 a year (Department of Health, 2000). The authors of this report urged that the response after an incident, which by tradition has aimed to identify those who should be blamed, must shift to address wider causes (Department of Health, 2000).

These reports have fuelled researchers' increasing focus on improving patient safety (Kohn et al., 2000) and have underscored the need to consider deeper systemic factors affecting patient safety (Department of Health, 2000). Despite copious research regarding medical incidents (Vincent, 2011) and the rapid growth of the patient safety research field (Hofoss & Deilkås, 2008), the topic remains both current and relevant (Dhillon, 2012). Thus, applying a systems approach as well as current concepts driving safety improvements from other areas appears essential to address patient safety effectively. For example, human factors and ergonomics (HFE), a field that adopts a systems approach to improving work design and safety (Buckle, Clarkson, Coleman, Ward, & Anderson, 2006; Carayon, 2012a; Dul et al., 2012), provides numerous theories and methods suitable for healthcare and may assist in enhancing patient safety (Berguer, 1999; Gurses & Carayon, 2009).

1.1.2 Improvement Work in Healthcare

Quality improvement (QI) is the most readily applied approach to achieving improvements to healthcare processes (Hignett et al., 2015). According to Øvretveit (2009), QI can be defined as 'better patient experience and outcomes achieved through changing provider behaviour and organisation through using a systematic change method and strategies' (p. 8). As this is an approach that healthcare has followed over the past 30 years (The Health Foundation, 2013), many healthcare organisations have QI departments or teams (Cantiello, Kitsantas,

Moncada, & Abdul, 2016), in comparison to the small number of HFE teams within healthcare organisations. In light of literature showing the necessity of considering additional factors relating to behavioural aspects of management, communication and teamwork in order for QI efforts to be successful and to achieve greater organisational performance (Abdullah, Uli, & Tarí, 2009), HFE appears as a promising ally in the endeavour to promote patient safety. Although healthcare practices have integrated QI over the past few decades (Cantiello et al., 2016), researchers have only recently begun to demonstrate that understanding and including HFE and safety science are essential to improve patient safety (Palatnik, 2016).

As a multidisciplinary science, HFE draws upon numerous sciences, including but not limited to engineering, psychology, organisational management, anatomy, physiology, biomechanics, anthropometry and design (Hignett et al., 2015). Although theoretically based, this field's key emphasis is on practical implications (Vincent, Moorthy, Sarker, Chang, & Darzi, 2004). Hence, HFE can contribute to the design and implementation of useful care models, information technologies, systems and workplaces in healthcare (Carayon, 2012b) as well as offer theory and practical solutions for patient safety (Waterson & Catchpole, 2016). Furthermore, as it draws upon a broad base of different disciplines, HFE offers the necessary knowledge to analyse and understand workload and risk factors that affect safety and performance in the healthcare environment (Berguer, 1999; Buckle et al., 2006; Gurses & Carayon, 2009). This theoretical basis assists with understanding the human mechanisms involved in error, behaviour and performance and the effect of system characteristics on these mechanisms (Carayon, 2012b; Vincent, Taylor-Adams, & Stanhope, 1998). HFE also provides the theoretical basis and methods for applying a systems approach to the analysis and design of safer healthcare systems (Berguer, 1999; Buckle et al., 2006; Carayon, 2012a; Gurses & Carayon, 2009; Vincent et al., 1998).

1.2 Research Purpose and Problem

The executive summary of the IOM report '*To Err is Human: Building a Safer Health Syste*m' includes the following quote: 'It may be part of human nature to err, but it is also part of *human nature to create solutions, find better alternatives an*d meet the challenges ahead' (Kohn et al., 2000, p. 15). In a world where increased automation and enhanced technology

are seen as strengths and means for improving safety, personally, I find this quote highlights some of the reasons that healthcare staff are an asset and unique irreplaceable component that contributes to safety in the healthcare. Most of the work in healthcare, either directly or indirectly, relates to patient care (Carayon & Friesdorf, 2006; Hignett, 2001). As a result, work in this sociotechnical system can be complex and carry a large degree of uncertainty (Carayon & Friesdorf, 2006; Carayon & Wood, 2010), especially as every patient case can be unique. Furthermore, work providing patient care involves a high degree of intimacy and requires sensitivity (Dixon-Woods, Yeung, & Bosk, 2011). Even though the staff's efforts constitute their work, on the other end of the interaction is the patient, for whom the situation can have life-altering implications. Consequently, the above quotation describes attributes that can make a world of difference for the patient.

A recent personal experience during my PhD forcibly called my attention to the uncertainty surrounding some medical conditions, the lack of prescriptive ways to address them and the use of weak signals. Moreover, being in the system and requiring treatment gave me the opportunity to observe some of the challenges created by work or treatment spanning several subsystems within the healthcare system that staff and patients then experience as challenges. My situation entailed a large degree of uncertainty regarding the condition, bringing home to me that in some contexts the presentation can be unique in every patient, and treatment, in this context, is predominantly based on expert opinion. Thus, I found that the medical teams' responses and decisions, despite a large degree of uncertainty regarding my case, made all the difference, not only to the care I received but, ultimately, my recovery. To my good fortune, my medical team had the positive attributes the above quote describes.

Patient safety offers a key challenge in this work system, especially due to the nature and embedded risks of modern healthcare systems (Gopher & Donchin, 2012). Current concepts driving safety improvement all focus on promoting proactive safety. As highlighted in the above quote, and advocated by the Safety-II perspective, the human role should be considered as an asset, a necessary resource that provides flexibility and resilience (Hollnagel, 2014) along with an adaptive capacity that allows the system to respond (Braithwaite, Clay-Williams, Nugus, & Plumb, 2013). This concept is particularly relevant for healthcare due to

the nature of the work in the system. However, specific methods and means for achieving proactive safety remain elusive.

To achieve a proactive approach to safety, the current concepts driving safety improvements (Lekka, 2011; Rankin, Lundberg, Woltjer, Rollenhagen, & Hollnagel, 2013) suggest one needs an awareness of the current status of the system and address problems as they arise. A potential means of achieving proactive safety involves the use of weak signals, that provide an indication of the system status and therefore provide an opportunity to address problems as they arise. Weak signals can be defined as information that provide an indication of upcoming or emerging events that may have significant implications, whereby the information provided is often imprecise, ambiguous and incomplete, which requires active identification and processing[1]. However, the knowledge on weak signals is largely distributed across numerous fields and an integrated conceptual representation of weak signals is still to be established. This may be one reason why the application of weak signals to enhance task performance and system safety is still underdeveloped. The purpose of this research was to investigate weak signals that may contribute to achieving proactive safety as well as potentially aiding with task success.

1.3 Research Question, Aim and Objectives

To address the research problem described in the previous section, the research question posed in this thesis was:

What are the weak signals in healthcare that may identify that a task or process may not be completed successfully?

The aim of this thesis is to provide the theoretical basis and approach to guide research into weak signals that present in healthcare work systems. This aim can be broken down into two sub-aims. Firstly namely, to explore the system context from which weak signals emerge, and secondly develop a theoretical framework to investigate weak signals in healthcare. It is

[1] This definition was generated as part of this research and the development of this definition is described in Chapter 3 (p. 71).

essential to explore the context from which weak signals may emerge, as weak signals both need to be extracted from the context, emerge as a result of the context and may provide information about the context. Detection, recognition and interpretation of weak signals and what counts as a weak signal frequently depends on the context and the individual 'lens' through which weak signals are seen (Jørgensen, 2012). To achieve these two sub-aims, this research intends to address the following objectives:

1. Identify the key weak signal elements and develop a definition of weak signals for the healthcare context to be operationalised in the different healthcare case studies based on a review of literature on weak signals from a variety of different fields. (Chapter 3)
2. Develop and test a framework of the key elements of weak signals for different healthcare contexts that function at different system levels, including at a micro (i.e. task), meso (i.e. process) and macro (i.e. organisational) level. This includes highlighting and depicting the work system elements from which weak signals emerge for the different healthcare contexts. (Chapters 5-8)
3. Develop an analysis approach and compile recommendations for the application of the weak signals in healthcare framework to different healthcare contexts. (Chapters 6-9)
4. Identify how the different elements of weak signals in general may support improvement work in the healthcare environment. (Chapter 9)

1.4 Research Approach and Design

Based on the philosophy of pragmatism, a case study strategy was applied using both qualitative and mixed methods to answer the research question and achieve the aims and objectives. An exploratory qualitative research design was adopted spanning four case studies that occurred sequentially. Figure 1 illustrates the research design.

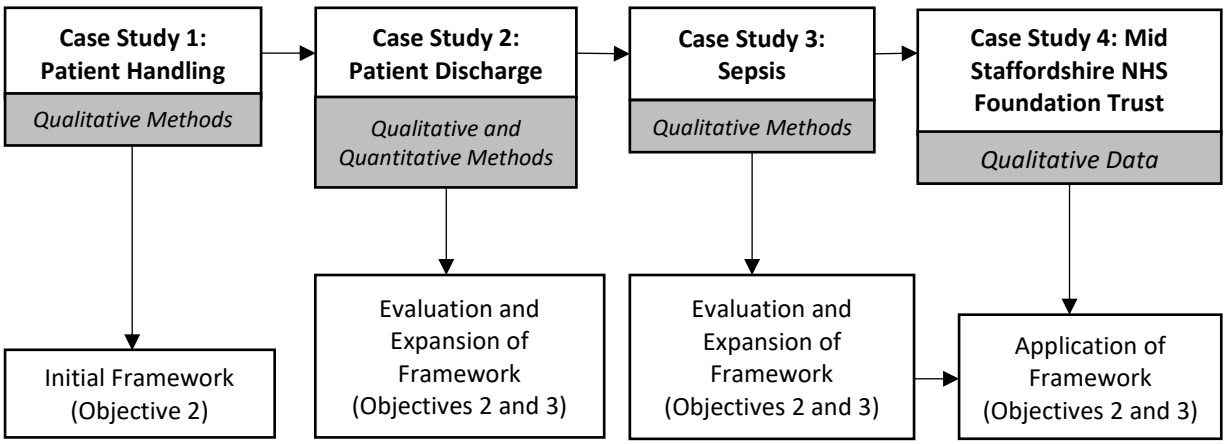


Figure 1: The exploratory sequential multiphase design adopted in this research to address the research objectives.

An initial framework was generated from a synthesis of literature on weak signals, in Chapter 3. The framework was then applied to four explorative and descriptive case studies, that featured different healthcare themes (Chapters 5 to 8). Case Study 1 examined weak signals in patient handling, Case Studies 2 evaluated weak signals in the context of patient discharge from hospital care to community care, and Case Study 3 scrutinised weak signals in the care processes relating to sepsis. Case Study 4 applied the final version of the framework to a different context from those used to develop it and investigated the presence of weak signals in an example of a healthcare organizational failure, namely the failings at the Mid Staffordshire NHS Foundation Trust.

1.5 Outcomes and Contributions of this Research

The key outcomes of this research included generating a conceptual structure for the knowledge on weak signals, the means of applying this theory through the development of the weak signals in healthcare framework and analysis approach, as well as contributing to the knowledge on weak signals that present in the healthcare context. The conceptual structure for the knowledge on weak signals and the contribution to weak signal knowledge obtained in this research can be summarised through five key questions on weak signals the results from this research can answer. The five key questions included: what are weak signals;

why are they weak; why are they important; why is understanding them important; and how might we start to understand them and operationalise them?

At the time this research was conducted, there was no clear compilation nor structure for the theoretical concepts associated with weak signals in healthcare. Furthermore, guidance on how to explore weak signals in healthcare with the aim to work towards operationalising them was limited, with weak signals having been only explored in a limited number of specific healthcare contexts. The work presented in this thesis addresses both of these deficits. The key contributions of this work are not only examples and an understanding of weak signal use in specific healthcare contexts, but more importantly a conceptual structure for the knowledge on weak signals and a means of applying this theory through the weak signals in healthcare framework and analysis approach.

1.6 Structure of the Thesis

This thesis contains ten chapters, with an overview of the thesis structure, contribution and content of each chapter described in Table 1. Chapter 1 includes the research problem, aim, approach and thesis structure. Chapter 2 provides a general review of the literature regarding the healthcare work system, why a systems approach is needed and an overview of safety theory and current concepts driving safety improvement. Chapter 3 provides a more focused literature review on weak signals and proposes the initial framework for the analysis of weak signals in healthcare that is to be applied, evaluated and expanded in the case studies presented in Chapters 5 to 7. Chapter 4 provides the methodology for this research as a whole to highlight how the different case studies were to come together to address the research topic. The individual case study chapters (Chapters 5 to 8) include a method section specific for each of the case studies. Each case study also includes a brief review of the literature to provide the context for that case study and a discussion of the results relevant for that specific case study. Chapter 8 applies the final version of the framework to explore the presence of weak signals in the failings surrounding the Mid-Staffordshire NHS Foundation Trust disaster. Chapter 9 provides a synthesis of findings of the case studies, a discussion of the common themes across the case studies and the practical implications of this research. The method and approach applied in this research are also evaluated, including a discussion of the

strengths and limitations. Finally, the overall conclusions, the contribution of this work to knowledge and future work are presented in Chapter 10.

Table 1: The thesis structure, contribution, and content of each chapter.

Contribution	Chapter	Content
Background and Underlying Methodology	**Chapter 1:** Introduction	The research problem, aim, approach and thesis structure are stated.
	Chapter 2: Literature Review – Setting the Scene	The general context for the research is provided and identifies how weak signals fit into the wider safety literature.
	Chapter 3: Focused Literature Review – Weak Signals	A synthesis of the available literature on weak signals that is relevant from a HFE perspective is described. An initial framework on investigating weak signals in healthcare is proposed.
	Chapter 4: Methodology	The underlying philosophy, research question, aims and objectives, the theoretical basis and research design used to address the research questions posed is described.
Data Collection, Analysis and Individual Case Study Discussion	**Chapter 5:** Case Study 1 – Patient Handling	The framework (Version 1) is applied in a case study on patient handling. At the end of the chapter, a second version of the framework is proposed.
	Chapter 6: Case Study 2 – The Discharge Process: From Hospital to Community-based Care	The framework (Version 2) is tested in the context of patient discharge from hospital to community-based care. In the discussion, a third version of the framework is proposed. An analysis approach to support the framework is developed and tested in this chapter.
	Chapter 7: Case Study 3 – A Systems Perspective of Sepsis Cases	The framework (Version 3) and analysis approach is applied in the context of healthcare work associated with the treatment of sepsis. At the end of the chapter, the analysis approach is refined and a final version of the framework (Version 4) is proposed.
	Chapter 8: Case Study 4 – Mid Staffordshire NHS Foundation Trust Disaster	The presence of weak signals in the failings surrounding the Mid-Staffordshire NHS Foundation Trust disaster are explored using the framework (Version 4) and analysis approach.
Discussion and Reflection	**Chapter 9:** Final Synthesis and Discussion	This chapter provides a cross-case study discussion, discussion of the practical implications of this research and a reflection of the applied research approach.
	Chapter 10: Conclusion and Future Work	This chapter provides a summary of the research approach and key findings, as well as the knowledge contribution and suggestions for future work.

Chapter 2: Literature Review – Setting the Scene

This chapter provides an overview of the literature that describes the broad context with regards to the domain (i.e. healthcare) and the field, namely safety, wherein this research is positioned and the basis for the methodological decisions made in Chapter 4. As the four case studies included in this research focused on different areas in healthcare, this chapter aims to provide the common theoretical basis that underlies all the case studies in this thesis. The focus of the literature review in this chapter was breadth before depth; consequently, not all contrasting views are presented here as they lie beyond the scope of this thesis. Furthermore, this chapter aims to position weak signals relative to the main paradigms associated within the safety literature. A more in-depth literature review on weak signals has been included in the next chapter (Chapter 3) and the subsequent case study chapters provide more in-depth literature for each of the different healthcare contexts.

As the focus of this literature review was breadth before depth, this chapter provides a narrative literature review organised thematically. This chapter initially describes the healthcare context, followed by the development of safety theory and related concepts and, finally, the current concepts driving safety improvements. The section on the healthcare context, which aims to describe the work environment underlying this research, includes the characteristics of work in healthcare systems and the need for adopting a systems approach. This is followed by a description of the development of safety theory and related concepts in more detail, including a brief history and the origins of safety theory, followed by key theories on error, adverse events and system failures. This area of the literature provided the theoretical underpinnings of this research independent of the specific context. The final section of this literature review focused on the current concepts driving safety improvements, including the concepts of safety culture, high reliability organisations theory, resilience engineering and Safety-I and Safety-II.

2.1 The Healthcare Context

2.1.1 Characteristics of Work within Healthcare

Healthcare is differentiated from other industries in that a central component of many tasks, either directly or indirectly, relates to patient care (Carayon & Friesdorf, 2006; Hignett, 2001). As

a result of this, work in this domain often involves a degree of intimacy and sensitivity regarding the services it provides and the associated trust and compassion that working in this system requires (Dixon-Woods, Yeung, et al., 2011). Furthermore, work in this setting is different from other industries as it is affected by the 'variability in patients and circumstances, the need to adapt processes quickly, the rapid changing knowledge base and the importance of professionals who use expert judgement in dynamic settings' (Kohn et al., 2000, p. 160–161).

The care provided to patients must meet six requirements: to be safe, effective, efficient, patient-centred, timely and equitable (Institute of Medicine Committee on Quality of Health Care in America, 2001). In order to achieve these requirements, various staff with different skills must interact, collaborate and work towards the common goal of providing healthcare (Carayon, 2012b; Carayon & Friesdorf, 2006; Janowitz et al., 2006). Moreover, healthcare staff are required to follow both rigid procedures and adaptive techniques due to the degree of variability the patient brings into the healthcare environment, potentially resulting in a highly routinised procedure containing unexpected outcomes (Bagnara et al., 2010). In addition to the above-mentioned elements, healthcare requires teamwork and clear communication in order to provide continuity of care by liaising with other shifts (Shepherd, 2001) and collaborating with staff from different specialities in order to treat the patient (Carayon & Friesdorf, 2006; Shepherd, 2001).

The above discussion makes clear that numerous subsystems must work together efficiently and communicate effectively to achieve the desired work goals (Braithwaite et al., 2013; Carayon & Friesdorf, 2006; Janowitz et al., 2006). In addition, many tasks require healthcare staff to interact with the patient, their families and numerous machines (Carayon & Friesdorf, 2006). This combination of processes, technologies and human interaction make healthcare systems highly complex in nature (Department of Health, 2000) and fitting the description of a complex sociotechnical system (Braithwaite et al., 2013; Buckle et al., 2006; Carayon & Friesdorf, 2006; Janowitz et al., 2006).

The rapidly changing and dynamic environment of healthcare systems make them open systems that exhibit properties of emergence, adaptation, self-organisation, herding, hierarchy and networking (Braithwaite et al., 2013). Self-organisation occurs as a result of the

members within this system being well-trained professionals with considerable autonomy (Braithwaite et al., 2013). Furthermore, professionals in this system not only collectively organise themselves based on speciality but also form informal local networks (Braithwaite et al., 2013). The industry is also subject to public interest as numerous external stakeholders are involved (Braithwaite et al., 2013). These external stakeholders include but are not limited to governments and health insurers and can often be described as functioning at the blunt end (Braithwaite et al., 2013). The influence of external stakeholders has resulted in frequent top-down regulatory demands that stand in contrast to bottom-up localised organisational behaviours (Braithwaite et al., 2013). Those at the blunt end often become involved when errors occur, assigning blame to those at the sharp end (i.e. frontline staff) who have the ability to directly affect patient safety (Braithwaite et al., 2013). In addition to self-organisation, emergent behaviours that occur due to staff's adaptive capacity result, as numerous tasks may require an improvised response due to the unpredictable nature found in this field (Braithwaite et al., 2013). From these interactive behaviours, cultural and sub-cultural features arise, which subsequently form a nested structure within the system (Braithwaite et al., 2013).

A key consideration in understanding work within a system is the degree of coupling, especially because numerous subsystems must work together in healthcare (Braithwaite et al., 2013; Janowitz et al., 2006). Coupling refers to the extent of dependence among system components, which can be either tightly or loosely coupled (Tamuz & Harrison, 2006). Specific departments or procedures are inherently tightly coupled as they are time-dependent (e.g. emergency procedures, anaesthesiology) (Tamuz & Harrison, 2006); however, other areas can be very loosely coupled (e.g. physical rehabilitation) (Bagnara et al., 2010). Historically, healthcare systems have been predominantly loosely coupled (Cook & Rasmussen, 2005), which has allowed for quickly identifying and intervening in problems (Tamuz & Harrison, 2006) and the absorption of excessive workload by other areas in the system (Cook & Rasmussen, 2005). This form of coupling is beneficial, allowing healthcare systems, which are often operating at the limits of their capacity, to continue functioning (Cook & Rasmussen, 2005). Nevertheless, as the system becomes saturated with work, this results in tighter coupling, and therefore unexpected failures (Cook & Rasmussen, 2005). Tight coupling also results in a decrease in redundancies and a reduction in buffers that might otherwise mitigate

negative events (Tamuz & Harrison, 2006). Furthermore, healthcare systems are becoming tightly coupled due to modern management techniques and information systems in an attempt to reduce inefficiencies (Cook & Rasmussen, 2005).

By considering these system properties, it becomes clearer why it is essential to understand the system for a specific domain when exploring safety. For example, the changes in coupling within healthcare may result in a decrease in buffers that may affect patient safety and quality of care the patient receives. Furthermore, the description of the system properties start to reveal how they may impact work and therefore the requirements of care outlined earlier in this section.

As highlighted above, numerous factors including a number of organisational factors (Johnson, 2004), affect healthcare work. It can be discerned from the literature that there is an interaction between the constraints established by the blunt end of the healthcare system, the requirements of care that are mandated in this domain and system properties of work that staff at the sharp end of this system experience. The latter include self-organisation, emergent behaviours and autonomy. All of these aspects highlight the necessity to look at work in this domain and patient safety from a systems perspective. Adopting a systems approach facilitates identifying the factors that affect safety at all levels of the system (Leveson et al., 2016) and therefore, it is not surprising that many countries have adopted a systems approach to improve patient safety (Hofoss & Deilkås, 2008).

2.1.2 A Systems Approach to Healthcare Work

The systems approach advocates that complex systems are composed of interrelated components, and if dissembled, the properties of the components will change (Karsh, Waterson, & Holden, 2014). Two key models are included in this section to depict the system structure within healthcare. The first, the input-transformation-output model of healthcare professional performance developed by Karsh and colleagues (2006), is a general multi-level work system model derived from open systems theory. The second is the SEIPS 2.0 model, proposed by Holden and colleagues (2013), which is frequently used to analyse work in healthcare.

The input-transformation-output model of healthcare professional performance (Karsh et al., 2006), depicted in Figure 2, has a multi-level nested structure, which is a key characteristic of sociotechnical systems (Karsh et al., 2014). The levels can either represent different ranks of the organisational hierarchy or individual units of analysis consisting of the individual, team or organisation; the context for each level is provided by the level above it (Karsh et al., 2014). The framework provides an understanding how the elements of a system can interact to influence the performance of staff and ultimately affect patient safety (Karsh et al., 2006).

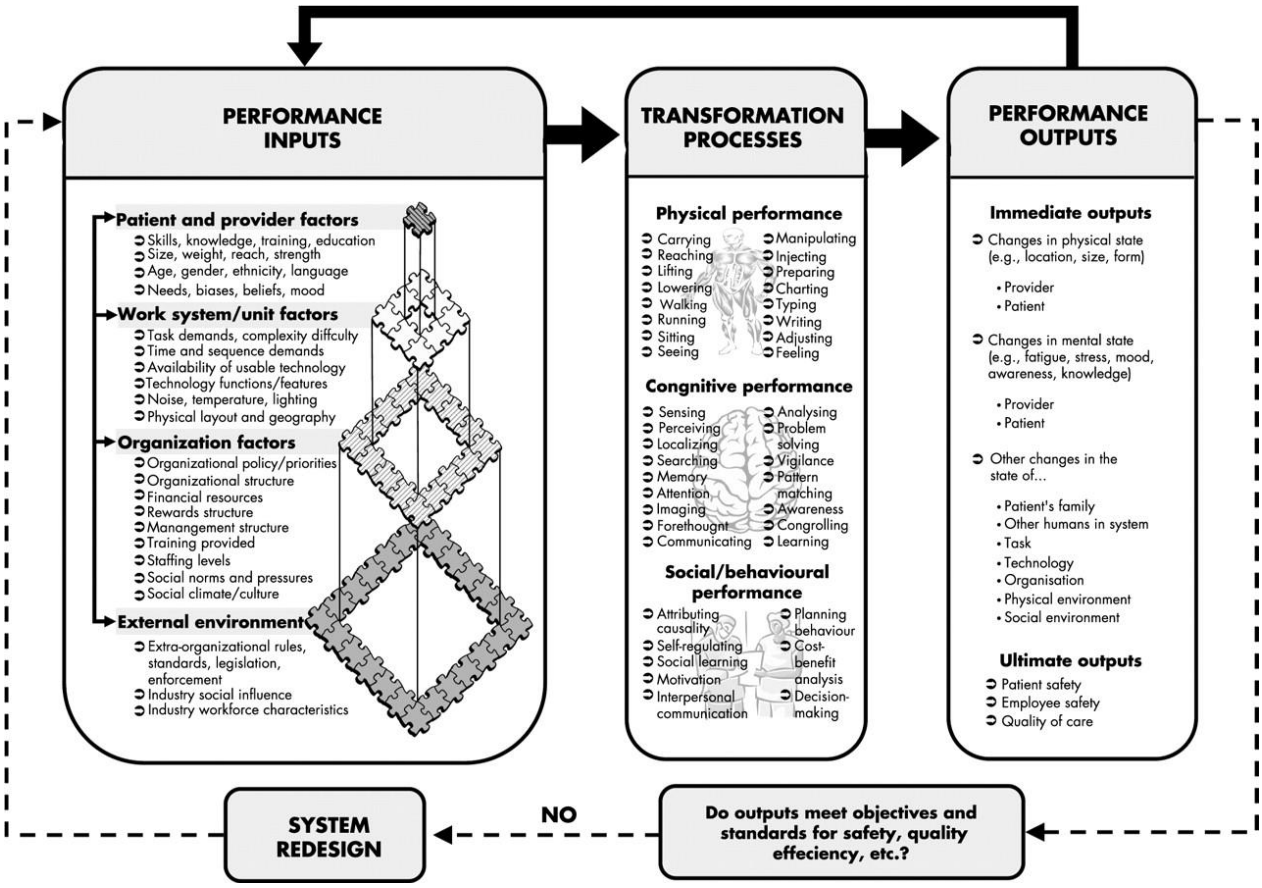


Figure 2: Input-transformation-output model of healthcare professional performance (Karsh et al., 2006). Reproduced with permission from BMJ Publishing Group Ltd.

The left side of Figure 2 depicts the work system, inputs and hierarchies of other systems within which the system exists (Karsh et al., 2006). This nesting of systems is an important consideration as they affect provider performance and, consequently, safety (Karsh et al., 2006). Transformations, depicted in the middle of Figure 2, are the process of converting the inputs to outputs with physical, cognitive and behavioural transformations resulting in new configurations of the system (Karsh et al., 2006). The performance outputs, depicted on the

right-hand side of Figure 2, can be considered as the new state of the system following the transformation process.

The Systems Engineering Initiative for Patient Safety (SEIPS) 2.0 model, the second version of the model originally proposed by Carayon and colleagues (Carayon, Schoofs Hundt, Karsh, et al., 2006), is the second model relevant to this study. This model provides a structure for the analysis of the processes and relationships of various system elements that occur in healthcare (Carayon, Schoofs Hundt, Karsh, et al., 2006). The model includes components from the Donabedian (1978) Structure-Process-Outcome model of healthcare quality (as cited in Carayon et al., 2014), which is a model that has been frequently used in quality improvement in healthcare (Mitchell, Ferketich, & Jennings, 1998). The SEIPS model has been used to identify influencing factors of healthcare processes (Boston-Fleischhauer, 2008; Carayon, Schultz, & Schoofs Hundt, 2004; Wetterneck et al., 2006), performance obstacles and facilitators for healthcare staff (Carayon, Schoofs Hundt, Alvarado, Springman, & Ayoub, 2006; Gurses & Carayon, 2007) and to describe different healthcare work systems (Catchpole & McCulloch, 2010; Wiegmann et al., 2010).

The SEIPS 2.0 model, comprises three key components: the work system, processes and outcomes (Carayon et al., 2014). The work system is composed of six elements, which include the person, tasks, tools and technologies, the organisation of work, the physical environment which is referred to as the internal environment, the external environment and organisational conditions (Carayon et al., 2014; Carayon & Friesdorf, 2006). The person element in the SEIPS 2.0 model refers to both healthcare providers and patients (Holden et al., 2013), as the latter also plays a large role in the task of patient care (Hignett & Richardson, 1995). The outcomes, resulting from the interaction of processes and the different work system elements, are patient outcomes, which consist of quality of care and patient safety, as well as employee and organisational outcomes (Carayon et al., 2014). Figure 3 depicts the SEIPS 2.0 model.

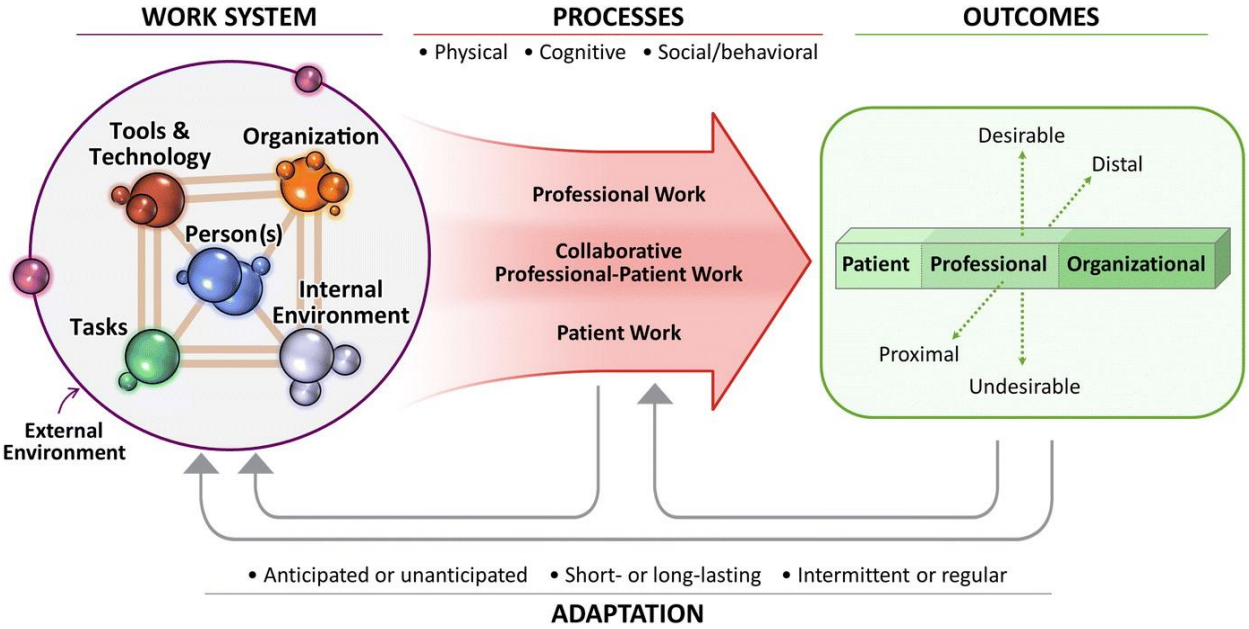


Figure 3: SEIPS 2.0 Model (Holden et al., 2013). Reproduced with permission from Taylor & Francis.

These two models were included in this literature review and this research as they both provide different depictions of the system as well as having many similar core elements. The nested depiction of Karsh's input-transformation-output model provides a better structure from which to anchor the case studies included in this research, highlighting how they span the different levels within the healthcare system. The SEIPS 2.0 model has been applied in numerous different healthcare contexts and therefore provides various examples of potential application methods for this model. Furthermore, as the SEIPS 2.0 model is based upon a well-known quality improvement model, this may assist in providing greater traction for the results with healthcare staff.

2.2 Development of Safety Theory and Related Concepts

Safety in sociotechnical systems is an emergent property that is neither constant nor permanent (Leveson, 2017; Robertson et al., 2015), and especially in healthcare, it is a dynamic property (Cook & Rasmussen, 2005). This concept is usually expressed in terms of different forms of adverse events and reasons for their occurrence (Hollnagel, 2012), and traditionally has been addressed by analysing adverse events to identify the sources of error (Hofoss & Deilkås, 2008; Hollnagel, 2012). However, human error and system failure in

healthcare are often difficult to detect (Carayon & Friesdorf, 2006). As the origin of safety theory will affect how it has developed and is now perceived, it is essential to first describe the development of safety theory. Furthermore, this will have implications for the key models relating to error, adverse events and system failures, all of which contribute to society's understanding of safety. This section will describe the development of safety theory and these key theories.

The development of safety theory can be seen as having followed three ages (Hale & Hovden, 1998) that focus on different causes of risks rather than different concepts of safety (Hollnagel, 2014). The first age, described as improving safety using technical measures, occurred during the industrial revolution when technology was unreliable and represented the dominant threat to safety (Hale & Hovden, 1998). The second age focused on addressing human factors and individual behaviour issues (Hale & Hovden, 1998). Initially, methods applied during the first age were extended to include the human factors component, but these were soon replaced with more specialised approaches, namely human reliability assessments (Hollnagel, 2014). Both reactive and proactive safety measures were developed, for example, accident investigations and risk assessments, respectively (Hollnagel, 2014). As a result of the limitations of the approaches from the first two ages, a third age arose that focused on safety from a management and culture perspective (Hale & Hovden, 1998). This third age adopts a systems perspective to safety, requiring alternative ways of thinking (Hollnagel, 2014). This perspective corresponds with the idea that understanding the organisational processes is necessary to understand tightly coupled organisations that have non-linear functioning (Hollnagel, 2014). As described earlier in this chapter, healthcare can be seen as a domain such as this. Although the transition from each age to the next corresponds with a new category of causes, the main focus has remained on adverse outcomes, accidents or incidents, proposing that safety could be improved by eliminating the causes of these (Hollnagel, 2014).

Traditionally, accidents and system failures have been considered the result of error (Woods, Dekker, Cook, Johannesen, & Sarter, 2010) and therefore researchers have developed numerous theories to explain how errors occur and potentially how to reduce them to increase system safety (Hollnagel, 2014). A discussion of the relevant literature regarding

errors appears below, followed by an exploration of the literature regarding accidents and system failures, following the same progression as the ideology of safety: initially at an individual level and evolving later to incorporate a systems approach.

2.2.1 Error

The study of error originated in two separate fields, psychology and cognitive engineering (Le Coze, 2015a). These diverse origins allow error to be defined and analysed from different perspectives. From a psychological perspective, error, as defined by Reason (2001), is the deviation of human performance from the task's intended action, which may or may not result in a negative consequence. From the cognitive engineering perspective, Rasmussen (1982) defined error as a misfit between the individual and the task or machine. This second definition more specifically states an expansion of the context in which the error occurs. In the healthcare context, clinical or medical error is defined as the failure to apply the correct care, improper implementation of a planned action or application of an incorrect plan (Kohn et al., 2000). Following the 1979 Three Mile Island nuclear accident, international interest in the field of 'human error' grew, and a link between the study of error in these two fields was formed (Le Coze, 2015a). As the different approaches for studying error provide information from different perspectives, adopting both perspectives can be beneficial (Le Coze, 2015a). Furthermore, some of the key theories from both fields have been developed off work from the other. Reason provided a taxonomic approach to error, while Rasmussen offered a grounded model based on observation, which promised a practical approach to error (Le Coze, 2015a). Models and theories from both the psychological and cognitive engineering domains are described below.

One of the best-known human factors models for explaining how errors occur at the individual level is Rasmussen's (1983) skill-rule-knowledge model (Le Coze, 2015a). This model identifies four levels of behaviour (Le Coze, 2015a; Sanderson & Harwood, 1988), with the first or skill-based level corresponding with behaviour that consists predominantly of automated routines (Rasmussen, 1983). The second level, the rule-based level is concerned with behaviour related to the perception of familiar but unusual situations (Rasmussen, 1983; Shepherd & Stammers, 2005) and considers behaviours as a result of past experience (Sanderson & Harwood, 1988). The third and fourth levels refer to the knowledge-based

category, indicating a situation that an individual finds completely unfamiliar (Shepherd & Stammers, 2005) or that takes place as a result of unforeseen conditions, respectively (Rasmussen, 1983). This model provides a functional framework that describes different levels of human information processing (Rasmussen, 1983), which can help explain the development of different patterns of errors, particularly in the terms of the control of complex systems (Sanderson & Harwood, 1988; Shepherd & Stammers, 2005). In Chapter 3, *Section 3.1.4.1* (p. 58) provides a more detailed description of this model.

Based on the above model, Reason (2001) developed a classification system that groups errors into three categories as a result of the type of deviation that occurs. The first category, trips and stumbles, specifically signifies an unintended alteration in the upright posture (Reason, 2001). The second category of errors is slips and lapses (Reason, 2001), which refers to the unintended actions that deviate from the planned response (Reason, 2001) and occur at a skill-based level (Bridger, 2009; Reason, 2006). Slips denote the use of inappropriate attention levels, while lapses are associated with memory failures (Carayon & Friesdorf, 2006; Reason, 2001). Slips or lapses usually occur within well-learnt behaviours and are frequently referred to as absent-minded actions (Bridger, 2009). The third category of errors involves mistakes that occur on a higher level of information processing in comparison to the other two (Carayon & Friesdorf, 2006; Reason, 2001). The two types of errors in this category are rule-based mistakes and knowledge-based mistakes (Reason, 2006). The deviation at this level occurs at the selection of the action rather than at the action execution point (Reason, 2001). This third category is extremely challenging to detect and recover from; however, the system usually has regulations in place for their prevention (Reason, 2001).

The problem with adopting only an error perspective regarding safety is that it implies a single root cause which may result in oversimplifying the potential problems (Vincent, 2003). Counteracting human error sources that have been identified has proved ineffective in preventing accidents (Rasmussen, 1997). As a result, alternative approaches and perspectives on adverse events, accidents and system failures has been sought. More recently, error has been seen as a reflection of deeper system problems and rather a symptom of failure (Reason, 2000; Woods et al., 2010). Similarly, the idea has emerged that patient safety and errors should be considered effects of the healthcare delivery system in which they occurred (Hofoss

& Deilkås, 2008). To better understand adverse events and their context, a systems approach to the errors that lead to adverse events and system failures must be adopted. Furthermore, an analysis of adverse events should aim to be proactive and forward-looking to enhance safety by identifying gaps and inadequacies within the system (Vincent, 2003).

2.2.2 Adverse Events, Accidents and System Failures

Historically, adverse events, accidents and system failures have led to investigations into the source of error and breakdowns within the system (Woods & Cook, 2002). Based on the analysis of major industrial accidents in various industries (e.g. transport, nuclear and petrochemical industries), the regulatory and research focus has shifted from individual towards organisational factors (Flin, Winter, & Cakil Sarac, 2009) and systemic vulnerabilities (Le Coze, 2015b; Woods & Cook, 2002). Research has shown that unintended failures frequently occur as a result of a complex interaction between human behaviour, technology, sociocultural and organisational factors (Donaldson, 2002). Also, with the shift to organisational factors, organisational preconditions to system failures are being seen as increasingly important for safety management (Pidgeon, 1998). As a result, the idea of safety has migrated from a micro-view to more of a macro and sociotechnical view (Le Coze, 2015a) and from focusing on error to the mechanisms and system factors that lead to error (Rydenfält, Ek, & Larsson, 2014). A systems approach to safety regards errors and adverse events as a consequence of systemic factors, 'a flawed system', and insists that the conditions under which the work is done must be altered (Reason, 2000), rather than attempting to change 'flawed individuals' (Leveson et al., 2016). Industries that have successfully implemented this strategy (e.g. commercial aviation) have achieved significantly lower accident rates (Leveson, 2011). A similar transition involving the perspective on safety is also taking place in healthcare, as the IOM report (Kohn et al., 2000) highlights.

In other industries, such as aviation, learning from accidents and near-misses is a well-established practice (Vincent, 2003). Unfortunately, in the field of healthcare, such practices are not as well engrained, and methods are underdeveloped by comparison (Vincent, 2003). Traditionally, safety, in general, and patient safety, in particular, have been addressed by analysing adverse events to identify sources of error and determine root causes for adverse events (Hofoss & Deilkås, 2008; Hollnagel, 2012). The problem with adopting this perspective

is that it implies that a single root cause is present (Vincent, 2003). Two key safety models that move away from identifying root cause errors and towards identifying system factors relating to adverse events are described below. These are the dynamic safety model (Rasmussen, 1997) and the Swiss cheese model (Reason, 2000). A third theory, Normal Accident Theory (Perrow, 1984), will be described since it highlights how the characteristics of complex systems make them disposed to adverse events and accidents.

The dynamic safety model, proposed by Rasmussen (1997), describes the operating space in sociotechnical systems and the three boundaries that affect safety (Cook & Rasmussen, 2005). These three boundaries, which form a safety envelope (Rydenfält et al., 2014), encompass unacceptable performance, economic failure and unacceptable workload. An additional factor, the error margin, provides a perceived boundary to performance failure (Rasmussen, 1997). Moving further from one boundary involves moving closer to the other two (Cook & Rasmussen, 2005). The location of the operating point within the sociotechnical system is influenced by gradients that move it away from the workload and economic failure boundaries and towards the unacceptable performance boundary. Because the environment is dynamic, the operating point and the marginal boundary, which is controlled by sociotechnical processes, continuously move (Cook & Rasmussen, 2005). The system's operating point will drift towards the performance failure boundary if the gradients from economic failure or unacceptable workload become too strong (Cook & Rasmussen, 2005). Near-misses relative to this model occur when the operating point falls outside the marginal boundary but not outside the performance boundary, and efforts are made immediately to bring it back inside the marginal boundary (Cook & Rasmussen, 2005). The dynamic safety model illustrating the three boundaries and gradients that affect the system's operating point is depicted in Figure 4.

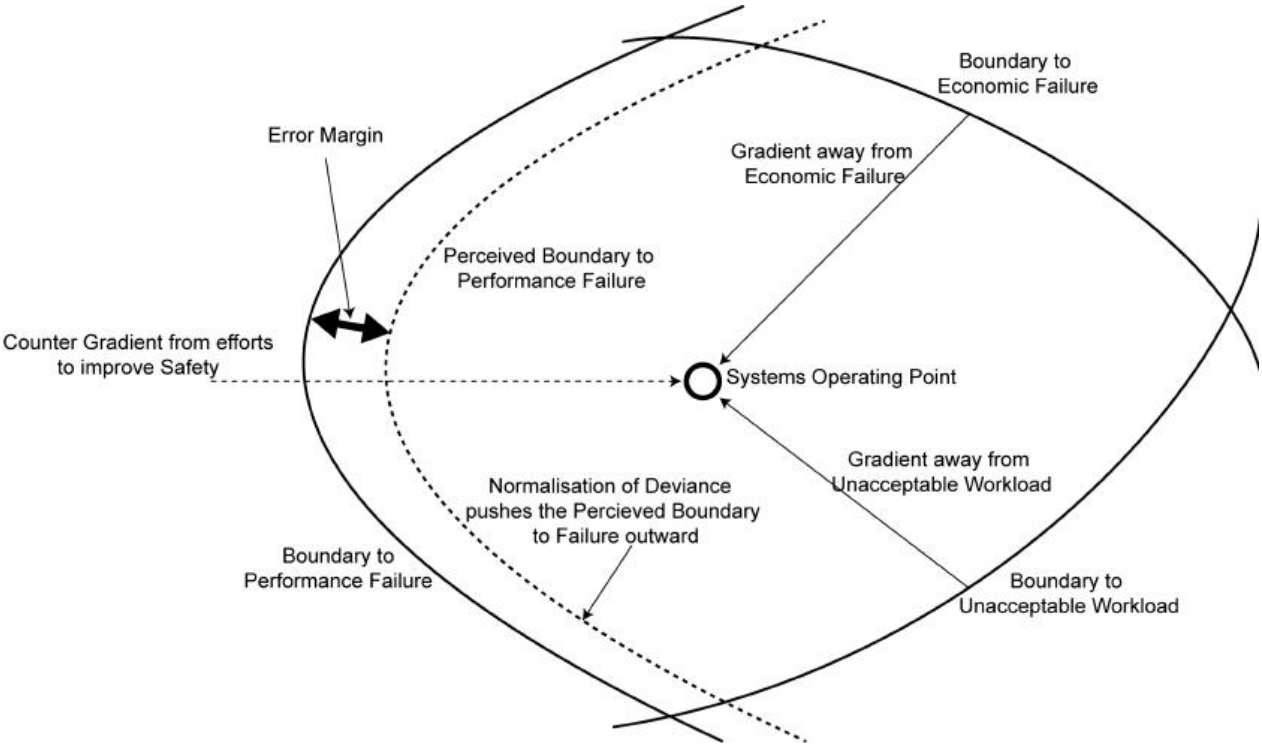


Figure 4: Rasmussen's Dynamic Safety Model illustrating the three boundaries forming the safety envelope. Adapted by permission from BMJ Publishing Group Ltd. (Cook & Rasmussen, 2005; Rasmussen, 1997).

The Swiss Cheese model by Reason (2000) provides a model of how adverse events can occur despite various defence layers that have been designed within the system. The defences consist of different barriers that may be either physical, functional, symbolic or incorporeal in form (Hollnagel, 2008). These defence layers comprise procedures, supervision, training and physical barriers (Reason, 1997). Frequently, combinations of different barrier forms are used, whose function can either be passive or active (Hollnagel, 2008). Each defence layer has holes, like a slice of Swiss cheese, which continually change in location and size (Reason, 2000). The individual holes in one slice usually do not cause an adverse event, but aligning several holes in different layers produces an opportunity for an accident to occur (Reason, 2000). As the holes in the layers are the result of two different error conditions (active and latent failures), the combination of the two conditions results in an adverse event (Reason, 2000). The term active failures refers to errors made at the sharp end of the system (Woods et al., 2010). These types of errors, which have a brief but immediate effect (Reason, 2001), take the form of slips, lapses, mistakes and procedural violations (Reason, 1990). The second error condition, latent failure, is due to managerial and organisational influences and creates

long-term weaknesses in the defences (Reason, 2000) and occurs at the blunt end of a complex system (Woods et al., 2010). In the 1970s, Turner proposed that disasters develop over long periods of time as a result of 'incubating' social phenomena through interactions between human and organisational arrangements of the sociotechnical system (Pidgeon, 1998). As a result of this incubation period, latent errors accumulate, and the system becomes vulnerable (Pidgeon, 1998). Turner also argued that warnings or signals of deteriorating situations existed; however, as a result of 'cultural denial', the problems go unaddressed during the incubation period (Pidgeon, 1998). The Swiss Cheese model provides a depiction of Turner's description of how disasters occur.

An additional theory that describes a specific subset of accidents is Perrow's Normal Accident Theory (Sagan, 2004), which describes how accidents occur in error-inducing systems (Weick, 2004) and accounts for system accidents (Perrow, 2004). In this view, the accumulation and alignment of seemingly unrelated events create malfunctions that produce accidents (Perrow, 2004). Furthermore, as these interactions are invisible, the operators within the system arguably neither expect nor comprehend these malfunctions (Perrow, 2004). Consequently, Perrow referred to system accidents as normal accidents that are an intrinsic characteristic of complex systems (Perrow, 2004). Perrow's theory identifies two main structural components of systems that characterise accidents: interactions and coupling (Sagan, 2004). Interactions, which can be either linear or complex, indicate the degree to which components are unexpected, unplanned or not visible (Tamuz & Harrison, 2006). Coupling, which can be described as either loose or tight, refers to the extent of dependence among system components (Tamuz & Harrison, 2006). This second structural component, which has been described in more detail earlier in this chapter, highlights how errors may frequently occur in healthcare.

2.2.3 System Failures in Healthcare

The previous literature has described error, and how this may contribute to adverse events and system failures in general. As is clear from the description of the healthcare context in *Section 2.1*, healthcare as a domain has several unique characteristics and therefore one needs to describe how system failures within healthcare context present.

Safety in healthcare is complicated because medical harm is typically distributed and individualised, proceeding in a subtle, gradual way but with serious effects (Schulman, 2004; Vogus et al., 2010). As a result, system failures in healthcare are often difficult to detect and investigate (Walshe & Shortell, 2004). Furthermore, such failures can result in creating dangerously unreliable healthcare organisations (Vogus & Hilligoss, 2016) that keep offering services despite the breakdown in healthcare services (Walshe & Shortell, 2004). In these cases, patient safety incidents can be described as visible manifestations of system failures (Walshe & Shortell, 2004). These failures usually lead to high-profile events in which many patients have been harmed; moreover, media reports typically bring such incidents to light, instead of systems for quality management or improvement (Walshe & Shortell, 2004). Some examples of failures of healthcare systems include the London Ambulance Service Computer-Aided Dispatch (LASCAD) System (Beynon-Davies, 1999; Finkelstein, 1993), the Mid Staffordshire NHS Foundation Trust (Roberts, 2013) and the Maidstone and Tunbridge Wells Infection Outbreaks (Healthcare Commission, 2007). The above-mentioned examples are briefly summarised below to illustrate system failures in healthcare.

The failure of the LASCAD System occurred in 1992 due to a technical failure in the automated deployment system, which resulted in numerous 999 (i.e. emergency) calls going unanswered and unaddressed (Beynon-Davies, 1999). As a result of this system failure, patients experienced a delay in receiving treatment, leading to the loss of life for approximately 20-30 people (Beynon-Davies, 1999). One problem that contributed to this system failure included the omission from the specification of many tasks done 'naturally' that were not necessarily documented (Mackie & Sommerville, 2001). Thus, the new system did not consider these small but necessary tasks. This incident highlights an example of discrepancies between 'work-as-done' and 'work-as-imagined', a key concept of Safety-II that will be discussed later in this chapter.

The system failings surrounding the Mid Staffordshire NHS Foundation Trust resulted in unacceptable standards of care for patients between 2004 and 2009 (Roberts, 2013). During this time, there was a noted rise in patient mortality rates and complaints regarding clinical care, with an estimate of between 400 and 1200 excess deaths occurring during this time period (Roberts, 2013). Numerous reviews, audits and reports were conducted during the

time of this event, and many of the reported concerns involved staffing and management. The investigation found that staffing shortages, operational problems and a lack of leadership meant that despite the best efforts of the staff, the quality of care was compromised, and patient safety was put at risk (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a). Chapter 8 will offer a more detailed description of this example.

The Maidstone and Tunbridge Wells infection outbreaks occurred between 2005 and 2007, resulting in the death of approximately 90 people, whereby *Clostridium difficile* bacteria was definitely or probably the main cause (Healthcare Commission, 2007). Even though this was a biological event (i.e. outbreak of *C. difficile* bacteria), and the Commission was unable to say exactly how many of the deaths were due to the care received (Healthcare Commission, 2007), numerous system factors ultimately contributed to how this event progressed and, therefore, the outcome (Waterson, 2009). Examples of how smaller system issues contributed to this event included the effect of bed occupancy on hygiene practices, management practices that failed to prevent or handle the outbreak, understaffing and a lack of resources (Waterson, 2009).

These examples, though anecdotal, describe different examples of system failures in healthcare that nevertheless share numerous common themes in terms of contributing system factors. For example, the failures were often as a result of long-standing problems; moreover, staff, stakeholders and external bodies may have been aware of the problems, though they were not actively addressed, and these failures often occurred in dysfunctional organisations (Walshe & Shortell, 2004). Additionally, negative performance information was suppressed, poor outcomes were habitually explained away (Vogus & Hilligoss, 2016) and problematic organisational cultures were present (Goodwin, 2018). Often, these system failures featured smaller failures, which may be considered as early warning signs or weak signals, that occurred prior to the larger event – which, if addressed effectively, might have prevented consequential failures (Sitkin, 1992 as cited by Edmondson, 2004). Such system failures invariably result in numerous types of harm not only to the patient and their families but also to staff and the healthcare organisations, for example, in the form of litigation, effect on reputation and the resulting investigation costs (Walshe & Shortell, 2004). The above-mentioned examples highlight some of the areas that the current concepts driving safety

improvements are trying to address, such as problematic organisational cultures, through improving safety culture.

2.3 Current Concepts Driving Safety Improvements

This section of the literature review provides a brief outline of the current concepts driving safety improvements. As described earlier in this chapter, there has been a shift from an individual to a more organisational perspective, not only in safety theory but in the theories that explain error and accident causation. Similarly, recent research has increasingly focused on controlling major risks and meeting safety objectives from a more sociological perspective, involving concepts such as safety culture, high-reliability organisations theory and resilience engineering (Lekka, 2011). An overview of these concepts has been included in this section. In addition to these concepts, Safety-II will also be described.

2.3.1 Safety Climate and Safety Culture

Multiple studies have emphasised safety culture as a current concept driving safety improvements, specifically in healthcare (Hofoss & Deilkås, 2008; Kennedy, 2001; Najjar et al., 2013; Nieva & Sorra, 2003). Not only was this concept highlighted by the IOM report in 2000 (Ammouri, Tailakh, Muliira, Geethakrishnan, & Al Kindi, 2015; Kohn et al., 2000; Mardon, Khanna, Sorra, Dyer, & Famolaro, 2010; Singla, Kitch, Weissman, & Campbell, 2006), but approximately nine years later, Leape and colleagues (2009) reaffirmed that safety improvement was dependent on this concept of safety culture.

Safety culture provides the means for addressing organisational properties of patient safety (Reiman, Pietikäinen, & Oedewald, 2010). This is as the social and organisational context in which behaviour occurs exerts an influence on behaviour (Leveson, 2017). By engineering the context, one could facilitate creating and changing safety culture (Leveson, 2017). Positive safety culture has also been shown to relate to fewer adverse events in hospital (Mardon et al., 2010) indicated by Patient Safety Indicators (Mardon et al., 2010; Singer, Lin, Falwell, Gaba, & Baker, 2009), and a positive assessment of care from patients (Sorra, Khanna, Dyer, Mardon, & Famolaro, 2012). Moreover the presence of safety culture can minimise the occurrence of disasters (Olive, O'Connor, & Mannan, 2006), and high levels of patient safety

culture can result in improved patient outcomes, leading to reduced healthcare costs (Ammouri et al., 2015). A lack of safety culture has been identified as a key cause of unsafe practices (Guldenmund, 2010a).

Safety culture first appeared as a concept following the Chernobyl nuclear disaster in 1986 (Flin et al., 2009; Halligan & Zecevic, 2011; International Nuclear Safety Advisory Group, 1986) and has since that time been embraced by numerous industries and, more recently, the healthcare industry (Halligan & Zecevic, 2011). Despite the term being in use for more than thirty years, disagreement remains regarding the definition and conceptualisation of safety culture (Halligan & Zecevic, 2011). One debatable issue regarding safety culture involves the difference between 'culture' and 'climate' (Guldenmund, 2000; Halligan & Zecevic, 2011; Olsen, 2009; Waterson, 2014), whereby occasionally they are used interchangeably (Halligan & Zecevic, 2011), despite differences in definitions. The term safety climate is defined as features, attitudes and values related to risk and safety management (Flin et al., 2009), which emerge through social processes (Waterson, 2014) that reflects the underlying culture (Denison, 1996). In comparison with safety culture, safety climate is said to change more readily (Olive et al., 2006), be more temporary and less stable than safety culture (Guldenmund, 2014), and arguably constitutes the quantifiable element of safety culture (Colla et al., 2005; Gaba, Singer, Sinaiko, Bowen, & Ciavarelli, 2003). Researchers have adopted numerous definitions for safety culture (Pidgeon, 1998); however, debating the differences in definitions falls outside the scope of this work. Safety culture, which draws on a systems approach (Waterson, 2014), can be defined as the beliefs, values and norms shared by organisational members in terms of what is considered important (Sorra & Nieva, 2004), as well as how organisational structures and systems operate and interact. This influences the attitudes, behaviours and social norms that promote safety (Singer et al., 2009). Safety culture is the aspect of organisational culture that relates to safety-relevant aspects (Clarke, 1999) and tends to be a broader concept than safety climate (Hammer & Manser, 2014).

The components, features or properties of safety culture have elicited less of a debate among researchers (Waterson, 2014). Reason (1997) identified components of safety culture based on the premise that an informed culture is a safe culture. The components of safety culture include a reporting culture, just culture, flexible culture and a learning culture (Reason, 1997).

A reporting culture refers to the willingness of frontline staff to report errors and near-misses. This attitude is often influenced by whether a 'blame culture' exists in the organisation (Waring, 2005) and relates to a just culture, which refers to organisational practices relating to support regarding reporting or disciplinary action pertaining to errors. A flexible culture refers to management's trust in the front-line staff's knowledge to respond to situations (Reason, 1997). Finally, a learning culture refers to an organisation's practices to analyse reported information and implement appropriate change (Jones, Skinner, Xu, Sun, & Mueller, 2008). All these components result in an organisation becoming highly reliable (Jones et al., 2008).

The characteristics that identify a positive safety culture and a strong safety climate include a commitment to improvement of safety behaviours on all organisational levels, organisational learning, open and clear communication free from intimidation that promotes a good reporting culture (Kirk, Parker, Claridge, Esmail, & Marshall, 2007; Olive et al., 2006), a predisposition for resilience and flexibility to adapt to new situations and constant vigilance to ensure safety (Olive et al., 2006). In a literature review focusing specifically on the healthcare context, Sammer and colleagues (2010) organised the range of safety culture properties they identified into seven subcultures. These subcultures, which include communication, teamwork, learning, just, evidence-based, patient-centred and leadership (Sammer et al., 2010), are depicted in Figure 5.

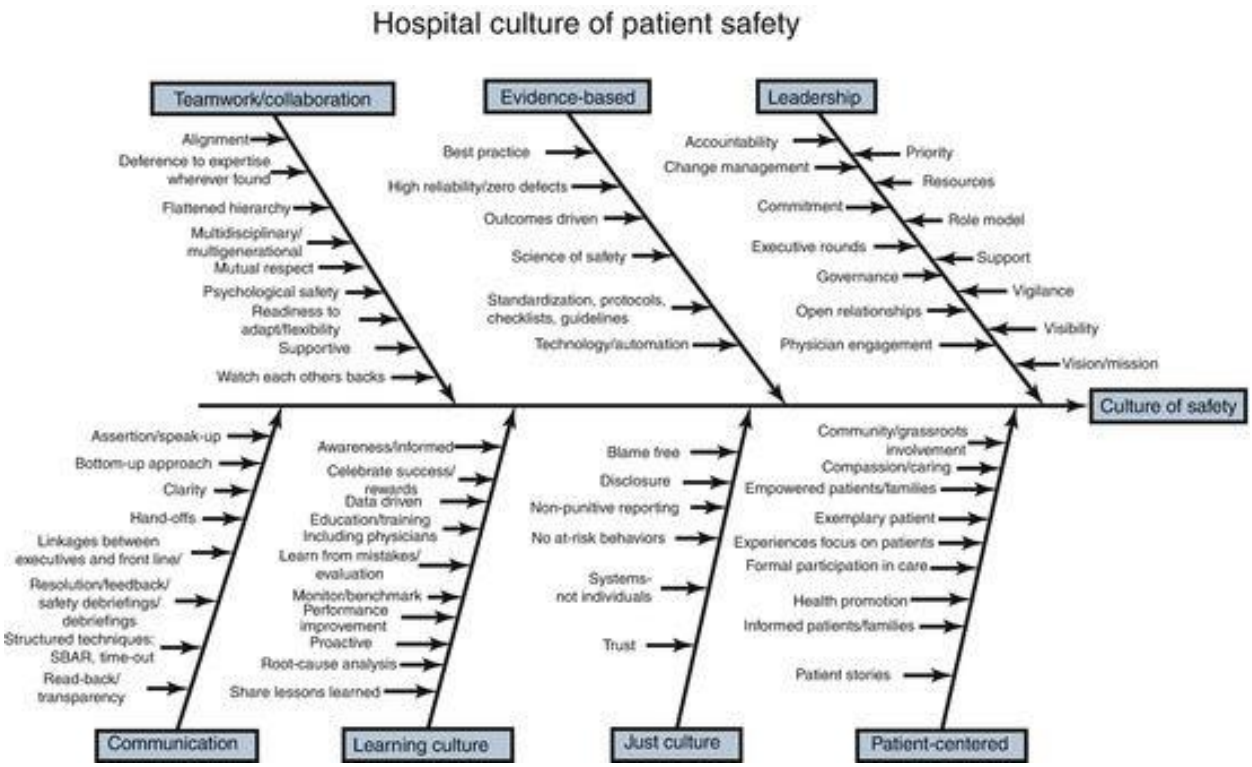


Figure 5: The properties and seven subcultures that contribute to the hospital culture of patient safety (Sammer et al., 2010). Reproduced with permission from John Wiley and Sons.

Culture functions to guide behaviour (Olive et al., 2006), and cues or signals have been identified as an element of the social processes of patient safety culture (Reiman et al., 2010) that may assist in guiding behaviour. As a result, it is thought that patient safety culture affects patient safety as it affects the preconditions of work, influences the possible actions within that situation (Reiman et al., 2010) and provides an anchor for behaviours (Guldenmund, 2010a). Safety culture is said to guide the normal behaviour of workers in terms of the risks taken, rules followed and concerns raised about safety (Flin et al., 2009). Based on evidence from both healthcare and other high-risk industries, safety culture influences and plays a key role in the establishment of safety programmes (McCarthy & Blumenthal, 2006). Moreover, this phenomenon is an essential precondition for the improvement of patient safety (Robida, 2013). The importance of safety culture has also been highlighted by High Reliability Organisations (HRO) theory (Pidgeon, 1998), which is one reason organisations have also tried to improve their safety culture, namely so that they can become HROs (Lekka, 2011).

2.3.2 High Reliability Organisations Theory

The High Reliability Organisations (HRO) paradigm was developed following Normal Accident Theory by a research group at the University of California, Berkeley in the 1980s (Rochlin, 1996) to compile similarities between high-hazard industries (e.g. aircraft carriers, air traffic control and nuclear power) that demonstrate a high level of safety (Roberts, 1990; Weick, 1987). HROs are complex systems operating in hazardous environments (Baker, Day, & Salas, 2006), whereby adverse events in these systems are frequently prevented or avoided (Bagnara et al., 2010). HROs are not error-free but rather understand that reliability is achieved through continuous management of variations (Weick, Sutcliffe, & Obstfeld, 1999), and they actively anticipate potential failures due to a constant preoccupation with failure (Lekka, 2011). These types of organisations achieve high safety levels because they perform proactive analysis and repairs continuously (Bagnara et al., 2010) and are constantly seeking to improve reliability by preventing errors and improving error recovery (Sutcliffe, 2011). As HROs recognise complexity and that systems are tightly-coupled, they are reluctant to simplify concerns regarding safety (Bagnara et al., 2010).

HRO theory is one means for bridging research on system safety and accident causation (Sutcliffe, 2011), representing a workstream that aims to address system safety in relation to high-hazard work and technologies (Weick et al., 1999). This approach aims to understand the conditions under which these types of organisations achieve high safety performance levels (Lekka, 2011) and provide insight into adaptive organisational forms operating in complex environments (Sutcliffe, 2011). Such organisations are seen to have a proactive approach to safety (Lekka, 2011); thus, research into HROs has focused on two components of achieving reliable performance, namely prevention and resilience (Sutcliffe, 2011). Prevention has predominantly focused on adherence to procedures to reduce unwanted performance variance. However, prevention alone is not enough and will also require adaptation to surprises, emphasizing the need for the second component, resilience (Sutcliffe, 2011). Resilience includes the ability to maintain functioning despite fluctuations, absorb strain, recover from untoward events and learn from previous events (Weick & Sutcliffe, 2007).

A key feature of HROs, proposed by Weick and Sutcliffe (2007), is that of 'collective mindfulness' (Chassin & Loeb, 2013). This feature is present in HROs through five unique characteristics that enhance reliability (Weick, 1987), including a reluctance to simplify, sensitivity to operations, a preoccupation with failure, a commitment to resilience and a deference to expertise by ensuring decisions are made by experts regardless of the organisational structure (Weick et al., 1999). The characteristics of a preoccupation with failure, a reluctance to simplify and a sensitivity to operations allow HROs to facilitate problem detection and anticipate unexpected events (Weick & Sutcliffe, 2007). The characteristics of commitment to resilience and deference to expertise allow HROs to contain and manage problems successfully if they occur (Weick & Sutcliffe, 2007).

An underlying concept of HROs is that despite experiencing errors, the errors do not disable the organisation (Sutcliffe, 2011). This outcome is generally achieved through dynamic organising principles (Weick et al., 1999), in that these organisations have mechanisms to monitor and report signals indicating a breakdown of the system (Barton & Sutcliffe, 2009; Sutcliffe, 2011). Dynamic organising requires the organisation to act mindfully (Sutcliffe, 2011) as well as have the flexibility and capability to respond to these indicators and events (Weick & Sutcliffe, 2007). By having a preoccupation with failure, the organisation is always alert for the smallest signal of a new developing safety threat, even in light of their current safety record (Chassin & Loeb, 2013; Cochrane et al., 2017).

HRO theory has emerged as a strategy to improve patient safety in healthcare due to the success that other industries such as aviation have demonstrated (Bagnara et al., 2010; Cochrane et al., 2017; Pronovost et al., 2006). Concepts such as the under specification of structures, which means the greatest expertise is available at the lowest practical level so that solutions can be implemented more effectively, are highly appealing to healthcare, allowing for those closest to have the greatest chance of responding expediently (Hales & Chakravorty, 2016). Furthermore, although principles relating to redundancy, incident reporting and accident analysis have already been implemented in healthcare systems (Tamuz & Harrison, 2006), and pockets of high reliability exist at a level of clinical staff behaviour and at a unit level (Vincent, Benn, & Hanna, 2010), studies on system safety perception suggest that healthcare is far from being HRO (Gaba et al., 2003). One reason may be that healthcare is

substantially different from 'traditional' HROs, such as nuclear and petrochemical industries, and does not share the same characteristics (Bagnara et al., 2010; Nemeth & Cook, 2007). In healthcare, safety tends to be predominantly reactive, whereas HROs have a proactive approach to safety (Chassin & Loeb, 2013). In addition, the five principles that guide high reliability are seldom observed in healthcare (Chassin & Loeb, 2013). This may be due to underdeveloped underlying infrastructure (Vogus & Hilligoss, 2016), such as behavioural, cognitive and workplace elements (Weick et al., 1999). Consequently, HRO theory may not be appropriate or directly transferable to healthcare (Chassin & Loeb, 2013; Cochrane et al., 2017). Some have suggested that HRO theory should not be prescriptive but rather informative and that healthcare should draw inspiration from other HROs rather than trying to emulate them (Vincent et al., 2010). Others have suggested that resilience may be a more suitable route to improving safety in healthcare than HRO theory (Nemeth & Cook, 2007).

2.3.3 Resilience Engineering

Resilience engineering is a paradigm influenced by a range of disciplines, including human factors, engineering, safety science and cognitive psychology (Anderson et al., 2016), which was developed to understand and manage safety in sociotechnical systems (Macrae, 2014a; Steen & Aven, 2011). This field offers an alternative to safety and safety management (Hollnagel, 2013) and originated due to the belief that conventional safety management and risk assessment methods are no longer adequate for today's complex systems (Hollnagel, 2007). Resilience engineering aims to create and maintain systems to be able to cope and adapt to changing environments (Nemeth & Cook, 2007). The emphasis of this paradigm is on understanding how success is obtained as well as how individuals learn and adapt in an environment containing faults and hazards (Hollnagel & Woods, 2006). The approach recognises that organisational systems operate close to performance limits and are inherently flawed, as a result requiring timely management of deviations once they are detected (Nemeth & Cook, 2007).

Resilience can be defined as 'the intrinsic ability of a system to adjust its functioning prior to, during, or following changes' to maintain the required operations of the system (Hollnagel, 2011, p. 16). This characteristic can be considered a fundamental quality that exists within individuals, groups and systems (Horne III & Orr, 1998). Resilience engineering focuses on this

attribute as a result of organisational processes that produce resilience at the level of a team or unit as opposed to individual psychological resilience (Anderson et al., 2016). Everyday adaption is required to address the fluctuations and unexpected events that occur while working in complex systems, which can be referred to as performance variability (Rankin et al., 2013). Performance variability within a system is both normal and necessary for the functioning of the system; therefore, safety cannot be obtained by constraining this variability and rather adverse events occur due to unexpected combinations of everyday performance variability (Hollnagel, 2007).

The key principles of resilience include top management commitment, flexibility, learning, awareness (Hollnagel, 2006), open communication and a non-punitive approach towards error reporting (Vogus & Sutcliffe, 2007). These principles overlap with other safety management paradigms (Costella, Saurin, & de Macedo Guimarães, 2009), such as safety culture and HROs. The four capabilities of resilience are the ability to anticipate what may potentially happen, monitor the current state, respond effectively when something occurs and learn from past experiences (Hollnagel, 2009). Resilience fosters learning from a wide array of experiences and identifies the shortcomings of the system, monitors the system operating levels relative to the performance limits and promotes the management of deviations as they emerge (Vogus & Sutcliffe, 2007). Such deviations and near-misses provide information about the overall health of the system and are considered a source for learning (Vogus & Sutcliffe, 2007). Within this context, learning becomes both an input and an outcome of resilience (Vogus & Sutcliffe, 2007). In addition, resilient organisations are better able to identify signals as forms of up-to-date information about ongoing operations and changes in the system, allowing an organisation to anticipate changes (Hollnagel, 2012; Hollnagel & Woods, 2006; Vogus & Sutcliffe, 2007). For organisations to become resilient, they need to have four main processes: prevention, protection, learning and vigilance (Brizon & Wybo, 2006).

An abstract model of the key theoretical concepts of resilience engineering developed for healthcare has been proposed by the Centre for Applied Resilience in Healthcare (Anderson, 2014). Figure 6 depicts the Concepts of Applying Resilience Engineering (CARE) model, which portrays the interactions between a system's components that may lead to success or failure

(Anderson, 2014). This model states that healthcare providers need to adapt and adjust their work, taking demand and available capacity into account. This interaction explains the differences in work-as-imagined and work-as-done and may result in either success or failure (Anderson, 2014). Work-as-imagined refers to the intended alignment of the demands of the system, which include patient acuity, numbers and quality standards, and the capacity, which involves staff levels, skills and equipment to meet the demands (Anderson et al., 2016). Adjustments and adaptations occur because demand and capacity are never completely aligned, resulting in work-as-done (Anderson et al., 2016). Outcomes include both successes and failures that affect patients, staff and the organisation (Anderson et al., 2016).

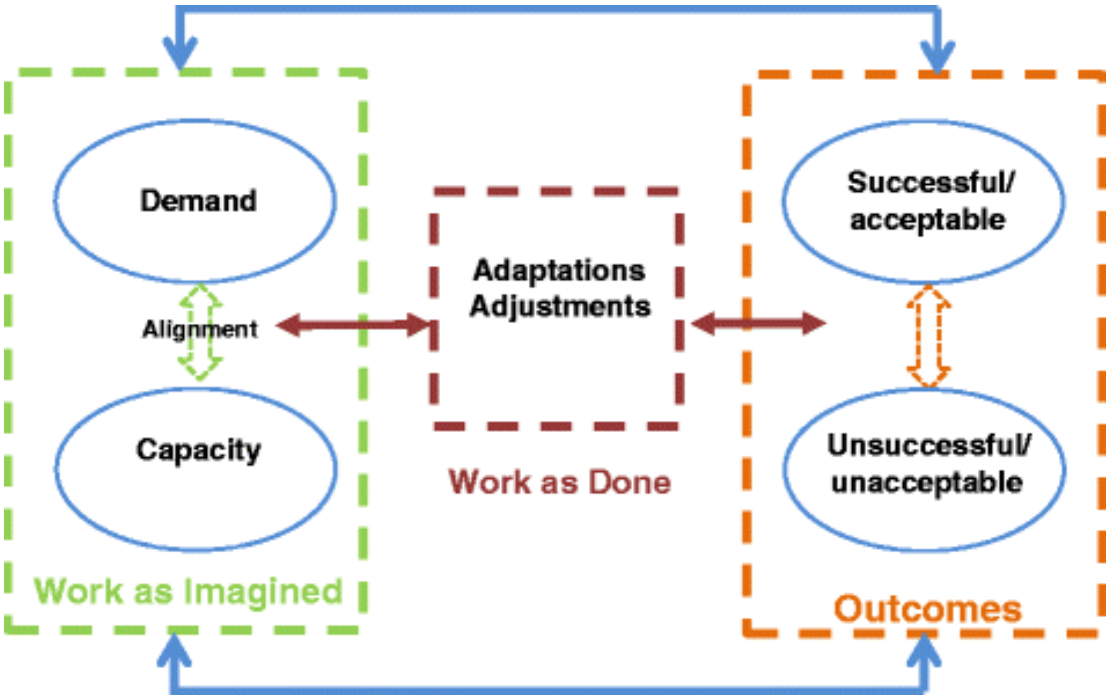


Figure 6: The Concepts for Applying Resilience Engineering (CARE) model – a model of organisational resilience in healthcare (Anderson et al., 2016). Used under Creative Commons CC BY 4.0 licence.

As resilience represents a system's intrinsic ability to adjust its functioning during or following disturbances within the system to maintain the required operations (Hollnagel, 2011), an additional paradigm that aims to assess a system's functioning, irrespective of whether the outcome is successful, is Safety-II (Hollnagel, Wears, & Braithwaite, 2015; Shorrock, 2014). The Safety-II concept may provide additional theories and methods for assessing and developing resilience and is a current concept driving safety improvements.

2.3.4 Safety-I and Safety-II

Safety, as defined by the *Oxford Dictionary*, is 'the condition of being protected from or unlikely to cause danger, risk, or injury'. Based on this definition, traditional safety, which has also become known as Safety-I, is characterized predominantly by 'something it is not' (Hollnagel, 2014), in that safety is a lack of risk or danger. The fact that most safety concerns in the past have originated from adverse outcomes has further enforced this definition (Hollnagel, 2014). As a result of these origins, various presumptions underpin this perspective of safety (Safety-I). These include the presumption that things go wrong due to identifiable failures of components, technology, individuals or procedures; that one can determine the root cause of accidents in terms of the cause-effect relations within the system (the causality credo); that systems are decomposable; and that the functioning of system components is distinctly bimodal, in that something either works or does not (Hollnagel et al., 2015). Furthermore, safety's focus on adverse events and incidents invokes both practical and psychological consequences (Hollnagel, 2014). This perspective has often adopted an approach that emphasises seeking out failures and malfunctions and eliminating their causes or improving barriers (Hollnagel, 2014). Such a method, however, limits the possibility of learning to infrequently occurring events; as a result, the costs and resources associated with safety concerns compete with other costs (Hollnagel, 2014).

The Safety-I definition focuses on decreasing the number of adverse events to the lowest feasible quantity (Hollnagel, 2014) and therefore creates a problem concerning measurement and how to quantify safety. Based on this definition, safety is measured indirectly and by what happens in its absence (Hollnagel, Leonhardt, Licu, & Shorrock, 2013), meaning accidents and incidents (Hollnagel et al., 2015), and as a result, the greater the safety within the system, the less there is to measure (Hollnagel, 2014). From this perspective, safety management starts once something has been identified as a risk or has gone wrong (Hollnagel et al., 2015). In contrast, Safety-II, defined as 'the ability to succeed under varying conditions, so that the number of intended and acceptable outcomes is as high as possible' (Hollnagel, 2014, p. 179), presents an alternative approach to measuring safety (Hollnagel, 2014).

The key principles and theories underpinning Safety-II are the concepts of performance adjustments, performance variability, work-as-done as opposed to work-as-imagined

(Hollnagel et al., 2015), trade-offs and emergence (Shorrock, 2014). This new perspective aims to provide insight into how organisations, units and individuals within the system continually achieve desirable outcomes despite adversity and strain (Vogus & Sutcliffe, 2007). Safety-II not only looks at the positives or successes (Shorrock, 2014) but also includes all possible outcomes and hence normal everyday performance (work-as-done). Work-as-done refers to how work tasks are really executed by staff, as opposed to work-as-imagined, which refers to the prescribed means for how work should be completed (Hollnagel et al., 2015). Safety can be achieved through aligning work-as-done with work-as-imagined (Hollnagel et al., 2015). This perspective creates a far greater number of opportunities for learning (Hollnagel, 2014) as well as better aligning with business and operational goals due to the focus on the effectiveness of performance (Shorrock, 2014). Furthermore, this alternative perspective on safety can be considered complementary and not in competition with the more traditional perspective on safety (Safety-I) (Hollnagel et al., 2013).

Contrasting Safety-I and Safety-II reveals the shift in paradigm that Safety-II provides to the concept of safety (Shorrock, 2014). Hollnagel and colleagues (2013) have provided a comparison of the key components of the two definitions of safety, which have been summarised and extended in Table 2. As yet, no legislative force addresses Safety-II in contrast to Safety-I. In addition, data, literature and methods for studying successful human and organisational performance as defined by Safety-II remain scarce and new tools in addition to those currently adopted by Safety-I need to still be developed for Safety-II (Hollnagel, 2014). This new perspective on safety allows for a shift in focus that considers the human as an asset instead of a liability and promotes a proactive safety management approach (Rankin et al., 2013). Along similar lines, following several major system failures during the 1980s, there has been a drive to shift from identifying organisational preconditions for failure to developing knowledge of specific factors that may assist in enhancing safety (Pidgeon, 1998). This is similar to Safety-II's focus of a "system's ability to succeed under varying conditions". In addition to this development, there has been an appeal to move beyond error in order to understand system failures by considering second stories, avoiding hindsight bias, and understanding work as it is performed, as described by 'work-as-done' (Woods & Cook, 2002).

Table 2: Overview of the key components of Safety-I and Safety-II. Adapted from Hollnagel, 2014, p. 147.

	Safety-I	**Safety-II**
Definition/ Focus	Ensuring 'as few things go wrong as possible'	Ensuring 'as many things as possible go right'
	Technical, human and organisational causes of failure	System's ability to succeed under varying conditions
Safety Management Principle	Reactive Approach: Response to an adverse event or if unacceptable risk is identified	Proactive Approach: Continuously anticipate developments and events
Risk Management Approach	Identify causes and contributory factors and constrain performance by reinforcing compliance and eliminating variability	Understand conditions where performance variability can become difficult to monitor and control
View of "Human Role"	Human seen as a source of error (predominantly a liability or hazard)	Humans are seen as a necessary resource and provide flexibility and resilience
Foundations	• Systems are decomposable • Functioning is bimodal • Work-as-imagined	• Performance is variable • Performance adjustments are essential • Work-as-done
Mechanisms	Causality Credo	Emergent
Manifestation	Occurrence of adverse events or recognised risks	All possible outcomes
Regulatory requirements	Set and predominantly well-defined	No requirements to look at what works well
Models	Swiss cheese model	Resilience
Tools	Root cause analysis, AcciMap, STAMP	

As healthcare systems are composed of numerous systems within a system (Braithwaite et al., 2013), this type of arrangement can be described as an intractable system; therefore, for the system to function, clinical work is and must be variable and flexible (Hollnagel et al., 2015). In practice, the people in the system and their flexibility and adaptability are the factors ensuring that this complex system works and is reliable (Hollnagel et al., 2015). Consequently, examining work in healthcare in the context of work-as-done as opposed to work-as-imagined is necessary (Wears, Hollnagel, & Braithwaite, 2015). As a result of this examination and in consideration of how the demand and complexity of healthcare are growing, this field will benefit from adopting a Safety-II approach (Hollnagel et al., 2015). One example of how Safety-II has been studied in healthcare was the analysis of an incident reporting system that appears to be functioning 'normally' to better understand the processes involved in reporting and learning (Hewitt, Chreim, & Forster, 2016). Another example was the analysis of the Michigan Keystone initiative, a project aimed at reducing central line insertion bloodstream infections, to understand why this project was successful (Dixon-Woods, Bosk, Aveling, Goeschel, & Pronovost, 2011).

As with most paradigms, there are those in favour and those not for Safety-II. Support for this paradigm is visible in related concepts such as the CARE model emerging from resilience engineering, that incorporates key principles common to both Safety-II and resilience engineering, such as work-as-done and work-as-imagined. This is not that surprising as key models and theories from both fields have emerged from the same prominent authors (e.g. J. Anderson, J. Braithewaite and E. Hollnagel). Furthermore, elements of Safety-II align well with other current but slightly older concepts driving safety improvement, for example safety culture. In line with the third age of safety, researchers have been analysing adverse events in the context of the organisational and safety culture in which they occur (Hofoss & Deilkås, 2008). Although the assessment of safety culture has originated from a Safety-I perspective, a closer inspection of the literature reveals the compatibility of assessing safety culture from a Safety-II perspective (Macrae, 2014a).

Then there are those that are hesitant to accept Safety-II (e.g. Smith & Valenta, 2018) and those that argue against it (e.g. Leveson, 2020), challenging it as a paradigm and its practical application to enhancing safety. This may be due to several reasons, including the novelty or modernity of this paradigm, as the first textbook on this was published in 2014, a lack of defined and prescribed methods, and that some underpinning principles are not 'new' to the safety field. The distinct divide in opinion on this paradigm was personally experienced by the author of this thesis at the Healthcare Systems Ergonomics and Patient Safety (HEPS) conference in 2016, whereby the discussion regarding the acceptance and application of this safety approach in the healthcare domain was explored. During this conference, two camps emerged, one where participants were presenting new ways of applying Safety-II to their work in healthcare and the other that expressed the opinion that this perspective would not be accepted in their healthcare organisations. The Safety-II paradigm has been included in this thesis and underpinned some of the questions explored in this research as it not only supports other current concepts driving safety improvements but also provided a novel approach to incidents by trying to determine 'what worked well'.

2.4. Conclusion – The 'Gap' to be addressed

This chapter aimed to provide the theoretical basis and a common underlying context across the case studies presented later in this thesis. This goal was achieved by describing the healthcare context, followed by a brief description of the development of safety theory and related concepts, and finally establishing the current concepts driving safety improvements. Unconventionally, to identify the gap this research aims to fill, one first needs to outline the overlap of the paradigms, theories and literature described in this chapter.

The literature review highlighted that most of the current concepts driving safety improvements have a degree of overlap. In addition to advocating a proactive approach to safety (Lekka, 2011; Rankin et al., 2013), these concepts promote addressing problems as they arise. This is similar to the concept of risk management, a more traditional approach to safety. Risk management aims to understand failure and uncertainties and includes incident reporting and analysis to address underlying threats and improve safety (Macrae, 2014a). A continual process (Weick, 1987) of uncovering and dealing with errors is needed as sociotechnical systems are imperfect and degrade over time, consequently requiring active management (Macrae, 2014a). The current concepts driving safety improvement specifically resilience engineering and the Safety-II perspective may assist in providing new and alternative means for risk management and the improvement of safety within a system (Furniss, Back, Blandford, Hildebrandt, & Broberg, 2011). Furthermore, HRO theory shares several similar traits to the theory of resilience engineering (Le Coze, 2016; Lekka, 2011), including domains such as situation awareness (Le Coze, 2016), and both have been successfully applied to high-risk systems such as aviation and nuclear industries (Lekka, 2011). Though originating from different fields, HRO from the social sciences and resilience engineering from engineering and cognitive sciences (Le Coze, 2016) both include trying to develop a safety culture (Costella et al., 2009) and aim to enable organisations to return from error states to normal operation as quickly as possible (Lekka, 2011). Both approaches offer principles for organisations to improve their safety and reliability (Lekka, 2011) and are key contributors to the field of safety (Le Coze, 2016).

Addressing problems as they arise, a common theme across the concepts driving current safety improvements, may promote safety in that, when problems are small, there may be more ways to solve them. However if these problems develop, they tend to become entangled with other problems, resulting in fewer options for solutions (Sutcliffe, 2011). One means of addressing problems as they arise involves the use of weak signals, which conceptually is also related to 'a preoccupation with failure' from HRO theory (Cochrane et al., 2017). Furthermore, the process of vigilance specifically ties resilience engineering to weak signals, as vigilance is 'the ability of a system to detect and interpret weak signals' (Brizon & Wybo, 2006). Such signals assist in detecting deviations and facilitate swift and flexible action (Vogus & Hilligoss, 2016; Weick et al., 1999). The notion of warnings, signs or signals features in most of the current concepts driving safety improvements described in this chapter, as can be seen in Table 3, which highlights excerpts from the literature presented in this chapter pertaining to the concept of weak signals.

Table 3: Excerpts that reference weak signals (also referred to as signals, warnings, signs or cues) from the literature presented in this chapter.

Theoretical Field	Reference to signals, warnings or cues
Adverse Events, Accident and System Failures (Section 2.2.2, p. 23)	Turner also argued that *warnings or signals* of deteriorating situations existed; however, as a result of 'cultural denial', the problems go unaddressed during this incubation period (Pidgeon, 1998).
System Failures in Healthcare (Section 2.2.3, p. 25)	Often, these system failures featured smaller failures, which may be considered as *early warning signs*, that occurred prior to the larger event – which, addressed effectively, might have prevented consequential failures (Sitkin, 1992 as cited by Edmondson, 2004).
Safety Culture (Section 2.3.1, p. 29)	*Cues or signals* have been identified as an element of the social processes of patient safety culture (Reiman et al., 2010), which may assist in guiding behaviour.
HRO Theory (Section 2.3.2, p. 31)	Having a preoccupation with failure, the organisation is always alert for the smallest *signal* of a new developing safety threat, even in light of their current safety record (Chassin & Loeb, 2013; Cochrane et al., 2017).
Resilience Engineering (Section 2.3.3, p. 33)	In addition, resilient organisations are better able to identify *signals* as forms of up-to-date information about ongoing operations and changes in the system, allowing an organisation to anticipate changes (Hollnagel, 2012; Hollnagel & Woods, 2006; Vogus & Sutcliffe, 2007).

The concept of weak signals appeared in the overlap of the theories included in this chapter, and within this overlap lies the gap this research aims to address. The current concepts driving safety improvements aim to enhance safety through consideration of the wider system, and attempt to address deeper system elements that are engrained and complex, for example

culture and resilience. This is no simple task. In healthcare this particularly is highlighted in that patient safety is still a current topic of interest (Dhillon, 2012), both in the NHS and internationally, despite the large quantities of research available (Vincent, 2011). Resultantly, clear means of enhancing these deeper system elements that contribute to safety, remain elusive. This research aims to address one element within a common gap across the current concepts driving safety improvement, namely, how to operationalise these systemic changes to elicit these desired characteristics through enhancement of one common element. As can be seen in Table 3, the use of weak signals is a common mechanism across these different safety concepts and by exploring weak signals in more depth, this research aims to contribute to knowledge to address this gap. Weak signals can provide the opportunity to prevent incidents if their potential significance is identified and individuals respond to them (McLeod, 2015). By addressing weak signals and system drift, a proactive approach to improved safety performance can be established (Carrillo & Samuels, 2015; Dekker, 2011). This chapter provides the context wherein the gap this research aims to address exists. A more focused literature review on weak signals associated with safety follows in the next chapter, wherein which this gap will be explored in more detail.

Chapter 3: Focused Literature Review – Weak Signals

As highlighted in the previous chapter, a common theme across current concepts driving safety improvement is the concept of weak signals indicating problems and 'system drift' that, if addressed, may aid in promoting a proactive approach to safety management (Carrillo & Samuels, 2015; Dekker, 2011). This chapter provides a synthesis of related literature from different fields that may be relevant for understanding weak signals from a HFE perspective. Furthermore, this chapter provides the theoretical perspective from which this research will be approached to understand the processes and mechanisms underlying weak signals. In contrast to the previous chapter, this scoping literature review focuses on depth to provide as holistic as possible of an understanding of the underlying concept of weak signals that may affect behaviour.

The aims of this chapter are to provide a synthesis of the available literature on weak signals and identify the key elements to investigate weak signals in healthcare. To address this aim, this literature review intended to address the following objectives:

- Review the available literature on weak signals from a variety of fields.
- Compare the different terms available that represent the concept of weak signals and justify selection of the term 'weak signal'.
- Develop a definition of weak signals so that it could be operationalised in the subsequent case studies.
- Identify the core elements that form the structural components or attributes of weak signals.
- Identify the behaviours associated with weak signals and potential theories that would describe these mechanisms.
- Draft a preliminary practical framework to guide the research on weak signals in the subsequent case study chapters.

This contributes towards addressing the overall aim of the thesis, which is to provide the theoretical basis and approach to guide research into weak signals that present in healthcare work systems, by providing the theoretical foundation upon which to develop a framework and analysis approach for weak signals in healthcare in the subsequent case studies.

This chapter will first review the relevant literature on terms and definitions associated with the concept of signals, the properties of signals, and the processes associated with the detection, identification and processing of signals. This is followed by an overview of related theories and constructs that may be applicable to understanding the mechanisms underlying signal processes. The relevant literature is then synthesized and compiled to generate the underlying structure from which a preliminary draft of the framework is generated that is to form a conceptual representation of weak signals in healthcare. In the section where the literature is synthesised (Section3.2, p. 70), justification for the selection of the term 'weak signals' is provided, and a definition is generated. This chapter concludes with the first version of this framework that is to be tested and expanded in the subsequent case studies.

3.1 Review of Literature – Signals and Related Theories and Constructs

The concept of signals, warning signs or cues, under various names, has received increasing attention in recent years in relation to organisations improving safety (McLeod, 2015). These signals have been identified retrospectively in numerous organisational disasters (e.g. the Challenger, Chernobyl, Deepwater Horizon and Exxon Valdez disasters), and the associated investigation reports suggest that signals appear well in advance of the final triggering event of these disasters (Hensgen, Desouza, & Kraft, 2003). Also within the healthcare context, early warnings, signals and weak signals have been identified retrospectively in numerous healthcare disasters, for example, the failures of care discovered in the Mid Staffordshire case (Macrae, 2014b) and the Bristol Royal Infirmary (Walshe & Shortell, 2004; Weick & Sutcliffe, 2003).

The concept of signs, similar to the idea of weak signals as used in this thesis, has been most extensively studied in the field of semiotics (Tarasti, 2001), which is the study of sign and symbol systems (Edgerton, 2010) and their construction, usage and meaning (Jackson & Hogg, 2010). Furthermore, this field of study investigates the relationship between signs and the aspects they reference as well as the properties and the use of signs (Jackson & Hogg, 2010). While semiotics has predominantly focused on linguistics and non-verbal communication (Tarasti, 2001), this field does provide some relevant literature on elements relating to the

concept of weak signals that may be useful from a HFE perspective. As a result, relevant elements from the field of semiotics are included in the literature review below.

Numerous other fields have explored this concept from a practical perspective. Signals and terms that refer to a similar underlying concept have been used in the safety-related literature as early as the 1950s. For example, Powell and colleagues (1953) referred to the possibility of 'warning and threat' phenomena that precede man-made disasters. Weak signals, under this specific term, have been studied as early as 1975 in the field of strategic management (Ansoff, 1975). In addition, the concept has also been studied in the fields of business management (Ejdys, 2017; Haeckel, 2004; Schoemaker & Day, 2009), future studies, which focuses on predicting upcoming trends for organisational and management systems (Hiltunen, 2006, 2008, 2010; Holopainen & Toivonen, 2012; Kaivo-oja, 2012; Mendonça, Cardoso, & Caraça, 2015), information theory and cybernetics (Coffman, 1997a) and decision-making for firefighting (Barton & Sutcliffe, 2009; Okoli, Watt, & Weller, 2017). More specifically and relevant to this thesis, researchers have also studied signals in the field of safety as they relate to risk and resilience in aviation (Macrae, 2014a), human performance models (Rasmussen, 1983), as cues in the Bristol Royal Infirmary disaster (Weick & Sutcliffe, 2003), cues that form part of neonatal intensive care unit (NICU) nurses' patient assessment skills (Crandall & Getchell-Reiter, 1993; Militello, 1995), gut feelings in diagnostic reasoning of general practitioner (GP) traineeships (Stolper et al., 2015), cues for assessing risks of patients developing depression before and during IFN-a treatment (Hepgul et al., 2012), cues for early recognition of sepsis (Patterson et al., 2016) and situational cues in anaesthesiology (Gaba, Howard, & Small, 1995), as well as being discussed in a review of healthcare management and safety (Kerfoot, 2004).

3.1.1 Signals - Terms and Definitions

Signals and related concepts have been described in the workplace under numerous terms and colloquial phrases, including 'something just feels funny', 'a hunch' (Coffman, 1997a) and 'gut feelings' (Stolper et al., 2015), as well as red flags (Coleman, Parry, Chalmers, & Min, 2006). Additionally, across different research fields, the concept of signals has also been studied under numerous names or terms (Brizon & Wybo, 2009). These designations include 'threats of impending danger' (Turner, 1978), early warnings (Øien, Utne, & Herrera, 2011),

warning signals (Mendonça, Cardoso, & Caraça, 2012), cues (Crandall & Getchell-Reiter, 1993; Okoli et al., 2017; Weick & Sutcliffe, 2003), critical cues (Endsley, 1995), leading indicators (Raben, Bogh, Viskum, Mikkelsen, & Hollnagel, 2017) and emerging issues (Hiltunen, 2010). Table 4 lists numerous identified synonyms for terms that describe signals or a similar underlying concept, their sources, and the research fields where they originated. Table 5, which provides a review of the definitions of some of these terms, further supports the notion that these terms refer to a common underlying concept.

Table 4: Synonymous and related terms for weak signals and examples of sources where these terms have been used.

Terms (Examples of Sources)	**Fields or Context**
Threats of impending danger (Turner, 1978)	Accident analysis
Early warnings (Kerfoot, 2004; Øien et al., 2011)	Nursing management, Safety science
Warning signals (Mendonça et al., 2012)	Future studies
Hunch (Weick, Sutcliffe, & Obstfeld, 2005)	Sensemaking
Weak signals (Barton & Sutcliffe, 2009; Brizon & Wybo, 2006; Vogus & Hilligoss, 2016)	Organisational safety, Wildland firefighting, Resilience, High reliability in healthcare
Early warning signs (Barton & Sutcliffe, 2009)	Organisational safety
Signals (Hensgen et al., 2003)	Crisis management
Signs (Eco, 1976; Tarasti, 2001)	Semiotics
Cues (Barton & Sutcliffe, 2009; Crandall & Getchell-Reiter, 1993; Gaba et al., 1995; Hepgul et al., 2012; Johannesen & Wiig, 2017; Klein, Calderwood, & MacGregor, 1989; Klein, Pliske, Crandall, & Woods, 1999; Militello, 1995; Okoli et al., 2017; Weick & Sutcliffe, 2003)	Organisational safety and reliability, Intuitive decision-making in nurses, Situation awareness in anaesthesiology, Cues indicating the patient's status risk of developing depression, Sensemaking in emergency departments, Naturalistic decision-making, Nurses' patient assessment skills, Decision-making on the fireground, Sensemaking
Critical cues (Barton & Sutcliffe, 2009; Endsley, 1995)	Situation awareness, Organisational safety and reliability
Leading indicators (Raben et al., 2017)	Resilience in healthcare
Emerging issues (Hiltunen, 2010)	Futures studies
Gut feelings (English, 1993; Stolper et al., 2009)	Clinical decision-making and intuition, Diagnostic reasoning

Due to the degree of ambiguity associated with the concept of weak signals, discussion regarding a definition can be found across research fields (Coffman, 1997a; Hiltunen, 2010). Furthermore, possibly due to the common understanding of what these terms refer to, such terminology is frequently used in publications without defining exactly what is meant by the term. Considering the different terms listed in Table 4: many were not necessarily defined in the associated publications. As a result of the differing views of signals generated by the research community (Hiltunen, 2010), various definitions, in addition to the different terms used, have been produced. Accordingly, Table 5 presents a list of terms and definitions for

the underlying concept of signals, as well as the research field from which these have been extracted.

Table 5: Examples of terms and definitions synonymous with weak signals, along with the field of research whence the definition has been extracted.

Term	Definitions	Author	Field
Signs	'…signifies something and stands for something other than itself'	(Desouza & Hensgen, 2004, p. 57)	Knowledge management
Signal	'An object used as a sign to convey warning, direction, or **information**.'	Oxford English Dictionary	
	'Continuous quantitative **indicators** of the time-space behaviour of the environment'	(Rasmussen, 1983, p. 260)	Human performance
Weak Signals	'A seemingly random or **disconnected** piece of **information** that at first appears to be background noise but can be recognized as part of a **significant** pattern by viewing it through a different frame or connecting it with other pieces of information.'	(Schoemaker & Day, 2009, p. 86)	Business management
	'Imprecise early **indications** about **impending** impactful **events'**	(Ansoff & Mcdonnell, 1990, p. 20)	Strategic management
	'unstructured information and its **implications** to the organization are at an early stage very hard to define'	(Ilmola & Kuusi, 2006, p. 991)	Corporate decision-making
	'information was **informal** and/or **ambiguous**, so that the **threat** to flight safety was not clear.'	(Vaughan, 1996, p. 244)	Aviation safety
	'Signs **warning** of a financial, psycho-social or technological risk, that are **difficult to detect**.'	(Guillaume, 2011, p. 3)	Safety
Early warning signals	'foretell an **untoward incident'**	(Kerfoot, 2004, p. 29)	Healthcare management
Threats of impending danger	'piece or several pieces of **information** that require identification and processing by the appropriate psychological or social system'	(Turner, 1978, p. 42)	Man-made disasters
Cue	'any stimuli with **implications** for action'	(Okoli, Weller, & Watt, 2016, p. 95)	NDM
	'Cues can be **small bits** of **information, events** or simple familiar structures, and people turn to earlier scripts, schemes, or frames to ascribe meaning to cues and decipher the situation.'	(Johannesen & Wiig, 2017, p. 4)	Sensemaking
Gut feelings	'… a sense of alarm, i.e. the feeling that there may be something wrong with the patient, **without knowing exactly what and why**.'	(Stolper et al., 2015, p. 500)	Health Science Education

*Words in bold describe the common elements across the definitions related to information and upcoming events. Bold and underlined words describe the common elements across the definitions related to the type of information signals provide.

Although the definitions are slightly different for the different terms and even for the same term explored in different contexts, common elements can be identified across the definitions, which supports the notion that the different terms refer to one underlying

concept. The key elements include information (Ilmola & Kuusi, 2006; Mendonça et al., 2015; Schoemaker & Day, 2009; Turner, 1978; Vaughan, 1996) that provides an indication (Ansoff & Mcdonnell, 1990; Guillaume, 2011; Kerfoot, 2004; Mendonça et al., 2015; Rasmussen, 1983) of upcoming or emerging events (Ansoff & Mcdonnell, 1990; Mendonça et al., 2012, 2015) that may have significant implications (Ilmola & Kuusi, 2006; Okoli et al., 2016; Schoemaker & Day, 2009). A final key element identified across most of the definitions was the reference to the type of information that signals provide (Ansoff & Mcdonnell, 1990; Ilmola & Kuusi, 2006; Mendonça et al., 2012, 2015; Schoemaker & Day, 2009; Stolper et al., 2015; Vaughan, 1996), in that it is often imprecise (Ansoff & Mcdonnell, 1990), ambiguous (Hensgen et al., 2003; Vaughan, 1996), incomplete (Mendonça et al., 2012) and may require active identification and processing (Turner, 1978).

One additional concept, similar to signals, that must be mentioned at this stage of the literature review is leading indicators as recently studied in healthcare in the context of a Safety-II approach (Raben et al., 2017; Raben, Bogh, Viskum, Mikkelsen, & Hollnagel, 2018). Raben and colleagues (2017) defined this term as 'signs or symbols used as active monitoring to control current and future behaviours or actions to achieve desired outcomes' (p. 2). Similar to the definitions provided above, this description also contains elements referring to information on upcoming events and suggests that this too refers to the underlying concept being described in this chapter.

This section highlights some of the ambiguity associated with the concept of signals. This is potentially due to the numerous different terms for the same underlying concept, the different definitions, and as the word is a common term, the frequency of use of the term in the literature without providing a definition. As a result of this, in *Section 3.2.1* (p. 71), the term to be used in this research will be clearly stated and justified as well as providing a definition that will support the research in the subsequent case studies. Although the definitions and terms refer to the same underlying concept, the differences that present as adjectives (e.g. early, weak, critical) associated with the term and slight differences in definitions may be as a result of differing degrees of properties (e.g. temporal location, strength). An additional example of a property described in the definitions was the quality of the information, typically phrased as 'informal', 'ambiguous' and 'unstructured'. In addition

to this property, the literature yielded several additional properties pertaining to signals, which will be described next.

3.1.2 Properties of Signals

The literature seldom describes the properties or characteristics of signals, perhaps due to their elusive nature. However, it is possible to extract the characteristics or properties from elements contained within the definitions of signals, described above, as well as the specifying characteristics authors use to generate the typology for the signals they observe. Some such properties identified in the literature and across the definitions included the strength of the signal (Hiltunen, 2010), whether signals signify a threat or an opportunity (Coffman, 1997a), and the form of the information, such as a signal being subjective or objective. The first property that will be described in more detail is signal strength, which is not only a common feature in several definitions (see Table 5) but is also used in several typologies described later in this section. Following this, the different types of signals and the properties that can be inferred from the typologies will be described.

3.1.2.1 Strength of Signals

Strength is a key characteristic often used to differentiate between signal types. Despite this, defining a scale for the strength of signals is challenging (Hiltunen, 2010), and therefore researchers in various fields have generated diverse theories regarding signal strength. The most common theories, which find support in the literature, specify that the strength of a signal is linked to the degree of difficulty in interpreting the signal (Hiltunen, 2010), denote how readily discriminable the signal is (Kaivo-oja, 2012; Nevin, 1969), discuss the precision of the signals (Turner, 1978) or indicate the difficulty in recognising the significance of the information they contain or the difficulty in projecting the potential implications for future events (McLeod, 2015). Strong signals provide a specific indication (Guillaume, 2011) and are easier to detect and understand in terms of future implications (McLeod, 2015). In contrast, weak signals are often vague (Ansoff & Mcdonnell, 1990). The more precise the signal, the more likely it will be recognised (Turner, 1978). However, in most cases, warning signals are not precise (Turner, 1978). Weak signals must 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). Tasks and situations where staff

need to manually monitor parameters and integrate data and information over time to determine whether a system is within normal operating boundaries involve inherently weak signals (McLeod, 2015). This is as staff have to rely on complex perceptual and cognitive work to detect and integrate the data into a signal about the state of the process (McLeod, 2015). An additional aspect that may contribute to the vague nature of weak signals is the lack of clarity regarding whether signals are merely signs of emerging issues or are themselves emerging issues (Hiltunen, 2010).

In addition to the degree of interpretation required, signal strength is also dependent on the context within which the signal is found (Hiltunen, 2008). In combination with the possible subjective element of signals, a signal may appear weak to one individual and strong to another (Hiltunen, 2008, 2010). This phenomenon is explained by semiotics, considering that analysing words, gestures or situations is an interpretative process, and consequently, a fixed literal meaning is not possible (Edgerton, 2010). Signals that completely rely on the situation or context in which they appear are weak signals and have no inner force themselves (Tarasti, 2001). Strong signals communicate the properties of their situations without being completely reliant on the context (Tarasti, 2001). A final element that might impact signal strength is whether the information contained in the signal is objective or subjective, as signals can be in the form of either tacit or explicit knowledge (Koivisto, Kulmala, & Gotcheva, 2016). Conflicting ideas or theories exist on whether weak signals can be subjective, objective or possibly both (Hiltunen, 2010). However, the type of knowledge contained within signals can be transferred between people via socialisation and altered from tacit to explicit by transforming the tacit knowledge into an understandable form through externalisation (Kaivo-oja, 2012).

Several theories exist on the elements that strengthen weak signals, namely the proximity to the event, the number of signals and the combination of numerous signals. With regards to the proximity of the event, the theory is that the strength of the signal will progressively increase with time as the proximity of the event increases and as more extensive knowledge of the event becomes available (Ansoff, 1975). If a sufficient number of signals are identified, the possibility of identifying the emerging event should increase (Hiltunen, 2010), as the signals are strengthened as more information from other signals is combined (Hiltunen, 2008;

Krippendorff, 2009). Furthermore, it has been suggested that numerous weak signals can be strengthened through the application of HFE design principles (McLeod, 2015).

3.1.2.2 Types of Signals

Authors from different research fields have used diverse properties to classify signals into a variety of types. Several additional properties can be identified from the typologies used in different research fields. Table 6 describes the different classifications along with the associated field and source. Furthermore, these classifications were categorised in this review according to the defining criteria or properties used for the typology and have been based on the type of information signals provided (e.g. Vaughan, 1996), the perceptibility of the signals (e.g. Coffman, 1997b), the relation to an event (e.g. Hiltunen, 2010), the occurrence or frequency of the signal (e.g. Vaughan, 1996), the form (e.g. Tarasti, 2001), the source (e.g. Eco, 1976; McLeod, 2015; Tarasti, 2001), the temporal components of the signal (e.g. Tarasti, 2001) and the type of outcome it predicted (e.g. Stolper et al., 2009). The classifications were divided into two categories in this review: typologies based on a single property and typologies based on multiple properties of signals.

Five sources of literature described single property typologies, based on the perceptibility, event-, source- and outcome-related information of signals. Eco (1976) identified two types of signals, which the author referred to as signs, based upon the source; specifically, natural signs originate from physical events from natural sources, and non-intentional signs are signs originating unintentionally from human behaviour. Coffman (1997b) identified three types of weak signals based on their degree of perceptibility: signals beyond one's perception, signals within one's perception but unrecognised by one's mental models and signals recognised by one's mental models that result in modifying one's behaviour. Mental models are internal representations of situations, actions, objects or people that underpin one's understanding of a system and are built on experience and observation (Wilson, 2001). These models facilitate explaining and predicting the behaviour of a system (Wilson, 2001). Hiltunen (2010) differentiated between signals that represent information relating to emerging events or signals that constituted the emerging event. McLeod (2015) also identified two types of signals, type A and type B, based on the source of the signals. Type A signals are given off by equipment or instrumentation indicating the current state of the system, whereas type B

signals originate from the behaviour and actions of individuals in the system that indicate the system's defences are being eroded (McLeod, 2015). In contrast, Stolper and colleagues (2009) identified two types of signals, those that provided a sense of concern or alarm and those that provided a sense of reassurance.

Table 6: The different classifications of signals, the source, and the field of research from which it stems.

Author	Description	Classification	Field
Single Property Typologies			
Eco (1976)	1) Natural signs – Physical events from a natural source 2) Non-intentional signs – Human behaviour not intentionally emitted	Source-related	Semiotics
Coffman (1997b)	1) Signals beyond perception 2) Signals within perception but unrecognised by possessed mental models 3) Signals recognised by mental models that are used to modify behaviours	Perceptibility	Business management
Hiltunen (2010)	1) Early information or initial symptoms of an emerging event 2) The emerging event itself	Event-related	Future studies
McLeod (2015)	1) Type A – Signals originating from equipment or instrumentation about the state of the process or operation 2) Type B – Signals about the process of undertaking an activity. These include signals given off by behaviour, decisions, or actions of individuals in the system	Source-related	Human factors (Oil, gas and process industries)
Stolper et al. (2009)	1) Sense of alarm 2) Sense of reassurance	Outcome-related	Clinical decision-making
Multiple Property Typologies			
Vaughan (1996)	1) Routine signals – repeated signals that become routine due to the frequency 2) Mixed signals – information indicating trouble that is interspersed with information indicating all was well 3) Weak signals – informal and ambiguous information so that the threat to safety is not clear	Occurrence and Information-related	Accident analysis
Tarasti (2001)	Six species of signs: 1) Pre-signs – the state before signs are formed 2) Trans-signs – signs in transcendence 3) Act-signs – signs actualised in the present world 4) Endo- and exosigns – exosigns refer to signs in the outside world, and endosigns refer to signals inside the mind 5) Internal/external signs 6) Quasi-signs – signs that should not be read as if they were true	Temporally-, form- and source-related	Existential semiotics

Two studies used multiple property typologies for signals. The combination of properties employed to differentiate between the different types of signals included occurrence and information-related properties, as well as a combination of temporal, form and source properties. In their analysis of the Challenger Launch Decision, Vaughan (1996) identified

three types of signals related to safety in the form of routine signals, mixed signals and weak signals. These signals differed from one another by the type of information they provided and the frequency of their occurrence (Vaughan, 1996). In the field of existential semiotics, a sub-field of semiotics, Tarasti (2001) identified six types of signals, referring to them as signs, that were differentiated by temporal aspects, form and source-related elements. Of those six, those relevant to this thesis were exo- and endosigns. These types of signs, related to the form or source, were divided into those present in the outside world (exosigns) and those created in the mind (endosigns). Furthermore, through communication of the endosigns, additional exosignals can be created (Hiltunen, 2010).

The most common typology was the source-related typology, identified in three of the seven sources (e.g. Eco, 1976; McLeod, 2015; Tarasti, 2001). This appears to be the most practical typology with respect to if one knows where to look for signals one may be able to locate them. Both the perceptibility (e.g. Coffman, 1997b) and information-related (e.g. Vaughan, 1996) typologies, can be seen as dependent on signal processing, an aspect that may vary greatly between individuals. For the typologies of event (e.g. Hiltunen, 2010), outcome (e.g. Stolper et al., 2009) and occurrence (e.g. Vaughan, 1996), these may have been determined retrospectively. This raises several questions; namely can these categories be applied prospectively and are they practical. It was decided not to predefine a typology for the case studies included in this research, but rather allow the typology to emerge from the data and select a categorisation scheme with the greatest practical application.

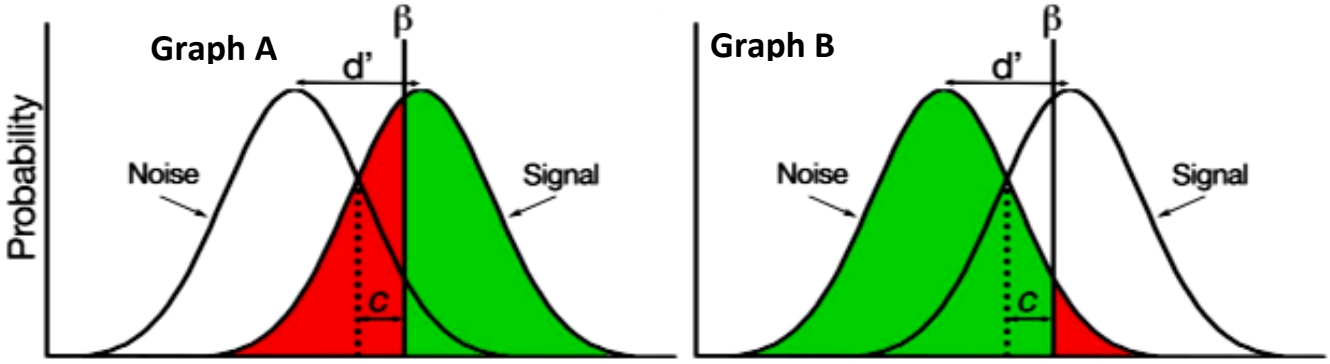
3.1.3 Detecting, Identifying, Processing and Responding to Signals

As previously mentioned, signals do not always reflect a complete and true state of the emerging event; thus, they often require searching and examining sources of information (Hiltunen, 2010). Signals can be easy to miss when they are hidden in noise (Harrysson, Métayer, & Sarrazin, 2014) and can be described as existing amid a 'context of uncertainty' (McLeod, 2015). They provide an opportunity to enhance safety only if they are detected and processed accurately and early enough (Hensgen et al., 2003). Signals may originate from numerous sources, and how they are processed will affect behaviour and the response to the unfolding event that they may indicate (Hensgen et al., 2003). Several theories from different

fields offer an understanding of how signals are detected and identified. The two main theories in this respect include signal detection theory and information theory.

Signal detection theory, from the field of sensory psychology, was proposed by Green and Swets (1966) and provides a theoretical basis for understanding signal detection (Nevin, 1969). Even though this theory was originally designed for visual detection, the principles can be applied informally to describe influencing factors of signal detection as used in the context of this research. Notably, signal detection does not precede nor follow identification (Swets, Green, Getty, & Swets, 1978). Thus, this theory aims to provide a general framework on detection and identification in a unified manner (Swets et al., 1978) and provide the probability of correctly identifying a signal amidst noise (Anderson, 2015).

The theory proposes two variables, one that can be ascribed to the sensory mechanisms and the second relating to decision-making criteria, that influence the probability of detecting a signal (Luce, 2003). The first is an indirectly derived measure of the sensitivity of the receiver (Swets et al., 1978), known as d' (Nevin, 1969). The second variable, decision-making criteria, is known as β and is subjective and affected by the individual's bias (Anderson, 2015; McLeod, 2015). This aspect is influenced by how likely the individual believes the signal to be, the anticipated cost of raising a false alarm and the perceived benefit of acting on the signal (McLeod, 2015). Sensory mechanisms (d') are independent of the internal strength of the decision-making criteria (β) (Anderson, 2015). In short, the theory provides hypothetical representations of the noise and signal probabilities that occur within the decision-maker (Anderson, 2015) and illustrates the need to differentiate between correct detections and false reports (Nevin, 1969). These representations are depicted in Figure 7. A correctly identified signal occurs to the right of the decision-making criteria (β) in graph A, and a correctly rejected false signal occurs to the left of the decision-making criteria (β) in graph B (Anderson, 2015).



* The green areas represent correctly identified signals (Graph A) or correctly rejected false signals (Graph B). The red areas signify the probability of a missed signal (Graph A) or responding to a signal that was a false alarm (Graph B).

Figure 7: Hypothetical representations of signal and noise probabilities taken from Anderson (2015). Adapted under Creative Commons CC BY licence.

This theory can also be applied to the characteristics identified that influence signal strength (*Section 3.1.2.1,* p. 48). The characteristics of interpretability, discriminability and precision will be influenced by the sensitivity of the receiver as these are the elements that allow for the identification of the signal amongst noise. The characteristics of significance and projection will be influenced by the decision-making criteria of the individual.

Following the detection of the signal, the next key component to consider is the transmission and communication of signals, considering the high likelihood that this information may need to be transmitted to others in the work environment to generate an appropriate response. Modern information theory, also called communication theory (Luce, 2003), was first proposed in 1948 by Claude Shannon (Shannon & Weaver, 1964) and focuses on how information is transmitted (Krippendorff, 2009). In particular, this theory describes how signals are communicated, sent or received, irrespective of the meaning of the signals (Shannon & Weaver, 1964). The theoretical components described in this theory will be considered instead of the mathematical components, as the latter are not within the scope of this research. Depicted in Figure 8 is an abstract model of communication, taken from the field of semiotics and based on the model of communication by Shannon and Weaver (1964).

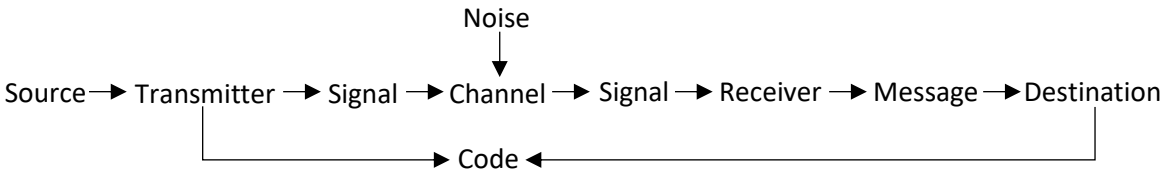


Figure 8: Schematic representation created by De Mauro (1971) of a simple communication transmission as described by Shannon and Weaver (1964) from the field of semiotics (Eco, 1976).

This theory identified three levels of communication problems (Shannon & Weaver, 1964). The first level, known as the technical problem, is concerned with the accuracy of transference of signals or information (Shannon & Weaver, 1964). The process begins with the source of the information generated in a certain situation. A transmitter is activated and converts the message from the information source into a signal, which is referred to as the coding process (Shannon & Weaver, 1964). The signal then travels through a communication channel, which is the medium used to transmit the signal, and is picked up 'downstream' by a receiver. The receiver converts the signal into a string of elements that constitute a message for a set destination (Eco, 1976; Shannon & Weaver, 1964). The destination is the end point, either a person or object, for whom the message is intended (Shannon & Weaver, 1964). The second level, the semantic problem, involves the interpretation of the meaning of the signal by the receiver, compared with the intended meaning of the sender (Shannon & Weaver, 1964). The third level, the effectiveness problem, refers to the degree of success in the signal being interpreted and a resultant action taken based on this interpretation (Shannon & Weaver, 1964).

Factors that affect the transmission process include noise and the coding process. Noise refers to the signal becoming altered and distorted through the transmission process (Eco, 1976; Shannon & Weaver, 1964), which may result in the signal being difficult to detect (Eco, 1976) as well as an increased uncertainty in the message contained in the signal (Shannon & Weaver, 1964). Redundancy can provide a means of combating the effects of noise (Krippendorff, 2009; Shannon & Weaver, 1964). The second factor, the coding process, is the means by which a given signal generates a message (Eco, 1976). In this case, the code would

be the interpretation process, assisting with extracting the meaning from the signal to form a message.

In addition to the above two theories, researchers have identified several additional factors that influence the detection and identification of signals, which tie to signal detection theory. Detection and recognition of signals and what counts as a signal frequently depends on the context and the frame of interpretation (Jørgensen, 2012). The individual 'lens' through which signals are identified and then transmitted ultimately frame the signal in a specific context (Jørgensen, 2012). These refer to the sensitivity of the receiver as described in signal detection theory. Additional factors include previous outcomes, known errors (Laming, 2001), and the person who receives the signal (Hiltunen, 2008, 2010). These refer to the decision-making criteria of signal detection theory. Other factors include signal strength (McLeod, 2015) and environmental factors (Hiltunen, 2008; Tarasti, 2001). Regarding the context, certain signals appear 'in connection with' specific situations, providing the temporal-local position of the signal (Tarasti, 2001). The characteristics of the organisation also influence whether signals are enhanced or suppressed (Hensgen et al., 2003). Environmental factors, including safety culture, affect both identification and the response to weak signals (Kerfoot, 2004). For signals to prompt action, significance needs to be attached to them (Klein, 2003), emerging from the situations in which the signals appear and affecting the need and type of response (Tarasti, 2001). Furthermore, signals that are detected and understood may still not be acted on due to competing priorities, the assumption that other areas of the system will intervene to prevent the potential event (McLeod, 2015) or strong sociocultural barriers that can prevent people from passing signals on or taking action (Carrillo & Samuels, 2015). Communication theory and the factors that affect this process have been included in this review as it was hypothesised that these may be relevant to understanding how weak signals are transmitted and may affect the identification and response to weak signals.

If signals are detected early enough and a response is taken, two potential outcomes include initiating action and resources to prevent the incident or alternatively initiating additional resources to obtain additional information on the potential threat that the signal has suggested (Hensgen et al., 2003). However, if a signal has been identified and transmitted, but the organisation has no system with a triggering mechanism, the appropriate response

cannot be generated (Hensgen et al., 2003). One model that places signals in the context of disasters and crises is the pre-crisis signal detection model proposed by Hensgen et al. (2003). As highlighted in numerous accident reports, these types of signals are usually visible in the pre-crisis phase, (e.g. the failings of care at the Mid Staffordshire NHS Foundation Trust (Francis, 2013)) and can either trigger a response or result in searching for additional information. The trigger depends on the types of signals that activate it and can result in either an action or no action (Hensgen et al., 2003). Figure 9 depicts this model.

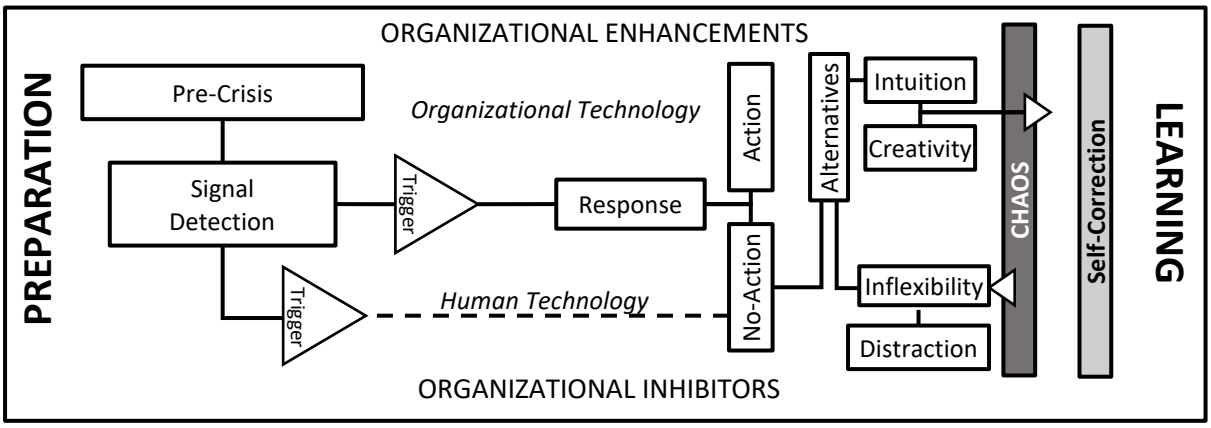


Figure 9: The Pre-Crisis Signal Detection Model (Hensgen et al., 2003). Adapted by permission from John Wiley and Sons.

Accessing and using signals, especially weak signals, is often a challenge, as people may lack the ability to effectively recognise the early signals of a drift into failure (Dekker, 2011), and the climate may restrict open conversation that allows staff to question elements (Schein, 2013). Additional barriers to utilising weak signals in the work environment include organisational and cultural related factors (Macrae, 2014b), including fear of giving and receiving feedback. Moreover, weak signals may be disregarded as the organisation may be overconfident due to past success, and as work is still often completed in silos, the transmission of signals may be prevented (Carrillo & Samuels, 2015). Additional barriers include that weak signals frequently appear to be mistakes; and because frontline staff are most likely to see the weak signal, they may not feel comfortable mentioning its appearance to their supervisor, who may be perceived as the expert (Carrillo & Samuels, 2015). Healthcare organisations can improve their means of using signals to enhance safety and address developing risks by promoting practices that produce and amplify signs of ignorance, continually define identifiable fears of failure, and discover and circulate knowledge of

systemic risks to patient safety and potential improvements on a routine basis (Macrae, 2014b).

3.1.4 Related Theories and Constructs

A consideration of different theories can facilitate a better understanding of how signals are perceived, processed and acted upon. This section aims to describe several relevant theories and constructs that may provide an understanding of the underlying processes used for the identification and processing of signals. Due to the breadth of the relevant paradigms to be considered, the depth included was limited to identifying the implications of these theories for the concept of signals. Given that signals relate to information processing and considering the cognitive processes involved, related theories on information processing are essential and needed to be included in this review. As a result, the more general aspects of human cognition from the field of psychology will be described first, including information processing and the skills-rules-knowledge (SRK) model. This will be followed by more specific constructs relating to intuition and macro-cognition theories in the form of naturalistic decision-making, situation awareness and sensemaking (Klein et al., 2003).

3.1.4.1 Information Processing and the SRK Model

Information processing is required to respond to stimuli – in this case, signals – and to coordinate actions to complete tasks successfully (Carswell & Stephens, 2001; Shepherd, 2001). Numerous models are available to explain human information processing (Carswell & Stephens, 2001), with most models proposing that the stimulus is internalised and interpreted, followed by selecting an appropriate response (Carswell & Stephens, 2001; Shepherd & Stammers, 2005). Researchers have proposed that the information passes through numerous stages, with the information being altered, combined and retained in different stores, such as the short-term sensory store, working memory and long-term memory at each stage (Carswell & Stephens, 2001). Figure 10 depicts a combined general information processing model that features the different stages and information stores mentioned here.

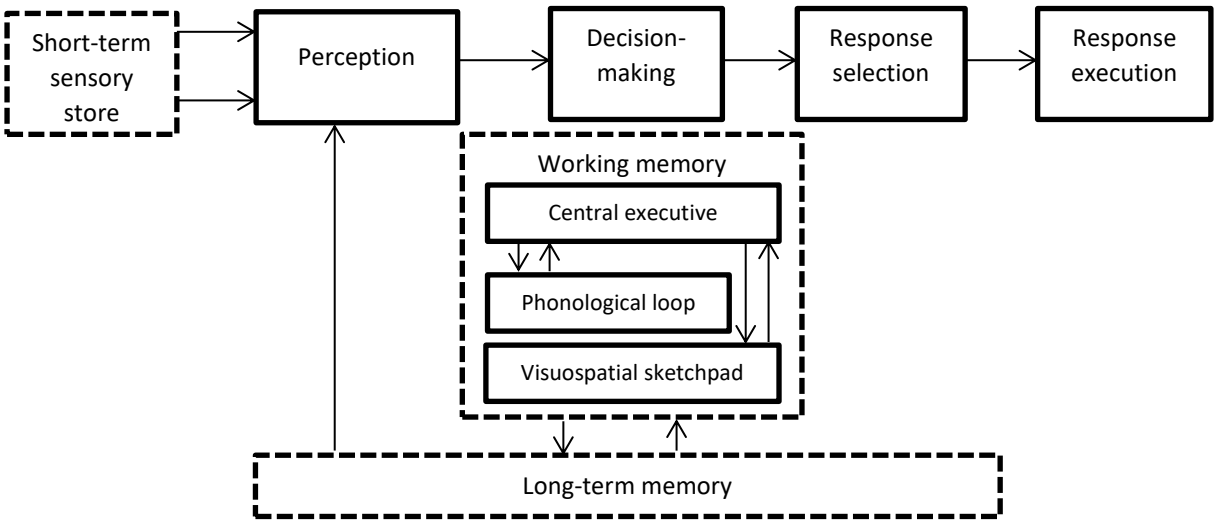


Figure 10: An information processing model proposed by Carswell and Stephens (2001) that has been based on the work of Atkinson and Shiffrin (1968), Baddeley (1997) and Wickens (1992).

The incoming information is first stored in the sensory register, which rapidly deteriorates if attention is not allocated to the data (Carswell & Stephens, 2001). Although a degree of processing can occur without attention (Proctor & Read, 2001), if the individual pays attention to the information, it is then processed by perception. Afterwards, it is then processed by the working memory, whereby the perceived information is integrated with internal information to allow the individual to make a decision and select a response (Bridger, 2009; Carswell & Stephens, 2001). The information is then stored at a semantic level that is linked to various structures (Bridger, 2009) in the long-term memory so that it can be recalled later (Carswell & Stephens, 2001). Plausibly, the incoming information could present itself as a signal and could then be processed like other information, as this model describes. Based on the consolidated information, the individual will then need to decide how to respond (Carswell & Stephens, 2001). The skills-rule-knowledge model provides a theoretical description of how the response is selected based on the information processed.

The skill-, rule- and knowledge-based (SRK) model was developed by Rasmussen to describe behaviour as a result of constraints from a deterministic environment (Rasmussen, 1983), specifically for human operators of complex automated systems (Sanderson & Harwood, 1988). However, this model can be applied to describe responding action to signals that indicate a threat or opportunity in the work environment. The model identified three types

of behaviour, as its name ('skill-, rule- and knowledge-based') reflects (Bridger, 2009; Lipshitz, 1993; Sanderson & Harwood, 1988). This model proposes that if a worker is confronted with a task requiring a response, the individual will most likely initially try a familiar response before adopting a more novel approach to complete the task (Shepherd & Stammers, 2005). A key feature of this model is the role that information from the environment plays relating to the different types of behaviour, presented in the form of signals, signs and symbols (Rasmussen, 1983). The SRK model is depicted in Figure 11.

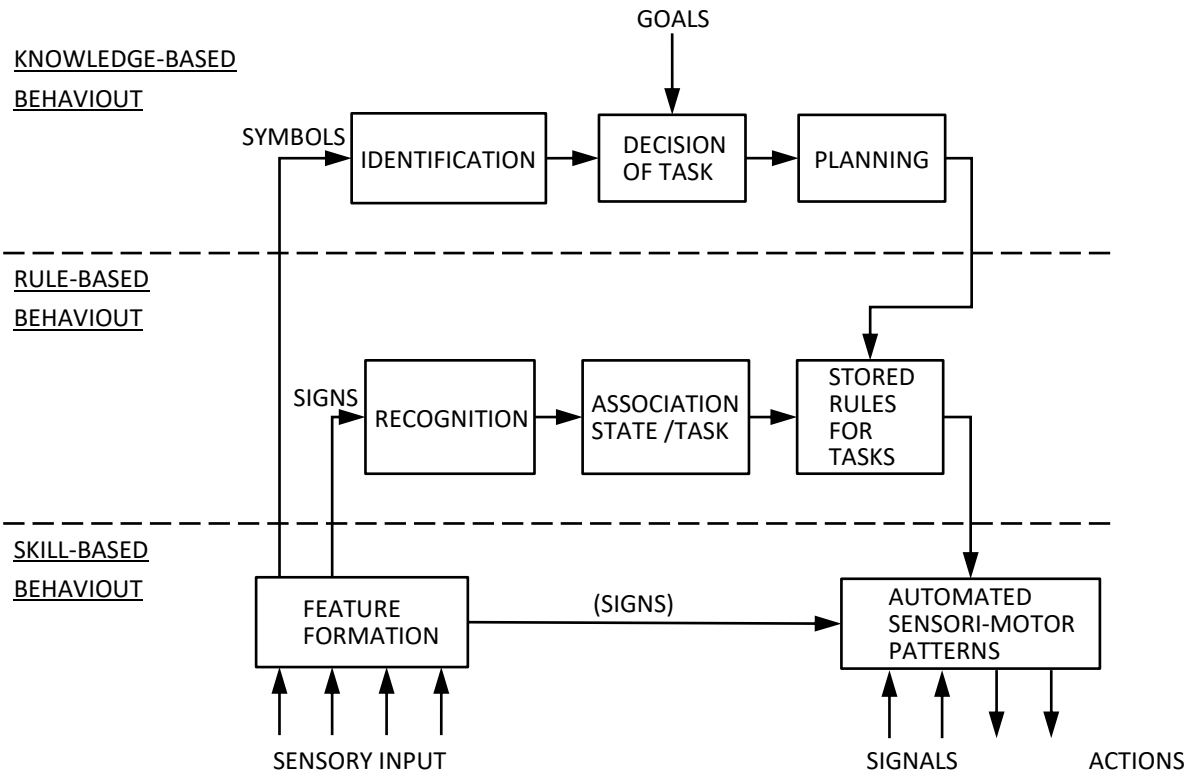


Figure 11: The SRK model featuring the three different levels of human information processing. Adapted from (Rasmussen, 1983). Original image © 1983, IEEE.

Skill-based behaviour includes expert sensorimotor performance that occurs without conscious attention and is controlled by a dynamic mental model of the decision-maker's movements and environment in real time (Rasmussen, 1983). This phenomenon allows the individual to adjust their action rapidly based on feedback. The sensory input or information at this level is processed as signals that trigger an action directly without explicit consideration of the meaning of the information (Lipshitz, 1993; Rasmussen, 1983). Signals in the context of the SRK model are sensed information, indicating continuous quantitative time-space

variables of behaviour in the environment (Rasmussen, 1983, p. 260). In comparison, rule-based behaviour is controlled by rules and specific knowledge that can be explicitly stated by the decision-maker; information at this level is processed as signs that indicate a certain type of situation and activate predetermined actions (Rasmussen, 1983; Sanderson & Harwood, 1988). Signs in this context cannot be used to generate new rules or be applied in functional reasoning (Rasmussen, 1983). This level requires recognition of the situation that is both familiar to a degree and unusual (Rasmussen, 1983) in order to invoke a rule to dictate the action, also described as cue-task association (Lipshitz, 1993; Rasmussen, 1983). Lastly, knowledge-based behaviour occurs in unfamiliar situations (Shepherd & Stammers, 2005), whereby an appropriate action requires a more comprehensive understanding of the situation, goals and environment (Rasmussen, 1983). The information at this level is processed as symbols (Shepherd & Stammers, 2005), which can be used for predicting and explaining unfamiliar behaviour (Rasmussen, 1983); these symbols are used to construct as well as engage mental models of the relationships in the environment (Rasmussen, 1983).

3.1.4.2 Intuition

Intuition has frequently been described as 'gut feelings', 'hunches' or a 'sixth sense' (Cioffi, 1997). As a result of the tacit nature of this knowledge, several definitions have been generated (Okoli et al., 2016). For example, intuition has been defined as 'understanding without a rationale' (Benner & Tanner, 1987, p. 23) or the means for reaching a conclusion using less than explicit information. Furthermore, the presence of emotions may play a role (Gobet & Chassy, 2008).

Intuition has been identified as a defining characteristic of expertise (Benner, 2004; English, 1993; Gobet & Chassy, 2008). Consequently, researchers have asserted that clinical decision-making may involve some intuitive thought process that is based on experience (Stinson, 2017). Intuition has also been said to occur as a result of recognising previously experienced patterns and detecting subtle changes (Stinson, 2017). Environmental and informational cues serve an essential function in this process (Okoli et al., 2016), in that they can be unconsciously linked to form a pattern (Klein, 2003). If a few cues are identified, seeing others may be expected; and this generates a sense of familiarity (Klein, 2003). The expert develops an expectation of events through experiences (English, 1993) and a memory network, which

are cognitively represented as schemas (Okoli et al., 2016; Paas, Renkl, & Sweller, 2004). The outcomes of intuition are a holistic understanding of the situation (Gobet & Chassy, 2008) and usually tacit information that leads individuals to feel confident in their judgement despite not being able to fully justify a reason for such assurance (Dörfler & Ackermann, 2012).

Because of the uncertain nature in which intuitive judgements occur, heuristics may be considered a component or strategy for determining these judgements (Cioffi, 1997). The concept of heuristics suggests that individuals can process information to estimate the probability of judgement in situations based on personal experience (Cioffi, 1997). According to heuristics, a judgement is made as a result of comparing the current situation to a similar one to determine how it differs (Cioffi, 1997). However, this model of decision-making does not hold true for all situations, such as complex real-world scenarios with time constraints (Klein, 2003). The Naturalistic Decision Making (NDM) paradigm provides an alternative theory of how decisions are made, aiming 'to demystify intuition' (Kahneman & Klein, 2009, p. 516) or 'unpack intuition' (Gore & Sadler-Smith, 2011) by identifying the signals experts use to make decisions (Gore, Flin, Stanton, & Wong, 2015), even if those signals are difficult to articulate and include tacit knowledge (Kahneman & Klein, 2009).

3.1.4.3 Naturalistic Decision Making

Naturalistic Decision Making (NDM) is a paradigm concerned with understanding and explaining the decision-making process experts use in applied 'real-world' settings, which are dynamic and complex (Gore et al., 2015; Klein, 2008; Zsambok & Klein, 1997). NDM originated in 1989 as a result that the theory at that time explained optimal decision-making in well-structured and controlled environments but not in applied settings where time was typically limited; goals were vague, competing, and uncertain; and unstable conditions were present (Klein, 2008). This perspective has studied how individuals make decisions in such applied situations as those found in the fields of aviation, healthcare and military services (Klein, 2015a). The types of tasks where this type of decision-making may occur include those containing aspects of real-time reactions to dynamic and continually changing conditions, poorly defined tasks, time pressure and severe consequences for mistakes (Klein & Klinger, 1991). Researchers have suggested that experienced individuals seldom engage in the process

of choosing from several options (Klein, 2015b; Lipshitz, 1993) and rarely deliberate the advantages and disadvantages of the different options (Klein & Klinger, 1991). Instead, this paradigm proposes that individuals make decisions in certain situations using prior experience by being able to rapidly categorise situations using schema and the process involves both intuition and analysis to obtain a decision (Klein, 2008).

At the time of the NDM movement's official inception, several theories, models and advances in cognitive psychology were found to be applicable to understanding the phenomenon (Klein, 2008). One such model is the SRK model (Rasmussen, 1983), described earlier in this section. The other key NDM model considered as relevant to signals was the Recognition-Primed Decision (RPD) model (Klein, 1989). The RPD model has not been proposed as an alternative to other decision models but instead offers a description of processes on the other end of the decision continuum (Klein & Klinger, 1991). At the one end of the continuum are conscious, deliberate and highly analytic strategies, while at the other end of the continuum is the RPD model for strategies that do not need to be optimised or adapted and require little conscious deliberation (Klein & Klinger, 1991).

The RPD model (Klein, 1989; Klein, Calderwood, & Clinton-Cirocco, 1986) is a descriptive model that represents the decision-making process in time-sensitive real-world settings by individuals with a high level of expertise (Lipshitz, 1993). This model combines two processes, situation assessment and mental simulation (Klein, 1993), and includes elements of problem-solving and decision-making (Klein & Klinger, 1991). The process that is followed is one of situation recognition, serial option evaluation and mental simulation (Klein & Klinger, 1991). Situation recognition involves classifying the situation as typical or novel (Lipshitz, 1993). Cues, which are generated by the situation, allow the individual to recognise patterns, priming the decision-making process (Klein, 2003). Pattern recognition also identifies the most relevant cues, provides expectations that serve as accuracy checkers of the situation assessment, offers an understanding of the types of goals that can be accomplished in the situation and identifies the actions to be taken (Klein, 1993, 2008). It is this pattern-matching that allows individuals to circumvent option generation and comparison (Klein, 2015b) and facilitates the selection of action scripts, which are routines for responding. These scripts are then tested for viability using mental simulation with mental models (Klein, 2003) to assist

individuals in understanding current and predicting possible future states (Klein, 2015b). Consequently, the individual will either implement, modify or reject the action (Klein, 1993; Lipshitz, 1993). Options are generated and evaluated serially (also known as serial option evaluation) until a suitable one is identified (Klein & Klinger, 1991). A simplified representation of the RPD model is illustrated in Figure 12.

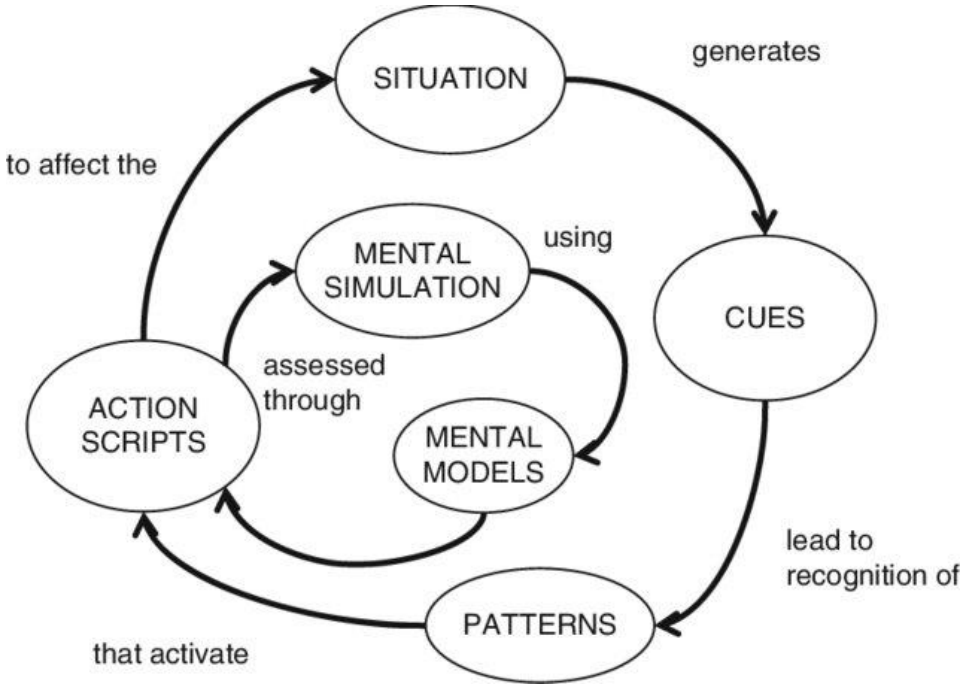


Figure 12: The Recognition-Primed Decision Model for complex strategies (Klein, 2003).

This model accounts for rapid decision-making using experience without having to compare options (Klein, 1993). In some contexts where time pressure and ambiguity are present, recognitional decision-making will be used more often; contrariwise, in others where abstract data and pressure to justify decisions are present, analytical approaches will be used more often (Klein, 1993). The advantage of this approach is that it allows the decision-maker to react quickly and effectively (Klein, 1993). The disadvantages include that this type of decision-making requires a level of expertise; hence, if sufficient expertise is not available, an effective course of action may not be considered first, or the situation may not be mentally simulated accurately to identify hazards (Klein, 1993). The model relates to sensemaking, described later in this section, in that it relies on past experience (Weick, 1993). The challenge associated with this type of decision-making is making sense of the events and the context rather than choosing between alternative options (Klein, 2015b). This is achieved through

situation awareness (Endsley, Hoffman, Kaber, & Roth, 2007) and sensemaking (Gore et al., 2015; Klein, 2015b).

3.1.4.4 Situation Awareness

Endsley (1988, p. 97) defined situation awareness as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future'. This type of awareness allows the individual to gather the necessary knowledge to decide on the most suitable course of action to meet the objectives (Endsley, 1988) and is required for identifying subtle cues, evolving situations and special characteristics of situations or high order goals (Gaba et al., 1995). This concept applies to weak signals since some of the perceived elements in this definition may refer to signals. Furthermore, another reason this is a key construct for understanding weak signals is that a vital aspect of situation awareness is filtering the data coming in from the environment for the detection of relevant situational cues (Sarter & Woods, 1991), which may also suggest that situation awareness needs to be adjusted (Gaba et al., 1995).

Although situation awareness has its roots in the field of aviation (Golightly, 2015), it has been explored in other fields. Examples of situation awareness studied in the field of healthcare include medical decision-making in anaesthesiology (Gaba et al., 1995), in the use of huddles in a children's hospital (Goldenhar, Brady, Sutcliffe, & Muething, 2013), in emergency medical dispatch (Blandford & William Wong, 2004) and in teleoperation performance (Riley, Kaber, & Draper, 2004). Situation awareness can be described as an emergent system property (Golightly, 2015); therefore, it can occur at an individual level as well as across teams, which can be referred to as 'shared situation awareness' (McLeod, 2015). Specifically in healthcare, aggregated patient data, in the form of an electronic overview, can contribute to staff's situation awareness of at-risk patients (Mackintosh & Sandall, 2010).

Situation awareness must be developed and maintained (McLeod, 2015) to generate a constantly evolving representation of the environment (Jones & Endsley, 1996). It is often defined in terms of decisions, goals and requirements for a specific job (Endsley, 2000) and the key elements of this construct are described in Endsley's (1988) aircrew decision model,

as depicted in Figure 13. The model describes how situation awareness occurs and its relation to decision-making and performance.

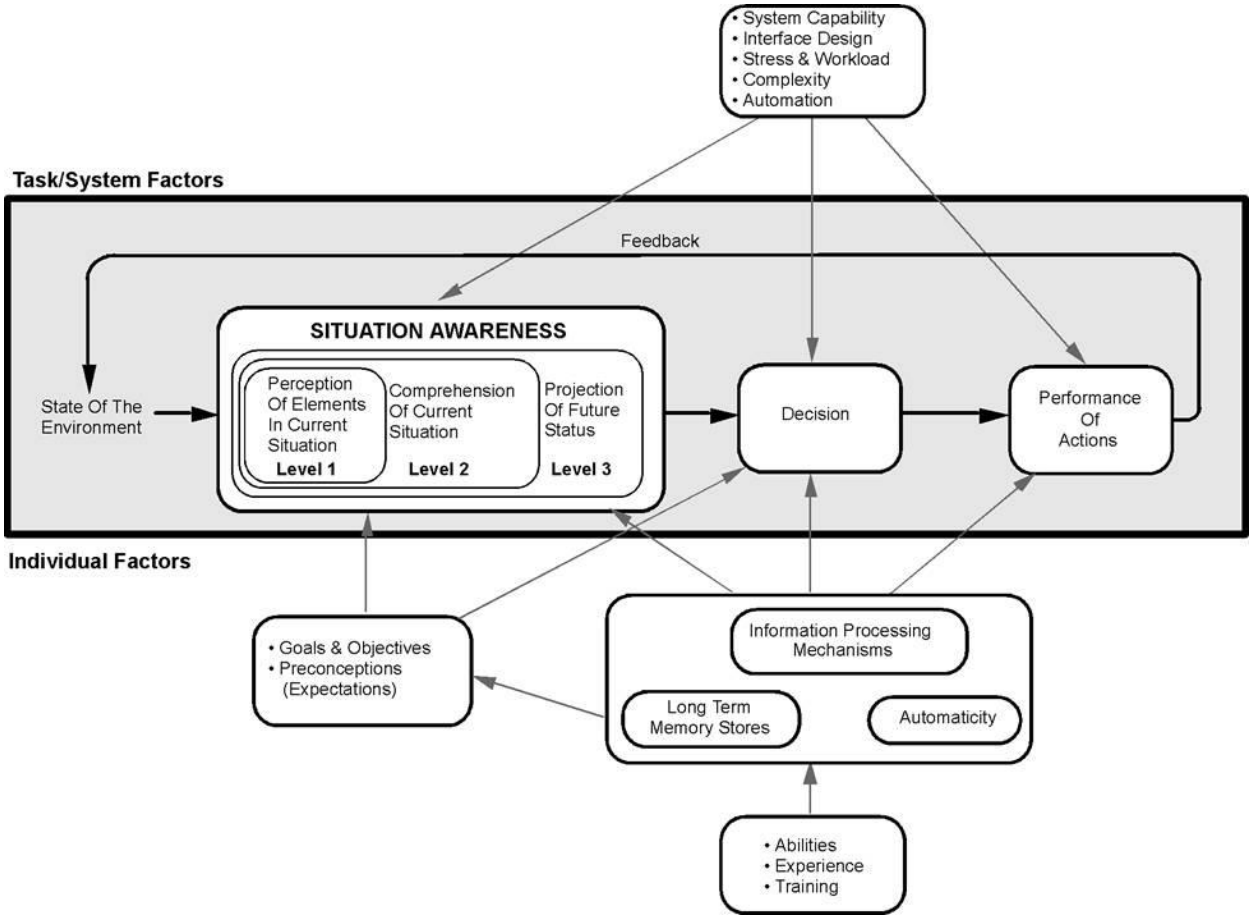


Figure 13: Situation Awareness and the Aircrew Decision Model (Endsley, 1988). Reproduced with permission from SAGE Publications.

Endsley (2000) identified three levels relating to the different levels of cognition. Level 1 includes the perception of the necessary information including cues or signals (Endsley, 2000); errors at this level are associated with a failure to accurately perceive the information available (Jones & Endsley, 1996). Here, the environment is processed in parallel with memory stores, and cues prompt attention to be focused on certain elements (Endsley, 1988). Level 2 is associated with the comprehension of information and requires the combination, interpretation, storage and retention of information identified in the first level (Endsley, 2000). Errors at this level include failures to comprehend the situation as a result of a lack of, incomplete or inaccurate mental model (Jones & Endsley, 1996). Multiple fragments of information are integrated and evaluated for relevance and significance in relation to the

individual's goals (Endsley, 2000). The final level of situation awareness involves projection to predict future events, which has implications for making decisions in a timely manner (Endsley, 2000). Errors at this level occur as a result of being unable to mentally project the actions and their consequences (Jones & Endsley, 1996). All three levels are essential to situation awareness (McLeod, 2015), with Levels 2 and 3 essential for work in complex environments (Jones & Endsley, 1996). Moreover, skilled experts are most proficient at the final level of situation awareness (Endsley, 2000).

Situation awareness is separate from decision-making but forms a critical input for the process (Endsley, 1988). The quality of this process and outcome is influenced by the individual's capabilities, training and experience as well as their expectations, objectives and current workload (Endsley, 1988). Temporal aspects also have significant implications for the formulation of situation awareness, as this quality builds over time (Endsley, 1995). This includes temporal dynamics associated with events and the perception of time (Endsley, 1995). The individual must consider the available time before an event occurs or before an action needs to be taken. Such temporal aspects are key elements of Levels 2 and 3 of situation awareness (Endsley, 2000).

3.1.4.5 Sensemaking

Sensemaking is the process of developing plausible explanations to understand novel events (Maitlis & Christianson, 2014), interpreting reality and rationalising what people do (Weick, 1995). This process can occur on an individual or group level (Maitlis & Christianson, 2014) and is essential for organising and influences human behaviour (Weick et al., 2005). Sensemaking is initiated by cues that represent vague outcomes and disrupt the current understanding of the situation (Maitlis & Christianson, 2014). In the context of this research, the cue may be a weak signal. The process occurs as a result of an exchange between action and interpretation (Thomas, Clark, & Gioia, 1993; Weick et al., 2005). Thus, an understanding of the situation is developed through exploration using actions and interaction with the subject and by identifying patterns through retrospection (Weick, 1988; Weick et al., 2005). Action is essential for interpreting the situation as people may not be sure what the 'appropriate action' might be until it has been taken; consequently, 'actions determine the situation' (Weick, 1988). In some situations, the reactions create new problems, as was the

case in the Bhopal disaster (Weick, 2010). However, the action also allows for further sensemaking in that the cues, which are generated through action, are often intertwined with tasks (Weick, 1988). Action also facilitates the testing of the recently developed understanding of the situation (Maitlis & Christianson, 2014). The assimilation of cues over time results in awareness that can modify the individual's sense regarding the situation (Gioia & Mehra, 1996). This process continuously revises the 'story', so the situation becomes more comprehensive and incorporates more observable information (Weick et al., 2005).

Sensemaking occurs explicitly when a discrepancy exists between the current and the expected state of the world (Louis, 1980; Weick et al., 2005). However, this process is also ongoing and subtle (Weick et al., 2005). Due to the discrepancy between the expected and current state, certain cues are used to create a plausible explanation of what is happening to restore the expected state and continue the action (Weick et al., 2005). On an individual level, sensemaking requires connecting cues with frameworks, such as schema and mental maps, in order to interpret the situation (Bingham & Kahl, 2013; Harris, 1994; Hill & Levenhagen, 1995). These frameworks provide meaning; in turn, they are affected by meaning (Weick, 1993). From a social perspective, sensemaking is related to language and written texts, with collective sensemaking occurring in an ongoing and iterative manner through conversations (Maitlis & Christianson, 2014). Sensemaking is a micro-mechanism, but has the capability of producing organisational changes over time, as it allows states over time to become connected (Weick et al., 2005). It also facilitates other key organisational processes (Maitlis & Christianson, 2014), such as inhibiting or producing strategic change (Gioia & Chittipeddi, 1991), organisational learning (Gioia & Thomas, 1996; Ravasi & Turati, 2005) and innovation (Hill & Levenhagen, 1995; Ravasi & Turati, 2005).

Sensemaking includes seven properties. It is retrospective, constitutes a social process through which meaning is generated, and is influenced and constructed by the context through individual and organisational identity. It is an ongoing dynamic process that involves segmenting and bracketing information, focusing on cues in and from the environment and action, the situation is interpreted, and the environment modified (enactment). Lastly, sensemaking is driven by the acceptability of possible interpretations (Weick, 1995). As sensemaking is influenced by the local context, institutional structures will influence people's

actions and the meaning of their actions (Johannesen & Wiig, 2017). In healthcare, because of the institutional structure, medical sensemaking is often distributed across the healthcare system (Weick et al., 2005). As a result, scheduling in healthcare is essential to transfer information across boundaries. As the knowledge of the unfolding situation concerning the patient spans time, the locus is systemwide; therefore, the coordination and information distribution must be effective to allow for sensemaking to occur across shifts (Weick et al., 2005). Medical sensemaking also involves thinking and acting out conversationally (Weick et al., 2005) as well as simultaneously interpreting knowledge with known frameworks and examining new frameworks and new interpretations. Developments over time progressively reveal that a previous action may become an incorrect action in the present time (Weick et al., 2005). Furthermore, as sensemaking entails the local context, it is influenced by various social factors such as communication, which enables sensemaking through interactive talks and the ability to exchange information and share understanding. This also plays a role in articulation, which is the process of making tacit knowledge more explicit (Weick et al., 2005). Additional factors that influence sensemaking include organisational culture (Harris, 1994), as it is used to interpret experience and generate behaviour (Guldenmund, 2010a) and prevailing work practices (Maitlis & Christianson, 2014).

Two key constructs related to sensemaking that apply to weak signals as investigated in this research are sensegiving and sticky frames. Sensegiving is the process of influencing the sensemaking of others with the aim of redefining the organisational reality (Gioia & Chittipeddi, 1991). However, as the ones receiving sensegiving have their own interpretations of the information, they are able to resist the associated strategic change (Sonenshein, 2010). This phenomenon is relevant to this research as it may describe how weak signals are transmitted between individuals and through organisations. The other key concept of sensemaking for this research is that of sticky frames, as mentioned in Maitlis and Christianson's (2014) review of sensemaking. This second concept comes into play when reoccurring cues are discounted (Maitlis & Christianson, 2014), as they do not align with an individual's expectations that are embedded within their frame or mental model (Maitlis & Sonenshein, 2010). Although frames or mental models are continuously developing, expectations tend to become 'stuck' in them (Konlechner, Latzke, Güttel, & Höfferer, 2019). An example of this phenomenon is described in Weick's (2010), re-analysis of the Bhopal

disaster, whereby the cues were dismissed as they indicated something that was inconceivable and did not align with the current frame, even though it was no longer valid. This concept has implications for this research with reference to the interpretation of weak signals and whether action is taken.

3.2 Synthesis of the Weak Signal Literature – Development of the Weak Signals in Healthcare Framework

The aim of this section is to develop a systematic framework for the analysis of weak signals in healthcare through a synthesis of the literature and theory triangulation. An integrated framework on weak signals is necessary because, although the information and research on this concept have been approached from numerous perspectives, it is distributed across a range of fields, and the theoretical basis is to some degree incoherent and unstructured. This has been highlighted earlier in this chapter. As a result, a degree of overlap exists across studies, but the practical application of the findings is limited, and a future direction for research in this concept remains unclear. Through theory triangulation, the distributed knowledge can be organised, the key elements of this concept clarified and theory developed, built and tested to guide the research in a more systematic way (Bennett, 1997). The framework aims to provide a conceptual structure to support further research on this topic. Just as the SRK model provides a language to discuss behaviour types (Sanderson & Harwood, 1988), this framework aims to provide the language to discuss and structure research examining weak signals in healthcare.

As a first step, the literature from the previous section was compiled to form a comprehensive definition for the meaning of the term ‘weak signal’ in the context of this research and justification for the selection of the term ’weak signal’ was provided. The literature was then organised to summarise the structural properties or attributes of signals, compile the relevant theories describing the underlying processes or behaviours associated with signals and describe the influencing factors of behaviours of behaviours of signals. Although these core aspects compiled refer to signals in general, all of these aspects are relevant for weak signals as investigated in this research. This compilation was used to develop a first draft of the framework.

3.2.1 Term and Definition

The literature review outlined in Section 3.1 of this chapter demonstrates how the underlying concept associated with weak signals has been described using different terms (Brizon & Wybo, 2009). Within semiotics, Saussure has proposed a dyadic structure for signs (Edgerton, 2010) that helps explain the numerous terms for a common underlying concept. This structure includes a signifier, which is a word or phrase related to a mental concept, known as the signified (Edgerton, 2010). Table 5 (p. 46) in this chapter demonstrates that numerous signifiers (e.g. signals, warnings, cues, weak signals) stand for the same signified or mental concept.

The term selected to represent the concept investigated in this thesis was 'weak signals', even though a broad range and differing strengths of signals were included. This decision reflects the fact that strong signals (defined by McLeod (2015) as those originating from equipment about the current state) in healthcare may still be potentially described as weak signal. This is because the signals from equipment in healthcare often still require a degree of interpretation and consideration of the context (Macrae, 2014b; McLeod, 2015). Furthermore, the elements that define strength, namely discriminability (Kaivo-oja, 2012; Nevin, 1969), interpretability (Hiltunen, 2010), subjectivity (Hiltunen, 2008, 2010), the precision of the signals (Turner, 1978) and the deduced significance of the information that the signals contain (McLeod, 2015) are predominantly related to factors that are influenced by the receiver's individual characteristics. This is captured by the two variables described in signal detection theory (Green & Swets, 1966), namely that the detection of weak signals can be either influenced by an individual's sensitivity to the signal or their internal decision-making criteria, and therefore, it could be argued that numerous signals may be described as weak due to the complexity of work in healthcare and the uncertainty often associated with patient care.

Despite the differing terms and their definitions, *Section 3.1.1.* has provided a basis for a generic definition across the different fields. Considering the definitions provided in Table 5 (p. 46), common elements can be identified among them. These have been stressed in Table 5, in that the elements have been underlined or marked as bold. By compiling the key concepts from these definitions, a broader, usable definition of weak signals related to safety

and task performance can be created. Table 7 below documents how the definition used in this research was compiled. In summary, a cross-domain definition of weak signals related to safety and task performance for the application to the healthcare context is as follows:

> *Weak signals are information that provide an indication of upcoming or emerging events that may have significant implications, whereby the information provided is often imprecise, ambiguous and incomplete, which requires active identification and processing.*

Table 7: Compilation of common elements, concepts and references from different research fields to generate a definition of weak signals related to safety.

The definition components and relevant references used						
	Definition Component	Information	that provides an indication	of upcoming or emerging events	that may have significant implications	with specific reference to the type of information that they provide.
	Relevant References	• Ilmola and Kuusi, 2006 • Mendonça et al., 2015 • Schoemaker and Day, 2009 • Turner, 1978 • Vaughan, 1996	• Ansoff and Mcdonnell, 1990 • Guillaume, 2011 • Kerfoot, 2004 • Mendonça et al., 2015 • Rasmussen, 1983	• Ansoff and Mcdonnell, 1990 • Mendonça et al., 2015, 2012 • Raben et al., 2017	• Ilmola and Kuusi, 2006 • Okoli et al., 2016 • Schoemaker and Day, 2009	• Ansoff and Mcdonnell, 1990 • Ilmola and Kuusi, 2006 • Mendonça et al., 2015, 2012 • Schoemaker and Day, 2009 • Stolper et al., 2015 • Vaughan, 1996
Fields	Corporate Decision-Making, Future Studies, Business Management, Strategic Management, Man-made Disasters, Aviation Safety, Safety, Healthcare Management, Human Performance, Health Science Education.					

In the SRK model (Rasmussen, 1983), information that influences the different levels of behaviour (i.e. skills-, rule- or knowledge-based behaviour) is perceived in the form of signs, signals or symbols. The concept of weak signals that this thesis investigates relates to information from the environment described by Rasmussen (1983) predominantly in the form of signs and symbols, and not signals. Signs in the SRK model indicate different environmental states that relate to conventional actions, while symbols allow for the prediction of unfamiliar behaviour in the environment using abstract constructs of process structures (Rasmussen, 1983). Although only symbols and not signs can be directly processed, signs can still activate different behaviour patterns (Rasmussen, 1983). This research aimed to investigate weak signal types that could affect behaviour and potentially improve safety.

3.2.2 Development of a Framework for Understanding Weak Signals Relating to Safety

3.2.2.1 Attributes of Weak Signals

From the literature on strength and types of signals described in *Section 3.1.2* (p. 48), the structural properties or attributes of signals were compiled. Table 8 presents the attributes identified, a description of the attributes, and examples of sources where these attributes have been mentioned. A total of five attributes were identified, with the attribute of strength having six sub-attributes. This division reflects the difficulty of defining a scale for signal strength (Hiltunen, 2010) and the literature provided numerous descriptions related to different attributes affecting signal strength. The characteristics associated with strength included interpretability, discriminability or perceptibility, precision, perceived significance of the future event, the subjective or objective nature of the information contained in the signal and whether it was context-specific. Although these attributes refer to signals in general, all of these attributes, including the sub-attributes on strength, are relevant for weak signals as investigated in this research. As highlighted in the previous section, as even strong signals may appear weak, all of these attributes were considered when analysing the weak signals identified in this research.

Table 8: The attributes of signals identified from the literature review, including the sub-attributes that have been associated with the attribute of signal strength.

Attributes	Sub-attributes	Description (Examples and references that described these attributes)
Outcome type		Whether the signal indicates a negative or positive event (e.g. a sense of alarm or reassurance (Stolper et al., 2009)).
Event		The signal is a specific event, error or outcome that indicates a larger event (Hiltunen, 2010).
Source		The origin of the signal (e.g. natural and non-intentional signs (Eco, 1976), Type A and B (McLeod, 2015), endo- and exosigns (Tarasti, 2001)).
Frequency		The rate the signals occur (e.g. routine signals (Vaughan, 1996)).
Strength:	Interpretability	Degree of difficulty in interpreting the signal (Hiltunen, 2010).
	Discriminability/ Perceptibility	Degree of difficulty of distinguishing the signal from noise (Coffman, 1997b).
	Precision	Clarity of the information and the indication the signal provides (e.g. mixed and weak signals (Vaughan, 1996)).
	Perceived significance	Interpretation of the significance and future projection of the event that the signal indicates (McLeod, 2015).
	Subjective/ Objective	Whether information contained in the signal is either objective or subjective in nature.
	Context-specific	Degree to which the signal is reliant on the context (Hiltunen, 2008; Tarasti, 2001).

3.2.2.2 Behaviours of Weak Signals

The paradigms and models described in *Section 3.1.3* (p. 52) and *Section 3.1.4* (p. 58) provide the theoretical basis for understanding the underlying processes or behavioural components of weak signals. While the attributes can be considered as the structural elements or characteristics of weak signals in this research, the behavioural components can be construed as the functions or processes involved in utilising weak signals, for example, the detection, identification, processing and action selection or transmission of weak signals. Four of the sub-attributes relating to signal strength were also identified as relating to the behavioural aspects associated with signals. Interpretability relates to the processing and interpretation components, while discriminability or perceptibility relates to the detection component. Additionally, precision relates to the processing component, and perceived significance relates to the interpretation component. The different paradigms and models discussed in *Section 3.1.3* and *Section 3.1.4* were mapped on to the behaviour components of weak signals to identify which theory supports which processes. The results are depicted in Figure 14.

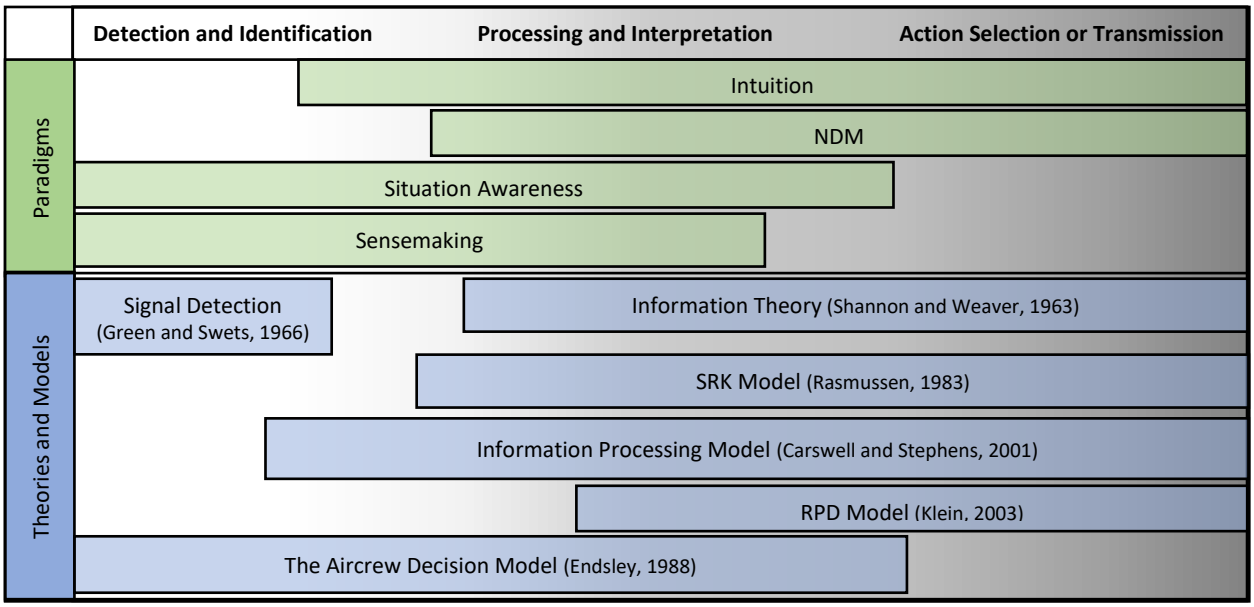


Figure 14: The paradigms and models that describe the behaviour components of weak signals, namely detection, identification, processing and action selection or transmission.

In Figure 14, the phases of the behaviour components of weak signals are presented as a continuum because the boundaries between these phases are often unclear. For example, signal detection theory (Green & Swets, 1966) emphasises that signal detection does not proceed or follow identification (Swets et al., 1978). This theory assists in explaining and

identifying influencing factors for the detection and identification stage. Situation awareness and the aircrew decision model (Endsley, 1988) supply the theory for understanding how weak signals may be identified and processed. Sensemaking provides a theory to understand how weak signals may be detected and interpreted, with action playing an essential role in the generation of additional weak signals and the interpretation process (Weick, 1988).

The other paradigms that describe decision-making – information processing, the SRK model, intuition and NDM – may provide an understanding of how a response is chosen for the weak signals identified. These different paradigms provide theories for decision-making in varying contexts. The SRK model (Rasmussen, 1983) and the information processing model (Carswell & Stephens, 2001) may provide an understanding of how weak signals are processed and interpreted, as well as the possible response behaviours generated in certain situations. The paradigm of intuition may be more applicable in situations where greater uncertainty is present (Cioffi, 1997), and where time is available, heuristics may be used in the processing of weak signals and action selection. In complex situations with time restrictions, NDM and the RPD model may provide a more appropriate theory for understanding how rapid decisions are made. The RPD model does not describe how weak signals are detected but does describe how they may be processed and result in action. Information theory (Shannon & Weaver, 1964) offers an understanding of how weak signals may be transmitted between individuals and the potential problems that may be encountered during the interpretation, action and transmission phase.

3.2.2.3 Influencing Factors of Behaviours of Weak Signals

From the literature, it was also possible to compile the different influencing factors for the different behaviour components of weak signals. Influencing factors were described for the detection, identification and action selection components. Table 9 lists the influencing factors for these behaviour components. The factors shown to influence the detection and identification of weak signals include person-specific factors (Hiltunen, 2008, 2010), the context (Jørgensen, 2012; Tarasti, 2001) and environment factors (Hiltunen, 2008; Tarasti, 2001). Specific person-related factors identified include the sensitivity of the receiver (Swets et al., 1978), the individual's frame of interpretation (Jørgensen, 2012), their subjectivity and bias (Anderson, 2015; McLeod, 2015) and their ability to detect signals (Dekker, 2011).

Context-specific factors identified include knowledge of previous outcomes and known errors (Laming, 2001). Environment specific factors include safety culture (Kerfoot, 2004) and organisational characteristics (Hensgen et al., 2003).

Table 9: Influencing factors for behaviour component of signals

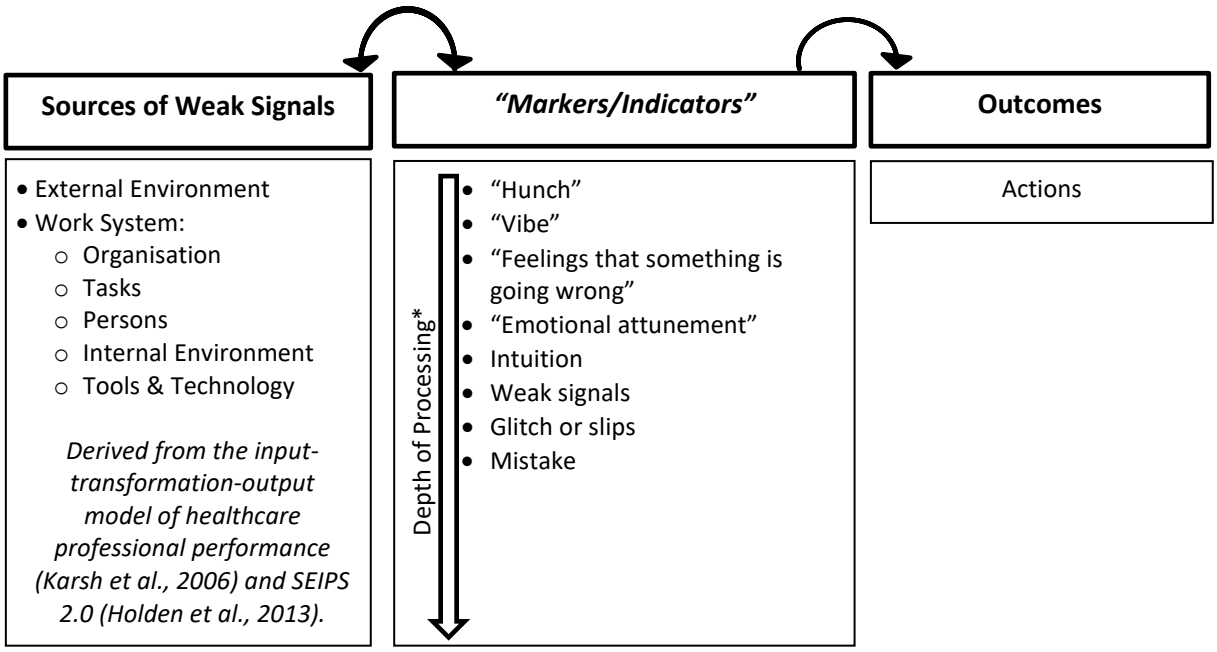
<table>
<tr><th>Detection and Identification</th><th>Action</th></tr>
<tr><td>Person-related factors (Hiltunen, 2008, 2010):
• Frame of interpretation (Jørgensen, 2012)
• Decision-making criteria (e.g. subjectivity, bias) (Anderson, 2015; McLeod, 2015)
• Ability to detect signals (Dekker, 2011)
• Sensitivity of the receiver (Swets et al., 1978)</td><td rowspan="3"><u>Response Selection</u>
Individual-related:
• Significance of what the signal indicates (Klein, 2003)
• Underlying assumptions of who will address signal (McLeod, 2015)
• Perceptions of associated repercussions (Carrillo & Samuels, 2015)

Organisation-related (Macrae, 2014b):
• Safety culture (Kerfoot, 2004)
• Sociocultural barriers (Carrillo & Samuels, 2015)
• Competing priorities (McLeod, 2015)
• Means for generating a response (Hensgen et al., 2003)</td></tr>
<tr><td>Signal strength (McLeod, 2015)</td></tr>
<tr><td>Context (Jørgensen, 2012; Tarasti, 2001):
• Previous outcomes (Laming, 2001)
• Known errors (Laming, 2001)</td></tr>
<tr><td>Environment factors (Hiltunen, 2008; Tarasti, 2001):
• Safety culture (Kerfoot, 2004)
• Organisational characteristics (Hensgen et al., 2003)</td><td><u>Transmission Specific</u>
• Noise (Eco, 1976; Shannon & Weaver, 1964)
• Coding process (Eco, 1976; Shannon & Weaver, 1964)
• Climate (Schein, 2013)
• Seniority of the individual who identified the signal (Carrillo & Samuels, 2015).</td></tr>
</table>

The factors that influenced action selection could be categorised as aspects that affected response selection or transmission. The aspects affecting response selection could further be grouped into individual-related or organisation-related categories. Individual-related factors included the significance of what the weak signal indicates (Klein, 2003), the underlying assumptions of who will address weak signal (McLeod, 2015) and the perceptions of associated repercussions (Carrillo & Samuels, 2015). Organisation-related factors included safety culture (Kerfoot, 2004), sociocultural barriers (Carrillo & Samuels, 2015), competing priorities (McLeod, 2015) and the means for generating a response (Hensgen et al., 2003). Factors that influenced whether a weak signal was transmitted included noise (Eco, 1976; Shannon & Weaver, 1964), the coding process (Eco, 1976; Shannon & Weaver, 1964), the work climate (Schein, 2013) and the seniority of the individual who identified the signal (Carrillo & Samuels, 2015).

3.2.2.4 Weak Signals in Healthcare Framework (Version 1)

As a first draft of the framework, a basic structure was applied that consisted of three components: the source of the weak signals, the possible terms and depth of processing required and the outcomes of the weak signals which referred to actions. The function of this framework was to provide a structure for understanding the elements of weak signals that can affect performance and patient safety. The elements include the kinds of data that form weak signals and how individuals interact and respond to weak signals. The resulting framework was built through the case studies using theoretical models, described earlier in this chapter, that provided plausible and reliable descriptions of behaviour to assist in developing an understanding of the attributes (structural components) and behaviours (functional components) for weak signals. Figure 15 illustrates the first version of this framework.



**Depth of processing can be described by the skill-rule-knowledge model (Rasmussen, 1983)*

Figure 15: A proposed framework (Version 1) for the investigation of weak signals related to safety behaviour and task performance in healthcare.

In this first version, the source component of the framework, which listed potential sources of weak signals, was derived from the input-transformation-output model of healthcare professional performance (Karsh et al., 2006) and the Systems Engineering Initiative for Patient Safety (SEIPS) 2.0 model (Holden et al., 2013). The input-transformation-output model

is a general multi-level model of a work system that considers open systems theory and other sociotechnical models, such as that proposed by Carayon et al. (2006) (Karsh et al., 2006). Additionally, the source element of the framework was expanded to incorporate the work system elements from the SEIPS 2.0 model (Holden et al., 2013). The resulting structure reflects the underlying system structure of both models. The SEIPS 2.0 model was selected as it provides a framework for the analysis of processes and the relationship of various elements within a work system and has been specifically designed for the healthcare context (Carayon, Schoofs Hundt, Karsh, et al., 2006). Because weak signals can be deemed information regarding the status of the system and may indicate areas of risk (Macrae, 2014b), considering the sources of weak signals may reveal key additional information. Having a systems approach underlying this framework was essential to facilitate analysing and understanding the work, actions and events in healthcare, including weak signals (Karsh et al., 2014). The framework further hypothesised that during the work process, the worker would receive indicators or signals of different strengths from different sources requiring different levels of processing. The processing and influence the weak signals may have on the performance of tasks can be explained by the skill-rule-knowledge model of behaviour (Rasmussen, 1983).

Although the initial draft of the framework does not include numerous aspects identified in the literature summarised in *Section 3.1* (p. 43), this basic version was used as a starting point, allowing the development of the framework to be data-driven, using the literature to support the results in developing and expanding the framework. This framework functions to provide something between a model and a method that contains a structure for the understanding of weak signals that can affect performance and patient safety. The structure includes an understanding of the key elements of weak signals and a means for analysing these elements, ultimately providing a basis for working towards operationalising weak signals for improved safety in healthcare. The framework intends to achieve this aim by providing an understanding of where weak signals may be found, what might affect them, the information they may contain, which outcomes they may indicate, the context in which they may appear and the factors that may influence them.

3.3 Conclusion

This chapter aimed to provide the theory and a preliminary structure for interpreting and understanding the data in the subsequent chapters (Chapters 5 to 8). This aim was achieved by providing a synthesis of the available literature on weak signals from different fields and identifying the key elements to investigate weak signals in healthcare to provide a theoretical basis for the concept of weak signals to be applied from a HFE perspective. Based on the focused literature review, a definition of weak signals was compiled, the structural properties or attributes of signals were summarised, the relevant theories that potentially describe the underlying processes or behaviours associated with signals and influencing factors for these behaviours were collated. This information was used to draft a preliminary framework for investigating weak signals in healthcare, with this process being documented in this chapter. Based on this review and the broader review on the healthcare work environment and safety provided in Chapter 2, the next chapter contains the methodology underpinning the case studies investigated in this research.

Chapter 4: Methodology

The broad literature review presented in Chapter 2, which set the context for this research, revealed that preventable adverse medical events remain a current topic of interest (Dhillon, 2012), both in the NHS and internationally, despite the large quantities of research available (Vincent, 2011). Furthermore, a shared theme identified in that chapter focused on a proactive approach to safety that has gained momentum in recent safety theories and research. A common underlying element associated with current safety improvement approaches is the presence and use of weak signals for anticipation and awareness. Chapter 3 provided the theoretical underpinnings for the investigation of weak signals in healthcare upon which this research was based. This chapter specifies the underlying philosophy, the research questions, aims and objectives, the theoretical basis and research design aimed to address the research question posed. Additionally, the justification for the research design and selection of the research methods are described in greater detail.

4.1 Research Question, Aims and Objectives

The focus of this research was on exploring one element associated with current safety approaches, namely weak signals, which will be discussed in more detail in *Section 4.2.3* (p. 87) of this chapter. Weak signals provide information regarding the current system (Macrae, 2014b) and, when identified and acted upon, enable success through pro-activeness by providing an opportunity to address issues in a cost-effective and timely manner (Vogus & Sutcliffe, 2007). The research question addressed in this thesis was:

'What are the *weak signals in healthcare that may identify that a task or process may not be* completed successfully?'

In working towards answering this question, the aim of this thesis is to provide the theoretical basis and approach to guide research into weak signals that present in healthcare work systems. This aim can be broken down into two sub-aims. Firstly, explore the system context from which weak signals emerge, and secondly develop a theoretical framework to investigate weak signals in healthcare. It is essential to explore the context from which weak signals emerge, as weak signals both need to be extracted from the context, emerge as a

result of the context and may provide information about the context. To achieve these two sub-aims, this piece of research aims to address the following objectives:

1. Identify the key weak signal elements and develop a definition of weak signals for the healthcare context to be operationalised in the different healthcare case studies based on a review of literature on weak signals from a variety of different fields. (Chapter 3)
2. Develop and test a framework of the key elements of weak signals for different healthcare contexts that function at different system levels, including at a micro (i.e. task), meso (i.e. process) and macro (i.e. organisational) level. This includes highlighting and depicting the work system elements from which weak signals emerge for the different healthcare contexts. (Chapters 5-8)
3. Develop an analysis approach and compile recommendations for the application of the weak signals in healthcare framework to different healthcare contexts. (Chapters 6-9)
4. Identify how the different elements of weak signals in general may support improvement work in the healthcare environment. (Chapter 9)

As the researcher's values and beliefs will influence the research design, methods and how the results are interpreted (Bowling, 2002), stating the philosophy upon which the research has been based becomes necessary. This explanation will provide the context in which the methods have been selected and how results were analysed and interpreted (Bowling, 2002).

4.2 Methodology and Research Design

The context within which data are collected, processed and analysed is defined by the researcher's underlying philosophy (Saunders, Lewis, & Thornhill, 2009). Moreover, the research design, including the approach, method choice and strategy, must be cohesive with the research question, aims and objectives as well as being justified and explained (Saunders & Tosey, 2013). In the following sections, the underlying research philosophy, theoretical basis and approaches selected to address the aims and objectives of this research will be described and justified. Additionally, the focus and research design for each case study will be briefly described, as well as how this contributes to addressing the overarching research

aims, objectives and answering the research question posed. An overview of the underlying methodology and research design adopted in this thesis is depicted in Figure 16.

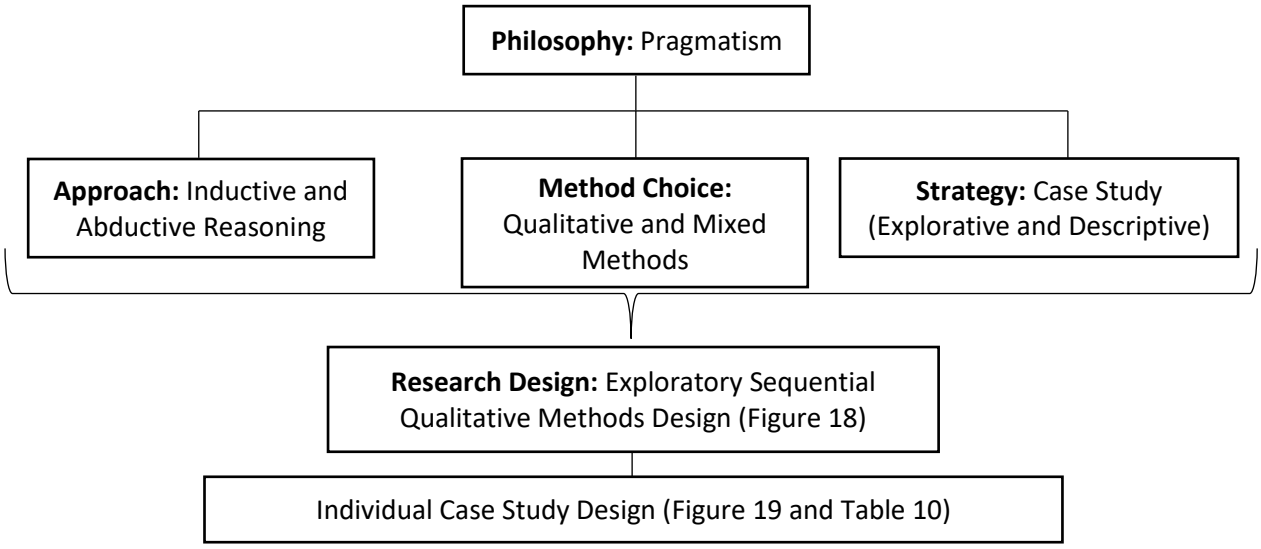


Figure 16: The underlying philosophy, approach, method choice and strategy applied in this research and how these aspects contributed to the overall research design.

4.2.1 Research Philosophy

The underlying philosophy of this research is pragmatism, which recognises that the world can be interpreted in numerous ways and emphasises the importance of the findings having practical consequences (Creswell, Klassen, Plano Clark, & Clegg Smith, 2011; Saunders et al., 2009). This philosophy lies between positivism and interpretivism, which are mutually exclusive paradigms (Hignett & McDermott, 2015) that provide distinct assumptions about the social world (Bowling, 2002; Ochieng, 2009). Pragmatism provides the researcher with the freedom of choice of adopting the methodological approach that best suits the research problem (Robson & McCartan, 2016) as well as a variety of analysis methods, including mixed methods (Hignett & McDermott, 2015). As behaviour is dependent on context (Rasmussen, 1997), fieldwork is essential for the study of safety. Additionally, as the healthcare environment is complex, a pragmatic worldview provides the widest range of suitable methods to address the research question.

The philosophical point of view must be defined, particularly as weak signals may be considered elements from both a positivism and interpretivism perspective. In the view concerning what 'weak signals' constitute, a pragmatic philosophy provides the most appropriate approach, reflecting the standpoint of the author that weak signals can be both observable and quantifiable elements, which could be studied from a positivism worldview, as well as being objects that are created through social constructions, which would be studied using an interpretivism philosophy (Bowling, 2002). The advantage of the pragmatism philosophy is that it allows even conflicting perspectives to be described (Hignett & McDermott, 2015) and recognises the importance of both the physical world and the emergent social and psychological world (Robson & McCartan, 2016).

Furthermore, although risk and safety have traditionally been studied using a positivism philosophy (Guldenmund, 2010b), interest has recently increased regarding the social aspects of safety, such as safety culture (Reason, 1997). By adopting pragmatism, elements of interpretivism can be adopted that would allow consideration of how constructs are understood (Guldenmund, 2010b) and facilitate the investigation of emerging elements of complex systems, which is a key feature of safety (Robertson et al., 2015). Pragmatism sees analysing human behaviour in the context of the environment as being analogous to experimental and scientific enquiry (Robson & McCartan, 2016); this approach is particularly suited for HFE, which explores existing work system problems that are influenced by their context (Carayon et al., 2015).

A principle benefit of pragmatism is that it allows greater depth in studying the proposed concepts because more approaches are available (Creswell, 2014; Saunders et al., 2009). This philosophy permits the selection of more than one research approach (inductive and abductive), ontology (objective and subjective), data type (qualitative and quantitative) and the use of multiple methods to find the necessary information to address the research objectives (Onwuegbuzie, Dickinson, Leech, & Zoran, 2009a).

4.2.2 Research Approach, Method Choice and Strategy

4.2.2.1 Research Approach

The term research approach was defined by Peirce (1931) as the manner of 'conscious scientific reasoning' (as cited by Kovács & Spens, 2005). The approach used in this research included inductive and abductive reasoning. Both approaches are aimed at developing theory (Saunders et al., 2009). Inductive reasoning has a more linear approach that begins with observation to determine emerging theories (Bowling, 2002; Kovács & Spens, 2005) and aims to compile fragmentary pieces of information to create a connected view of the phenomenon using a conceptual framework (Saunders et al., 2009). That said, this process of reasoning does not corroborate or falsify theories (Saunders et al., 2009).

Abductive reasoning looks at data to determine which aspects contradict or fit the existing theory (Saunders et al., 2009). Similar to inductive reasoning, the process may start with a set of observations or with prior theoretical knowledge (Peirce, 1931 as cited by Kovács & Spens, 2005). Following this phase, suitable theories are identified to support the observed phenomenon (Kovács & Spens, 2005), a procedure known as 'theory matching' (Dubois & Gadde, 2002). Data capturing and theory matching are done in a cyclical process to build theory (Dubois & Gadde, 2002; Saunders et al., 2009). The reasoning focuses on elements that pertain to specific situations and not the generalisable aspects of the situation (Kovács & Spens, 2005) and requires interpreting individual phenomena with the aim to understand the concept in a novel way using a new conceptual framework (Dubois & Gadde, 2002). The outcome of this form of reasoning is that it provides the best possible explanation but not a positively verified conclusion relating to the phenomenon (Kovács & Spens, 2005). The process of abductive reasoning and its relation to theoretical and empirical research is depicted in Figure 17.

This approach of generating knowledge was applied across various elements of this research and all included case studies. Specifically, in Chapter 3, theories from a variety of scientific fields have been presented to develop a new conceptual framework on weak signals, which was then evaluated against the empirical research from Case Studies 1, 2 and 3. Theory was used in an iterative process with data collection in this research to design and guide data collection as well as to discuss the outcomes of the case studies.

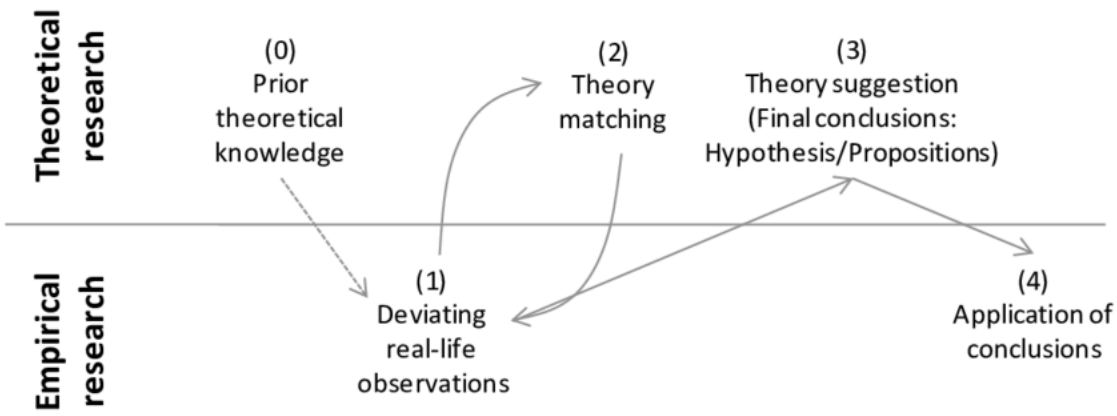


Figure 17: The abductive reasoning process and its relation to theoretical and empirical research (Kovács & Spens, 2005).

4.2.2.2 Method Choice

The decision to use qualitative or quantitative methods depends on the context and purpose of the research (Bowling, 2002). The predominant method choice for this research was qualitative, with the exception of Case Study 2, which combined both quantitative and qualitative elements in a mixed methods approach. The mixed methods approach will be described in more detail in Chapter 6 on Case Study 2. Qualitative methods were selected as the predominant method choice, as this method choice aims to study people, their experience and phenomena in the context they occur and collect naturally occurring data (Bowling, 2002; Mays & Pope, 1995). Consequently, this method choice involves fieldwork, which supports the exploration of processes and meanings of events (Ochieng, 2009). Such methods describe the qualities of social phenomenon in words rather than numbers (Bowling, 2002; Hignett & McDermott, 2015).

This type of method is being increasingly used in HFE (Hignett & McDermott, 2015); moreover, the healthcare field is increasingly acknowledging the value of this type of research (Sim, 1998). Qualitative methods are highly suitable for theory development (Ochieng, 2009; Yin, 2003) and offer the advantage of exploring topics and collecting rich data on complex issues (Bowling, 2002). The disadvantages of this method include that the data may be open to subjective interpretation, the results may not be entirely replicable (Chi, 1997) and may not necessarily be applicable to a wider population (Ochieng, 2009). As the focus in qualitative

research is on depth of data, sampling is usually purposefully derived and relies on smaller numbers in comparison to quantitative research (Tuckett, 2004). Rigour for qualitative methods can be improved by clearly stating the theoretical framework upon which the research is based as well as explicitly describing the methods, context and analysis approach, specifying the sample included, applying triangulation to test the validity of the results and including raw data to support the results, interpretation and conclusions derived (Bowling, 2002).

The qualitative data collection methods in this study included observations, interviews, focus groups and document analysis to capture knowledge and experience relating to weak signals and the context wherein they occur. Both structured texts (pre-existing documents, incident reports) and unstructured texts (e.g. transcripts, interviews, focus groups) comprised the types of qualitative data used.

4.2.2.3 Strategy

The strategy adopted in this research was case studies, which commonly adopts abductive reasoning (Dubois & Gadde, 2002). Case studies focus on a particular circumstance within a 'real-life' context (Yin, 2003), and the complexity of a single case is explored in depth (Bowling, 2002). This approach is an ideal strategy for understanding complex social phenomena as it does not require the control of behavioural events (Yin, 2003). The phenomenon investigated in this thesis involved weak signals relating to safety behaviour, and as the boundaries of this phenomenon could not be separated or distinguished from the context, the case study strategy was the most suitable for this research.

This research started with a within-case analysis to identify the weak signals for each case study. Cross-case patterns were sought by travelling back and forth between the data and the emerging theory to refine and adjust the framework. By using multiple methods and data sources, a deeper understanding and greater complexity of each of the cases could be captured, and the results were validated by triangulation (Bowling, 2002). As a part of the process, explorative and descriptive case studies were selected for the research. The exploratory component investigated how weak signals were experienced by staff, while the descriptive component of the case studies aimed to depict a situation or phenomenon in the

context that it occurred. The latter component described how weak signals may relate to the events of patient handling, care transitions and sepsis.

An alternative strategy that should be briefly mentioned is that of phenomenology. Although this research is not primarily phenomenological in nature, some of its aspects are underpinned by the principles of phenomenology, which is associated with the discovery of key characteristics of a phenomenon from individuals' experiences (Creswell, 2014). The phenomenological aspects of this research were to understand and describe weak signals relating to safety behaviour and task performance.

4.2.3 Research Paradigm

The research paradigm is the theoretical foundation or system of scientific ideas upon which this enquiry is based, providing the context in which the research question is posed, and the results are interpreted (Bowling, 2002). The literature review in Chapter 2 establishes the background and basis for this research, upon which the following four case studies are based. As was highlighted in Chapter 2, enhancing the capacity for healthcare to learn more effectively from when things go wrong (Donaldson, 2002) is essential, along with the ability to identify how to promote proactive safety elements as described by Safety-II, high reliability and resilience.

The literature review also revealed that most of the current concepts driving safety improvements have a degree of overlap. In addition to advocating a proactive approach to safety (Lekka, 2011; Rankin et al., 2013), these concepts promote addressing problems as they arise, considering a key hindrance to organisational safety being unable to redirect ongoing actions as needed (Barton & Sutcliffe, 2009). One means of addressing emergent problems and an indicator to redirect ongoing actions is through the use of weak signals, which also relates to the concept of 'a preoccupation with failure' from HRO theory (Cochrane et al., 2017). In other words, weak signals may assist in detecting deviations and facilitate swift and flexible action (Vogus & Hilligoss, 2016; Weick et al., 1999). Although weak signals may not be sufficient to drive change, noticing early warning signals is necessary for organisational safety (Barton & Sutcliffe, 2009). The concept of warnings, signs or signals featured in most of the current concepts driving safety improvements described in Chapter 2.

Weak signals can provide an opportunity to prevent incidents if their potential significance is identified and they are responded to (McLeod, 2015). By addressing weak signals that may indicate system drift, a proactive approach to improved safety performance can be established (Carrillo & Samuels, 2015; Dekker, 2011). Consequently, this research investigated weak signals associated with task success and safety. In addition to the investigation of weak signals, the context wherein such signals might occur relative to safety was explored. As research on safety has shown that unintended failures typically result as a complex interaction between human behaviour, technological aspects, sociocultural factors and organisational factors (Donaldson, 2002), a systems approach provided the theoretical basis and a key underlying premise for the research design and analysis of the resulting data. Furthermore, a systems approach was essential since detection and recognition of weak signals and what counts as a signal also depend on the context and the frame of interpretation (Jørgensen, 2012). The focused review of literature in Chapter 3 compiled the relevant information on weak signals and supporting theories of how they are identified, interpreted and used.

4.2.4 Research Design

As highlighted in the focused literature review (Chapter 3), the concept of weak signals is relatively 'fuzzy' and not always directly measurable. Nevertheless, as they are a feature experienced by staff, they are accessible through numerous qualitative assessment techniques. Furthermore, as tools and models relating to weak signals are limited, the exploratory nature of the predominantly qualitative approach facilitated the identification of key themes and assisted with the development of a comprehensive framework. As investigating staff behaviours and actions in the context in which they occur is necessary, it was essential that the methods allowed for field-based data capturing or the data sources to reflect in situ events. An exploratory sequential qualitative research design (depicted in Figure 18) was adopted to achieve this goal, comprising several case studies that occurred sequentially and were interlinked.

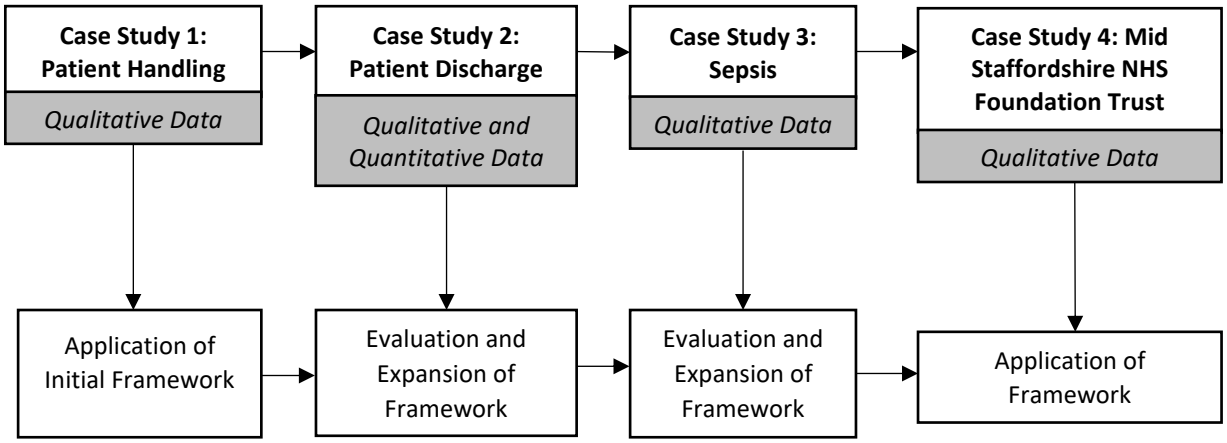


Figure 18: The exploratory sequential qualitative design adopted in this research.

The purpose of this design was to qualitatively explore the concepts of weak signals in one sample first and then to determine whether the qualitative findings and framework could be applied to different healthcare areas. The main type of data collected in this research involved qualitative data, allowing elements of the context to be captured, which could be particularly useful in eliciting conclusions and developing a deeper understanding of the phenomenon that quantitative data would not be able to provide (Jick, 1979). Furthermore, this research design was aimed at developing and generating theory and guiding generalisation (Brown et al., 2008a).

The four case studies included in this thesis investigated various healthcare themes. Case Study 1 investigated patient handling, Case Study 2 investigated the context of patient discharge from hospital care to community care, and Case Study 3 investigated the care processes relating to sepsis. Case Study 4 investigated the presence of weak signals in an example of a healthcare organisational failure, namely the failings at the Mid Staffordshire NHS Foundation Trust. The NHS, even though it is one organisation, is a highly complex system composed of numerous subsystems, with care processes spanning numerous subsystems. The case studies that formed this research analysed processes that traversed different levels of the system. Accordingly, Figure 19 depicts the case studies relative to the different system levels they investigated, mapped on the performance input component as described by the input-transformation-output model of healthcare professional performance (Karsh et al., 2006).

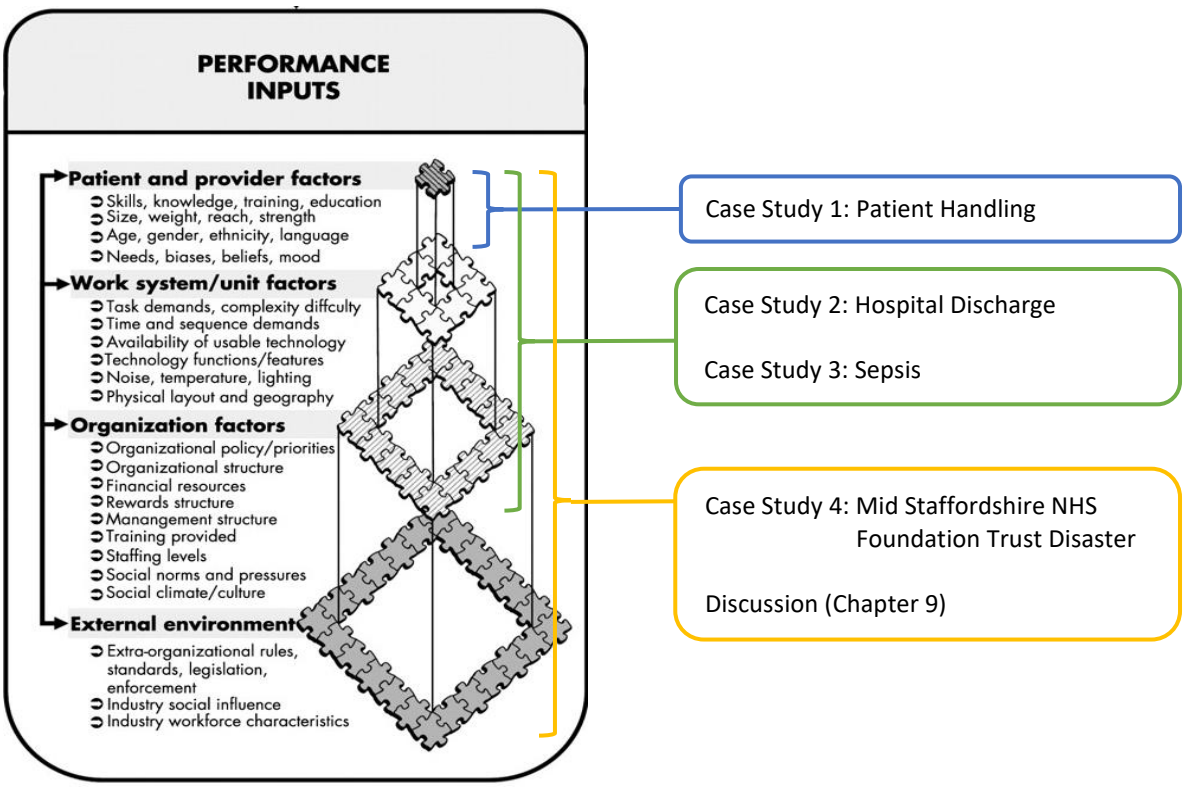


Figure 19: The different system levels investigated in the case studies, mapped on the performance input component of the input-transformation-output model of healthcare professional performance. Adapted by permission from BMJ Publishing Group Ltd. (Karsh et al., 2006).

This multimethod qualitative design consisted of four diverse case studies that addressed different components and aimed to collectively address the research question posed at the beginning of this chapter. Case Study 1 examined the system level concerned with the patient and provider factors. Case Studies 2 and 3 explored processes that required the input from numerous healthcare subsystems, spanned several system levels, specifically those concerned with the patient and provider factors, the work system/unit factors and organisational factors. This scope was essential; understanding the micro-level social process is necessary in order to understand the organisational practices that contribute to safety (Barton & Sutcliffe, 2009). Case Study 4 discussed the potential relevance of weak signals across the system with reference to organisational failure.

Each case study employed a different research design to best address the aims of that case study. As knowledge emerges from the relation of empirical data to theoretical models

(Malterud, 2001), Chapter 3 aimed to provide the theoretical basis through a synthesis of the literature for the empirical studies presented in Chapter 5 to 8 that followed. The first case study adopted an explorative design and tested the weak signals in healthcare framework developed in Chapter 3 in a case study on the task of patient handling. The second case study adopted a convergent parallel mixed methods design to test and apply the modified framework from Case Study 1 to a different healthcare process, in this case, patient discharge from hospital care into the community healthcare setting. In the third case study, the framework was applied once again to a different healthcare example, this time, the treatment of sepsis. This case study adopted a descriptive design and employed document analysis to test the framework. At the end of each of these case studies, the framework was evaluated and updated. The final case study explored the role of weak signals in one example of a healthcare organisational failure, by adopting an exploratory design and applying document analysis. A more detailed method and description of the research design for each individual case study will be supplied in the chapter featuring that case study. Table 10 provides a summary of the research design for each case study.

Table 10: Summary of the research design employed for each case study.

	Case Study 1 (Chapter 5)	***Case Study 2 (Chapter 6)***	***Case Study 3 (Chapter 7)***	***Case Study 4 (Chapter 8)***
Healthcare Area	Patient Handling	Patient Discharge	Sepsis	Organisational Failure
Focus	Testing of framework in the context of patient handling	Testing of framework in the context of patient discharge	Testing of framework in the context of sepsis	Exploration of weak signals in an organisational failure example
Research Design	Exploratory Qualitative Design	Convergent Parallel Mixed Methods	Descriptive Qualitative Design	Exploratory Qualitative Design
Triangulation	Theory Triangulation	Method and Data Triangulation	Data Triangulation	Not applied
Methods (n)	• Focus Groups (n=2)	• Observations (n=5) • Focus Groups (n=9) • Incident Reports Analysis (n=348) • Document Analysis (n=1) • Interviews (n=10)	• Survivor and Tribute Story Analysis (n=99) • Document Analysis (n=2)	• Document Analysis (n=2)

Triangulation was a key component of this research design. This refers to the 'combination of methodologies in the study of the same phenomenon' (Denzin, 1970, p. 297) or, alternatively, the process of where results from one data source are corroborated through the results of a

different data source (Brown et al., 2008a). Especially in qualitative research, this process can assist in illuminating the context, examining a phenomenon from numerous perspectives and providing a deeper understanding of the concept (Jick, 1979). Utilising several sources or methods enables seeking convergence and corroboration across the different data sources (Bowen, 2009). Furthermore, this approach will assist in reducing the impact of potential biases (Bowen, 2009), improve the internal validity of the study (Barbour, 2001), promote an increased understanding of complex phenomena (Jick, 1979; Malterud, 2001) and allow for the capture of a more holistic view of the element being studied (Jick, 1979).

This research used triangulation as a strategy to enhance the validity of the results through the convergence of information from different data sources (Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2014). More specifically, methodological triangulation and theory triangulation were applied in this research. Chapter 3 applied theory triangulation to compile the available literature on weak signals relating to safety behaviour to generate a framework for the investigation of weak signals in the healthcare environment. Case Study 2 used both method triangulation and data triangulation. Method triangulation involves using several methods to validate and corroborate the data obtained (Bowen, 2009). This research design also employed 'between methods' triangulation, which allows for convergent validation which enhances the trustworthiness of the findings (Carter et al., 2014). Between-methods triangulation assists with validity in that it ensures that any variance in the findings is not a result of the method, conferring a degree of external validity (Jick, 1979). Likewise, within-method triangulation, which requires comparing results across the different comparison groups, was used in Case Study 2 to develop confidence in the emerging theory and check internal reliability (Jick, 1979). Case Study 3 employed data triangulation, as different document sources were used in the analysis for this case study, validating the data by gaining multiple perspectives from different data sources (Carter et al., 2014). Across all the case studies, theory triangulation was used since this method required applying different theories on a common theme (i.e. how weak signals are processed and interpreted) to analyse and interpret the data (Carter et al., 2014; Jick, 1979).

4.3 Data Capturing Methods and Sources

The main form of data collected was qualitative data, some of which was used to generate quantitative results (in Case Study 2). The three basic types of qualitative data sources include spoken (interviews and focus groups), visual (observation) and written data (documents) (Hignett & McDermott, 2015). This study involved collecting all three sources of qualitative data to assist in addressing the research question posed. A combination of 'naturally occurring data' (e.g. observation of pre-existing meetings, analysis of incident reports and pre-existing documents) and 'researcher-provoked data' (e.g. interviews and focus groups) was used in this research (Silverman, 2006). Each of these methods will be outlined below, including key considerations, strengths and limitations. The methods applied for each case study will be described in more detail in the subsequent case study chapters. Following this section, the analysis approach will be described.

4.3.1. Observation

Observation is a traditional mainstream method of enquiry from the fields of social sciences, psychology and organisational analysis, which has been used in healthcare dating back to Hippocrates (Bowling, 2002). This method entails systematically watching, listening and recording a phenomenon of interest in the context in which the phenomenon occurs (Bowling, 2002). This method facilitates an understanding of behaviour, actions and interactions (Kirk, McClelland, & Fulton Suri, 2015) better than merely collecting narrative descriptions of these aspects (Bowling, 2002). Furthermore, observation of individuals in their working environment has the benefit of observing the effects in context, considering uncontrolled conditions and the effects of personal characteristics (Cronbach, 1975). Case Study 2 in this research used acknowledged observation sessions that included both structured and unstructured observation methods. The unstructured observation (qualitative approach) was used to develop a framework and checklist for the assessment of variables during discharge meetings that were observed using a structured approach (quantitative). Qualitative observation was recorded using field notes, and quantitative observation was recorded using a checklist (Gratton & Jones, 2004).

Advantages of observation include the directness of this method in that a phenomenon can be recorded when it happens, it can be applied in the 'natural setting', and it allows the identification of behaviours possibly not apparent to participants or that participants are unwilling to disclose (Creswell, 2014; Gratton & Jones, 2004). Among the limitations of this method are the possibility that the phenomenon may be misunderstood, the associated difficulties in data capturing such as ensuring key issues are documented (Gratton & Jones, 2004), observer bias, the influence of reactive effects (i.e. the Hawthorne Effect) and the potential lack of representativeness of the observations (Bowling, 2002). Although observer bias can be circumvented by having more than one observer (Bowling, 2002), this was not possible in this research. However, as the observer was witnessing an unfamiliar situation, the likelihood of ignoring or taking activities for granted was reduced (Bowling, 2002); meanwhile, the benefit of having one researcher was that the data was standardised from one external perspective only (Stanton et al., 2005). Furthermore, the observational results were verified by independent sources as part of a triangulated research approach (Bowling, 2002). The Hawthorne Effect, which refers to people changing their behaviour as a result of being observed (Sharples & Cobb, 2015), was also considered when analysing results.

4.3.2 Interviews and Focus Groups

Interviews and focus groups are popular (Greenwood, Kendrick, Davies, & Gill, 2017; Morgan, 1996) and commonly used techniques for knowledge elicitation and acquisition (Bisantz, Roth, & Watts-Englert, 2015; Shadbolt & Smart, 2015). Both can be considered as forms of guided conversations about the interviewee's or participants' perspective or knowledge of a specific phenomenon (Kirk et al., 2015; Shadbolt & Smart, 2015). These techniques enable the capture of subjective and self-reported data from participants (Sharples & Cobb, 2015). In healthcare research, interviews and focus groups are some of the most commonly used methods (Gill, Stewart, Treasure, & Chadwick, 2008; Sim, 1998), possibly because this method is highly suited for research in the healthcare environment but also due to the topics investigated in healthcare (Schroeder & Neil, 1992).

4.3.2.1 Interviews

Interviews aim to encourage participants to speak freely about experiences and behaviours relating to the topic being investigated (Bowling, 2002). They also allow for data capturing of

concepts that may be difficult or inappropriate to measure (Gratton & Jones, 2004). Although interviews tend to have smaller sample sizes compared to such methods as questionnaires or surveys, they tend to gather richer data on the phenomenon studied (Gratton & Jones, 2004). Interviews can either contain standardised questions (structured interviews), have a topic list but no fixed questions (unstructured interviews) or have a semi-structured format that is a combination of both structured and unstructured approaches (Bowling, 2002; Gratton & Jones, 2004; Kirk et al., 2015; Shadbolt & Smart, 2015). The data are then recorded either through written notes or by audio-recording the interview (Gratton & Jones, 2004). However, the subjective nature of this data-gathering method must be considered when interpreting and reporting results (Sharples & Cobb, 2015).

A combination of convenience and purposive sampling was used in this research, which refers to the sampling of subjects for reasons of convenience and deliberate non-random sampling of participants with a particular characteristic, respectively (Bowling, 2002). The 'rule of thumb' regarding sample sizes for interviews is that once similar themes start to emerge from the participants, a sufficient sample size has been reached (Bowling, 2002). A key aspect of qualitative interviews is that they aim to increase insight into a social phenomenon rather than assume representativeness (Bowling, 2002). This lack of representativeness creates limitations to the generalisability of the results (Bowling, 2002).

The advantages of the interview method include the flexible and adaptable nature of interviews (Sharples & Cobb, 2015). Moreover, they provide the opportunity to probe to gain additional information through clarification and elaboration, and they allow for the emergence of unexpected data and for responses to be put in context (Gratton & Jones, 2004). Disadvantages include the fact that this technique is resource-intensive, only feasible with small samples (Bowling, 2002) and may be susceptible to interviewer bias (Creswell, 2014). Lastly, the quality of the data is dependent on the interviewee's responses, which are influenced by recall, misperception and incorrect knowledge (Gratton & Jones, 2004). These weaknesses can be overcome with the use of appropriate probes, neutral language and validation of the interpretation of the results by others (Gratton & Jones, 2004). Furthermore, the reliability of interview data can be enhanced through maintaining a consistent

interviewing environment, a standardised interview schedule and, with the interviewee's permission, recording the interview for transcription (Gratton & Jones, 2004).

4.3.2.2 Focus Groups

Focus groups were used to explore weak signals in healthcare in Case Studies 1 and 2, as this technique allows for the capture of in-depth information on lived experiences and access to elements that may not be accessible via other methods (Billson, 1989; Kitzinger, 1994; Liamputtong, 2012). This method was selected to discuss and identify a wide range of weak signals with the participants instead of using the Critical Decision Method (Klein et al., 1989), which focuses on a specific incident, limiting the types of weak signals that could be compiled. Focus groups combine elements of both interviewing and participant observation (Massey, 2011). A unique key feature of this method is that it utilises group dynamics, both complementary and argumentative interaction (Kitzinger, 1994), to stimulate discussion, explore contrasting views and gain insight into a topic in depth (Bowling, 2002; Kitzinger, 1995; Liamputtong, 2012). Results emerge as a consequence of both individual contributions and group interaction (Kitzinger, 1994).

Focus groups are similar in structure to unstructured interviews with small groups of participants led through discussion (Bowling, 2002; Gratton & Jones, 2004) and tend to have a more semi-structured or unstructured form than interviews (Bisantz et al., 2015). These types of structures allow participants to comment and interact (Bisantz et al., 2015). The interviewer takes the role of the group moderator, using a discussion guide aimed to elicit and stimulate conversation and direct the discussion (Gratton & Jones, 2004; Massey, 2011). As this method provides access to participants' subjective experiences regarding social phenomena, it is suitable for studying safety behaviour, which can be considered a social phenomenon. The discussions are usually audio-recorded, in addition to taking observational notes during the focus group (Bowling, 2002; Gratton & Jones, 2004).

A key consideration for focus groups is the group composition (Bisantz et al., 2015), as the participants' characteristics will affect the quality of the interaction and discussion (Gill et al., 2008; Onwuegbuzie, Dickinson, Leech, & Zoran, 2009b). Groups must be carefully balanced to ensure high-good quality data (Bowling, 2002), and participants must be carefully selected

regarding their experience, current roles and work interaction with the other participants (Kitzinger, 1995; Sim, 1998). The group should be representative of the sample of the population being researched while avoiding large discrepancies in job status, which might inhibit participants' willingness to participate (Bridger, 2009). This research used pre-existing homogenous groups (i.e. participants had a common element, for example, senior staff involved in patient handling), aiming to enhance interaction and discussion due to the commonalities and shared experiences (Liamputtong, 2012).

Additional essential aspects to consider are the number of participants per focus group (group size) and number of focus groups (Liamputtong, 2012). The literature reports varying ranges for ideal focus group sizes (Tang & Davis, 1995). The number of participants influences the degree of interaction and discussion and, consequently, the diversity of information they provide (Onwuegbuzie et al., 2009b). Most sources suggest an optimum group size falls between the range of four to twelve participants (Tang & Davis, 1995). However, depending on the topic and participants, focus groups as small as two (Sharples & Cobb, 2015) or three can be successful (Gill et al., 2008), as long as sufficient output of information is generated, and every participant has sufficient opportunity to speak (Bisantz et al., 2015; Tang & Davis, 1995). As this research was based on an exploratory design, the literature recommended numerous focus groups with smaller sizes and a less structured format to facilitate gathering a maximum amount of information (Tang & Davis, 1995). Researchers have suggested that focus groups should be run until 'theoretical saturation' has been reached (Carlsen & Glenton, 2011). Even though there are mixed views on how many focus groups are required to reach saturation, suggestions have implied that saturation can be reached with two to five focus groups per category; however, the number of focus groups depends on the composition of the groups and the complexity of the research question (Carlsen & Glenton, 2011).

The advantages of focus groups are that they provide depth and insight into the topic under investigation (Gill et al., 2008), allow further exploration of information revealed during the focus group, and offer a flexible tool that can be used for numerous topics in diverse settings (Liamputtong, 2012). The disadvantages of focus groups include that if care is not taken, certain participants may influence the group discussion (Liamputtong, 2012), and the transcription and analysis may be complex and time-consuming (Bowling, 2002; Gill et al.,

2008). Lastly, as focus groups require mutual self-disclosure, certain topics may be unacceptable for discussion (Morgan, 1996).

4.3.3 Document analysis

Document analysis is frequently used in qualitative research and constitutes the process of reviewing and evaluating documents in both printed and electronic form to synthesise data (Bowen, 2009). Documents, which are socially produced artefacts (Bowling, 2002), can help uncover meaning and develop understanding relative to the research question (Merriam, 1988). In addition, this procedure can assist in providing the context within which the phenomenon occurs, providing data and contextualising results (Bowen, 2009). Documents can be analysed either qualitatively, focusing on the social and cultural context of the document, or quantitatively, counting the frequency of key themes (Bowen, 2009).

This research used documentation in the form of investigation reports, including official incident reports and Ombudsman reports, and individual stories regarding experiences, in the case, the survivor and tribute stories written by sepsis patients and their friends and families. In addition to these documents, written material generated from transcription and notes relating to the focus groups, interviews and observation session were also used in the analyses. This research utilised document analysis as a complementary method (Case Studies 1 and 2) in addition to a stand-alone method (Case Studies 3 and 4). Document analysis is a strategy that is particularly useful within the case study approach, as in some cases, documents may be the only viable source of information on events related to complex social phenomena (Bowen, 2009). This research used document analysis to provide the context within which the participants worked, as a source of data, to contextualise results and to corroborate results from other methods.

A key consideration for document analysis is the necessity to understand that records, even official records, cannot be treated as firm evidence of what they report since they may not contain an accurate or complete record of the event (Bowen, 2009). Hence, it is necessary to determine the authenticity, accuracy, comprehensiveness and representativeness of the documents (Bowen, 2009). Additional key considerations include the original purpose of the document, the intended audience and whether it was the result of first-hand experience or

came from secondary sources (Bowen, 2009). The reliability and validity of documents vary; documents are rarely perfect and cannot alone be considered as a complete and accurate representation of the phenomenon being investigated. That said, they are considered valuable sources of data about society (Bowling, 2002).

The advantages of document analysis include convenience, as many documents are readily available in the public domain (Bowen, 2009), analysing documents usually involves low cost in comparison to other research techniques (Creswell, 2014) and offers an effective means of gathering data, especially for events that cannot be observed (Bowen, 2009). Additionally, documents are 'unobtrusive', 'non-reactive' and stable (Bowen, 2009) as they are not affected by the research process in the same way that participants may be influenced by the researcher's presence (Bowen, 2009; Bowling, 2002; Merriam, 1988). Limitations of document analysis include that they may be viewed as too subjective, imprecise, imperfect and unrepresentative. Moreover, as they are social constructions of reality, they may be biased (Bowen, 2009; Bowling, 2002). As documents are usually created for purposes other than research, they may offer insufficient detail to directly and solely answer the research question (Bowen, 2009). Nonetheless, as they are independent of the research, the use of documents may improve the reliability of the data (Bowen, 2009). As documents may be subject to editing, error, loss and falsification, the researcher must consider the process of construction in addition to the content, along with the authenticity, completeness and representativeness of the documents (Bowling, 2002). As a result of these limitations, triangulation is an essential feature to improve the validity and reliability of the results (Barbour, 2001; Bowling, 2002).

4.4 Analysis Methods and Models

This section describes the data analysis process applied in this research. All case studies included a qualitative analysis component. A quantitative analysis was performed only for Case Study 2 and involved counting the frequency of themes during the observation of discharge meetings. The specifics for the quantitative analysis process will be described in more detail in Chapter 6. Qualitative analysis of the transcriptions, field notes from the focus

groups and observations, flipchart summaries from the focus groups, reports and other documents was performed for all the case studies and will be described in more detail below.

4.4.1 Qualitative Analysis

The qualitative analysis process involved preparation and organisation of the data, thematic analysis, data display and, finally, drawing conclusions and verification of the results. For the incident reports used in Case Study 2 and the survivor and tribute Stories used in Case Study 3, the data was prepared in Microsoft Excel (Microsoft Corporation, 2020). All audio data from Case Study 1 and Case Study 2 were transcribed, which yielded the most rigorous means of analysing this type of data (Onwuegbuzie et al., 2009b). The transcribed data were organised using NVivo 11 (QSR International Pty Ltd, 2015) according to the questions or prompts from the discussion guides used in each case study.

A thematic analysis, as outlined by Braun and Clarke (2006), was conducted on the qualitative data. Thematic analysis consists of data familiarisation, generation of initial codes, determining and reviewing themes and finally reaching agreement on defining and naming themes (Braun & Clarke, 2006). This method comprises a popular approach to qualitative analysis (Boyatzis, 1998; Wiggins, 2004), which focuses on identifying themes and patterns with the aim to generate descriptions of a phenomenon (Braun & Clarke, 2006) and identify patterns of behaviour (Aronson, 1994). By collating the data into themes, the aim is to form a comprehensive representation of the participants' collective experience (Aronson, 1994). Rather than linear, this process was iterative and reflexive (Fereday & Muir-Cochrane, 2006), requiring the qualitative data to be decontextualised, which necessitated the extraction of subject matter and re-contextualisation of the results. This last step ascertains that the patterns identified still hold with the original context from which they were extracted (Malterud, 2001).

Generation of initial codes involved categorising the data using both categories defined before data capture as well as categories that emerged from the analysis of the data. Coding involved assigning labels to pieces of data, of varying sizes, that contained the same theoretical or descriptive idea (Hignett & McDermott, 2015). This research used both theory-driven codes as well as data-driven codes. The initial round of coding employed themes

generated from theory ('coding down') (Fielding, 1993), namely the components of the SEIPS 2.0 model (Holden et al., 2013) or the discussion guide. Following this procedure, codes from the data were developed ('coding up') (Fielding, 1993), otherwise known as emergent codes. After the initial rounds of coding, the codes were refined in that the coding categories were compiled, collapsed, expanded and revised to form themes reflecting the main issues identified (Javadi & Zarea, 2016). Semantic themes, which reflect the patterns that existed in the data and were grouped according to content, summarised or interpreted meanings (Javadi & Zarea, 2016). Latent themes were developed following the semantic themes. This step required interpreting the semantic themes to create a theory based on the patterns identified and the wider framework upon which the work was based (Braun & Clarke, 2006; Javadi & Zarea, 2016). Next, concept-matching to the relevant literature was performed (Bowling, 2002; Creswell, 2014). For the weak signals analysis, inductive coding was used since there was little theory to inform the development of codes at the onset of the study (Bowling, 2002). Data could be coded in more than one category, facilitating conceptual and theoretical development (Bowling, 2002). Codes and themes were used to assist with integrating the data gathered via different methods (Bowen, 2009). Data display methods used in this research included tables and graphical formats. This step helped ensure interpretive rigour, demonstrating clearly how the data interpretations were achieved (Rice & Ezzy, 1999 as cited by Fereday & Muir-Cochrane, 2006).

Although the disadvantage of this method is its time-consuming nature (Bowling, 2002), the advantages include that it is flexible and reflective (Braun & Clarke, 2006; Javadi & Zarea, 2016), allows for the development of rich codes, and provides the opportunity to develop new categories that may not have initially been thought of (Bowling, 2002). Additional advantages include its flexible systematic approach (Braun & Clarke, 2014), and enabling the synthesis of data from different sources (Boyatzis, 1998). Lastly, as it is not tied to a specific philosophy or epistemological position, this method can be used across a range of theoretical approaches (Braun & Clarke, 2006).

For the qualitative analysis, the computer-assisted qualitative data analysis software, NVivo Version 11 (QSR International Pty Ltd, 2015), was used. The software allowed for the systematic organisation and management of data through the collection of sources and the

generation of nodes identified in the sources that were used to create themes (Hignett & McDermott, 2015). The software also permitted the modification and merger of nodes, development of visualisations to support new perspectives and development of an audit trail of analyses, which could assist in enhancing the reliability of the research (Sharples & Cobb, 2015). The benefit of using this software was that the themes maintained their contextual position in the raw documents or transcripts, allowing the researcher to build subsets of themes with the aim to describe the data (Bowling, 2002).

4.4.2 Framework for analysis

The analysis was guided by the SEIPS 2.0 model (Holden et al., 2013) to identify common themes from a systems perspective. This model was selected as it is healthcare-specific, incorporates a systems approach, and is applicable to a large number of healthcare scenarios (Carayon et al., 2014; Carayon, Schoofs Hundt, Karsh, et al., 2006). Furthermore, this version of the model assists in generating an understanding of the collaborative work required and various work system configurations that may produce barriers and facilitators (Carayon, Wooldridge, Hoonakker, Schoofs Hundt, & Kelly, 2020) that contribute to the work system context. As the SEIPS 2.0 model was used as a basis for the focus group discussion guide, initial data reduction was done using the components described in the SEIPS 2.0 model, including the aspects of the sociotechnical work system, work processes or outcomes as pre-defined nodes. This template and form of pre-defined codes assisted with organising the text for further analysis and helped provide a clear trail of evidence for these studies supporting credibility. The SEIPS 2.0 aspects and underlying components are described in *Appendix A1*. By adopting a systems approach, the aim was to identify and understand not only the system components that might affect patient safety, workflow and processes in healthcare (Holden et al., 2013) but also the context wherein weak signals in healthcare might occur.

4.5 Validity and Reliability

The concepts and terms ‘validity’ and ‘reliability’ originate from quantitative methodology (Hignett & McDermott, 2015) and, as such, do not translate directly to qualitative data (Creswell, 2014). The aim of validity and reliability is to improve research rigour by reducing bias and errors in the process (Bowling, 2002). Reliable and valid analysis of qualitative data

is more difficult, specifically where ambiguity may be present (Gratton & Jones, 2004). In qualitative research, these elements must be incorporated in the broader understanding of the rationale and assumptions underlying the research to ensure reliability and validity (Barbour, 2001). Key mechanisms applied to improve validity and reliability in this research included triangulation, reflexivity and member checking.

Validity, which refers to issues of generalisability, applicability and transferability of the results, consists of internal and external validity (Creswell, 2014; Hignett & McDermott, 2015). Internal validity refers to a study investigating what it describes (Malterud, 2001). In contrast, external validity refers to the context of the findings being applied across time and place (Brown et al., 2008b; Malterud, 2001). The strategies to establish internal validity used in this research included the richness of the descriptions, linking the results to theory (Hignett & McDermott, 2015) and the use of an audit trail (Hignett & McDermott, 2015). Strategies to establish external validity included comprehensive descriptions of the original samples and the context (Malterud, 2001), as well as specifying the scope, boundaries and variations (Hignett & McDermott, 2015).

Triangulation was also used to strengthen the validity of this research (Gratton & Jones, 2004), as internal and external validity was also established through triangulation of methods and data sources (Hignett & McDermott, 2015). Triangulation improves the trustworthiness of the data and safeguards against results being attributed to an artefact of a single source, methods, researcher bias or respondent bias (Bowen, 2009), as well as addressing reactivity (Bowen, 2009). The internal and external validity was also assessed for each case study during the discussion of the results by reviewing the analysis process and considering the effects of context and bias (Malterud, 2001). A disadvantage of triangulation includes the difficulty of performing this process properly; through using different methods, the different forms may not allow direct comparison (Barbour, 2001). The triangulation applied to this work is described in detail for each case study in the research design section of this chapter. Case Study 2 used respondent validation, which happens when the interpretation of the results is presented to the participants for verification (Walker, 1989), potentially improving both internal and external validity (Mays & Pope, 1995). This procedure enabled the refinement of the explanations (Barbour, 2001). Qualitative reliability refers to the consistency and quality

of the data and results (Creswell, 2014; Hignett & McDermott, 2015). Strategies to establish this type of reliability included stating the research question unambiguously and clearly connecting the results to the theory (Hignett & McDermott, 2015).

One means to ensure reliability and validity involves extensive member checking (Mays & Pope, 2000). Due to the nature of a doctoral study, the data capturing, and coding were conducted by one person, and the results were subsequently discussed with the supervisors. As extensive member checking was not possible, the results were presented at numerous internal project steering group meetings (for Case Study 2) and at numerous academic and healthcare-related conferences, which provided the opportunity for both academic and healthcare-related staff to further comment on the results. Moreover, for the focus groups, themes raised during the group were summarised and confirmed or amended at the end of the session with the participants. In addition to the above, respondent validation, which involves cross-checking research findings with respondents (Barbour, 2001), was used to confirm and refine the results from Case Study 2.

Reflexivity refers to how the data is shaped by the researcher and the research process (Mays & Pope, 2000). The underlying philosophy and overall research design of this work have been described in this chapter, including a discussion of how these factors led to the selection of the methods. A commitment to reflexivity and the effects of the researcher has been shown for each case study, as reflected in the discussions of the aspects of reliability, validity, limitations and strengths in the associated chapters.

4.6 Conclusion

This chapter described the research paradigm, methodology, research design and methods applied to address the research question. An overview of the methods and how they linked across the case studies to answer the research questions was presented. Additionally, aspects of reliability and validity were addressed. A more detailed method for each case study has been included in the case study chapters.

Chapter 5: Case Study 1 – Weak Signals for Tasks associated with Patient Handling

The focus of this chapter is to apply the weak signals in healthcare framework constructed in Chapter 3 to the context of tasks associated with patient handling. This chapter initially provides a brief description of the context, namely patient handling; the aims and objectives; followed by a description and justification of the methods applied; and finally, the results for this case study. This chapter concludes with a description of the limitations of this case study, modifications for the method, and a new version of the framework to be assessed in the next case study, which features a different healthcare context.

Behaviour, especially in clinical work, that contributes to care and safety is often not directly visible (Wears, 2012). Accordingly, the first case study in the series, aimed at exploring weak signals in healthcare, adopted an explorative approach to investigate weak signals and their context through the use of focus groups with a group of experts in patient handling. The purpose of this case study was to explore weak signals as a form of informal behavioural strategies, normally hidden from view, that contribute to safety and task success. This included identifying how staff register unexpected changes or disturbances (i.e. weak signals) within their work system, how staff adjust work, recognise and manage emerging complications (i.e. respond to weak signals).

5.1 Context – Patient Handling

A common task in healthcare, representing either a primary or secondary task (Hignett et al., 2004), is assisting less-able people in moving. The tasks that fall in this remit are referred to patient handling tasks and include lifting, transferring and repositioning patients (Nelson, Collins, Siddharthan, Matz, & Waters, 2008). These tasks aim to reposition a patient efficiently without unnecessary fatigue and strain to healthcare staff using their own body and the principles of biomechanics (Collins & Menzel, 2006). Some tasks may also be completed with aids and mechanical alternatives, for example, patient-lifting hoists (Garg & Kapellusch, 2012; Nelson & Baptiste, 2006).

Patient handling tasks are often physically demanding, performed in unfavourable conditions and contain a degree of unpredictability (Nelson & Baptiste, 2006). One reason for this may be due to the dynamic element and multiple variables patients can contribute to this task (Nelson & Baptiste, 2006). The nature of these tasks puts staff and the patient at risk if proper procedures are not followed (Nelson et al., 2003). For staff, such tasks have been associated with musculoskeletal disorders (Garg & Kapellusch, 2012; Nelson & Baptiste, 2006; Smedley, Egger, Cooper, & Coggon, 1995), especially due to the frequency and duration involved (Nelson & Baptiste, 2006; Nelson et al., 2008). The patient may be at risk of pain, fractures, contusions, skin tears and loss of dignity (Tuohy-Main, 1997 as cited by Nelson & Baptiste, 2006). Consequently, patient handling risk assessments and plans, which are an evaluation of identified hazards and development of safe ways of working controlling the risks for the carer, have been developed (Fray, 2010). To reduce the risk associated with these tasks, engineering, administrative and behavioural controls have been developed (Nelson & Baptiste, 2006) which modify the task, change the way the task is completed while managing the skills and physical abilities of staff, reduce manual effort through aids, equipment or the patient's contribution, and alter the location to reduce risks (Nelson & Baptiste, 2006).

As with all other work, patient handling is also influenced by numerous system factors, including patient-related factors, available resources, task and environment elements, as well as organisational elements (Nelson et al., 2008). Patient factors include their functional status, cognitive abilities, cooperation, health condition, fatigue and size (Nelson et al., 2008). Task-related risk factors consist of both dynamic and static elements of postures and movements, load (Lee & Chiou, 1994) as well as transfer type and location (Fray, 2010). Environmental factors that contribute to risk include inadequate space and poorly designed work layouts (Nelson et al., 2008). Furthermore, the behaviour that influences patient handling is also affected by peer group information, local and national guidelines, professional standards, health and safety information (Catino, Albolino, & Vannucci, 2005), as well as local work policies and philosophies (Nelson et al., 2008).

5.2. Aims and Objectives

The aims of this case study were to explore the context from which weak signals emerge and apply and expand the weak signals in healthcare framework (version 1) developed from literature in chapter three to the context of patient handling tasks. To achieve this first aim, namely, to explore the context from which weak signals emerge including the connection of the context to weak signals, this case study will address the following objectives:

- Explore the system factors associated with patient handling work from which weak signals may emerge.
- Explore weak signals relative to errors associated with patient handling tasks using the error taxonomy created by Reason (2001).
- Explore the factors affecting weak signal use, detection and response.

To achieve this second aim, namely, to apply and expand the weak signals in healthcare framework (version 1), this case study will address the following objectives:

- Determine the weak signals associated with patient handling and their sources.
- Discuss with staff how they come in contact and interact with weak signals.
- Expand the framework to include newly identified elements from the results of this case study.
- Explore the application of this framework in conjunction with Reason's error taxonomy (Reason, 2001).

5.3 Method

Patient handling was selected for the first case study as it constitutes a task that occurs predominantly at a patient and provider level, as depicted in the input-transformation-output model of healthcare professional performance (Karsh et al., 2006) in Figure 19 in Chapter 4. Although this task is influenced by the system in which it is performed, weak signals are unlikely to span several other subsystems in this case study for action to occur. The focus groups were run with experts in the field of patient handling, as the literature indicates that intuition arises from expertise (Benner, 2004; English, 1993; Gobet & Chassy, 2008), and it was hypothesised that weak signals might be identified through intuition.

5.3.1 Research Design

This case study was the first in a series as part of an exploratory sequential design that aimed to investigate weak signals in healthcare (Chapter 4, Figure 18). An explorative and qualitative approach was adopted for this first case study using a focus group method to investigate specific types of tasks and the possible outcomes, as well as identify weak signals that present in the work associated with patient handling. The semi-structured nature of the focus groups allowed greater emphasis on discussion of elements that emerged during the session than a structured focus group might have (Morgan, 1996). The focus group discussion guide was structured to explore the potential context of situations where safety might be a concern first, followed by a more specific discussion of weak signals that might indicate the task was not going to be completed successfully.

5.3.2 Protocol

A 60-minute session was held with two different focus groups comprised of members who had expertise in patient handling. This group was selected as the researcher had access to two different groups of experts in this field, and a level of expertise was necessary to explore intuitive responses and weak signals from the work environment. Before the start of each focus group, an introduction to the study was provided that included the aims and an overview of the topics to be discussed. Participants were also asked to complete consent and demographic information forms (*Appendix B1*).

The content of the focus group included the presentation of two examples of manual handling tasks, and then the discussion was led through a series of questions. The task scenarios described to the groups included a lateral bed transfer and an assisted transfer from a seated position to a standing position. The information presented included the task to be considered, the unit wherein it occurred, the staff present and the necessary patient handling information (e.g. the patient's capabilities). In the first group (Loughborough), due to a technical problem, the scenarios were only presented verbally. In the second group (Edinburgh), the scenarios were first presented verbally, followed by a short video clip of the tasks to be discussed. The following series of questions guided the discussion:

1. What could go wrong with this task? (Errors)
2. What external factors would influence this task? (External Factors)

3. How do you know the task is going wrong? (Weak Signals)
4. Do you use this knowledge next time you do this task? (Learning)

During the discussion, a summary of the key points raised by the group was compiled on a whiteboard or flip chart in view of the participants. The completed contents were photographed at the end of the session. The discussions of the focus group were recorded using two audio recorders and field notes. The audio data was transcribed, which was analysed together with the field notes and photographs of the summary points made during the discussion.

5.3.3 Participant Characteristics

One focus group was held with the Loughborough Alumni Research Forum (LARF) in patient handling, and the other was held with a group of manual handling advisors at the Western General Hospital in Edinburgh. The first group, conducted at Loughborough University, consisted of 10 participants with a mean age of 54 years (±7.69 years), having a mean total of 30 years' (±12.14 years) involvement in patient care and 10 years (±3.19 years) in their current positions. The second group, conducted at Western General Hospital, consisted of 7 participants with a mean age of 45 years (±7.17 years) and having a mean total of 25 years' (±7.95 years) involvement in patient care and 11 years (±5.63 years) in their current positions.

Table 11 presents the education and specialisation characteristics of the two groups. The Loughborough group consisted of nine participants with a Master of Science degree and one participant with a Bachelor of Science degree, while the Edinburgh group consisted of four participants with a Registered General Nurse degree, two participants with a Bachelor of Science honours degree and one participant with a physiotherapist diploma. The current positions held in the Loughborough group were four manual handling advisors or coordinators, five back care advisors or managers and one director and manual handling consultant. The role responsibilities of the participants in the Loughborough group included providing training, education, manual handling service components, advice, writing policies, workplace and risk assessments, accident investigation and facilitating patient handling. The current positions of the members of the Edinburgh group included two manual handling advisors or coordinators, four manual handling area leads, and one head of manual handling.

Their current positions encompassed being responsible for and delivering training, competency assessments, risk assessments, providing advice, ensuring compliance with policies, on-site support and equipment evaluation, as well as strategic and operational management of manual handling services.

Table 11: The education and specialisation characteristics of the participants of the two groups conducted at Loughborough University and at the Western General Hospital in Edinburgh.

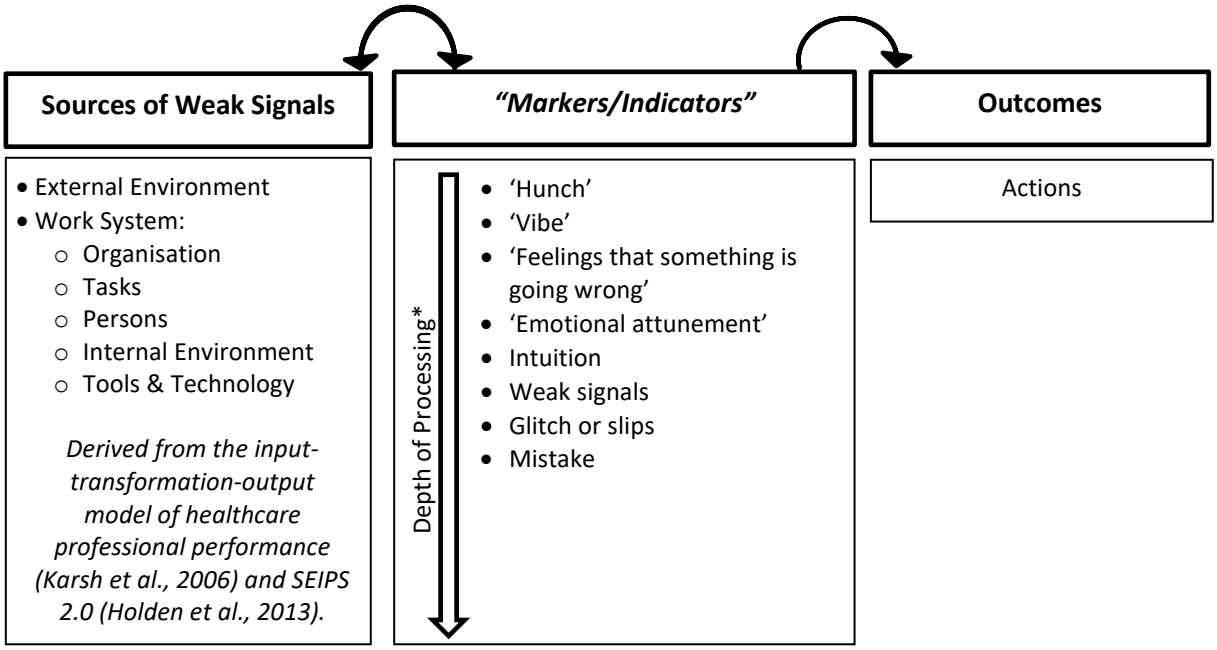
	Loughborough (Focus Group 1)	Edinburgh (Focus Group 2)
Education	9 – MSc Degree 1 – BSc Degree	4 – Registered General Nursing Degree 2 – BSc (Hons) 1 – Physiotherapist Diploma
Field of Final Specialisation	3 – Back Care Management 1 – Registered General Nursing Degree 6 – Not specified	1 – Occupational Therapy Degree 4 – Registered General Nursing Degree 1 – Physiotherapy Degree 1 – Not specified
Current Position	4 – Manual Handling Advisor/Coordinator 5 – Back Care Advisor/Manager 1 – Director and Manual Handling Consultant	2 – Manual Handling Advisor/Coordinator 4 – Manual Handling Area Lead 1 – Head of Manual Handling

5.3.4 Analysis Framework

A thematic analysis (Braun & Clarke, 2006) was done using NVivo Version 11 (QSR International Pty Ltd, 2015). The audio files from the focus groups were transcribed and organised using NVivo according to the questions from the focus group discussion guide (*Appendix B2*). The initial round of coding used themes generated from theory ('coding down') (Fielding, 1993), namely the error taxonomy created by Reason (2001) and the components of the SEIPS 2.0 model. Following this, codes were developed from the data (Fielding, 1993).

As part of the analysis, weak signals were identified and extracted from the data and compiled into a list. As the detection of signals is often dependent on knowing what to look for, in addition to the ability to perceive them (Gaba et al., 1995), this research aimed to compile a catalogue of weak signals. Using the descriptions provided by the participants, the sources, manifestation, and form of the weak signals were determined. The identified weak signals and their sources were then mapped onto the weak signals in healthcare framework (Version 1) depicted in the figure below (Figure 20). Based on the results and discussion from this case

study, as well as the literature on weak signals described in Chapter 3, the framework (Version 1) was expanded and modified to create Version 2 in the discussion section of this chapter.



**Depth of processing can be described by the skill-rule-knowledge model (Rasmussen, 1983)*

Figure 20: A proposed framework (Version 1) for the investigation of weak signals related to safety and performance in healthcare.

5.3.5 Ethical Approval

Ethical approval for this case study was granted by the Loughborough University Ethics Approval (Human Participants) Sub-Committee. All participants voluntarily agreed to participate and signed an informed consent form before the start of their focus group. Only aggregated results with no specific references to individuals have been presented at conferences and been included in this thesis.

5.4 Results

5.4.1 The Context: Errors and the Work System

The focus group discussion guide was structured to explore the potential context of situations where safety may be a concern first, followed more specifically by the weak signals that indicate that the task was not going to be completed successfully and the learning opportunities for patient handling tasks. The errors were categorised using Reason's (2001)

taxonomy according to the type of deviation that occurred based on the SRK model (Rasmussen, 1983). Table 12 shows the types of errors identified in each focus group per error category.

Common errors identified as lapses included errors relating to subtasks being missed (e.g. bed rail not lowered, brakes not applied), subtasks being completed inaccurately (e.g. incorrect board position, inappropriate bed height) and incorrect or poor postures and movements (e.g. kneeling on the bed). These instances were all classified as lapses due to the possibility that they might occur as a result of memory failures (Reason, 2001). The rule-based mistakes identified included inappropriate equipment use, applying an inappropriate transfer technique, an incorrect patient assessment and performing an unnecessary transfer. An incorrect patient assessment represented a knowledge-based mistake and was also characterised as a rule-based mistake. This error was categorised as both because it could occur through the inappropriate application of a rule but also as a result of a lack of knowledge.

Table 12: The types of errors identified in the focus groups per categories as defined by Reason's (2001) taxonomy .

Category (Description)	**Types of Errors**
Lapses: Actions deviating from the planned execution (Reason, 1995) that are associated with memory failures (Reason, 2001).	<u>Both Focus Groups:</u> • Incorrect board position • Inappropriate bed height • Brakes not applied • Incorrect or poor postures and movements
	<u>Focus Group 2:</u> • Bed rail not lowered
Rule-based mistakes: Deviation occurs at the level of the selection of action as opposed to the level of the execution of the action due to problems with the application of the rules (Reason, 1995).	<u>Both Focus Groups:</u> • Missing or inappropriate equipment (e.g. slide sheet) • Inappropriate technique applied • Incorrect patient assessment
	<u>Focus Group 1:</u> • Transfer not needed
Knowledge-based mistakes: Error due to insufficient knowledge of how to perform a task due to the novel situation (Reason, 1995).	<u>Both Focus Groups:</u> • Incorrect patient assessment
Other:	<u>Both Focus Groups:</u> • Poor communication with the patient
	<u>Focus Group 1:</u> • Failure to take lead

Additional errors identified included poor communication with the patient and a failure to take the lead. In terms of communication problems, this potentiality was seen as not only an error but also an error-producing condition, as the following extract reveals:

> 'In my view, it's an error because if you don't talk to each other, you can cause an error, if you don't talk to the patient, the patient hasn't got a clue of what's going on, so they might not cooperate.' (Focus Group 1)

A failure to take the lead may result in either no direct action or rash action that is not appropriate or not communicated to the rest of the team. This is highlighted in the quote below:

> 'It might also be the failure for someone to take the lead... That's the big thing I see. *Four people standing around the bed, no one is doing anything, or someone dives in* and starts to move before anyone else is going to join in.' (Focus Group 1)

Both these error types can be considered as error-producing conditions that are strongly tied to teamwork.

The influencing factors identified were categorised according to the work system component of the SEIPS 2.0 model (Holden et al., 2013). Influencing factors associated with the person component included patient dynamics and staff-related factors, for example, staff stress. Patient dynamics referred to the current health and state of the patient as well as the level of their cooperation. Staff stress levels may result in staff increasing the speed, acceleration and force of their actions as they rush to complete the task. Furthermore, staff-related factors may influence the team dynamic and communication, as highlighted by the following excerpt.

> 'I think it is communication, people are not communicating bec*ause they are so ratty with each other, and they are not concentrating on what they are doing. They just* want to get the task done.' (Focus Group 1)

In connection with the person element, several aspects could be attributed to the process component of the SEIPS 2.0 model. The professional work processes component included staff members' interaction with each other and team dynamics. An example of Focus Group 1's revelations on how team dynamics could affect patient handling was the effect of teams that were suddenly and only brought together for the purpose of that task and as a result

might not be 'cohesive'. Meanwhile, the collaborative professional-patient work processes included staff interaction and communication with the patient.

Influencing factors associated with the tools and technology component included equipment and the surface and grips of equipment involved. Influencing factors associated with the task component encompassed sub-elements of the task, such as posture (e.g. arm and foot placement), completion of the prerequisite aspects of the task (e.g. patient assessment) and the complexity of the situation or technique to be applied. The influencing factor associated with the internal environment component included the available space where the transfer was to be completed.

Organisation of work components included time pressures and poor safety culture as well as policies and procedures. Time pressures were associated with patient handling tasks because they frequently function as secondary tasks (Hignett et al., 2004), as the following quote demonstrates:

> 'These things are all done because of this pressure. To do the thing. *To get them on the commode or transfer them because they have got to go for a CT scan or whatever* it is, so there is that thing sitting there, that driver.' (Focus Group 2)

Meanwhile, Focus Group 1 labelled policies as a negative factor, which the group felt could lead to a lack of situation awareness by potentially restricting the way staff worked. The following excerpt offers an illustration of this point. 'It stops one from thinking because the *policy or the teacher says you must do it that way come hell or high water, rather than* thinking' (Focus Group 1). However, the same group also mentioned later that policies needed to be influenced by the learning opportunities that the group had described.

5.4.2 Weak Signals

Part of the focus group discussion was based on the question, 'How do you know the task is going wrong?' Staff were asked to apply this query for general patient handling tasks and for two specific scenarios involving the errors of not applying the brakes and for the task of accomplishing a sit-to-stand mobilisation for a non-compliant patient where patient cooperation was needed. *Appendix B3* reports the weak signals identified per task. Ten types of weak signals were identified in the focus groups that might present during patient handling

work. From the weak signals, it was possible to infer where they might have originated. The signals identified and their sources were mapped to the framework (Version 1) developed in chapter three to facilitate the analysis of weak signals in healthcare. This has been depicted in Figure 21.

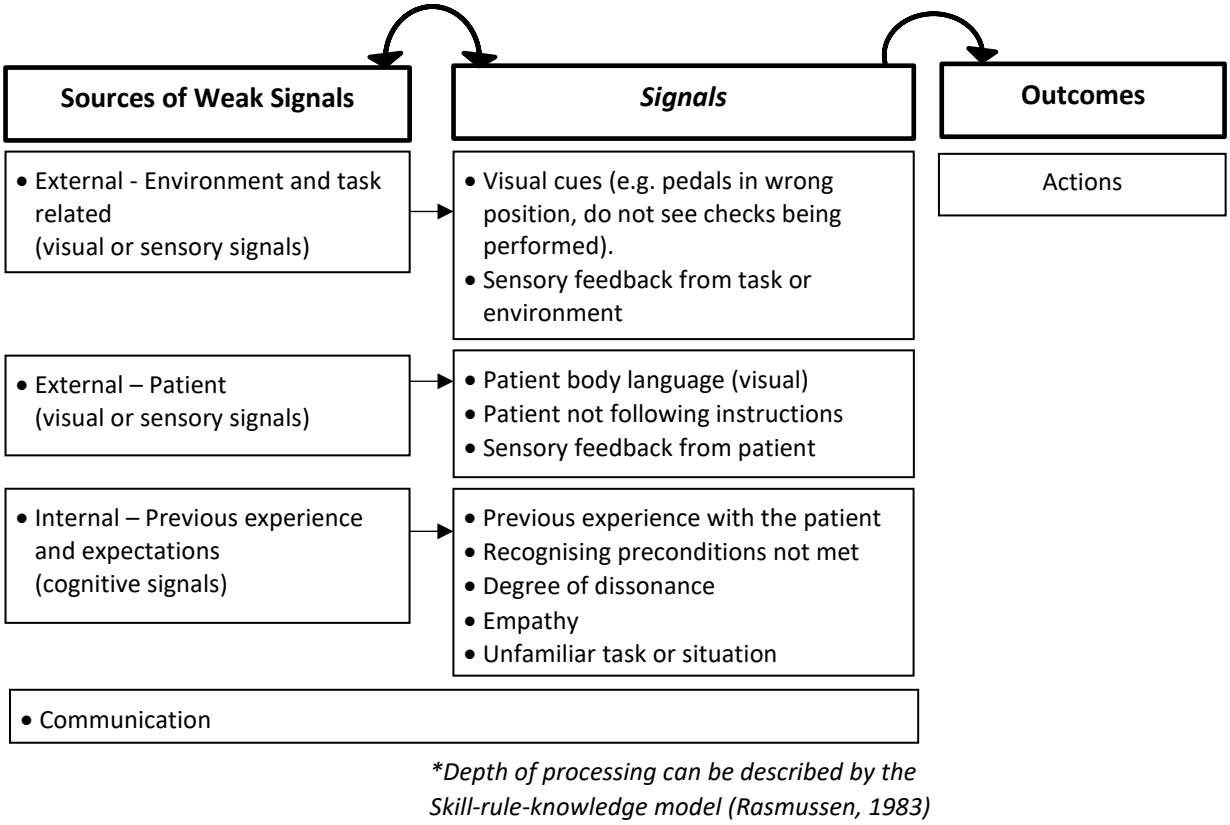


Figure 21: The results on weak signals for the patient handling case study overlaid on the weak signals in healthcare framework (Version 1).

The weak signals were classified as either originating externally (from the environment) or created internally by some form of processing by the individual. Weak signals that could be considered as originating from the environment included visual signals (e.g. seeing that the brakes on the bed were not activated prior to starting the transfer), feedback from the patient (e.g. their body language, posture and actions) or sensory feedback during the task (e.g. feeling that the brakes on the bed were not activated, application force required). Focus Group 1 felt that the visual signals were often a 'starting point'. An example of this identified by Focus Group 2 was the scenario that someone else on the team was adopting an unusual posture. Group members agreed that this signal would capture their attention, and one participant said their next step would be to 'let them carry on but let's see what happens

next'. In contrast, another participant proposed stopping the task and trying to get staff to question their own actions. Along the same lines, an example of a visual weak signal described in Focus Group 1 originating from the patient was that even though the patient said they could stand; the focus group participant described the following:

> 'But you could see… things that were clear were her torso, the way her torso was slumped in the chair… she didn't have good sitting balance in the first *place, so how* … if she can't sit properly, how could she stand?' (Focus Group 1)

This scenario is an example of a weak signal that provides contradicting information as the information the patient provided (their ability to stand) contradicted the visible signs regarding their lack of balance.

Internal weak signals that originated from previous experience and expectations included heightened awareness due to an unfamiliar aspect or element of the task or situation, previous experience with a specific patient, recognising that the preconditions of the task were not met, or a feeling involving a degree of dissonance and empathy. Both groups also identified communication as a weak signal. Focus Group 2 gave the example of 'communicating as well to say the brakes are on'. This example may constitute more of a transmission of a signal than a signal itself, with the exception if this communication is part of the routine behaviour, and its absence may indicate the subtask was not completed. Connected to communication was the signal labelled as empathy, which Focus Group 1 described as 'moving beyond communication'. This concept may be more of a process that allows for the identification and processing of signals as opposed to a signal. Empathy may provide the internal framework needed to interpret some signals, especially those originating from other people.

Although the mechanisms and processes that involve weak signals were not directly put as questions to the group, two examples of these emerged. In Focus Group 1, one participant started to discuss how 'one knows something is going wrong', as highlighted by the following quote:

> 'Do you have that intuitive feeling about the person for that moment, or do you *somehow unwittingly subconsciously refer to a similar incident somewhere that gives*

you that intuition? So, like something similar has happened before in your catalogue of experiences, and then you apply it to that scenario." (Focus Group 1)

The quote above demonstrates how processing of signals to reach an interpretation is largely subconscious. Moreover, the group felt that this process was frequently achieved as a result of experience with similar situations and that this ability developed over time. The second example came from a participant from Focus Group 2, who suggested that possibly as a result of being able to quickly project the potential consequences of the task and error, this capacity may allow them to identify weak signals. The following excerpt details the thought process attached to this concept:

'Do you think it is because we quickly think about con*sequence? Like we will quickly think about how likely that is to go wrong, and what the consequence would be. So,* you quickly weigh up...' (Focus Group 2)

Both quotes support the RPD model and the concept of mental frameworks described in chapter three for explaining the mechanism and processes associated with interpreting weak signals.

Furthermore, influencing factors involved in weak signal detection emerged without directly prompting staff on this topic. These included the familiarity of the action and situation, external pressures and drivers which might suppress signals, the stereotype associated with manual handling, the effect of habit, the ability to question the situation, especially regarding seniority or station, and the consequences of the situation. Both focus groups specified that unfamiliar aspects and actions would often trigger heightened awareness. This phenomenon is illustrated in the quote below, detailing how this reaction was initially triggered by a visual weak signal and prompted the search for additional signals.

'The situation is unfamiliar, like your awareness is then heightened. So, you like alright it's not just as smooth or so… [Question by moderator: Well, what made you think that?] … Well for me, it was when they put the pat sl*ide in under the bed that* looks like… Oh okay! Now I will pay more attention because this is unfamiliar.' (Focus Group 2)

The stereotype that manual handling should be hard work may apply specifically to the external signals associated with proprioception such as the application force required and the

sensory feedback that the patient provides (internal weak signals). As a result of this preconception, staff may rationalise not responding to these weak signals and may not consider the significance or implications. Staff also suggested that habits might be enough to prevent responding to weak signals, especially if they were to question the situation and it would require an unusual response. This phenomenon ties to how policies and procedures may have a negative effect on behaviour and prevent staff from doing something other than what the procedure dictates, even though it may not be the most appropriate action in that situation. The following excerpt from two participants in Focus Group 1 provides an illustration of this possibility:

> *Participant 1* – 'Sorry, it's just that if you solely rely on procedure, you switch off from…'
>
> *Participant 2* – 'Exactly. It's the ongoing systems that are affected by one person *perhaps not going against protocol or procedure but looking at an individual patient* …'

This discussion focused on how a patient might not require a lateral transfer from a bed to a trolley as they could safely mobilise themselves. Nevertheless, as it was the organisation's established procedure to hand over the patient between departments on a trolley, this task was done anyway. Staff further maintained that the system was so structured that this procedure was even more deeply ingrained, as the receiving department would not have a bed or trolley to receive the patient. This situation highlights that if an individual should respond to a signal, the action must fit into their current work system. Otherwise, an action that does not fit might deter them from responding to the weak signal. The following excerpt provides an illustration of this concept:

> 'So the ongoing system has been totally flawed because somebody has had the guts to stand up and say I am not going to do it… so it's got to be tied up with the other *systems involved with that, receiving the pat*ient.' (Focus Group 1)

Staff in the focus groups also identified mechanisms to prevent the task from going wrong, which would support the use of weak signals. These solutions included trained memory cues, for example, a rhyme to ensure all safety aspects of the task were completed, building individual checks into one's own behaviour (such as those developed through personal experience), being less task-oriented and more situation-aware, problem-solving, continuous

assessment of the situation and questioning actions. A participant in Focus Group 2 described how their training has changed to incorporate problem-solving, as the following quote shows:

> 'And we have tried to move away from the technique-based kind of "do this, do that, do that", it's more of an approach of trying to solve the problem… you might do it in slightly different ways' (Focus Group 2)

Focus Group 2 also identified continuous assessment of the patient during the manual handling task of a sit-to-stand transfer as providing information and proprioception weak signals. The following excerpt details this thought process:

> 'We are constantly assessing, so if you start to assess that they are not actually *coming with you, you have to do* more, they're doing less…You can only gauge that *by feeling i*t, you can't see that.' (Focus Group 2)

By being less task-oriented and more situation-aware, an individual may be more receptive to weak signals and more aware of how the task is progressing. Furthermore, questioning actions would hopefully reduce the negative effects of habituation, such as risks being normalised and explained away. Questioning one's own action, especially during the task, may assist in preventing error but also requires a degree of experience and possibly support from senior staff. The following quote supports this idea.

> 'I think… what we would say "this isn't working quite the way I would like" as opposed *to say the situa*tion where people just go with the flow and [wait] to see if what's being done is the incorrect thing… and that's really perhaps the question, is how we encourage people to question themselves.' (Focus Group 2)

The learning opportunities identified in the focus groups included the need for reflection, continuous assessment and empowerment. By incorporating reflection into the work environment, the rest of the team, co-workers or the individual themselves would benefit from the experience of learning to recognise weak signals more readily. Continuous assessment may provide the opportunity to identify weak signals originating from the patient or the environment. The need for empowerment would provide the opportunity for staff to question actions and potentially change the course of action based on the received weak signal.

5.5 Discussion

This first case study identified errors and influencing work system factors, the weak signals that indicate that something may be going wrong and opportunities to improve performance and safety from the perspective of experts in the patient handling field. The initial discussion in the focus groups centred around the types of things that go wrong, as these usually stand out to staff and are easy to recall. The errors identified were then categorised according to Reason's (2001) taxonomy, as this related to the SRK model (Rasmussen, 1983) which was identified as one of the models for understanding behaviour associated with weak signals. Identifying errors and influencing system factors provided the context to discuss and understand the examples of weak signals that arose in the focus group discussions. This section will include a discussion of weak signals in the context of errors and system factors, the attributes and behaviours of weak signals, as outlined in *Section 3.2.2.1* (p. 73) and *Section 3.2.2.2* (p.74) of Chapter 3, and how these results can be used to expand the framework.

Based on the results, some of the weak signals identified could be connected to the errors recognised and the influencing system factors described. This highlights the relevance of theories associated with error and taking the wider system into account when considering weak signals. The weak signals associated with the types of errors relating to subtasks being missed (lapses) included visual signals (e.g. seeing the brakes were not applied) and sensory signals (e.g. feeling the brake has not been applied). Since lapses occur as a result of memory failure (Reason, 2001), it may be more likely that other team members will point out these lapses in a group setting. For signals that can be identified through a team setting, the role of communication, the ability to speak up and teamwork in influencing the identification, processing and transmission of the signals and action based on these signals is evident. The error of inappropriate posture, also a lapse, may be connected to the weak signal that takes the form of proprioception, although only sufficient experience and training might lead to awareness of this type of weak signal.

Several influencing system factors were also identified as weak signals, including the patient's state and their cooperation. These aspects connect to the error associated with poor communication with the patient. However, some weak signals require the incorporation of

several pieces of information before deciding what the weak signal truly indicates and whether it is potentially false. This is shown in the example in the results where the patient provided contradicting information (their ability to stand) in comparison to the visible weak signals (their lack of balance). These two weak signals indicated both problematic elements while at the same time indicating all might go well, and therefore can be considered a mixed signal, as described by Vaughan (1996). This example underscores some of the elements in the definitions of weak signals provided in chapter three, specifically that the information is usually informal, ambiguous (Vaughan, 1996) and requires processing (Turner, 1978).

The examples of weak signals identified in the focus group discussions could be linked to the attributes and types found in the literature, described in Chapter 3. The weak signals were classified as either originating externally or created internally. This distinction aligns with the endo- and exosigns described by Tarasti (2001), referring to signs present in the outside world (exosigns) and signs created in the mind (endosigns). Although some of the examples of external weak signals relied more than others on information processing in order to be recognised, these signals required more general knowledge than internal signals. In contrast, the internal signals required a higher degree of processing reliant on experience as well as more individual knowledge. For example, the visual weak signals identified (e.g. pedals in wrong position, do not see checks being performed), by existing outside the individual in the environment, could be categorised as external weak signals and represent objective or explicit information, implying they may be considered stronger than other weak signals (Koivisto et al., 2016). Regarding the weak signal of sensory feedback from the task, though this signal is generated externally, the individual will need to compare the sensory feedback with the general knowledge of the force or movements usually required to complete the task to ascertain that this feedback is unusual. Accordingly, this signal contains a subjective element, is dependent on the context and makes it likely that this type of weak signal may be stronger to some individuals and weaker to others (Hiltunen, 2008, 2010). The internal weak signals identified were more dependent on specific experience than external signals are, for example, previous experience with this specific patient that would establish the context for the presenting signals. These types of weak signals can be categorised as weaker than others due to their dependency on context (Hiltunen, 2008), illustrating how a healthcare provider might not detect such signals if they lack specific knowledge of this context because the signals are

not based on general knowledge or experience. Weak signals may play a role in supporting behaviour controls, which includes the training of staff in protection principles (Nelson & Baptiste, 2006).

5.5.1 Weak Signal Behaviours

Although the behaviours associated with signals – detection, identification, processing, interpretation and action selection – were not discussed directly in the focus groups, elements associated with these processes emerged as a result of the discussion. One focus group member questioned whether weak signals were related to intuition and resulting from a 'catalogue of experiences' that are then applied to the scenario. In this example, the individual was describing intuition and heuristics as portrayed in the literature review in Chapter 3. However, the fact that the concept was posed in the form of a question highlights how the mechanisms behind weak signals are predominantly invisible to the user. This phenomenon may be the reason behind the difficulty in explaining decisions made using weak signals (Benner & Tanner, 1987).

The SRK model (Rasmussen, 1983) also provides a means for understanding the processing, interpretation and action selection processes for weak signals. The earlier quote from Focus Group 1 that described 'you somehow unwittingly subconsciously refer to a similar incident' and use a 'catalogue of experiences' indicates the first component of the RPD model (Klein, 1993) and rule-based behaviour as described by the SRK model (Rasmussen, 1983). Specifically, rule-based behaviour emerges in reference to a recognition phase, whereby there is an association with a task and stored rules for that task. Such behaviour may describe the processes for weak signals in more familiar contexts where rules for those tasks have been generated and the degree of processing and complexity in what the weak signal ultimately indicates may be limited. In the results describing the mechanisms for preventing tasks from going wrong, staff mentioned trained memory cues (e.g. a rhyme to ensure all safety aspects of the task were completed), which may be considered a rule in accordance with the SRK model. Weak signals contain different types of information in different formats and have different attributes, a phenomenon that lends itself to requiring different types of processing; therefore, different models may provide more suitable explanations of the underlying

processes. The knowledge-based behaviour level of the SRK model and other more complex models concerning decision-making may be more applicable to other types of signals.

Several influencing factors on the processes associated with the weak signals that the focus groups identified were also described in the literature (Table 9, p.76). These aspects included external pressures and drivers that may suppress signals (Hensgen et al., 2003). Factors such as staff's ability to question the situation, their seniority or station (Carrillo & Samuels, 2015) and the consequences of the situation (Klein, 2003), may influence staff's ability to respond to weak signals.

5.5.2 The Weak Signals in Healthcare Framework (Version 2)

This first case study compiled weak signals from focus group data and identified the weak signals indicating problems associated with manual handling tasks, that may result in a risk to patient safety and staff safety, from a biomechanical perspective. Moreover, the results revealed elements that the first version of the framework did not incorporate. These elements included if the signal originated externally or internally, the manifestation (form) of the signal (e.g. visual, sensory or cognitive) and the behaviours associated with signals, explicitly the detection, identification and processing of signals. The framework was redrafted to include these elements, leading to Version 2, which is depicted in Figure 22.

This subsequent version of the framework still contained all the elements from the first version but was expanded to capture greater detail of the presenting signals and provide an understanding of how signals may be detected, interpreted and processed. The signal component was expanded to include the forms of signals described in the framework as being either internal or external. Although an external signal may also generate an internal signal, the external signal that causes the experience of an internal signal may not always be present or known. External signals include visual, haptic, verbal, auditory or olfactory signals. In comparison, internal signals include the undefined experience of a 'hunch', 'vibe' or a general sense of 'something going wrong'.

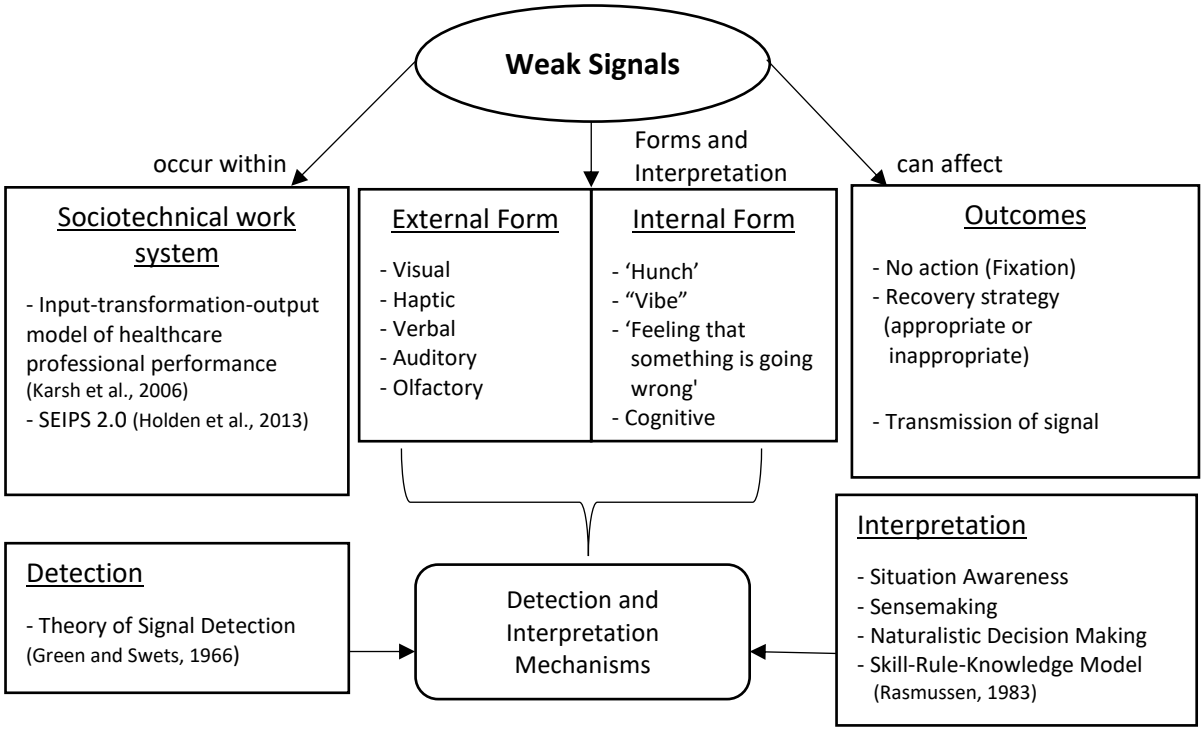


Figure 22: A framework for the investigation of weak signals in relation to safety behaviour and performance within the healthcare context – the weak signals in healthcare framework (Version 2).

This case study highlighted how several different theories may be relevant for the processing of weak signals. In the first version of the framework only the skill-rule-knowledge model (Rasmussen, 1983) was proposed. The footnote on the processing depth in the first version was removed in this second version to allow for the exploration of numerous theories to describe how signals may be processed and a separate element for the behaviour component of weak signals was added to the framework. The behaviour component describes the processes underlying the detection, interpretation and processing mechanisms, encompassing several theories, including the signal detection theory (Green & Swets, 1966), the concepts of situation awareness (Endsley, 1995), sensemaking (Weick, 1995), naturalistic decision making (Zsambok & Klein, 1997) in addition to the skill-rule-knowledge model of behaviour (Rasmussen, 1983). Additionally, the outcomes element was expanded to include several potential outcomes that the receiver of the weak signal may initiate, including no action, implementing a recovery strategy or transmitting the signal. Signals can affect outcomes in that, possibly as a result of fixation (De Keyser & Woods, 1990), no action may

be taken. Alternatively, a recovery strategy may be implemented, which may result in either an appropriate or inappropriate outcome.

5.5.3 Limitations

The limitations of this first study include a lack of data variety and a limited sample size. Moreover, the case study employed only qualitative data from focus groups. Although this approach provided a rich source of data, it would be beneficial to identify weak signals from other data sources. The sample size in this study was limited to two focus groups; nevertheless, these groups yielded rich data on weak signals that could be tied to the literature.

5.6 Conclusion

This chapter explored the context from which weak signals emerge and tested the first version of the weak signals in healthcare framework on a case study on patient handling. The first version of the framework focussed on identifying the sources of weak signals and examples of weak signals that present for the tasks associated with patient handling. The weak signals described indicated problems associated with manual handling tasks, that may result in a risk to patient safety and staff safety, from a biomechanical perspective. This case study identified different types of weak signals, potential underlying processes associated with the processing and interpretation of weak signals as well as the influencing factors that may affect weak signal detection and response generation.

The results highlighted that weak signals could have an internal form or an external form, with the former requiring a greater degree of processing and specific knowledge. The types identified, as described in the literature (e.g. Tarasti, 2001; Vaughan, 1996), included mixed signals, endo- and exosigns. The 'action' element of the framework was expanded to include a more detailed description of potential actions including the transmission of the signal. The signal detection and interpretation aspects described in the results were related to the concepts of empathy, the RPD model, mental frameworks, and situation awareness. The influencing factors affecting weak signals identified in the results included familiarity, external

pressures, habits, the ability to question a situation, the consequence of situation, and ability to respond within the system. The weak signals were also explored in connection with error categories described by Reason (2001). The framework was expanded to differentiate between the different forms of weak signals and the potential outcomes in greater detail than the first version of the framework. Furthermore, a secondary level, associated with the detection and the interpretation mechanisms associated with weak signals was added. Potential paradigms that may describe these behavioural elements were listed in the second version of the framework.

Based on the limitations of this first study, several recommendations for the next case study could be identified. Namely by increasing the sample size, this might facilitate identifying more signals. Furthermore, for the next case study, the aim should be to include multiple data sources to obtain greater support and increased reliability for the results on weak signals through data triangulation. Additionally, the analysis approach should be refined and made more specific to broaden the practical implications of these results and promote the development of a robust method for the analysis of weak signals.

Chapter 6: Case Study 2 – The Discharge Process: From Hospital to Community-Based Care

This chapter explores the work system and weak signals for a different healthcare aspect, namely, the hospital discharge process for patients who still require additional healthcare input from community healthcare staff. First, a brief description of the context for this case study based on literature is provided, followed by the aims, method and results. The findings of the study are subsequently discussed regarding the literature available on this healthcare process and the implications of the findings relative to the weak signals framework, which was evaluated and modified to create a third version.

6.1 The Context – Care Transitions and the Discharge Process

Patient care will often require input and collaboration from various healthcare providers and specialties (Bodenheimer, 2008; Carayon & Friesdorf, 2006; Wears, Perry, & Patterson, 2012). As a result, healthcare staff must communicate effectively (Braithwaite et al., 2013), provide care coordination, handoff to other staff and often participate in care transitions (Patterson, Roth, Woods, Chow, & Gomes, 2004). Care transitions occur in numerous healthcare settings (Hoonakker et al., 2019; Richter, McAlearney, & Pennell, 2016), for example between units, shifts and when discharging the patient from the hospital setting to a care home or their own home (WHO Collaborating Centre for Patient Safety Solutions, 2007). For the discharge process, which is a particularly complex healthcare process (Wong et al., 2011), collaboration and the coordination of different work systems (Werner, Gurses, Leff, & Arbaje, 2016) is required to ensure that continuity of care occurs (McDonald et al., 2007; O'Daniel & Rosenstein, 2008).

The discharge process requires a transition of care from one group of healthcare staff to another, and this creates distinctive challenges with regards to coordination due to the variety of organisations and healthcare providers that may need to be involved to provide the necessary care (Bisantz et al., 2012). Care coordination refers to the specific organisation of activities between two or more healthcare providers, possibly also the patient, to facilitate

the appropriate delivery of care and to ensure adequate continuity of care (McDonald et al., 2007). This coordination includes all the behaviours, information systems and decisions required to bring healthcare services together (Bisantz et al., 2012; Werner et al., 2016). Furthermore, continuity of care requires continuity of information (British Medical Association, 2004; Deeny, Gardner, Al-Zaidy, Barker, & Steventon, 2017). This requires staff to access, process, document and communicate patient-related information (Carayon, Schoofs Hundt, & Hoonakker, 2019). Additionally, continuity of information is an integral aspect for ensuring patient safety (Patterson et al., 2004), especially as trends show that more individuals are being involved in the care process (British Medical Association, 2004). The discharge process is not just a single event whereby the patient transitions from one place to another but rather a process that spans a range of time due to the prerequisites that must occur for this transition and the requirements following discharge (Werner, Tong, Borkenhagen, & Holden, 2019).

Due to the nature of the discharge process, numerous structural risks are present, which can result in failures at the 'sharp end' of the system (Greenwald, Denham, & Jack, 2007). Healthcare providers often encounter numerous challenges and barriers in coordinating care for a patient's discharge (Bisantz et al., 2012; Bodenheimer, 2008), and the quality of care often breaks down across these transitions (Arbaje et al., 2014; Hilligoss & Vogus, 2015). This may be a result of the fragmentation of the system (MacAdam, 2008), which occurs due to organisational separation, medical specialisation (McNeil, Strasser, Lightfoot, & Pong, 2016) and because work in healthcare often occur in silos (Carayon, Wooldridge, Hose, Salwei, & Benneyan, 2018). As a result of these silos, several barriers arise, namely, a breakdown in communication and coordination problems across boundaries (Anthony & Hudson-Barr, 1998; Carayon et al., 2018; Wong et al., 2011; World Health Organization, 2007) and scheduling difficulties (Carayon et al., 2018). Additional barriers to the discharge process identified in the literature included poor multidisciplinary teamworking (Katikireddi & Cloud, 2008), lack of availability of supporting services (Anthony & Hudson-Barr, 1998; Wong et al., 2011), a lack of involvement with the patient and their family (Anthony & Hudson-Barr, 1998) and delayed and poor information transfer (Nagpal et al., 2010). The identified barriers that predominantly affect the discharge process in the hospital environment were associated with discharge planning, not addressing the needs of the patient, transport problems, timing issues

(Wong et al., 2011), a lack of role clarity and role awareness (McNeil et al., 2016) and a lack of patient readiness (Anthony & Hudson-Barr, 1998).

As a result of these barriers, numerous problems may arise, including the breakdown in the quality of care and an increased risk to patient safety (Arbaje et al., 2014; Hilligoss & Vogus, 2015; WHO Collaborating Centre for Patient Safety Solutions, 2007). Additional problems associated with a breakdown in the discharge process include medication-related events due to information transfer problems (WHO Collaborating Centre for Patient Safety Solutions, 2007), delayed transfers of care (Bate, 2015), readmissions, reduced quality of care and injury or harm to patients (Forster, Murff, Peterson, Gandhi, & Bates, 2003; WHO Collaborating Centre for Patient Safety Solutions, 2007). Delayed transfers of care accrue substantial costs for healthcare organisations due to the cost of the occupied bed as well as the loss of income due to insufficient beds being available for admissions and elective procedures (Bate, 2015). Keeping patients in longer than necessary also poses numerous risks to the patient, which include a decrease in patient morale, a reduction in mobility, an increased risk of hospital-acquired infections (Bate, 2015) and an increased likelihood of the patient experiencing an adverse event (Andrews et al., 1997).

Facilitators of the discharge process identified in the literature included accurate and complete information transfer; checking the accuracy of information (Bisantz et al., 2012); conducting the discharge process in a timely manner; good communication with the patient, their family and all healthcare staff involved (Anthony & Hudson-Barr, 1998); effective discharge planning (Katikireddi & Cloud, 2008) and adopting a multidisciplinary approach (Wong et al., 2011). Studies aimed at investigating means to improve the discharge process have focused on care transitions for specific diseases (Werner et al., 2016); have been predominantly aimed at one subsystem in the discharge process, for example pre-discharge elements that exist in the hospital system, or they have focused on improving one element of the process. Interventions targeting the hospital subsystem include assessing the effect of hospital-based discharge planning (Gonçalves-Bradley, Lannin, Clemson, Cameron, & Shepperd, 2016; Phillips et al., 2004; Wong et al., 2011), the introduction of a complex discharge team (University Hospitals Birmingham NHS Foundation Trust, 2015) and improving communication of medication lists (Boockvar, Carlson LaCorte, Giambanco, Fridman, & Siu,

2006; Crotty, Rowett, Spurling, Giles, & Phillips, 2004). An example of interventions targeting one element of care transitions, also within the discharge process, include those aimed at improving communication and information transfer (e.g. East Lancashire Hospitals NHS Trust, 2015; Madden et al., 1998; Terrell et al., 2005). These interventions are predominantly focused on modifying roles or tasks (Werner et al., 2016) and do not consider the wider systems' context.

As the knowledge of how to optimise discharge care transitions is still incomplete and minimal (Arbaje et al., 2014), a recommended approach to investigate the discharge process would be to better understand the challenges and coping strategies healthcare staff employ in care transitions that cross organisations (Hilligoss & Vogus, 2015) so that it could inform the redesign process (Carayon et al., 2019). As demonstrated above, many studies only target or explore one subsystem in this process; as a result, there appears to be a gap in the literature with regards to compiling the different perspectives of the subsystems involved in the discharge process, how these subsystems are connected and the implications of the connections between the subsystems for barriers and facilitators.

The focus of this case study was on the care transition of patients from Healthcare of the Older Person (HCOP) wards in one hospital to their home or a care home where they would receive follow-up care from community healthcare staff. Care transitions are vulnerable points in the care continuum, especially for frail and older patients (Arbaje et al., 2014). The transitions for this patient group often account for a high percentage of all transitions that take place (Coleman, 2003) and usually involve the transition from one healthcare setting to another, namely, from hospital to a care home or, alternatively, to care received in the patient's home (Coleman, 2003). This group is also more prone to hospital readmissions compared to other patient groups (Coleman & Berenson, 2004). This may be because this patient group is often more vulnerable due to a high number of comorbidities (Werner et al., 2019); some of them may have cognitive impairments, making participation in the process difficult (Coleman, 2003); and they may have complex therapeutic needs (Anderson & Horvath, 2004).

6.2 Aims and Objectives

Three key aims underpinned this case study. The first aim was to explore the context from which weak signals may emerge and the connection of the context to the weak signal. The second aim was to apply the second version of the weak signals in healthcare framework to identify weak signals and their relevant elements for work associated with the discharge process from hospital to community-based care for patients from HCOP wards in one hospital. The third aim was to further develop the weak signals in healthcare framework to incorporate additional key elements that emerged from the results and develop support for the application of the framework.

To achieve the first aim, namely, to explore the context from which weak signals may emerge, this case study will address the following objectives:

- Explore the system factors associated with the discharge process through the generation of work system configurations. As this process spanned several healthcare subsystems, a key aspect was to understand the different perspective of these two subsystems on the same process.
- Identify influencing system factors associated with this healthcare process and how they may affect weak signals.
- Identify the facilitators and barriers associated with the discharge process from the perspectives of these two subsystems and explore how weak signals may be connected to them.

To achieve the second aim, namely, to apply the weak signals in healthcare framework the weak signals in healthcare framework (Version 2) to identify weak signals and their relevant elements for work associated with the discharge process, this case study will address the following objectives:

- Determine the weak signals, their sources and key elements of weak signals from the examples associated with the discharge process that arose in this case study relative to the framework.
- Explore the behaviours associated with weak signals by discussing with staff how they come in contact and interact with weak signals.

- Explore with staff the practical implications and factors that may affect weak signal use in everyday work, including the barriers associated with weak signals, and means of implementing weak signals. (Addressed in the verification and validation component)
- Verify and validate the weak signals identified in this case study and the key components of the framework. (Addressed in verification and validation component)

To achieve the third aim, namely, to expand the weak signals in healthcare framework (Version 2) to incorporate additional key elements that emerged from the results and develop support for the application of it, this case study will address the following objectives:

- Expand the framework to include newly identified elements from the results of this case study.
- Develop an analysis approach to support the use of the weak signals in healthcare framework.
- Identify the most practical theories that describe the underlying behaviours associated with weak signals, specifically for the detection, identification and interpretation of weak signals.

6.3 Method

6.3.1 Research Design

Due to the multiple system elements required for the discharge process, human factors and the systems approach provide highly suitable methods for the analysis and understanding of this process (British Medical Association, 2004; Carayon et al., 2011). Furthermore, by utilising a systems approach, human factors allows for the capture and analysis of the multilevel and spatiotemporal aspects of care processes (Carayon et al., 2018) as well as both the structure and process elements (Carayon, 2006; Karsh et al., 2014).

As the discharge process requires input from different healthcare subsystems (McDonald et al., 2007; O'Daniel & Rosenstein, 2008), different points in the process and the perspectives of different healthcare staff involved in the discharge process were considered in this case study, which adopted a mixed method design. As this case study focused on care transitions between Nottingham University Hospital (Trust A) and community staff from

Nottinghamshire Healthcare NHS Foundation Trust Health Partnerships Division (Trust C), data from both organisations was collected. The phases of analysis and the respective data sources are depicted relative to a simplified version of the patient pathway for the discharge process in Figure 23.

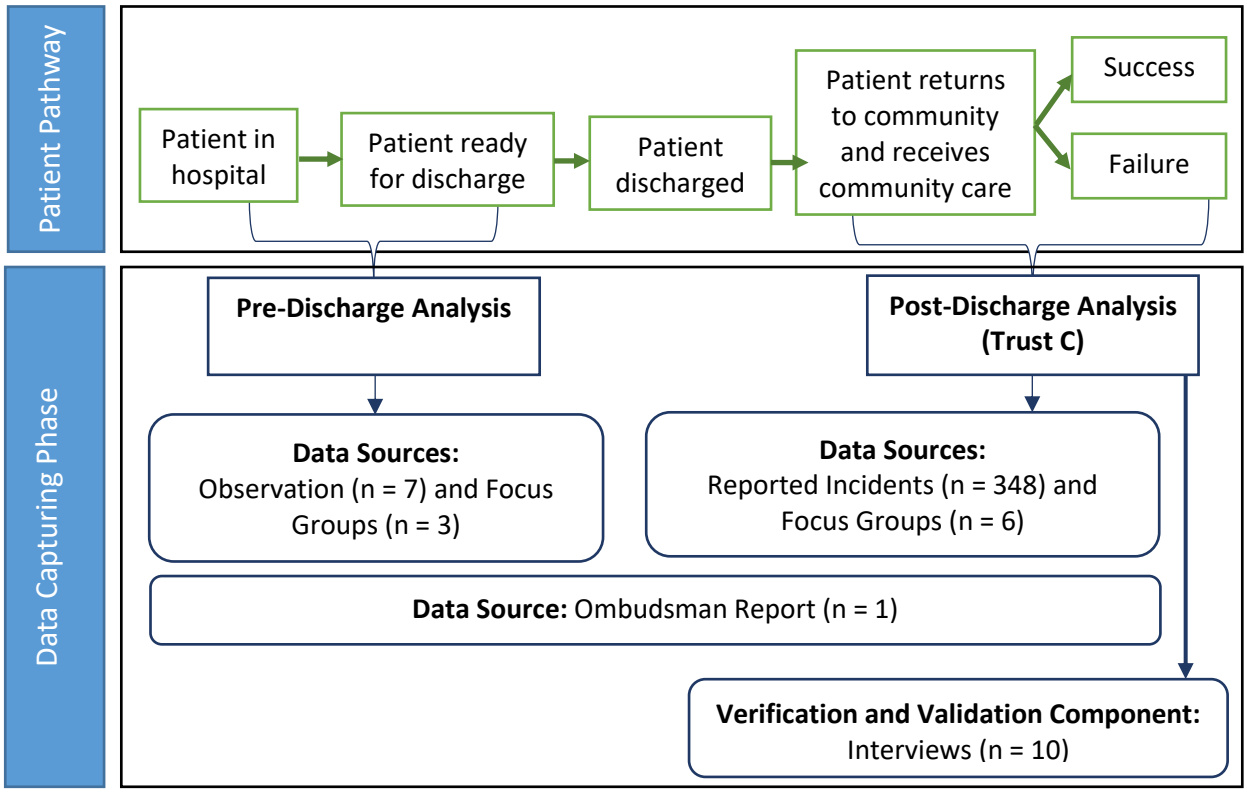


Figure 23: Simplified description of the patient pathway for the hospital discharge process and the different analysis phases, the data sources utilized and the sample sizes.

The pre-discharge analysis focused on analysing data collected from the hospital healthcare setting and included observation sessions and focus groups. The post-discharge analysis included an analysis of data collected from the community healthcare setting and consisted of an analysis of incident reports and focus groups with community staff from the three directorates that were included in the incident reports analysis (Trust C). Additionally, one Ombudsman report, titled '*A report of investigations into unsafe discharge from hospital*' published in May 2016 (Parliamentary and Health Service Ombudsman, 2016), was also analysed qualitatively. The verification and validation component of this case study was conducted with healthcare staff that participated in the post-discharge phase of this study, approximately a year and half after the focus groups. Interviews were conducted with 10 staff

that participated in the focus groups held with community healthcare staff involved in the discharge process, during which the identified weak signals were verified, and detailed examples of the behavioural elements were explored. Additionally, the barriers associated with weak signals and means of implementing weak signals were investigated during these interviews.

This case study captured both qualitative and quantitative data and adopted a convergent mixed method parallel design, depicted in Figure 24. In this design, the qualitative and quantitative date were collected simultaneously, analysed separately and then combined during the interpretation stage. The verification and validation component of this case study captured qualitative data used to verify the interpretation of the results and application of the framework. Mixed methods were selected for this research design as they allow for the development of a more thorough understanding of the research problem (Creswell, 2014), and the combination of methods provide the opportunity to highlight unique findings that may be missed by single methods (Jick, 1979). The combined interpretation of the results was included in this chapter.

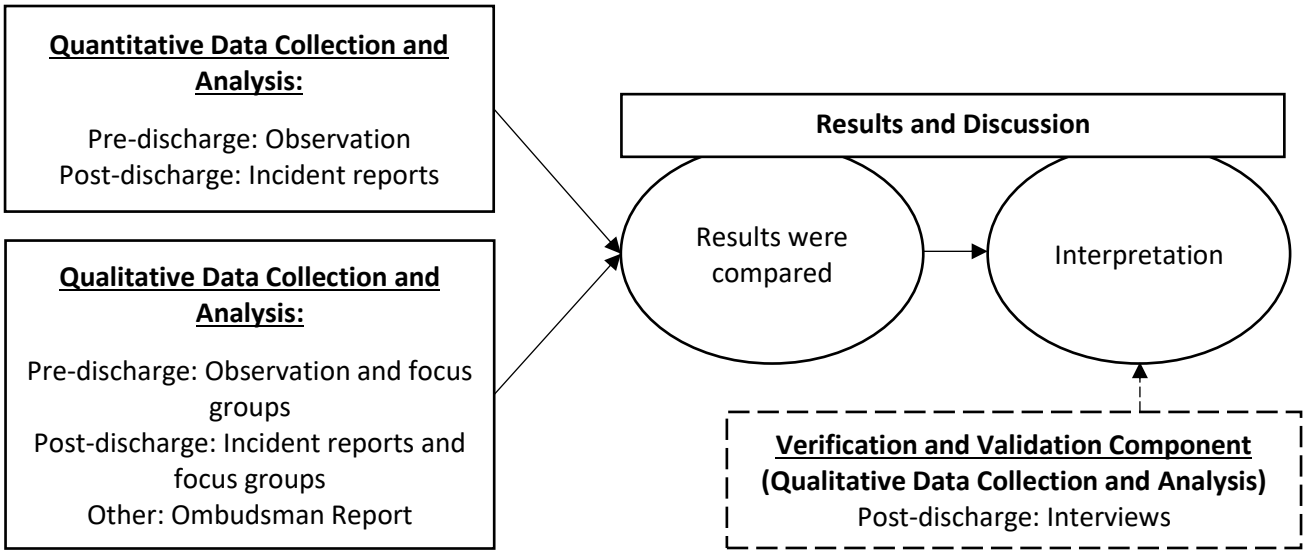


Figure 24: The convergent parallel mixed methods approach taken from Creswell (2014, p. 220) adopted for this research design.

Although both types of data were collected, the qualitative data was the predominant type of data collected as it provided 'rich' data to assist in the analysis of the staff's experience of

weak signals associated with care transitions relating to the discharge process in the settings in which they occur. Qualitative data in the form of focus groups, observations, incident reports, interviews and an Ombudsman report was analysed. Quantitative data was obtained through quantifying the qualitative data from the observations in order to provide an overview of the qualitative material (Malterud, 2001) and assist in better understanding the context.

6.3.2 Sample and Participants

For the pre-discharge analysis, observation sessions and focus groups were conducted. For the observation phase, two high-level meetings were observed in January 2016, and five weekly Target Action Group (TAG) meetings conducted between August 2016 and September 2016 were observed. A total of 28 participants took part in the observation phase (conducted between August 2016 and September 2016) and focus groups. In the observation of the five weekly TAG meetings, 14 hospital staff members provided participant information. The participants included discharge coordinators, ward managers and nursing staff. The participants' mean number of years involved in patient care and who attended the meetings was 17.03 years (±11.88 years), and the mean number of years in the current position was 7.78 years (±7.59). Three focus groups were conducted with hospital staff from the HCOP wards at Trust A, and the sample size of the focus groups consisted of three, five and six participants. The participants included discharge coordinators, deputy ward managers, occupational therapists, physiotherapists, nursing staff and a hospital consultant. The mean total number of years involved in patient care was 12.39 years (±9.17 years), and the mean number of years in the current position was 4.45 years (±5.69).

For the post-discharge analysis, a total of 39 participants took part in the focus groups, and 348 reported incidents were analysed. For the six focus groups conducted with community healthcare staff (Trust C), seven participants took part in each of the five of the focus groups, and the sixth focus group had four participants. The mean total number of years involved in patient care of the participants of the community focus groups was 16.61 years (±11.16 years), and the mean number of years in the current position was 3.57 years (±3.60). The participants included community and district nurses, locality managers, community physiotherapists, occupational therapists, assistant practitioners and a team leader of a care

home. The 348 reported incidents were all associated with the discharge process for adult patients requiring healthcare input from community healthcare staff either in their own home or care homes. The reported incidents were from the three directorates from Trust C who were involved in the focus groups. Of the 348 incidents, 190 originated in the financial year April 2014 to March 2015 and 158 from the financial year 2015 to 2016.

The verification and validation component of this case study consisted of interviews with 10 staff that participated in the focus groups held with community healthcare staff involved in the discharge process. An invitation to participate in these interviews was sent to the 39 participants from the focus groups held with community staff. The mean total number of years involved in patient care across the 10 participants was 22.70 years (±9.71) and the mean number of years in the current position was 6.02 years (±5.72). The current positions held by the participants interviewed included community staff nurses, clinical and nurse team leaders, community physiotherapists, a community matron, and a team leader of a care home team.

The participants for both hospital and community focus groups were invited through purposive sampling, meaning that only the staff involved in the discharge process were invited to participate in the focus groups. The focus groups were drawn from pre-existing work groups, but they were not necessarily groups that regularly met in this format, so the focus groups can be considered as partially constructed. This had the advantage that the pre-established group norms and leadership patterns were minimised (Liamputtong, 2012) while still potentially maintaining the social contexts within which decisions are made (Kitzinger, 1994). Furthermore, by conducting focus groups with staff that worked together, the effect of group conformity would hopefully be reduced (Kitzinger, 1994). Although some focus groups contained participants who had less than three years' experience with patient care, this did not restrict the discussion or hinder the flow within these groups. Purposive sampling was also applied for the validation component of this case study. Additional information pertaining to the sample characteristics of the data sources for the first component of this case study has been included in *Appendix C1*.

6.3.3 Protocol

All data capturing was conducted between 2016 and 2018. The focus groups with community healthcare staff were conducted between May and July 2016, and the focus groups with hospital staff were conducted between October and November 2016. The observation component of this study was conducted in January 2016 and between August and September 2016. All reported incidents associated with the discharge process for adult patients requiring healthcare input from community healthcare staff between April 2014 to March 2016 for the three directorates from Trust C were extracted in September 2016 from the organisation's incident-reporting database. For the verification and validation component of this case study, interviews with community healthcare staff were conducted between November 2017 and January 2018.

6.3.3.1 Observation of Discharge-Related Hospital Meetings

Two high-level meetings aimed at rapidly reducing delayed transfers of the care of patients currently requiring discharge were attended in January 2016. The meetings aimed to understand the system regarding the transfer of care associated with patient discharge and accurately capture the patients waiting in hospital beds beyond the date that they were medically safe for transfer. These meetings were chaired by the community lead and attended by senior staff from the system partners, which included social services, City Care, Community Health partnerships, matrons and ward managers (key managerial staff from both Trust A and Trust C). At the meetings, the discharge plans for patients on the HCOP wards were presented, and it was discussed how these could be escalated. During the meetings, the data recorded was in the form of field notes. Based on the 161 patient cases discussed at the first meeting, a general model of the discharge process and the influencing factors was generated. The model was generated by grouping the examples of the influencing factors and the reasons for delays in the process to form broader categories. Observation of a second meeting, where 204 patient cases were presented from the same wards that attended the first meeting, confirmed the model.

This model, included in the results in this chapter, was used to determine the frequency counts of the influencing factors and the reasons for the delays mentioned during the five weekly TAG meetings observed between August 2016 and September 2016. These meetings

were weekly meetings that occurred at the hospital to discuss the upcoming discharge plans for patients from HCOP wards among ward staff and ward managers from Trust A. Between five and seven wards took part in these weekly meetings, and over the five meetings observed, the discharge plans for 777 patients were discussed (mean = 155 patients discussed per meeting, SD = ± 27). As the data was collected through unobtrusive observation, the analysis was limited to the verbal content of the meeting. Informed consent was obtained from all staff present in the TAG meetings, but the collection of participant information was voluntary, and of the 26 staff members who attended the five TAG meetings, participant information was supplied by 14 of them. Additional information on the development of the quantitative method approach and the data capturing documents for this component of the case study have been included in *Appendix C2* and *Appendix C3*.

6.2.3.2 Document Analysis

The sample included in the document analysis consisted of one Ombudsman report and 348 reported incidents from Trust C. Both document sources reported information on patient cases whereby problems associated with the discharge process were experienced. None of the documents referred to patients or staff by name. The Ombudsman report, '*A report of* investigations into unsafe discharge from hospital', was published in May 2016 (Parliamentary and Health Service Ombudsman, 2016). This report focused on nine cases from recent complaints that were investigated by the Parliamentary and Health Service Ombudsman, which the report authors felt best illustrate the current problems associated with unsafe discharges from hospital.

The 348 reported incidents were all associated with the discharge process for adult patients requiring healthcare input from community healthcare staff, and were filed by community-based healthcare staff (e.g. nursing staff and rehabilitation staff). As 'one of the most widely implemented improvement strategies' (Macrae & Stewart, 2019, p. 2) in healthcare, analysing adverse incidents has been seen as a key mechanism to improving patient safety (Macrae & Stewart, 2019; Magrabi, Ong, Runciman, & Coiera, 2010). As a result, this data source was selected to be used in this case study. These incident reports were extracted from the Ulysses Incident Database, and the fields for free narrative text were analysed qualitatively. These included the following fields: 'details of the incident', 'additional details' and 'outcome

description'. A key consideration for analysing incident reports is that these reports predominantly detail errors of commission, and they are less likely to report other error types (Parry, Cline, & Goldmann, 2012).

6.2.3.3 Focus Groups

Exploratory focus groups were held with hospital healthcare staff from the HCOP wards involved in the observations and with community healthcare staff from the three directorates from where the incident reports were extracted. All staff that participated in the focus groups had work that regularly intersected with the discharge process. The focus groups were held in available meeting rooms within the hospital for hospital healthcare staff and at community healthcare centres for community healthcare staff. The focus groups aimed to better understand the system regarding the hospital discharge process and identify the influencing factors and other constraints on this care-transition process from hospital and community staff's perspectives. This method was selected as focus groups tend to provide an environment where the participants can share opinions, thoughts and perceptions in a neutral and non-threatening environment (Krueger & Casey, 2000).

The focus groups were composed of two consecutive components, with each component being approximately 45 minutes in duration with a 20-minute break between the two sessions. Prior to the start of the focus group, the project was described to the participants, and the project information sheet, the informed consent sheet and a demographic information sheet were distributed to them which they returned before the start of the first component in the focus group. These documents have been included in *Appendix C4*.

The emphasis of the first component in the focus group was on the elements of the discharge process that work well and improve patient safety, both of which can be described as proactive safety. These questions were derived from those suggested by Hollnagel (2014, p. 153). During the main discussion, the group was encouraged to develop a definition of a good discharge from the perspectives of the staff as well as that of the patient. Following this, the discussion was guided through the following series of questions:

1. What is the best or optimal way to perform your work? What personal elements ensure a good discharge? *(Person-related)*

2. What can happen unexpectedly during the task and how do you prepare for it? *(Task-related)*
3. Are tools in place that assist with this? *(Tool-related)*
4. What needs to be in place (requirements)? What do you require from your team or unit for the discharge to be a success? *(Team/group/unit/department)*
5. What organisational elements assist in ensuring that the discharge is a success? *(Organisational factors)*

The second component of the focus groups centred on the things that go wrong and possible error recovery strategies, including the identification of weak signals that indicate that a discharge may fail. A discussion with healthcare providers on adverse events has been identified as a 'good' source of 'data for proactive error prevention' (Andrews et al., 1997). Staff were asked to consider all aspects that 'could go wrong', not only failed discharges, which in this context was defined as a patient requiring readmittance to acute care within 48 hours after being discharged. The main discussion was guided through the following series of questions:

1. What could go wrong with this task? *(Error)*
2. What external factors would influence this task? *(External factors)*
3. How do you know the task is going wrong? *(Weak signal)*
4. When you know it is going wrong, how do you correct yourself? Can you pre-empt this? *(Reaction/Monitoring)*
5. Will you use this knowledge next time you do this task? *(Learning)*

The participants were encouraged to freely discuss any topics that arose as a result of the questions. The themes raised in the focus group were summarised on flipcharts, and at the end of the session, the participants were asked to comment to ensure that an accurate summary of the discussion was captured. The discussions from the focus groups were also recorded using audio recorders. The audio data was subsequently transcribed and analysed together with the compiled summary.

6.2.3.4 Verficication and Validation Component - Interviews

The weak signals framework was validated using interview data. The interviews were approximately 30 minutes in duration and held over the phone arranged at a time that was convenient for the participants. Only one staff member participated per interview. Prior to the interview, the participants were sent the project information sheet, the informed consent sheet, as well as a demographic information sheet. Furthermore, the participants were provided with the contact details of the researcher so that if any questions arose, these could be addressed prior to the interview. These documents have been included in *Appendix C5.* Prior to each interview, the signed informed consent form and the completed demographic information sheet was returned to the researcher.

The interview was structured to explore two different elements, namely verification and validation of the weak signals identified and discussion of potential means for enhancing the use of weak signals for task performance and safety. For the first component of the interview, staff were asked to provide a specific example for each category of weak signal sources identified, namely those originating from people in the system, the unspecified feeling staff got that something was wrong, tools and tasks as well as the environment. For each category of weak signals, the interviewer provided some broad examples initially to aid the discussion and then requested the participant to provide a specific example they had recently experienced that fell within that category. The specific categories and general examples provided to the participants have been included in part A of Table 13. Following the example given, participants were asked to elaborate on how the signal was identified, the information the signal provided, the reaction due to the signal and what had prompted the reaction. The interview guide utilised and the rationale for each question has been included in part B of Table 13.

Table 13: The discussion guide for the first component for the interviews for verification and validation of the weak signals identified for hospital discharge from a community staff's perspective.

Part A. Weak Signal Categories and Examples Provided to the Participants			
Source: Person 1. The patient's condition or behaviour 2. Interaction with the family 3. Previous experience with staff/patient	**Source: Person** 1. Hunch, vibe, or feeling that something is off.	**Source: Task/Tools** 1. Discrepancies in the documentation (e.g. referral or history) 2. Certain medications or treatment protocols	**Source: Environment and Organisation of Work** 1. The patient's home 2. Inter-organisational communication 3. Knowledge of the current status of other services

Part B. Interview Guide	
Interview Questions	**Rationale**
Can you give a specific example for this category of where you have encountered one of these weak signals?	Confirming examples of the weak signals collected previously in the first component of this case study. **Model component:** Confirming the forms of the signals as only the sources have been provided.
How did you identify this weak signal?	**Model component:** Detection processes
What information did this weak signal provide you with?	**Model Component:** Interpretation of the signal
How did you react to the weak signal?	**Model Component:** Outcome elements of framework
What made you react to the weak signal?	**Model Component:** Interpretation component of framework and related to outcomes as well as barriers and facilitators

The second component of the interview focused on identifying means for enhancing the detection of weak signals, the barriers associated with weak signal detection and the barriers associated with acting in response to weak signals. The three questions used for this component of the interview were:

1. What would be possible methods or means for identifying these weak signals during the discharge process?
2. What could prevent you from identifying these weak signals?
3. What would prevent you from responding to these weak signals?

The interviews were recorded using audio recorders and the data was subsequently transcribed.

6.3.4 Analyses

A combination of quantitative and qualitative analysis techniques was employed to guide the analysis to address the objectives of this case study. The data sources used to address each of these objectives have been listed in Table 14.

Table 14: The data sources used to address the objectives of this case study.

Case Study Objectives	Data Sources
Aim 1 - Explore the context from which weak signals may emerge and the connection of the context to the weak signal.	
1. Explore the system factors associated with the discharge process through the generation of work system configurations. As this process spanned several healthcare subsystems, a key aspect was to understand the different perspective of these two subsystems on the same process.	Observations, Focus Groups, Incident Reports Section 6.4.1
2. Identify influencing system factors associated with this healthcare process and how they may affect weak signals.	Observations, Focus Groups, Incident Reports ** Also addressed in the discussion section of this chapter*
3. Identify the facilitators and barriers associated with the discharge process from the perspectives of these two subsystems and explore how weak signals may be connected to them.	Observations, Focus Groups, Incident Reports ** Also addressed in the discussion section of this chapter*
Aim 2 - Apply the second version of the weak signals in healthcare framework to identify weak signals and their relevant elements for work associated with the discharge process from hospital to community-based care for patients from HCOP wards in one hospital.	
1. Determine the weak signals, their sources and key elements of weak signals from the examples associated with the discharge process that arose in this case study relative to the framework.	Focus Groups, Incident Reports, Ombudsman Report
2. Explore the behaviours associated with weak signals by discussing with staff how they come in contact and interact with weak signals. (Addressed in Phase 1/Component 1 and Phase 2/Component 2)	Focus groups, Incident Reports, Ombudsman Report, Interviews
3. Explore with staff the practical implications and factors that may affect weak signal use in everyday work, including the barriers associated with weak signals, and means of implementing weak signals. (Addressed in Phase 2/Component 2 of this case study)	Interviews
4. Verify and validate the weak signals identified in this case study and the key components of the framework. (Addressed in Phase 2/Component 2 of this case study)	Interviews
Aim 3 - Expand the weak signals in healthcare framework to incorporate additional key elements that emerged from the results and develop support for the application of the framework.	
1. Expand the framework to include newly identified elements from the results of this case study.	** Addressed in the discussion section of this chapter*
2. Develop an analysis approach to support the use of the weak signals in healthcare framework.	*Applied to the observations, focus groups, incident reports, and interview data.*
3. Identify the most practical theories that describe the underlying behaviours associated with weak signals, specifically for the detection, identification and interpretation of weak signals.	Interviews ** Addressed in the discussion section of this chapter*

6.3.4.1 Qualitative Analysis

Thematic analysis (Braun & Clarke, 2006, 2012) was used for the qualitative analysis of the data to identify and organise emerging themes. The results were analysed using NVivo 11 Software (QSR International Pty Ltd, 2015). The analysis underwent decontextualization whereby parts of the data were lifted out, and recontextualization whereby it was confirmed

that the patterns identified still fit the context (Malterud, 2001). Each data source was analysed independently for the first phase of this case study before the results were compared and combined during the interpretation stage. The results from the first phase were then compared to the results of the second phase (verification and validation component) during the interpretation stage.

An initial analysis was conducted to determine semantic themes, which reflect the patterns that exist in the data, and are grouped according to content, summarised or interpreted meanings (Javadi & Zarea, 2016). In this analysis, the responses were used to create the articulated data, which arises as a direct response to the question and prompts provided (Massey, 2011). The focus groups used pre-coded open-ended discussion questions, which resulted in the first round of coding being deductive. Data reduction was also done by using the pre-set codes and categorising all data according to the components described in the SEIPS 2.0 model, namely, into the aspects of the sociotechnical work system, the work processes or the outcomes (Holden et al., 2013). Following this, inductive coding was used within each system component to generate emergent codes. For the analysis of the incident reports from the Ulysses database, the goal of the qualitative analysis was not to try to establish a root cause but rather to try to identify as many contributing system elements as possible. Once the individual data sources were analysed, the interpretations were compared and combined results were generated.

A second analysis was conducted to determine latent themes and identify the attributional and emergent data. This required interpreting the semantic themes to create theory based on the patterns identified and the wider framework upon which the work is based (Braun & Clarke, 2006; Javadi & Zarea, 2016). The attributional data emerges from comments and discussions that relate to the hypotheses and research questions the researcher brings to the study (Massey, 2011). The results of this second analysis have been presented in this chapter.

The interview data for the verification and validation component of this case study was analysed deductively using the pre-coded questions from the interview guide and using the elements of the weak signals in healthcare framework. Once the results were compiled, these were compared with the results of the first phase of this case study.

6.3.4.2 Quantitative Analysis

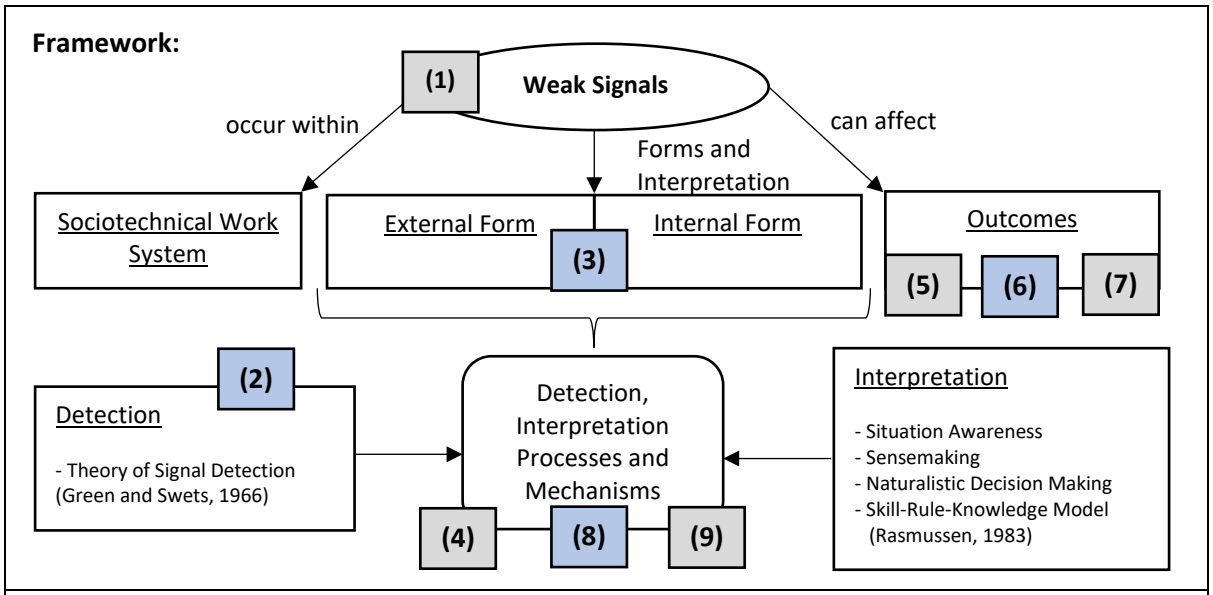
Quantitative data was obtained through quantifying the qualitative data from the observation component of this case study in order to provide an overview of the qualitative material (Malterud, 2001) and assist in better understanding the context. For the quantitative analysis of the observation data, the themes determined through the first two meetings observed in January were used to develop a list of influencing factors for the discharge process that was used to determine the frequency counts of these factors in the five TAG meetings observed between August 2016 and September 2016. The incident report data was then analysed to determine the frequency counts for how often the main factors identified in the observation data were mentioned in the analysed incident reports.

6.3.4.3 Work System Configuration

Part of the work system analysis was the generation of work system configurations. The purpose of this was to highlight the connections between these two subsystems for this healthcare process and provide the context wherein weak signals occur. The data was categorised according to the sociotechnical work system components and mapped onto the SEIPS 2.0 model. The format and method for generating the work system configuration was taken from the example provided in Figure 2 of the original paper by Holden and colleagues (2013, p. 1675). Since this analysis has been performed, other studies (e.g. Hay et al., 2020; Werner et al., 2020) have also adopted a similar approach to generating work system configurations.

6.3.4.4 Weak Signals Analysis

The focus group data, the Ombudsman report and the incident reports were included in the weak signals' analysis. Each data source was analysed using the framework and approach depicted in Figure 25. In this figure, the analysis stages have been mapped on to the second version of the weak signals in the healthcare framework, which was presented at the end of the previous case study.



Analysis Stages	
1. Extraction of the examples of weak signals from the data source	*Refers to structural elements of weak signals*
2. Categorisation of the weak signals according to its source	
3. Identification of the form of the weak signal	
4. Extraction of who identified the weak signal	*Refers to behavioural elements of weak signals*
5. Extraction of whether the weak signal was transmitted, to whom and by whom.	
6. Identification of whether the weak signal was missed	
7. Extraction of the response and outcome, if available	
8. Identification of the potential associated error	
9. Extraction of if the consequence was predicted	

** Stages in grey required direct data extraction. Stages in blue required categorisation and interpretation.*

Figure 25: The analysis approach using the weak signals in healthcare framework (Version 2) adopted in this case study.

First, the examples of the signals; who identified them; whether they were transmitted; to whom and by whom; the response and outcome, if available, and the predicted consequence, were extracted from the data sources. Following this, the signals were categorised according to their source and the form. From the data it was then inferred if the signal was missed and if the associated error could be identified. Figure 25 also highlights which elements were directly extracted from the data and which elements arose as a result of categorisation and interpretation. The figure also highlights which components of the analysis are associated with determining the structural elements or the behavioural elements of weak signals.

6.3.5 Validity and Reliability

This case study utilised method and data triangulation, which enabled corroboration of the results from the different data sources (Brown et al., 2008a) and enhanced validity by the

convergence of information from different sources (Carter et al., 2014). Furthermore, it assisted in illustrating the context, examining the phenomenon from numerous perspectives and providing a deeper understanding of the concept (Jick, 1979). This also had the advantage of reducing the impact of potential biases (Bowen, 2009) and improving the internal validity of the study (Barbour, 2001). The method triangulation assisted with validity as it ensured that the variance in results were not due to the method (Jick, 1979) and allowed for convergent validation, which enhances the trustworthiness of the findings (Carter et al., 2014). In addition to the above, respondent validation, which involves cross-checking research findings with respondents (Barbour, 2001), was used to confirm and refine the results in this case study.

Validity and reliability were improved through reflexivity. Regarding reflexivity, as the researcher had not been employed in healthcare prior to starting this thesis, the researcher brought limited bias and preconceptions to this piece of work. More specifically, as this case study involved two analyses on the same dataset that were conducted at different time points, this provided the researcher with an opportunity for reflexivity by looking again at the data and its initial interpretation for alternative conclusions (Malterud, 2001) and then reworking the analysis. The concern of transferability of the qualitative results was mitigated to an extent as the sample included several perspectives on the discharge process, namely, both hospital and community healthcare staff's opinions. This should also enhance the external validity as it should extend the context to which the conclusions can be applied (Malterud, 2001).

Although this research was predominantly qualitive in nature, the objectivity and intersubjectivity were enhanced as the theoretical standpoints and the researcher's frame of reference were clearly stated (Malterud, 2001). Furthermore, by including quotes from the data, the credibility was further enhanced.

6.3.6 Ethical Considerations

Ethical approval for this case study was granted by the Loughborough University Ethics Approval (Human Participants) Sub-Committee, and appropriate organisational approval was obtained from Nottingham University Hospitals NHS Trust and Nottinghamshire Healthcare

NHS Foundation Trust. All information was stored confidentially and the anonymity of the participants was ensured as none of the individual results were made available. Only the aggregated data was included in the presentation of the results, the published reports and the documents.

6.4 Results

The results were presented according to the objectives specified in Table 14, as opposed to per data source. The first two result sections provide the context and describe the system in which weak signals may present. Following this the weak signals identified are described in detail. By presenting the context first, the weak signals and their emergence will be made more visible. The results presented include a description of the work system; the facilitators and barriers, which both provide the context, and the weak signals associated with the discharge process. Following this, the results of the verification and validation component have been presented.

6.4.1 The Discharge Process – Description of the Work Systems

The results from the focus groups held with the hospital and community healthcare staff involved in the discharge process, the observation sessions and the analysis of the incident reports were used to generate work system configurations. The aim of this was to provide a description of these two subsystems, which function spatially and temporally apart, from the perspectives of staff that work in them and highlight how these subsystems link for this one type of healthcare process. The configural diagrams and the work system components from both healthcare subsystems are depicted in Figure 26.

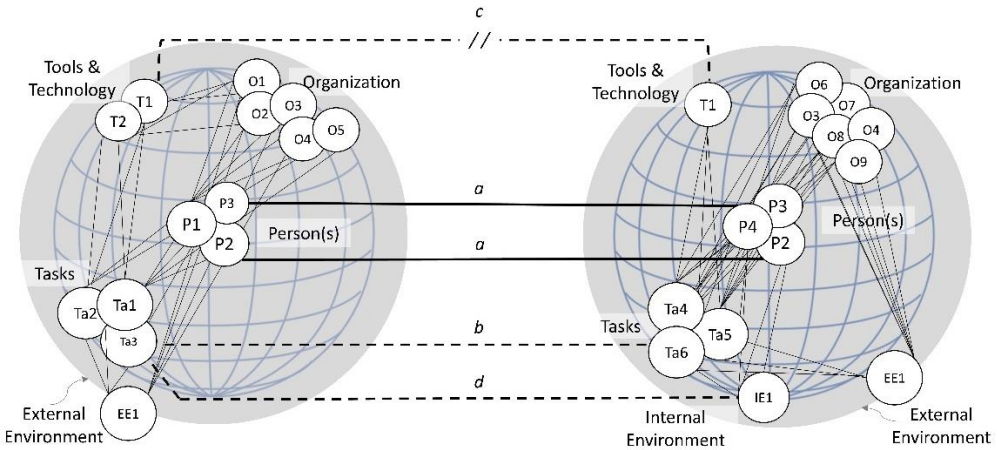
The Discharge Process from Hospital Staff's Perspective	The Discharge Process from Community Staff's Perspective
	
Active Agent(s): Hospital healthcare staff (e.g. doctors, nurses, therapists, administrative staff), patient, their family	**Active Agent(s):** Community healthcare staff (e.g. nurses, therapists), patient, their family
Performance is shaped by a combination of the following factors:	
Person(s) Factors: - **P1-Hospital Healthcare Staff:** Knowledge of the patient's current condition and home environment. Communication and collaboration with other healthcare staff. - **P2-Patient:** Patient is medically fit for discharge. The complexity of their case has been considered as this will influence the discharge plan. Patient is involved in the process. - **P3-Patient's Family:** The patient's family involvement in the process.	**Person(s) Factors:** - **P2-Patient:** Patient is medically fit for discharge. They are involved in the process; have given consent and have received the necessary education. - **P3-Patient's Family:** The patient's family are involved in the process, decision-making and used as an information source. - **P4-Community Healthcare Staff:** Communication and collaboration with the patient, their family and other healthcare staff involved. Knowledge of the patient's current condition, previous medical history, needs and their home environment.
Task Factors: - **Ta1:** Discharge planning, which is influenced by the complexity of the patient. - **Ta2:** Completing pre-discharge tasks (e.g. prepare patient, order equipment, complete assessments, book transport, submit referrals, complete necessary documentation, order medication). - **Ta3:** Time the discharge occurs.	**Task Factors:** - **Ta4:** Receiving the necessary referrals, information, and documentation. The information available will affect this task. - **Ta5:** Triage of the referrals and patients on caseload. This will be affected by the number of urgent referrals. - **Ta6:** Plan and conduct initial visit (*b* - this is influenced by the Ta3: time of the discharge.) Update care plan. The information available will affect this.
Technology (and Artefacts) Factors: - **T1:** Availability and accuracy of online patient information records - **T2:** Access to written documents. This is affected by legibility.	**Technology (and Artefacts) Factors:** - **T1:** Availability and accuracy of online patient information records.
Organisation of Work Factors: - **O1:** Subsystem coordination and communication (e.g. pharmacy, transport and discharge lounge) including teamwork, sharing knowledge and information - **O2:** Specific job roles (e.g. discharge coordinator) - **O3:** Between organization communication and collaboration - **O4:** Effect of organizational pressure (e.g. understanding the need to 'get patients out') - **O5:** Procedures (e.g. plan discharge upon admission)	**Organisation of Work Factors:** - **O3:** Between organization communication and collaboration - **O4:** Effect of organizational pressure - **O6:** Triaging of referrals and work schedule structure to create capacity and flexibility. - **O7:** Teamwork, sharing knowledge and information - **O8:** Specific job roles (e.g. triage nurse) - **O9:** Procedures (e.g. cut-off times for other services and standard operating procedures for different areas)
	Internal Environment Factor: - **IE1:** Access to and preparation of the home environment.
External Environment Factor: **EE1:** Day of the week, Funding	
a – The patient and their family are two constants across these two subsystems. *b – The task of planning and conducting initial visit by community staff (Ta6) is directly influenced by the task Ta3 (time of the discharge) which is determined in the hospital work system.* *c – Both subsystems require information from online systems, but staff may not have access to the same online systems, or the different online systems may not link.* *d* – The patient's home (Internal environment factor IE1) should be considered for the tasks of discharge planning (Ta1) and compl*eting the pre-discharge tasks (Ta2), which will influence the initial visit (Ta6).* This work system configuration of the discharge process is a high-level depiction of this complex process aimed at highlighting the current connections of the two subsystems involved in the discharge process, and as a result is not an exhaustive list of all the influencing factors.	

Figure 26: The configural work systems from the perspectives of hospital and community healthcare staff involved in the discharge process of patients from HCOP wards.

From the perspective of hospital staff, the people involved in their subsystem included other healthcare staff at their site (e.g. therapists and pharmacists) and the patient and their family. The patient and their family are two of the constants across these two work system configurations (solid line *a,* Figure 26). The tasks in this work system included discharge planning, completing the necessary pre-discharge tasks (e.g. ordering equipment, booking transport, submitting referrals) and initiating the discharge. Key tools and technology included access to physical documents (e.g. patient file) as well as up-to-date and accurate online information. Although both work system configurations rely on similar types of information that are stored digitally, staff mentioned that they often did not have access to online systems in the other work system (dashed line *c,* Figure 26). For the discharge process to occur in the hospital, internal subsystems need to coordinate and communicate (e.g. pharmacy, transport) and to support this, specific roles (i.e. discharge coordinator) and procedures (e.g. discharge planning) have been created. Furthermore, organisational pressures, such as bed availability, will influence this process. The external environment factor that influences the discharge process in both work system configurations was the day of the week the discharge occurred.

From the community healthcare staff's perspective, although there were some similarities, there were also some key differences in the work system configurations. The people that differed were the community healthcare staff (e.g. GPs, therapists and community nurses). However, one would expect the presence of both staff groups, hospital and community, in both work system configurations. A common barrier mentioned by both groups was a lack of cross-system interaction between staff. The tasks in this work system configuration included receiving referrals, triaging them as well as planning and conducting an initial and follow-up visits. The task associated with conducting an initial visit depends on the hospital task of when the patient is sent home (dashed line *b,* Figure 26). The key organisation of work elements identified by community staff included communication and collaboration between organisations, creating staff capacity to cope with incoming referrals, process-specific roles (i.e. triage nurse) and procedures that have been created to promote the safety of this process (e.g. cut-off times). The main internal environment factor for the discharge process is that of the patient's home. Even though this factor is physically present in the community healthcare work system configuration, this needs to be considered for several of the tasks in the hospital

work system configuration, namely, for the tasks of discharge planning and completing the pre-discharge tasks (dashed line *d,* Figure 26).

Additional information on the hospital work system factors that could influence the discharge process was obtained from the observational data. Based on the observation session conducted in January 2016, a model on the influencing factors prior to discharge was generated (depicted in Figure 27). The influencing factors for determining if the patient was ready for discharge and the possible reasons for delay were identified. The hospital wherein the observation sessions occurred had seven different types of discharge plans. These included 'return to the same care home', 'supported Integrated Health and Social Care Team (IHSCT) referral', 'repatriation', 'end of life', 'simple', 'fast track' and 'restart of package' discharge plans. Additional information regarding how the model was generated has been included in *Appendix C2.* Across the five meetings observed in August and September 2016, the discharge plans for 777 patients were discussed (mean = 155.4 patients discussed per meeting, SD = ± 26.77). The most frequently discussed discharge plan was for the return to the same care home, which was cited in 83 patient cases. This was followed by a restart of the package plan, cited in 63 cases; a supported integrated health and social care team (IHSCT) referral, cited in 59 cases, and a simple plan, cited in 57 cases.

Across the 777 patient cases, the most frequently cited contributing factor with regards to discharge-planning problems was related to family or partner support, which was cited 77 times across the five meetings. This was followed by the home environment, cited 33 times, and then, from the patient-related category, were the psychological factors of the patient, such as mental health, cited 20 times. The most frequently cited reason for a delay was the process-related factor of awaiting assessments or reviews (cited 155 times across the five meetings observed). This was followed by a change in the patient's health (cited 121 times) and awaiting a bed (cited 71 times) or other services, such as therapy services (cited 68 times). Additional information on the results from the observation data have been included in *Appendix C6.* These factors were also identified in the focus groups held with hospital and community healthcare staff.

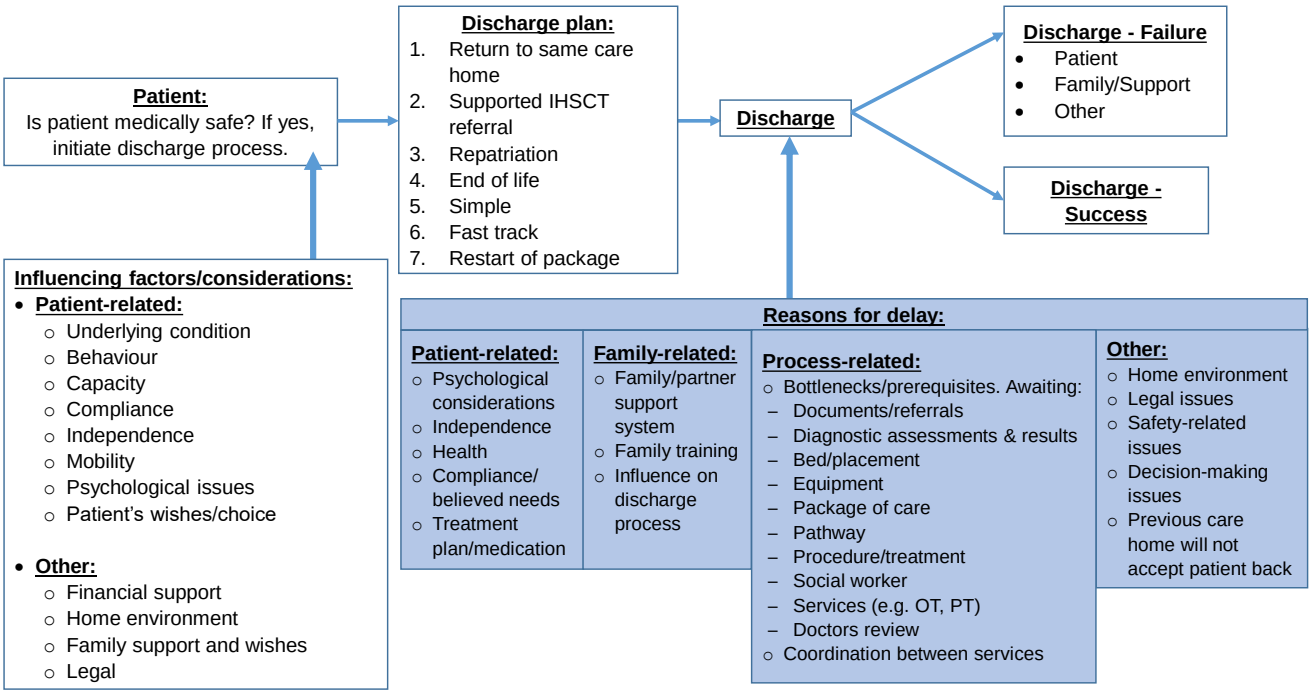


Figure 27: Model of the factors influencing the discharge process from the hospital staff's perspective derived from the observation sessions.

The above-described factors were also identified in the incident reports filed by community healthcare staff. Frequency counts for the main factors identified from the observation data were determined for the incident reports analysed. A comparison of these quantitative results has been presented in Table 15. The results in the table highlight that the most frequently influencing factors and reasons for delays and problems differ across these two work systems. In the hospital setting, the influencing factor on the discharge process most frequently cited was related to family or partner support and in the community healthcare setting, it was the home environment not prepared. In the hospital setting, the most frequently cited reason for delay was assessment- and review-related problems and in the community healthcare setting; it was referral-related problems. Even though the problems in the different work systems are expected to be different, this highlights the need to improve the discharge process as a whole and understand the delays and influencing factors that are most frequent in both subsystems.

Table 15: The quantitative data in the form of frequency counts and the percentage of common themes across the patient cases from the observation data and the community reported incident data.

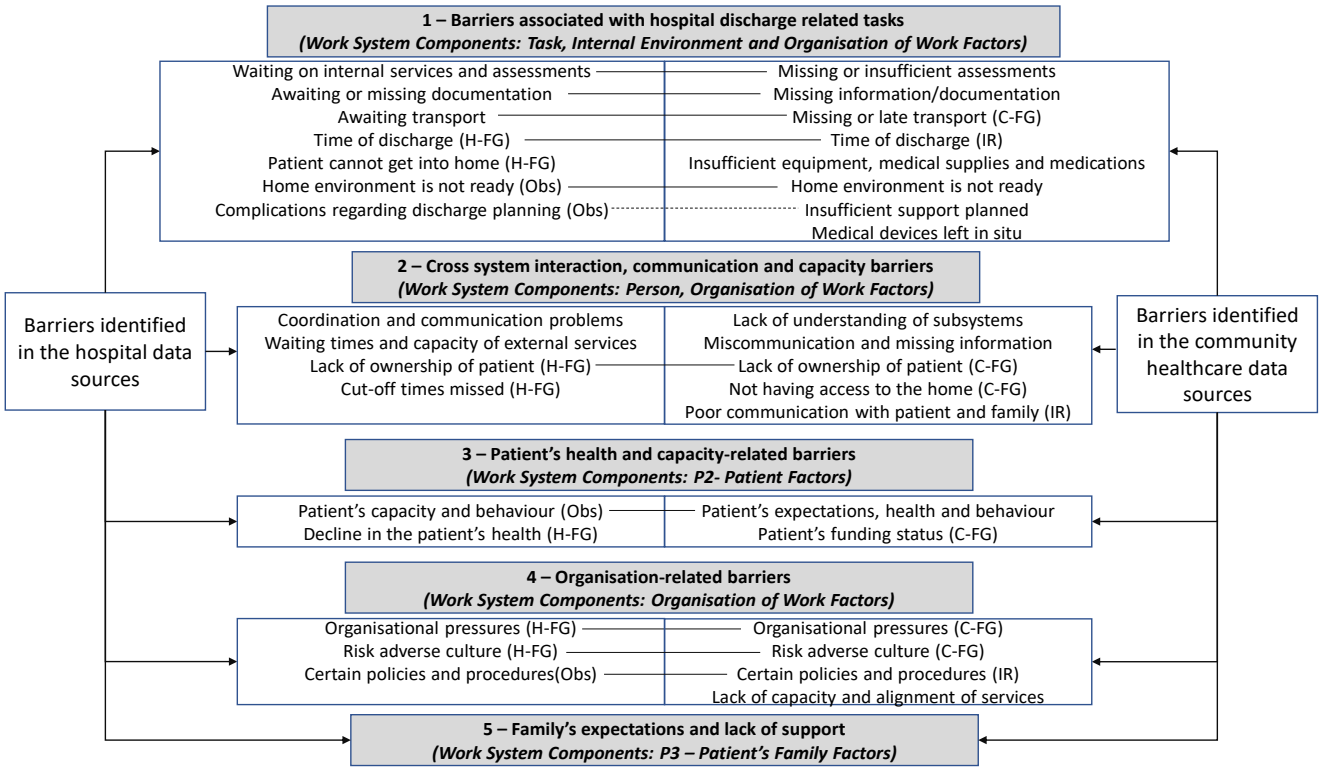
Work System		**Hospital**	**Community Healthcare**
Variable		**Observation Data** (Number and percentage of patient cases discussed, n=777)	**Incident Report Data** (Number and percentage of reported incidents, n=348)
Patient not medically fit for discharge		385 patient cases (49.55%)	13 incidents (3.74%)
Influencing factors on discharge planning	Lack of family or partner support	77 patient cases (9.91%)	1 incident (0.29%)
	Home environment not prepared	33 patient cases (4.25%)	32 incidents (9.20%)
	Mental health problems	20 patient cases (2.57%)	5 incidents (1.44%)
Reasons for delays and problems associated with the discharge	Assessment and review problems	155 patient cases (19.95%)	10 incidents (2.87%)
	Change in patient's health	121 patient cases (15.57%)	4 incidents (1.15%)
	Awaiting a bed	71 patient cases (9.14%)	0 incidents (0.00%)
	Awaiting bed or therapy services	68 patient cases (8.75%)	0 incidents (0.00%)
	Referral problems	17 patient cases (2.19%)	131 incidents (37.64%)
	Package of care problems	57 patient cases (7.34%)	32 incidents (9.20%)

6.4.2 Barriers and Facilitators of the Discharge Process

The previous section and Figure 26 highlight that although these two subsystems function spatially and temporally apart, they rely on each other for information and certain prerequisite actions for some tasks. The separation between these two work systems can result in the creation of several barriers that staff may face when working in this process. In addition to the focus group data, the observation sessions and analysis of the incident reports were used to identify themes relating to barriers to the discharge process. The observation data assisted in identifying barriers to the discharge process from the hospital staff's perspective and identified barriers that usually affected the process before the patient had left the hospital. The results from the incident reports identified barriers that were experienced by community healthcare staff, some barriers which may have originated in the hospital work system.

Five main themes that represented the barriers to the discharge process from the perspectives of both the hospital and the community healthcare staff were extracted, with the key differentiation being some of the identified subthemes. The main themes consisted of the barriers associated with hospital discharge-related tasks; a lack of cross system

interaction, communication and capacity; the patient's health and capacity; organisation-related barriers and the family's expectations and lack of support for the process. The main themes and subthemes of the barriers identified from the hospital and community healthcare data sources and how they connect between these two subsystems are summarised in Figure 28. The relevant work system components, as depicted in Figure 26, are listed for each main theme.



*Obs – Observation data, H-FG – Focus groups with hospital staff, C-FG – Focus groups with community staff, IR – incident report data

Figure 28: The main themes and subthemes relating to barriers to the discharge process from a hospital and community healthcare perspective and the associated work system components.

The facilitators for the discharge process were determined using the focus group data. Four main themes relating to facilitators of the discharge process were derived and represented the facilitators that both hospital and community healthcare staff use, with the key differentiation being some of the identified subthemes. The main themes and subthemes identified for the facilitators of the discharge process have been presented in Table 16.

Table 16: The main themes and subthemes relating to facilitators extracted from the focus groups held with hospital and community healthcare staff and the associated work system components.

Main Themes	**Subthemes**	
	Focus Groups with Hospital staff	**Focus Groups with Community Healthcare staff**
1 - Information availability, accuracy and gathering	Key information sources – online systems, family and patient as an information source and key documents. *(WS – P2, P3, T1, T2)*	
	Accurate information and documentation. *(WS – T1, T2)*	Independently gathering information. *(WS – Ta4)*
		Transmission of specific information.
2 – Cross-system coordination, communication and interaction	Good family and patient communication, involvement and education. *(WS – P2, P3)*	
	Good coordination of subsystems involved in the process. For the hospital setting, examples included the pharmacy, discharge lounge and transport departments. For the community healthcare setting, examples included GP, tissue viability nurses and other hospital sites. *(WS – O1, O3, O7)*	
	Good coordination and communication, with external subsystems involved in the process. *(WS1 – O3)*	
3 – Successful and timely completion of pre-discharge tasks	Patient is medically fit for discharge. *(WS – Ta1)*	
	Patient's home environment is ready for them, including installation of the necessary equipment. For community staff, this included having access to the home. *(WS – IE1)*	
	The correct level of support (e.g. care packages) has been organised in a timely manner. For community staff, this also included the sending of appropriate and accurate referrals for the different service providers. *(WS – Ta1, Ta2, Ta6)*	
	Transport home has been arranged for a suitable time of day. *(WS – Ta3)*	
		Patient-related healthcare tasks (e.g. accurate assessments, sufficient dressings, medical supplies and correct medication have been sent with the patient). *(WS – Ta2)*
4 – Organisation of work at a subsystem level	Individual behaviours, such as being flexible, organised and being able to prioritise. For hospital staff, this also included being able to voice one's opinions. *(WS – P1, P4)*	
	Specific organisational aspects and understanding of the organisational infrastructure and pressures. This included specific policies and procedures (e.g. hospital – escalation procedures, community – procedures of different areas and cut-off times), specific roles (e.g. discharge coordinator, community matron) and understanding the process. For this latter point, for hospital staff, this included understanding discharge procedures, and for community staff, this included knowledge of available resources and contacts. *(WS – O2, O5, O8, O9)*	
	Time the discharge occurs. For example, discharges before noon are more likely to go well. *(WS – Ta3)*	
	Good teamwork and sharing of information. This includes working as an integrated team, multidisciplinary team, sharing information and understanding the roles of other teams in the process. *(WS – O1, O7)*	
		Creating capacity through work scheduling and triaging referrals.
		Being aware and using alternative resources to provide unplanned care.

WS – This refers to the work system components in Figure 26 that these facilitators relate to.

The four main themes consisted of good information availability, accuracy and collection methods; good cross-system coordination, communication and interaction; successful and

timely completion of pre-discharge tasks and the good organisation of work at a subsystem level. Additional results on the facilitators and barriers identified for the discharge process, including description of the subthemes identified and supportive quotes from the focus groups, have been included in *Appendix C7*.

6.4.3 Weak Signals

The focus group data, the Ombudsman report and the incident reports were included in the weak signals analysis. The focus group data was used to collate an initial list of weak signal examples, which were grouped to create categories of weak signals relating to the discharge process. The incident report data and the Ombudsman report were then screened for examples using this initial list. Additional examples and categories were also compiled during this process. The information pertaining to the identified weak signals could be categorised according to whether they were associated with structural or behavioural elements of weak signals, as described in the weak signal's framework (Figure 25), which was applied in this case study. The text of the analysed documents and descriptions provided in the focus groups were then analysed to identify if any behavioural elements of weak signals could be extracted. The approach taken to compile the data and the weak signals analysis approach used to determine the structural and behavioural aspects for this case study are depicted in Figure 29.

Structural elements included examples of weak signals, the form the weak signal presents in could be inferred (e.g. visual signal) and the types based on their work system source. Illustrative quotes were used to highlight some examples of weak signals associated with the discharge process. Regarding the behavioural aspects, for some examples it was possible to extract if there was a response to the signal, and if it was transmitted. The document data provided information on the identifier of the signal; the receiver of the signal, if it was transmitted; the associated error and if it was actively sought. In contrast, the focus group data provided additional information such as the predicted consequence and error associated with the signal. To confirm, verify and validate the compiled weak signal results, interviews were conducted with community healthcare staff that participated in the focus groups approximately year and a half later (the results of which have been presented in *Section 6.4.3.3*, p. 169).

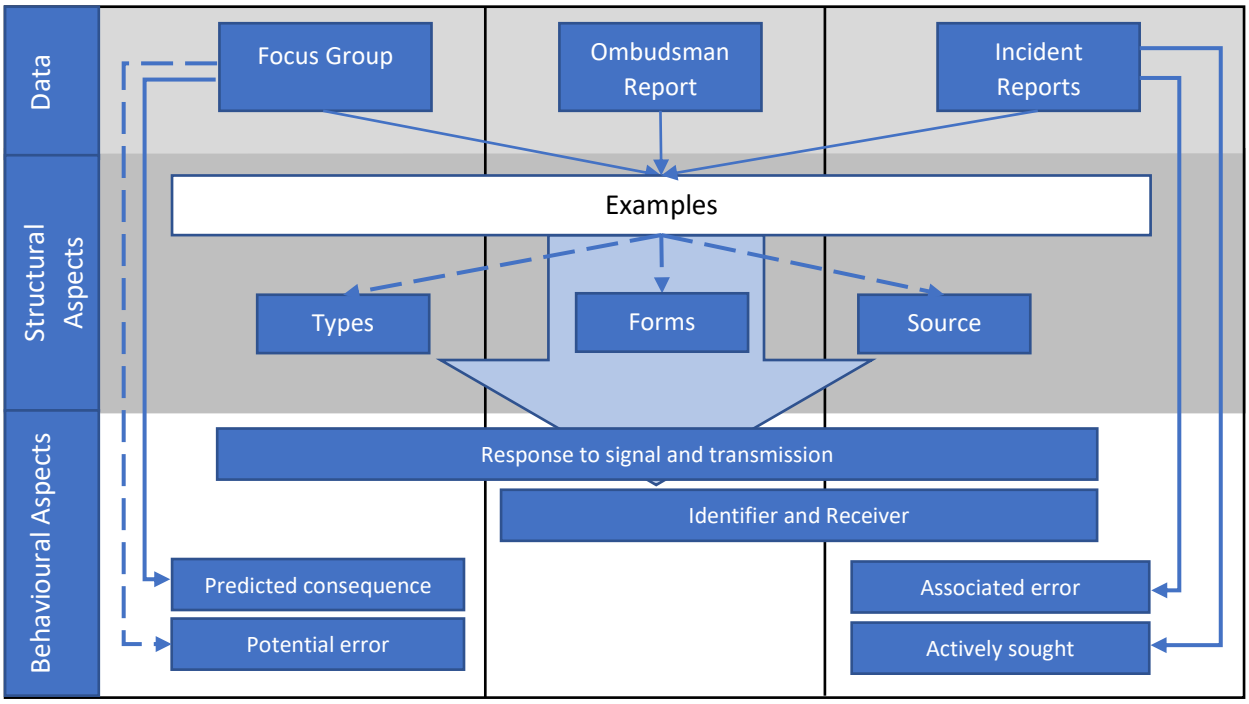


Figure 29: The data and approach to the weak signals analysis to determine the structural and behavioural aspects for the case study on patient discharge.

6.4.3.1 Structural Elements of Weak Signals

Across all data sources, a total of 435 examples of weak signals were collected. The examples of the signals were grouped according to the work system source. For 418 examples, a total of 46 different types were identified across all datasets. The remaining 17 examples were weak signals that explicitly described combined weak signals. A total of 94 examples from 30 types of weak signals were identified in the focus groups held with community healthcare staff, and a total of 38 examples from 17 types were identified in the focus groups held with hospital healthcare staff. The incident report data yielded 284 examples of weak signals from 44 types based on the work system source. The Ombudsman report yielded 19 examples of weak signals from eight types. A summary of the number of weak signal examples and types per data source has been included in Table 17.

Table 17: The number of cases analysed, the number of cases that contained weak signals, the number of examples and the identified signal types.

	Focus Group (Community)	Focus Group (Hospital)	Incident Report Data	Ombudsman Report	Total
Total number of cases	-	-	348	9	357
Cases containing weak signals	-	-	192	9	201
Number of signals examples	94	38	284	19	435
Number of types identified	30	17	44	8	46*
Examples of missed signals	-	-	9	9	18
Examples of combined signals	7	2	8	-	17

*Across all four data sources, a total of 46 different types could be compiled.

The weak signal sources identified included five of the six SEIPS 2.0 work system components, namely, weak signals originating from person, task, tools and technology, organisation of work and internal environment components. The work system component that had the largest number of examples of weak signals from the Ombudsman report and incident data, with a total of 206, was the 'Person' component. Types of signals from this work system source included patient type; verbal cues from the patient; unexpected contact from the patient, their family or other healthcare staff; the family's behaviour or appearance and other healthcare staff's behaviour, including staff's language or voiced concerns. A summary of the types and examples of the weak signals identified across all data sources for the SEIPS 2.0 'Person' work system component has been included in Table 18. This table also depicts the counts of weak signal examples identified in the Ombudsman report and incident report data. The weak signals were grouped according to which subsystem they presented in or were identified in (i.e. pre-, post-discharge or both).

Table 18: The weak signal types, examples and the forms identified across all data sources for the 'Person' SEIPS 2.0 work system component.

Source	Discharge Phase	Weak Signal Types (examples)	Forms	Count*
Person - Patient	Both	Patient type (e.g. end of life), appearance (e.g. looks unwell, distressed), behaviour (e.g. behaves confused), capabilities (e.g. mobility) and current health condition (e.g. potential for rapid deterioration)	Visual, verbal and cognitive	51
	Post-Discharge	Smell, verbal cues (e.g. regarding undocumented treatment, wounds, medication, safety and coping)	Smell, verbal, cognitive	22
		Unexpected contact (e.g. SOS call, self-referral), symptoms (e.g. pain, discomfort), physiological and physical signs (e.g. breathlessness, temperature) and wound appearance (e.g. leaking and smell of wound)	Verbal, smell, cognitive	29
Person - Family	Both	Appearance and behaviour (e.g. they appear or act distressed, anxious or frustrated)	Visual, Verbal	10
	Post-Discharge	Expectations, unexpected calls or contact (e.g. family/friends contacted services regarding visit), verbal cues (e.g. indicating concerns regarding safety, medication, not coping and raising concerns about the patient's ability to care for themselves)	Verbal	50
Person - Staff	Pre-Discharge	Behaviour (e.g. staff's language, they appear stressed), experience (e.g. experience level of staff relative to decisions made)	Visual, cognitive	0
	Post-Discharge	Unexpected contact from other healthcare staff (e.g. contact from carers, residential home, care home, GPs and therapy staff) and previous experience with this patient (their usual behaviour or state)	Verbal, cognitive	34
		Staff voiced specific concerns (e.g. regarding level of care and safety) and specific information transmitted (e.g. informed that patient was discharged by the GP, regarding medication, discharge, or leaking wound)	Verbal	10

*The count represents the number of signals presented in the incident report data and Ombudsman report. Signal types in the yellow cells were additional types identified only in the incident report and the Ombudsman report data.

A summary of the types and examples of the weak signals identified for the remaining SEIPS 2.0 work system components has been included in Table 19. The types of weak signals from the 'task' work system source included waiting on pre-discharge requisites, the planned care in comparison to the patient's needs and completing a holistic assessment. The types of weak signals from the 'tools and technology' work system source included documentation of patient-specific information, a treatment plan, missing or contradicting information in documents and medical devices, such as cannulas left in situ. An example of a weak signal relating to documentation of patient-specific information, and the only one of two identified by staff as indicating a potential staff safety risk was the documentation of problems associated with behaviour (e.g. substance abuse and history of violence). The second weak

signal associated with a potential staff safety risk was the appearance of the exterior of the house. However, this signal may also be associated with the patient not being at home.

Table 19: The weak signal types, examples and forms identified for the different SEIPS 2.0 work system components.

Source	Discharge Phase	Signal Types (examples)	Forms	Count*
Task	Pre-discharge	Waiting on pre-discharge requisite tasks (e.g. waiting on tests, medical reviews), previous home will not accept patient back	Cognitive	0
		Planned care relative to the patient's needs (i.e. support not planned), medication procedure for discharge not followed	Cognitive	2
	Post-Discharge	Holistic assessment (e.g. visual assessments, observations indicating sepsis), time of task (e.g. late in the evening, over the weekend), unplanned medical requests	Cognitive, verbal	14
		Tests indicating physiological signs (e.g. early warning scores, low blood sugar, chesty and pitting oedema), medical tests (e.g. indicating infection), type of discharge (e.g. self-discharge)	Visual, verbal, cognitive	10
Tools and Technology	Both	Documentation of patient-specific information (e.g. history of unsafe discharges, repeat readmissions, previous problems, certain medications)	Cognitive, Visual	13
	Pre-Discharge	Documentation of treatment plan (e.g. seen numerous professionals before they have seen staff involved in the discharge, medical test results)	Cognitive	1
	Post-Discharge	Documentation – missing or contradicting information (e.g. information sparse or inconsistencies on referral, missing information found when cross comparing documents)	Cognitive, Visual	3
		Documentation – discharge summary or referrals (e.g. vague referral and missing information, documentation indicates referral was needed but not done/received, information indicating other information was missing), discrepancies between documentation and equipment provided	Visual, cognitive	10
		Medical device in situ (e.g. cannula, clips, sutures), including presence of unknown medical devices (e.g. indwelling catheter)	Visual	29
Organisation of Work	Pre-Discharge	Awareness of current status of other services or departments, lack of clear planning by the medical team, patient is out lied to other areas	Cognitive	1
Internal Environment	Post-Discharge	Home environment untidy (e.g. hospital bags still visible), home not prepared (e.g. missing equipment visible, heating not on), exterior of home, smell (e.g. gas), state of the pets, untouched medication lying around	Visual, smell	6

*The count represents the number of signals presented in the incident report data and Ombudsman report. The signal types in the yellow cells were the additional types identified only in the incident report and the Ombudsman report data.

The types of weak signals from the 'organisation of work' work system source included an awareness of the current status of other services or departments, a lack of clear planning by the medical team and if the patient is out lied to another area. The types of signals from the 'internal environment' work system source included the home environment not being

prepared, untidy and untouched medication being visible. The latter two signals may indicate the degree to which a patient may or may not be coping at home. Although there were some common weak signals identified by both community and hospital healthcare staff, most were not. This may be because weak signals for hospital staff indicate something else (i.e. the discharge may be delayed or problems associated with discharge planning) than those to community staff (i.e. the discharge may fail or post-discharge problems may occurred). A more extensive breakdown of Table 18 and Table 19, and additional examples, have been included in *Appendix C8*.

For each of the weak signals identified, the form was determined. The forms of the signals included visual, verbal, olfactory and cognitive information. The cognitive information forms required a degree of interpretation to be able to identify the weak signals. An example of a cognitive form of a weak signal would be being aware of a current health condition that had the potential for rapid deterioration of the patient. These forms assisted in determining if the weak signal was internal or external. The weak signals identified as being internal included signals that are dependent on being generated by the individual who identifies the weak signals by compiling information from different sources, previous experience or training to realise the significance of that signal. The weak signals identified as being external included signals related to a medical device in situ, patient and family behaviour, patient signs and symptoms and signals related to voiced concerns. Weak signals related to medical test results could be internal or external, depending on whether the test includes information for the medical staff regarding the normal range of values for that test, which therefore would not require the staff to recall this from memory. All signals that were external were weak signals that required more general knowledge than specific knowledge for interpretation. An example of this would be the patient looking unwell. Some signals can be described as objective; these include medical tests, documentation of previous problems or patient history, a medical device in situ and patient behaviour and patient signs. Subjective signals include patient symptoms (this is also an indirect signal, which needs to be transmitted), and voiced concerns by the patient's family.

The different data sources provided different levels of detail and information pertaining to the signals. The focus group data provided rich descriptions of the weak signal types that were

identified in the other data sources. Illustrative quotes for one example of each SEIPS 2.0 work system component for both the pre-discharge and post-discharge phases have been presented in Table 20. Some of these examples already provide an indication of the meaning of the weak signals and the actions staff took, but this will be described in more detail in the next section.

Table 20: Illustrative quotes of weak signals identified by the hospital and community healthcare staff for each SEIPS 2.0 work system component.

Source (SEIPS 2.0)	Discharge Phase	Illustrative Quotes
Task	*Pre-discharge*	***Planned care relative to the patient's needs –*** 'We had a patient that had very *advanced dementia, and she was very mobile, no aids. The family was saying no* she wanted to go home. And I said, "well you know there is a high chance it's going *to go wrong in the first day or two, so is somebody going to be there or can please* somebody be there overnight just for the first one or two [nights] ..."' (Hospital Focus Group 2)
	Post-discharge	***Time of Task –*** 'That, for me, is a red flag when they are ringing at twenty to three *trying to push them out the door.* So, I'm very aware that this one is likely to be a very horrible discharge.' (Community Focus Group 4)
Tools and Technology	*Pre-discharge*	***Documentation that the patient has safeguarding concerns –*** 'You never know how it's going to be till it's sorted out so…' (Hospital Focus Group 1)
	Post-discharge	***Documentation with limited information –*** 'Alarm bells have rung for me before *when an end-of-life patient has been discharged and you have never heard of them. And you just get a paper referral that just says fast track – to die at home. You know nothing about that patient, not even a diagnosis, not even what the* prognosis is… As soon as you read something like that you think "oh no, it is going to be awful". And it is usually on a Friday afternoon.' (Community Focus Group 4)
Organisation of Work	*Pre-discharge*	***Lack of clear planning by the medical team –*** 'I think one of the weak signals is a *lack of clear planning by the medical team. Sometimes the medical team is not sure: should we, should we not, should we test, not test, is it end of life, not end of life? So that creates that weak signal that it is going to be difficult discharge* because the team is not clear what's going on.' (Hospital Focus Group 3)
Internal Environment	*Post-discharge*	***Exterior of patient's home –*** 'Sometimes you pull up at a person's house and just look and think "oh no"' (Community Focus Group 6)
Person - Patient	*Pre-discharge*	***Patient type/current health condition –*** *Participant 1* – 'Where people talk about end of life, but they are still *physically* quite good, that's a weak signal for me. Because you just think, "well they are going to go off the cliff at some point".' *Participant 2* – 'All it will take is one day, and they will wake up and never get out of bed again.' *Participant 1* – 'Yeah, that's it. It's making sure that people know, let's get the OT on board, let's get the social worker on board, let's get the paperwork done. Because if we leave it too late and they want to die at home, and … we miss the *boat, and they die in hospital. T*hen that's… a dignified death we have missed.' (Hospital Focus Group 2)
	Post-discharge	***Patient's appearance –*** 'A lady was discharged out of hospital on the Wednesday. I went in on Thursday, and she looked absolutely shocking. I could not believe she'd *been discharged. So, I phoned the doctor. The doctor came out, saw her. And last* week, she was admitted back in.' (Community Focus Group 1)

Source (SEIPS 2.0)	Discharge Phase	Illustrative Quotes
Person - Family	*Pre-discharge*	***Interaction with family –*** 'Have you ever had that feeling… where you know when *that person is going home, and that family do not care one tupans about them;* they've said they're going to look after him, but you know in your gut that they are not going to look after him, and he's g*oing to end up coming back in in a couple of* months. I hate that feeling.' (Hospital Focus Group 2)
	Post-discharge	***Unexpected calls or informal referral from family –*** 'You can anticipate when someone's not ready because … you get repeated phone calls, not necessarily off *them, but you might get it off friends and family just reporting little dribs and* drabs' (Community Focus Group 1)
Person - Staff	*Pre-discharge*	***Decisions made by less experienced staff –*** 'And it's whether or not you trust your staff as well isn't it. That they are making the right decision? Because sometimes, you don't know if the junior doctor is making the right decision.' (Hospital Focus Group 2)
	Post-discharge	***Unexpected contact from other healthcare staff –*** 'They often will ring the GP won't they, and the GP will get in touch with us.' (Community Focus Group 5)

Across the data sources, several combined signals were identified. In the incident report data, a total of eight combined weak signal examples were identified, and in the focus groups, a total of nine were identified. Combined weak signals were identified because the texts or focus group discussion made specific reference to two pieces of information from potentially different sources. Illustrative quotes of several combined weak signal examples have been presented in Table 21. Examples of combined weak signals include discrepancies within documentation (e.g. between patient capability and patient history), between test results and the discharge summary, medication present and medication documented and a combination of factors, including the patient's age, capabilities, medication and the time of discharge. An example of a weak signal as a result of a combination of factors is an elderly patient newly diagnosed as diabetic, prescribed insulin and being discharged at 10:00 in the evening.

Table 21: Illustrative quotes of combination weak signals identified by the hospital and community healthcare staff.

Combination Signals		Illustrative Quotes
Types	**Examples**	
Discrepancies	*Between information received and visual signals*	'I find it's usually when you get there, and they can't stand up. And they supposedly can stand up. That's not a good sign.' (Community Focus Group 6)
	Between what the patient says and visual signals	'They say, "Oh yes, had a shower this morning and got dressed" and you look and think "hmmm. He is still in the gown from the hospital. I don't think so."' (Community Focus Group 6)
	Patient appearance and family description	'if *the patient comes in very unkept or they got pressure sores, but the family have been in quite a lot and saying they are* doing fine.' (Hospital Focus Group 2)
Task and Documentation	*Time of request and missing information*	'So that is a signal for me *when somebody rings without any* information at twenty to three on a Friday afternoon.' (Community Focus Group 4)

One key type of weak signal, often described in incidents in general and leading up to disasters, is that of missed signals. These are predominantly identified retrospectively. A total of 18, nine signals in the incident data and nine in the Ombudsman report, were identified as missed signals or signals not acted upon. Due to the very nature of these types of signals, it is expected that they may be particularly difficult to identify and document. Examples of this included, the patient being discharged despite other healthcare professionals voicing concerns regarding the discharge; family or the patient voicing concerns regarding coping with the discharge; missed information in the patient's file on the vulnerability of the patient and the patient being discharged despite being medically unwell and showing physiological signs and symptoms of illness.

6.4.3.2 Behavioural Elements of Weak Signals

For the behavioural aspects, across all the data sources for numerous examples, it was possible to extract who identified the weak signal, information on the interpretation and whether a response to the weak signal was generated. A summary of how the behavioural elements were identified in the weak signals analysis and examples of the main categories within these elements has been depicted in Figure 30.

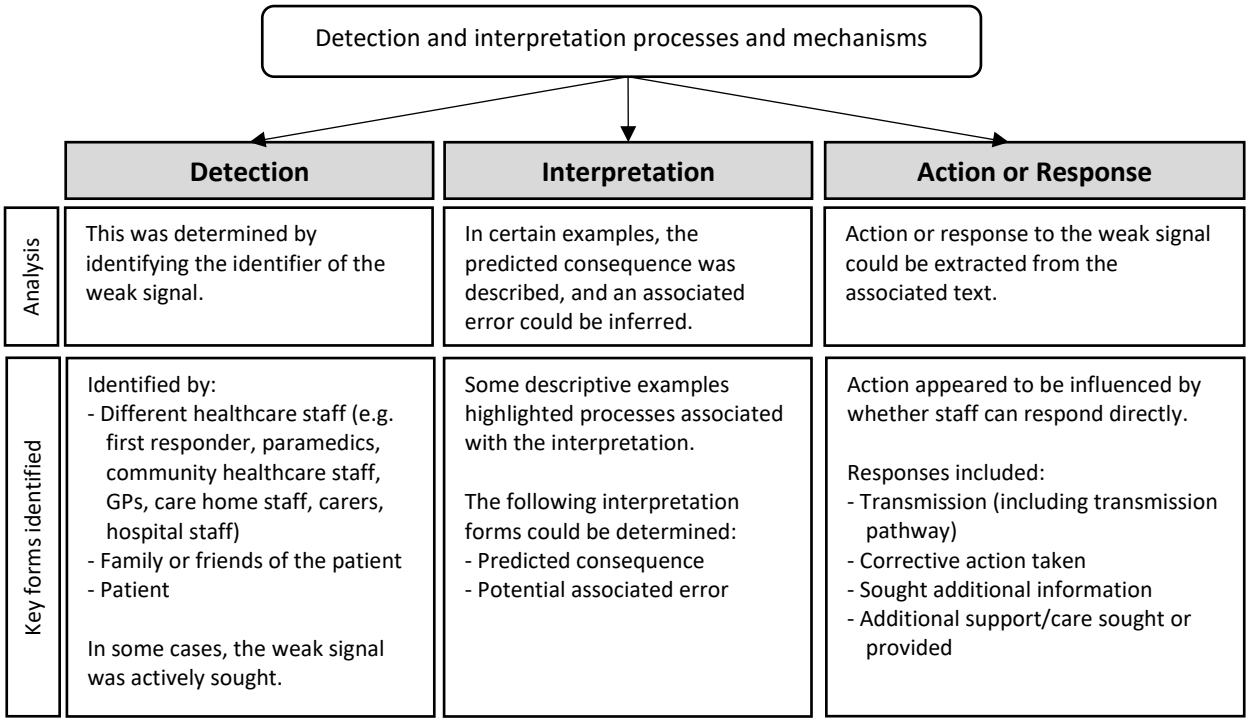


Figure 30: The analysis approach used to determine the behavioural elements of weak signals and the key forms of detection, interpretation and action or response identified across the data sources.

Not all the behavioural elements could be extracted for every case analysed. The Ombudsman report had additional information on the behavioural aspects in all nine cases reported. The community focus groups yielded 13 examples, and the hospital focus groups yielded nine examples that provided additional information relating to the behavioural aspects of weak signals. For 279 of the incident reports that contained weak signals, a minimum of the identifier of the signal could be extracted in each case. The information on the extracted behavioural elements could be categorised into three key elements, namely, that associated with weak signal detection, interpretation and response or action selection. In some examples, from the information included, it was possible to infer the associated error. An example of how the information associated with the weak signals was used to determine the behavioural elements is presented for three examples in Table 22 from the focus group data. Additional examples of weak signals with the behavioural elements extracted have been included in *Appendix C9*.

Table 22: Weal signal examples, their sources and the identification of the behavioural elements associated with the detection, interpretation and action or response selection.

Source	Example and Quotes	Detection, Interpretation and Action or Response
Person – Family	**Unexpected calls –** 'You can anticipate when someone's *not ready because if they have got access to, say, the HUB, you get repeated phone calls, not necessarily off them but you might get it off friends and family just* reporting little dribs and drabs.' (Community Focus Group 1)	**Detected by:** Community staff **Transmission:** Family – Community **Interpretation:** Patient was not ready for discharge **Interpretation – Potential error:** Patient potentially discharged too soon
Person – Staff	**Previous experience with patient (e.g. knowing their capabilities) –** 'Knew she wasn't really managing at *home. Had various conversations with the ward staff to communicate the issues that had been going on at home. Explained that she would need some form of equipment, care package, and everything set up prior to discharge. And she was just sent out without anything that you had recommended. And you have a gut feeling* that she's not really going to manage when she comes *home because you know how they were before* admission. You've recommended what needs to be set *up for a discharge to work well and for her to remain at* home.' (Community Focus Group 4)	**Detected by:** Community staff **Transmission:** Community – Hospital **Action:** Informed hospital of needs **Interpretation – Potential error:** Problem with discharge planning **Interpretation – Predicted consequence:** Patient will not manage at home
Tasks	**Holistic assessment** – 'I think it is making sure; it is being able to spot [it] as clinicians. It's when people aren't managing because it's their health, or people aren't managing because it's the social factors, or they are lonely and that's why they are calling out. And then what we do about that.' (Community Focus Group 1)	**Detected by:** Community staff **Interpretation:** Multiple meanings requiring interpretation **Action:** Seek additional information and provide appropriate response

6.4.3.2.1 Detection

The detection aspect of weak signals was inferred as the description of most cases included the 'contents' of the weak signal, and it mentioned the individual who had identified this information that represented the weak signal. In the majority of the cases, the weak signal was identified by a healthcare professional (e.g. GP, doctor, ambulance crew or non-specified medical staff) in this case study. In the remaining cases, it was the patient, their family or neighbour who identified the weak signals.

6.4.3.2.2 Interpretation

Although exact mechanisms underlying the interpretation of weak signals could not be determined, the focus groups did hint at potential mechanisms. This is highlighted in the following quote.

> ‘Well, it’s intuition isn’t it. You know this isn’t right; you need to do something… You have had a referral for a wound dressing. You walk in and you don’t go in and do that *wound and walk out. You just know. You are looking around and you know something* is not right, and as much as you have had the referral for that task… you restructure your time.’ (Community Focus Group 6)

Some weak signals required different degrees of processing. The interpretation, especially for more complex signals, may require multiple weak signals to be able to generate an indication of the potential outcome. This may result in the generation of combined signals, described earlier in the result section. The means by which community staff may compile numerous weak signals is highlighted in the following quote: ‘*You start to pick up on those little messages* that come through, and you think hang on a second … they probably were not ready to go home.’ (Community Focus Group 1).

Furthermore, weak signals may indicate more than just the content of the information they contain. An example of this was identified in the community focus group; it was the weak signal of a cannula still present in the patient following discharge. As the participant said, ‘If *they have missed something like th*at, that’s pretty obvious. What else have they missed?’ (Community Focus Group 2). An additional example was the weak signal of the state of the pets, which a community healthcare staff member described as being interpreted as ‘you *often get a good idea of how the patient is looking after themselves if the pet is not looked* after’ (Community Focus Group 4).

In some examples, staff stated the predicted consequence of the weak signal. These included that the discharge may be delayed; the discharge would potentially proceed poorly for the staff and the patient; the patient may not receive adequate care; and the patient would need to be readmitted following the discharge. The quote below highlights the predicted consequence and potential action for a weak signal, as described by hospital healthcare staff.

> ‘somebody saying you need to outlie that patient …, and you know in the back of your *head when that patient goes to [there] that they are not going to get the same* treatment as they would here. And it’s knowing when to say I don’t think that’s a good idea.’ (Hospital Focus Group 2)

In numerous examples, it was also possible to infer the potential associated error with the weak signal. An example of this is highlighted in the quote below, which indicated that the potential error was the patient being discharged too soon.

> 'We are told they are medically well, but then you get home and see signs they clearly aren't, and they probably shouldn't have come home as quickly as they have.' (Community Focus Group 2)

6.4.3.2.3 Action and Responses

One key form of response to the weak signal was the transmission of that signal. This may be due to the nature (e.g. subjective – patient symptoms), the location of the weak signal or that the initial identifier of the signal may not have been able to respond directly to the signal. For example, a patient suffering severe pain needs to transmit this signal to a healthcare professional to receive the required support. Certain weak signals require that the information be compiled or collated before the signal is 'created'. An example of this are weak signals found in documentation, such as frequent readmissions and reported incidents involving the patient. Due to the location and source of the weak signals, these need to be identified and transmitted to individuals who can comprehend and react to them. The transmission pathways of signals included patient to community or hospital staff; family to hospital staff; patient to their family, who in turn transmits the weak signal to healthcare staff (e.g. ambulance crew) and hospital staff to other hospital staff or the patient's family.

The weak signal of voiced concerns or unexpected contact from patients and their families may be considered not only as weak signals being transmitted but also as secondary weak signals. These were considered as secondary or indirect weak signals as something caused concern and resulted in healthcare services being contacted. In these cases, the initial triggering element is often not described. This 'contact' was considered a weak signal, providing the healthcare professional with an indication that something may be wrong. For example, that the patient is not coping with being at home.

Additional actions or responses to weak signals identified by community healthcare staff included seeking additional information and support, ordering same-day equipment and informing the hospital of patient needs to ensure that the patient is able to remain at home.

Actions or responses to weak signals identified by hospital healthcare staff included further assessments, adjusting team expectations, and pre-emptively advising the patient's family or other staff to enhance patient safety. Weak signals may also result in staff doubting the decisions made by other staff.

Community healthcare staff felt that generally using weak signals formed part of their everyday work. This is highlighted by the following quote.

> 'I think it's part of your job… as it happens all the time, so you walk in and think "oh gosh" and you come out with a list of things to do, but that's part of what we have to do.' (Community Focus Group 5)

Furthermore, the community healthcare staff that participated in this study had developed means of identifying and responding to weak signals. These include specific roles, such as the responder role and the 48-hour discharge coordinator, who function as a safety net. These roles allow staff to be able to actively seek weak signals by following up with recently discharged patients to ensure they are safe, as well as providing flexibility, and enabling staff to respond to the situations associated with weak signals.

> 'We try and prepare for these things by having the responder person don't we, within *the team. We know these things happen, and we know that people slip through. And so, I guess this is how we have reacted to it as community services by trying to have* a person available that could respond.' (Community Focus Group 1)

The way hospital staff may use weak signals is highlighted in the quote below.

> 'If I get a hunch, and I think it's a big hunch, at the back of my mind I have always got that, like you said, plan B. I know what I need to do. If they turn around and say it's *end of life, I have already thought about where can they go, what can they do, what* area do they live in, what care is out there...' (Hospital Focus Group 2)

The behavioural elements were explored in more detail in the validation component of this case study.

6.4.3.3 Verification and Validation of the Weak Signals Results and Practical Implications

The validation component of this case study was conducted with community healthcare staff that participated in the post-discharge phase of this study. Through the use of interviews with 10 staff that participated in the focus groups held with community healthcare staff involved

in the discharge process, the identified weak signals were verified and validated, and detailed examples of the behavioural elements were explored. Additionally, the barriers associated with weak signals and means of implementing weak signals were investigated during these interviews.

Each participant provided several examples of weak signals they had experienced for each category explored during the interview. No new examples of weak signals emerged during the interviews that had not already been identified in the other data sources and additionally no new elements associated with weak signals were identified. The interviews, however, provided an opportunity to explore these individual weak signals in more detail than was possible during the focus groups. The results from the interviews provided information on the behavioural elements associated with weak signals for the specific examples described by the interviewees and included how the weak signal was identified, what the weak signal indicates, the reaction to the weak signal and the prompt for the action. A summary of the behavioural elements that emerged from the interviews for the signal examples originating from tools and tasks has been provided in Table 23. A summary of the results for the remaining source categories has been included in *Appendix C10*.

Table 23: Behavioural elements of signals for the examples originating from tools and tasks.

Elements	**Tools and Task**
Examples	Concerns identified due to the patient's medication and diagnosis, review of documentation, lack of information provided, and mental health concerns.
Weak signal identification means	Signals were identified due to previous experience with the patient, review of the patient's history, upon initial visit and as a result of an incident.
Information provided by the weak signal	Indicating staff safety risks, problems with the discharge process and planned care, and patient and their family's inability to cope with the discharge.
Reaction to the weak signal	Seeking additional information from other healthcare providers, providing additional information to the patient and their family so they could make an informed decision, modifying staff schedules and working practices, and communicating with the patient and their family.
Prompt for reaction	Identified risk to the patient and staff, as well as a result of a duty of care.

Although no new examples of weak signals emerged, some weak signals were expanded on and described in greater detail. An example of this was the weak signal of information in the patient’s history that may pose a potential risk to staff safety. The participant that described

this example included the changes to work that were made as a result of this weak signal, which is described in the quote below.

> 'We had a gentleman discharged from hospital. The referral came through just for us *to go in and do insulin*... because they hadn't had time at the hospital to teach him to *do it himself. So when I looked into it and reviewed the referral and then reviewed his GP records, it actually had quite an extensive mental health history with problems with drugs, alcohol, being in and out of prison for being violent. So obviously none of that had come through on the referral from the hospital, it was only through review* of the documentation that we managed to pick that up... The first thing I did I actually *contacted the GP practice, and spoke to the GP who knows him, to get a bit more information to see what the risk was to my staff, if there was a risk because obviously* just because he has got all of that, it doesn't mean he's necessarily a risk now. I spoke *to the GP at leng*th about that... The staff went in initially in twos so they weren't on *their own and we put a system in place where the staff going in would ring somebody before they went in and when they came out, so that we could track better where* they were.' (Participant 5)

The above example highlights the weak signal (a history of mental health and behaviour concerns), the interpretation of the weak signal (this may be reason for concern or may no longer be relevant), the response to the weak signal (contacting the GP for additional information) and the changes to the work system as a result of verifying the weak signal (scheduling of staff and implementation of safety measures).

Weak signals associated with 'hunches' or unspecified feelings staff got that something was wrong was also explored during the interviews using the same interview guide as that used to steer the discussion on the other categories of weak signals verified. Staff were asked to consider a time where they experienced a hunch and then describe what may have generated it. As a result of this prompt, participants described other weak signals from known source categories that had already been identified in the other data sources in this case study. Examples of these included seeing the change in a more junior colleague's body language indicating stress, the patient or their family member's body language, safeguarding concerns identified during the initial visit, the visual appearance of a patient's wound, the appearance of the home environment that included bags of medication and unpacked clothing bags from

the hospital visit, and the patient appearing in a worse condition than prior to being admitted to hospital. The results from the interviews furthermore verified that the weak signals associated with the discharge process indicated problems with specific task elements, the process, staff wellbeing and safety, in addition to patient safety and health concerns.

The second component of the interviews explored means of promoting weak signal use in everyday work associated with the discharge process and focused on identifying means for enhancing the detection of weak signals, detection barriers and the barriers associated with acting in response to weak signals associated with the discharge process. A summary of these results has been included in Table 24. As already highlighted earlier in this chapter, one participant reiterated that community staff use weak signals as part of their daily work in a more informal manner. One of the reasons staff felt they had developed this capability is described by the following excerpt:

> 'In the community setting, things happen, changes happen all the time, so I mean... *you obviously have that experience because you are dealing with these situations* every day because you don't know what you are going to walk into' (Participant 6).

Table 24: A summary of the identified means for enhancing the detection of weak signals, the barriers associated with detection and the barriers associated with acting in response to weak signals.

Utilising Signals to Enhance Task Performance and Safety	
Means for detecting and identifying weak signals during the discharge process	• **Communication and Information elements:** cross-system collaboration, specific information on the patient's capabilities regarding medication, descriptive summaries in referrals to highlight concerns, access to unified patient information systems • **Training opportunities:** handovers to provide learning opportunities for less experienced staff, apprenticeships, opportunities for reflection, clinical supervision, review and discussion of incidents • **Organisation of work elements:** good management support and teamwork, adopting a holistic approach, using the first visit an assessment opportunity, and roles that function as a safety net (e.g. community discharge coordinator)
Barriers to identifying weak signals	• **Individual barriers:** a lack of knowledge, being too task-orientated, a lack of experience • **Organisation of work barriers:** time constraints, work pressures and the role 'not allowing you to think outside the box' • **Task barriers:** limited information provided in referrals, poor communication with the family
Barriers to responding to weak signals	• **Individual barriers:** complacency, insufficient knowledge and experience, lack of awareness • **Organisation of work barriers:** time constraints, management pressures and as a result of not having a supportive team Another barrier to responding to a weak signal was the patient resisting and refusing assistance, as if they have capacity, there is not much staff can do.

The strategies or means staff employ that may aid the detection and identification of weak signals included communication and information elements, training opportunities and organisation of work elements. Examples included providing specific information on the patient's capabilities regarding medication, cross-system collaboration, handovers to provide learning opportunities for less experienced staff, good management support and teamwork, and adopting a holistic approach. Additional examples have been included in Table 24. An example given that was a formal work system feature that is no longer available to staff in the areas that participated in this case study was the community-based discharge coordinator. The following quote highlights how this role assisted with the detection of weak signals:

> 'We used to have a discharge coordinator actually based in our office but they *did* away with the role… Anyone discharged from hospital, this person would ring up and *you know, ask a few questions to see if they needed to be assessed by a nurse. And if there were sort of alarm bells that rang, then this person would go out assess them* for whatever they need. But this role was disbanded about two years ago.' (Participant 10)

Barriers associated with identifying weak signals included time constraints, work pressures, a lack of knowledge, being too task-orientated, limited information provided in referrals, a lack of experience, poor communication with the family and the role not allowing you to think outside the box. An example of this last barrier is highlighted in the following quote.

> 'they can't really think out of the b*ox because they not really allowed to because they are only a band 3. So, I think sometimes that makes it difficult for them to pick up on* stuff like that because they are just following a system all the time' (Participant 9)

Regarding the barriers associated with responding to an identified weak signal, experienced staff felt that if a weak signal was identified, they would be required to act as part of their duty of care. However, when prompted further, the barriers staff identified included insufficient knowledge and experience, complacency, time constraints, lack of awareness, management pressures and not having a supportive team. An unusual barrier to responding to a weak signal identified included the patient resisting and refusing assistance, as if the patient has capacity to make these decisions, there was not much staff can do. However, the

participant that described this, did specify prior to taking no action all other options needed to be explored.

6.5 Discussion

This second case study in this series on weak signals in healthcare identified the work system context in which weak signals may occur, the barriers and facilitators in these work systems and the weak signals that may indicate that something may be going wrong for the hospital discharge process. This case study individually analysed an Ombudsman report, observation, focus group and incident report data, and then the results were combined at the interpretive stage of the analysis. The weak signal results were then verified and validated in a series of interviews approximately a year and half later. The work system, facilitators, barriers and weak signals will be discussed first relative to current literature. Following this, the results associated with weak signals will be discussed, including how the results were used to expand and modify the weak signals framework to generate a third version of this framework.

6.5.1 Discharge Process: The Work System, Barriers, Facilitators and Weak Signals

Healthcare systems have evolved into systems of systems and to improve safety and quality of care, a systems approach is needed (Carayon et al., 2018; Hofoss & Deilkås, 2008). This is specifically highlighted in this case study as although both subsystems included in this study are involved in the discharge process within one organisation, namely, the NHS, and are dependent on each other to deliver care requirements, they function temporally and spatially apart. Furthermore, the linkages between these two subsystems are limited, as described in the work system configurations and in Figure 26. The barriers and facilitators described in the results further highlight how the discharge process is a dynamic process that involves a 'bilateral interdependence' (Bisantz et al., 2012) among hospital and community healthcare staff. Moreover, capturing these interorganisational system interactions and the linking of different system elements is essential for understanding safety in these complex systems (Waterson et al., 2015).

The patient and their family are usually the only common physical link between subsystems (Carayon et al., 2020) and therefore play an important role (Bisantz et al., 2012). The role the

patient and their family can play in the barriers and facilitators is visible in numerous subthemes presented in the results. The facilitator of good family communication and involvement is linked to the barrier of families' expectations and lack of support, which were both identified for the hospital and community healthcare subsystems. The importance of the role of the patient and their family in this work system is also echoed in the weak signals results as not only did numerous signals originate from the patient and their family, but they also served to transmit these signals to healthcare staff. The patient and their family as a potential resource has been highlighted by the WHO (2007) as patients may have knowledge about their condition that healthcare staff may need to know (Howard-Anderson, Busuttil, Lonowski, Vangala, & Afsar-Manesh, 2016). In addition, the patient and their family may be able to provide information that could support the discharge process, which is currently being identified and used by staff informally in the form of weak signals.

The degree of separation of these two subsystems was also the cause for several other barriers identified in this study. One such barrier that is also present across numerous other healthcare processes and extensively cited in the literature is that of communication problems and missing information (Andrews et al., 1997; Forster et al., 2003; Werner, Malkana, Gurses, Leff, & Arbaje, 2017; Wong et al., 2011). This barrier has been associated with poor-quality care and high costs (Naylor, 2000). An additional barrier that is associated with information transfer problems is that of referral problems. This is both a pre-requisite task, an information-transferring task and a professional process element, and it was one of the most mentioned themes in the results from the community focus groups and incident reports. This is also reflected as a key problem with care coordination in the literature (Bodenheimer, 2008). This theme of communication and missing information was also perceived by staff as forming numerous weak signals. Some of these signals were very literal and included staff, the patient or their family voicing concerns, while others were more abstract in that missing information was indicative of potential problems. The transfer of information also provided the material that may contain weak signals (e.g. contradictions in the documentation).

The barriers identified suggest that these not only cause delays to the process, as revealed by the observation data, but also cause numerous incidents that community healthcare staff

witness, as reported by the results from the incident report data. The incident report data suggests that certain incidents occur as a result of particular pre-discharge tasks not being completed prior to discharging the patient, while for hospital staff, these are often tasks that may result in the discharge being delayed. For hospital staff, numerous barriers associated with hospital discharge-related tasks were also weak signals indicating that the discharge may be delayed or difficult. This highlights the point made by Hiltunen (2010) that weak signals may be signs of emerging issues or are rather emerging issues themselves. The weak signal of waiting on pre-discharge requisite tasks, may be indicative of that being a barrier, or potentially the whole discharge being more difficult due to the nature of the patient case.

Some barriers, even though they originate in one system, have effects that present in the other system. Examples of these include problems associated with referrals, insufficient equipment, medical supplies, and medications sent with the patient. These barriers, which present in the community healthcare subsystem, originate in the hospital subsystem when problems are encountered with completing the pre-discharge tasks (Figure 26, work system component Ta2). Similarly, weak signals may present in the one subsystem and require transfer to the other subsystem to result in action. An example of this would be if community staff knew some patient-specific information that would be relevant for discharge planning, which occurs in the hospital subsystem. This information would need to be transferred so that it could be used for the task of discharge planning. The results indicate that this information is not often readily transferred across these subsystems as community staff have developed facilitators to mitigate some of the effects of these types of barriers, for example by using alternative resources to provide same-day delivery of equipment and care. However, this is associated with an additional cost to the organisation.

Four main themes associated with facilitators were identified, of which several facilitate the use of weak signals and are related to supplemental interpersonal approaches, which allow for the workaround of operational barriers (Hilligoss & Vogus, 2015). Examples of these include information-collection methods; communication, which may yield additional signals, and the organisation of work, which may assist in responding to weak signals. An example of how the organisation of work may assist in responding to weak signals is the ability to be flexible and having roles, such as the discharge coordinator, that could act as a safety net and

potentially assist in identifying weak signals. The focus groups also highlighted that adopting a multidisciplinary team approach was a facilitator, and literature suggests that this approach can improve safety (Blegen et al., 2010) and facilitate communication (Anthony & Hudson-Barr, 1998). This may be relevant for weak signals as a key action may be to communicate the weak signal across the team to be able generate an appropriate response.

As weak signals may often require a translation of tacit knowledge to explicit knowledge, it is essential to understand the role of enablers with the regards on how the information may be transmitted and disseminated (Kaivo-oja, 2012). This highlights why it is essential to explore barriers and facilitators of behavioural elements of weak signals, which was explored during the interviews in the verification and validation component of this case study. The interviews explored means of promoting weak signal use in everyday work associated with the discharge process by discussing with staff the means of detecting and identifying weak signals and the barriers associated with the identification and responding to weak signals. The means for detecting and identifying weak signals as well as the barriers to identifying weak signals provided the influencing factors that affect the identification and interpretation elements of weak signals. The results also provided insight into why a signal may be missed or not acted upon (including why a signal may not be transmitted), for example being too task-orientated, time constraints and due too poor information.

6.5.2 The Weak Signals in Healthcare Framework (Version 3)

Numerous examples of weak signals were collected in this case study, that originated from a variety of sources. With reference to the literature on weak signals associated with hospital discharge, this case study identified all of the weak signals compiled by Katikireddi and Cloud (2008), which they referred to as known 'red-flag' warnings for patients at high risk of readmission. This case study compiled additional weak signals for a variety of sources and identified that the signals associated with the discharge process indicated problems not only with patient safety and patient health concerns, but also with staff wellbeing and safety, specific task elements and the general functioning of the discharge process. The validation component of this case study confirmed the weak signals identified and explored means of enhancing weak signal use through the identification of facilitators and barriers associated with the identification of and response to weak signals. Although no new information on

signals and the underlying structural and behavioural elements was obtained in the validation component, it did verify the results from this case study. For the examples discussed in the interviews, all the structural elements of the weak signals in healthcare framework could be applied and the interview approach allowed for the determination of more detailed descriptions of the behavioural elements for specific examples of weak signals.

This case study provided more in-depth information on weak signals than the first case study on patient handling. This may be as a result of the multiple data sources, increased variety of data types utilised and the increased sample size in this case study. Although this case study contributed and confirmed structural elements, including the source and form, the main contribution of knowledge this case study provides to weak signal information is information on the behavioural aspects. The behavioural aspects identified included the identifier of the signal, a response to the signal, whether it was transmitted, the receiver of the transmitted signal, whether the signal was missed, and whether it was actively sought. In addition, in some instances, the predicted consequence and error associated with the weak signal could be determined. The validation component also identified barriers and facilitators for using weak signals in this healthcare context.

Based on the key behavioural aspects identified in these results, of the paradigms described in chapter three, the theory that best supports these results and provides the most practical basis is that of situation awareness. Situation awareness, as defined by Endsley (1988, p. 97), is 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future'. The Aircrew Decision Model by Endsley (1988) provides a structure that supports most of the behavioural aspects identified in the results. It was not possible to determine the means of situation awareness Level 1 from the data, but the data did include, in most cases, who identified the signal, so Level 1 situation awareness could be implied. In some examples, participants described Level 2 situation awareness, which is the comprehension of information and requires the combination, interpretation, storage and retention of information identified in the first level (Endsley, 2000). An example of this is highlighted in the quote below:

> ‘On one breath they are saying they are mobile, and on the other page they are saying *they need bedrails. So, you think hang on a minute that ca*n’t be right. It just doesn’t quite add up, so that often gives you a sign to ask further questions.’ (Community Focus Group 4*)*

The third and final level of situation awareness is associated with projection to predict future events (Endsley, 2000). For this level, there were also examples where staff indicated what the predicted consequence would be of what the weak signal was indicating. This is highlighted by the exemplar quote below.

> ‘Had various conversations with the ward staff to communicate the issues that had *been* going on at home, explained that she would need … everything set up prior to *discharge. And she was just sent out without anything that you had recommended.* And you have a gut feeling that she’s not really going to manage when she comes *home because you k*now how they were before admission.’ (Community Focus Group 4)

Although the results from this chapter and the previous case study on patient handling hinted at several other theories to describe the mechanisms underlying the behavioural aspects of weak signals (e.g. intuition, RPD model), the majority of the results support the paradigm of situation awareness. As a result of this, the behavioural element of the framework was refined and expanded to incorporate the three levels of situation awareness, as described in the Aircrew Decision Model by Endsley (1988). This paradigm not only supported the majority of the results, and therefore was anticipated to be applicable to the majority of the situations analysed, but also provided the theoretical basis from which practical implications could be drawn. For example, if one knows who is most likely to identify a signal, support tools and interventions can be developed with this stakeholder in mind. The other paradigms (e.g. intuition, NDM), as described in Chapter 3, may provide theories for the behavioural elements of weak signals in unique and specific contexts.

Based on the results from this case study, the structural elements were modified and the behaviour elements were expanded to incorporate the three levels of situation awareness, as described in the Aircrew Decision Model by Endsley (1988). The revised framework is depicted in Figure 31. This version of the framework still contained the elements from the

first two versions, but it has been expanded to provide greater detail of how signals may be detected, interpreted and processed.

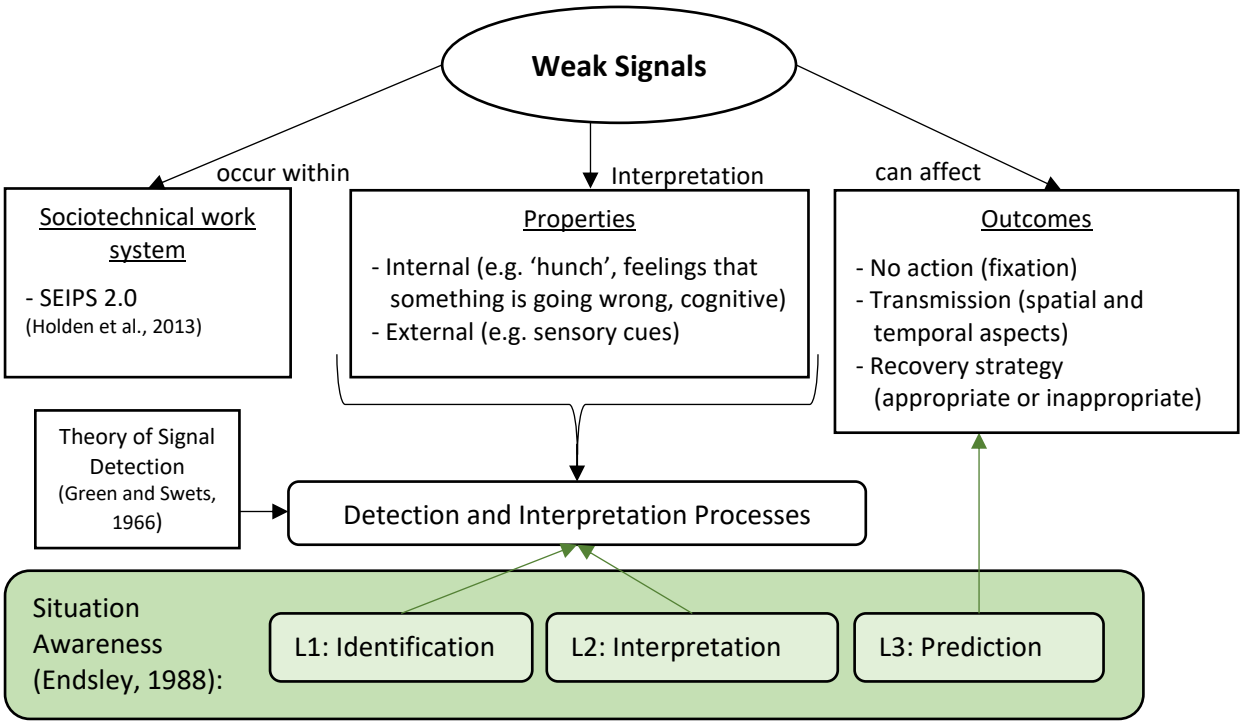


Figure 31: The weak signals in healthcare framework (Version 3).

6.5.3 Limitations

To enhance the strength and credibility of this case study, one needs to acknowledge the limitations that are associated with this research and the methods applied (Ioannidis, 2007). The limitations of this study included those associated with field-based research, the objectivity of qualitative research and self-reported data, the use of reported incidents as a data source, the sample size and the potential effect of bias, specifically for the validation component of this case study. Attempts were made to mitigate and reduce these limitations as much as possible, but some of these were unavoidable.

With field-based research, there is a lack of control of extraneous variables and an effect of the presence of the researcher, especially in observations. However, as healthcare processes need to be understood in the environment in which they occur, this was unavoidable. Similarly, regarding the limitations of the observation phase, the focus groups had the limitation of the effect of the presence of the researcher on the participants' responses.

Attempts were made to mitigate this by ensuring the participants prior to starting the focus groups that confidentiality would be maintained. The limitation associated with qualitative research, seen by some, may include the objectivity of the data; however, these methods provide in-depth information on behaviour in context (Cronbach, 1975; Jick, 1979), which was essential to address the aims of this thesis. Limitations associated with analysing incident reports include the effect of the structure of the form used to capture the incident details, they may not be representative of the events occurring in the system, they cannot be considered as a 'true' record of adverse events (Andrews et al., 1997; Boxwala et al., 2004) and may be incomplete and selective (Brown et al., 2008c). However, these provide a form of insight into incidents that may otherwise not be captured (Boxwala et al., 2004) and information that may be useful for understanding situation awareness (Jones & Endsley, 1996). Several of the above limitations were addressed in that data was collected from numerous independent sources, and through triangulation, the rigor and validity of the results were enhanced (Jick, 1979).

The limitation of the sample size specifically referred to the focus groups with hospital staff and the interviews of the validation component. The lower sample size in the hospital group compared to the community group was due to the population size of hospital staff that met the criteria being smaller than that of the community staff involved. It was not possible to conduct additional focus groups with hospital staff. A strength of the focus group design was that it was based on recommendations from literature. This study followed the recommendations of a minimum of three focus groups, which allows for the most prevalent themes to be identified (Guest, Namey, & McKenna, 2017) and two to five groups per category of participants (Carlsen & Glenton, 2011) for the community focus groups. Two focus groups were held with the different categories, namely, not only with the hospital and community categories but also within the community healthcare group. Two focus groups were conducted with each directorate involved in this post-discharge phase of this case study. Although the number of focus groups was pre-determined and influenced by staff availability, data saturation was reached across both categories of focus groups (hospital and community healthcare staff). For the validation component, although the sample size of the interviews was limited to ten participants, literature suggests that five to six interviews are sufficient to identify most themes (Francis et al., 2010; Morgan, Fischoff, Bostom, & Atman, 2002).

Furthermore, although the interviews provided more detailed examples, the main purpose was to verify the weak signal results from the other data sources, and as no new categories or elements on weak signals were identified, one can therefore assume that 'saturation' was reached with the 10 participants. A strength of this component was the use of interviews, which allowed staff to describe weak signals in greater detail and provided the participants the opportunity to position their responses within the context in which they felt they occurred (Gratton & Jones, 2004). Furthermore, the reliability of the interview data was enhanced through the application of a standardised interview schedule and recording the interview for transcription (Gratton & Jones, 2004).

An additional limitation associated with only the validation component of this case study was the potential effect of bias by providing the interviewees with generic examples prior to asking them to provide a specific one of their own. This may have restricted the types of examples they provided; however it was felt necessary as the concept of weak signals in healthcare has a vague element to it and several participants required additional clarification on what was being asked of them. To mitigate the influence of providing this prompt, the examples were standardised across all interviews and kept as generic as possible.

A general limitation of this study was that the coded data and the identified themes were done by one person and were therefore limited to one analysis perspective. This was as a result of the nature of a doctoral study. This did have the advantage of providing consistency across the methods and case studies so that only one external perspective (Stanton, Baber, & Young, 2005) had an effect on the results. Attempts to mitigate this limitation was that the results and analysis were discussed with the supervisors and were presented to both a range of academic and clinical audiences between 2016 and 2017 on eleven occurrences. This allowed for the opportunity of feedback and comments from both academics and clinical staff (Fereday & Muir-Cochrane, 2006).

The limitations associated with the results were mitigated to an extent in that across this case study, data was collected from numerous independent sources, namely, through the analysis of incident reports, observation sessions within the hospital environment and focus groups with staff both from the community and hospital. Through the triangulation of the results

obtained from different data sources, the validity of the results, even though predominantly qualitative in nature, were enhanced.

6.6 Conclusion

This case study explored the views of different healthcare staff involved in the discharge process regarding work system factors, barriers, facilitators and weak signals. The aims addressed in this case study included exploring the context from which weak signals may emerge, applying the second version of the weak signals in healthcare framework to identify weak signals and their relevant elements for work associated with the discharge and further developing the weak signals in healthcare framework and support for the application of the framework.

A mixed methods approach was applied utilising numerous different data sources, which yielded a large number of weak signal examples (a total of 435), that could be categorised into 46 category types based on the source. The signals described in this case study indicated problems associated not only with patient safety and patient health concerns, but also with staff wellbeing and safety, specific task elements and the general functioning of the discharge process. Through the application of the weak signals in healthcare framework in this case study, an analysis approach to support the use of the framework was developed. Additionally, this case study created a work system configuration (using the method described by Holden et al., 2013) for the hospital discharge process and determined the barriers and facilitators associated with this process. This provided additional depth for exploring the role of weak signals within the work environment, how they may be associated with system elements, barriers and facilitators as well as considering how hospital and community healthcare staff's perspectives may differ for the same healthcare process.

This case study not only developed an analysis method for applying the weak signals in healthcare framework, but the data also assisted in expanding the behavioural elements of the framework. The results from this case study assisted in refining the structural elements associated with the weak signals in healthcare framework and expanded on the behavioural elements of the framework. The behavioural element of the framework was refined and

expanded to incorporate the three levels of situation awareness, as described in the Aircrew Decision Model by Endsley (1988). This paradigm not only supported the majority of the results, and therefore was anticipated to be applicable to the majority of the situations analysed, but also provided the theoretical basis from which practical implications could be drawn.

Furthermore, through the use of interviews with 10 staff that participated in the focus groups held with community healthcare staff involved in the discharge process, the weak signals identified in the other data sources were verified and detailed examples of the behavioural elements were explored. The interviews also explored means of promoting weak signal use in everyday work by discussing with staff the means of detecting and identifying weak signals and the barriers associated with the identification and generation of a response to weak signals. These results also provided insight into why a weak signal may be missed or not acted upon, including why a signal may not be transmitted. The aim of the next case study was to apply Version 3 of the weak signals in a healthcare framework to a different healthcare context.

Chapter 7: Case Study 3 – A Systems Perspective of Sepsis Cases

This chapter explores the work system and weak signals for a different healthcare aspect, namely the identification and treatment of sepsis. The third version of the weak signals in healthcare framework was applied. This chapter consists of a brief description of the context based on literature, followed by the aims and objectives, method and results. The findings of this case study are subsequently discussed with regards to literature available on this healthcare context and the potential practical implications of the findings and the application of the weak signals in healthcare framework (Version 3) is evaluated.

7.1 The Context – Sepsis and Treating Sepsis

The aim of this section is to provide a brief description of what sepsis is, how it presents and how it is treated to provide the context for how human factors may support work associated with this clinical syndrome. This is necessary as the difficulties in identifying, diagnosing, and treating sepsis partially arise from the definition and pathology of sepsis, which in turn will affect work associated with treating sepsis.

Sepsis is a complex clinical syndrome (Kent & Fields, 2012; Namas et al., 2012) that is a major healthcare issue worldwide (Angus et al., 2001; Lang & Tasker, 2017; Namas et al., 2012; Vincent et al., 2006) with a mortality rate of 25% to 50% (Chege & Cronin, 2007; Wolf, 2012). The mortality rate is so high despite medication being available for the treatment of sepsis, as it has been found that signs and symptoms are often unrecognised and unmanaged (Chege & Cronin, 2007). The most recent view of the syndrome is that it is a complex pathophysiological disorder (Carré & Singer, 2008) characterised by a multisystem inflammatory response to a pathogenic attack (Namas et al., 2012) or infection (Carré & Singer, 2008).

Despite the increase in recent research, sepsis is not a new clinical condition, with the word and a similar underlying meaning having been used as early as c. 700 BCE (Geroulanos & Douka, 2006). Despite the age of this term and condition, there is still a degree of confusion

regarding the definition (Chege & Cronin, 2007). The first consensus on a definition for sepsis was only achieved in 1991 (American College of Chest Physicians/Society of Critical Care Medicine, 1992). However, the definition has often been over-simplified (Annane, Bellissant, & Cavaillon, 2005) and resultingly has been updated several times and the list of symptoms has been modified (Gyawali, Ramakrishna, & Dhamoon, 2019). There has been a drive to develop a more functional definition and as a result a new definition has been created through consensus three times over the last 26 years (Gyawali et al., 2019). The definition of sepsis in 2007 was 'a known or suspected infection accompanied by evidence of two or more of the Systematic Inflammatory Response Syndrome (SIRS) criteria' (Chege & Cronin, 2007, p. 158). More recently, sepsis has been defined as a 'life-threatening organ dysfunction caused by a dysregulated host response to infection' (Singer et al., 2016, p. 804). The focus of the definition has moved away from SIRS criteria, which are certain physiological measurements that indicate inflammation, as the specificity and sensitivity of these criteria were viewed as inadequate and unhelpful (Singer et al., 2016). These frequent changes in definitions and diagnostic criteria highlight how work associated with this clinical syndrome may be challenging.

Before 2016, it was advised to use the SIRS criteria to identify sepsis, whereas more recently it has been suggested that to identify sepsis there needs to be a suspected or documented infection and an sepsis-related organ failure assessment (SOFA) score greater than or equal to two (Gyawali et al., 2019). The SOFA score is determined through physiological variables relating to respiration, coagulation, liver, cardiovascular, central nervous system and renal function (Vincent et al., 1996). In addition to this, a quicker version of the SOFA score (qSOFA), that does not require laboratory tests, has been developed to assist with bedside screening of patients likely to have sepsis and poor outcomes (Singer et al., 2016). The qSOFA criteria include respiratory rate of 22/min or greater, altered mental activity, and systolic blood pressure of 100 mm Hg or less (Singer et al., 2016). Furthermore the course of sepsis is highly variable and influenced by factors such as age and pre-existing morbidities (Carré & Singer, 2008), which contribute to the difficulty in the quick diagnosis of the syndrome.

Due to the complexity of sepsis and despite individual mechanisms of the syndrome having been extensively studied, challenges in diagnosing and treating it remain (Kent & Fields, 2012;

Namas et al., 2012). One effective approach for the treatment of sepsis that has been identified includes providing aggressive treatment early, particularly within the first hour, and can influence severity, survival, morbidity and mortality (Chege & Cronin, 2007; Jones, Focht, Horton, & Kline, 2007). Despite evidence of the time-critical nature of sepsis, delays in diagnosing and treating of sepsis often occur. Aspects that cause delays in the identification and treatment of this syndrome include delays in diagnosis, lack of availability of beds and delays in nursing care (Burney et al., 2012). These can be considered system issues and therefore may represent areas where human factors can provide input and enhance work associated with these elements that affect the treatment and diagnosis process. Current interventions aimed at identifying and treating sepsis include clinical guidelines for the treatment and management of sepsis (Chege & Cronin, 2007; Kent & Fields, 2012) as well as increasing awareness regarding the signs and symptoms of sepsis through campaigns, for example the Surviving sepsis campaign (Chege & Cronin, 2007).

To better understand and develop treatments for sepsis, a systems approach has been recently adopted to expand the biological understanding of the mechanisms of sepsis (Namas et al., 2012). Furthermore, it has been suggested that to bring about successful change with regards to the treatment of sepsis, a system-wide approach needs to be developed that includes all healthcare staff, and even family and carers that come in contact with the patient (Lang & Tasker, 2017). Examples of current system approaches for the identification and triage of sepsis include generating public awareness at the public health and prehospital level done by the UK Sepsis Trust, developing support materials for professionals at the primary healthcare level, and the development of the Manchester Triage system or 'NICE Red Traffic Lights' in acutely ill children at the hospital or emergency department level (Lang & Tasker, 2017).

From a HFE perspective, a systems approach has not only been used to enhance the understanding of healthcare processes to improve patient safety (Gurses et al., 2012; Rivera, Karsh, & Beasley, 2008) but also to understand infection outbreaks within acute care settings to identify the contributing factors of the outbreaks from a larger system's perspective (Waterson, 2009). Similarly, a systems approach from a HFE perspective may offer a better understanding of the work processes and work systems wherein sepsis is diagnosed and

treated and may aid with the development of potential advancements so the system functions more efficiently and identification of sepsis can occur quicker. Recently there has been recognition that human factors could contribute to a better understanding of the treatment of sepsis, however these have been limited to a task level and do not consider the wider system perspective. Examples include the use of task analysis to understand the barriers associated with the treatment of sepsis for patients in the accident and emergency (A&E) department (Pinnington, Atterton, & Ingleby, 2016), evaluation of visual displays of sepsis scoring systems (Schubel et al., 2020; Weldon et al., 2018) and the usability of sepsis alerts (Rincon, Manos, & Pierce, 2017). There appears to be a gap in the literature of what human factors can offer by adopting a broader systems perspective for the treatment of sepsis and how the cross-system interactions can be supported so the treatment of the syndrome occurs within the prescribed time constraints.

7.2 Aims and Objectives

The aims of this case study were to explore the work system context from which weak signals associated with the identification and treatment of sepsis emerge and apply the weak signals in healthcare framework (version 3) to the context of work associated with the identification and treatment of sepsis. To achieve this first aim, namely, to explore the context from which weak signals may emerge, this case study will address the following objectives:

- Explore the system factors and work associated with the identification and treatment of sepsis that may affect weak signals through a systems analysis of documents on cases and the treatment of sepsis. This included the generation of a work system configuration for work associated with the identification and treatment of sepsis. The purpose of this was to highlight system considerations for the treatment of sepsis that may result in barriers or potentially facilitate the treatment of sepsis and provide the context wherein weak signals occur.
- Explore the different system factors, facilitators and barriers that contributed to the survivor and tribute stories that may affect weak signals.

To achieve this second aim, namely, to apply and expand the weak signals in healthcare framework and analysis approach, this case study will address the following objectives:

- Determine the weak signals associated with work pertaining to the identification and treatment of sepsis. This included identifying the source, type and form of the weak signal.
- Extract from the data the rationalisations of why the weak signal was not acted upon, which underpins behavioural elements of the framework.
- Extract how individuals in the narratives came in contact and interact with weak signals. This refers to the behaviour elements of the framework.
- Expand the framework and analysis approach to include newly identified elements from the results of this case study, specifically the element of rationalisations.

7.3 Methods

7.3.1 Research Design

To address the aims of this case study, an exploratory qualitative research design was adopted, depicted in Figure 32. As sepsis is a medical condition that can occur in any population type and therefore will present in numerous healthcare settings, the method adopted for this case study was that of document analysis. The advantages of this are that it is an efficient method and many documents are readily available (Bowen, 2009) which allowed for the accumulation of a larger sample size over a shorter time period. Documents that provided a large sample size and detailed processes associated with sepsis were used to generate a work system configuration for the identification and treatment of sepsis and for the application of the third version of the weak signals in healthcare framework.

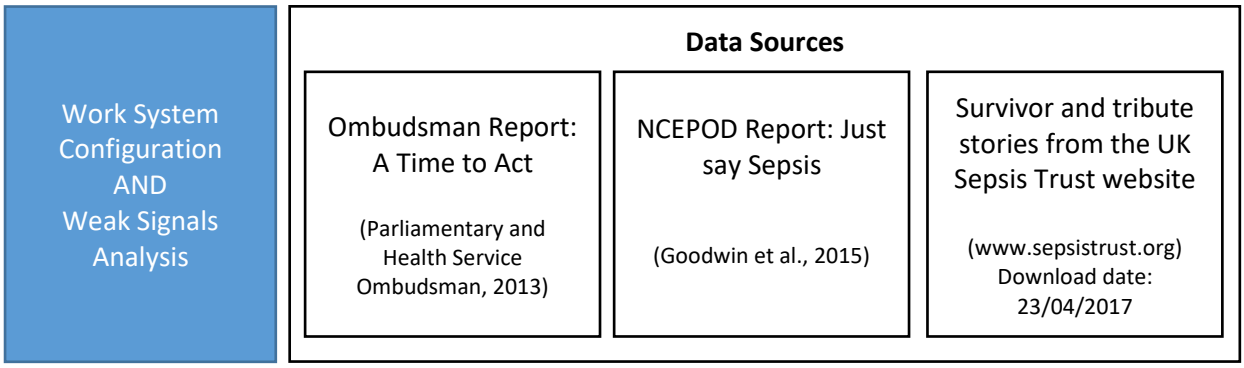


Figure 32: An overview of the approach adopted in the case study on sepsis including the different analysis phases and data sources utilized.

7.3.2 Sample

The data sources used in this case study included two reports, 'A Time to Act' (Parliamentary and Health Service Ombudsman, 2013) and 'Just say Sepsis' (Goodwin, Srivastava, Shotton, Butt, & Mason, 2015), as well as 99 survivor and tribute stories downloaded from the UK Sepsis Trust website (www.sepsistrust.org, download date: 23/04/2017). The survivor stories were personal accounts by either the patient or their family describing the patient's experience of surviving sepsis, and the tribute stories were personal accounts of a patient's experience with sepsis described by their family, whereby unfortunately the patient did not survive.

The Ombudsman report, '*A Time* to Act' (Parliamentary and Health Service Ombudsman, 2013), included stories from patients' families regarding poor care for the treatment of sepsis for these patients. This clinical report describes 10 cases of patients that had sepsis that did not receive the treatment required and tragically died. The patient's ages ranged from 8 to 75 and the cases in this report were evaluated by the report's authors using the current published guidance provided by the Surviving Sepsis Campaign, the National Institute for Health and Care Excellence (NICE), and other expert organisations including the General Medical Council (GMC).

The 'Just Say Sepsis' report (Goodwin et al., 2015), was generated by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) and reported on a study of the processes surrounding the treatment of sepsis. The study described in this report aimed to identify and explore factors associated with the treatment and care process for patients with sepsis. The findings of the report were based on 710 clinician questionnaires and 551 cases that were peer reviewed as part of their study. This report included very brief descriptions of nine cases of sepsis in patients aged over 16 years old that supported the report's key findings.

The survivor and tribute stories were downloaded from the UK Sepsis Trust website (www.sepsistrust.org) on 23/04/2017. A total of 44 tribute stories and 55 survivor stories were available on the website and were downloaded for analysis. The majority of the survivor stories were in the age group of 21 to 30 years of age. The largest number of tribute stories originated from the age group 61 to 70 years of age. Of the 99 stories, 70 (40 survivor and 30

tribute stories) originated from England, 19 were unspecified, five from Scotland, three from Wales and one each from the Isle of Man and Northern Ireland. All the tribute stories were told by friends and family, 43 of the survivor stories were told by the patient and 12 survivor stories were told by friends and family of the patient. The distribution of the stories per age group and per type is graphically represented in Figure 33.

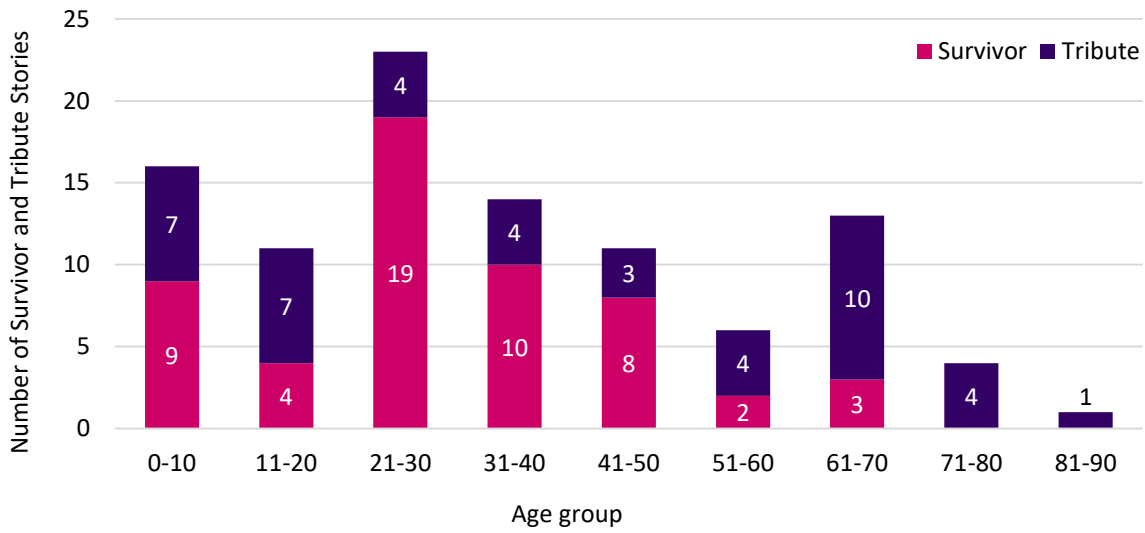


Figure 33: The number of stories analysed per age group for the survivor and tribute stories in the sample.

7.3.3 Protocol and Data Analysis

All documents included in this case study were open access and readily available on the internet. The 'Time to Act' report (Parliamentary and Health Service Ombudsman, 2013), '*Just* Say Sepsis' report (Goodwin et al., 2015) are available on the internet in pdf format and were downloaded for this case study on 14/05/2016 and 07/09/2017 respectively. The survivor and tribute stories were text elements on the UK Sepsis Trust website, which were extracted on 23/04/2017 and stored in an Excel document.

All three document types were imported into NVivo 11 (QSR International Pty Ltd, 2015) and analysed using thematic analysis (Braun & Clarke, 2006, 2012). The SEIPS 2.0 model (Holden et al., 2013) and the weak signals in healthcare framework (Version 3) were used to underpin the analysis, with the initial data reduction and analysis done using pre-set codes derived from these two models. Following this, emerging themes for the different system components was

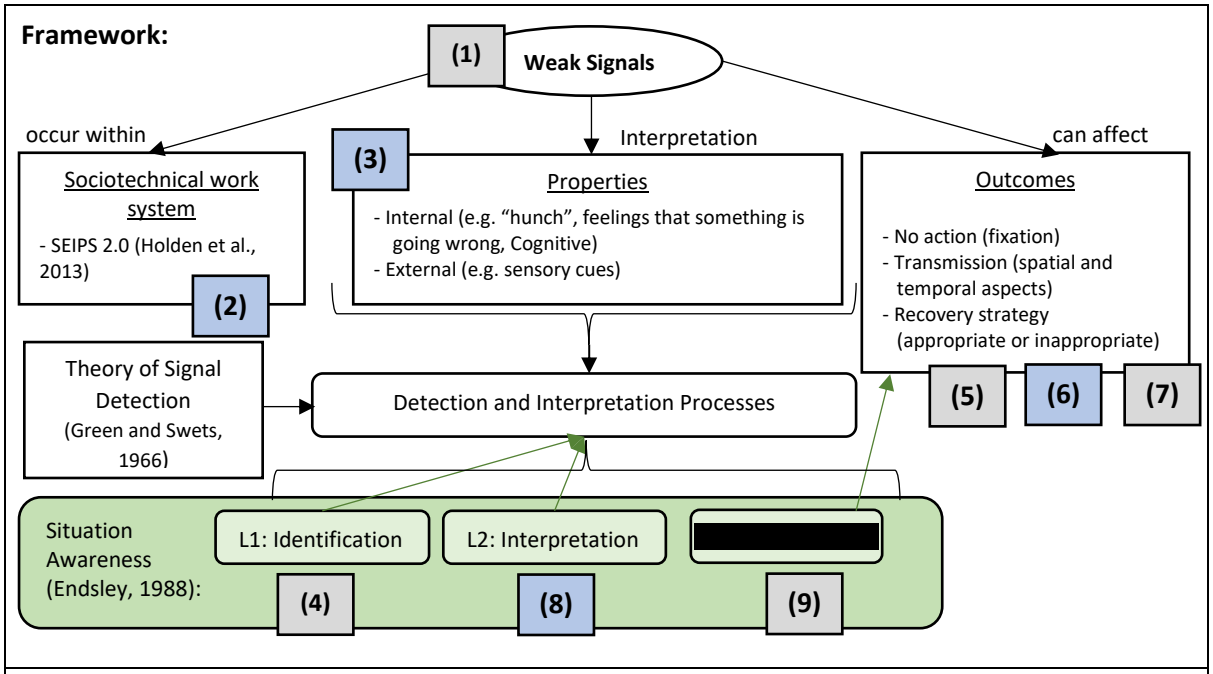
extracted using an inductive approach, which were collated and mapped to the SEIPS 2.0 model. For the weak signals analysis, once the examples were identified the text was analysed inductively to identify any new components for the weak signals framework.

7.3.3.1 Work System Configuration

All the documents analysed were used to compile the work system configuration. Each data source was analysed independently before the results were compiled to form a work system configuration for this case study. The benefit of applying a system's approach to understanding the processes related to treating a patient with sepsis, is that it may provide unique insight into understanding how system elements may facilitate or hinder the treatment and diagnosis of sepsis. The format and method for generating the work system configuration was taken from the example provided in Figure 2 from the original paper by Holden and colleagues (2013, p. 1675) and the same approach used in Case Study 2 (Chapter 6) was applied. Additionally, the survivor and tribute stories were analysed to explore the differences in their work system elements, which may have contributed to a successful outcome or resulted in a delay.

7.3.3.2 Weak Signals Analysis

Weak signals were identified and grouped according to their sources, the types were inferred, and the associated rationalisations were identified. The aim and objectives of this analysis were to identify and extract the weak signals associated with sepsis, determine the possible sources and the actions and responses to these weak signals. The weak signals in healthcare framework (Version 3) was used for this analysis and is depicted with the analysis approach in Figure 34.



Analysis Stages	
1. Extraction of the examples of weak signals from the data source	*Refers to structural elements of weak signals*
2. Categorization of the weak signals according to its source	
3. Identification of the form of the weak signal	
4. Extraction of who identified the weak signal	*Refers to behavioural elements of weak signals*
5. Extraction of if the weak signal was transmitted, to whom and by whom.	
6. Identification if the weak signal was missed or not acted upon	
7. Extraction of the response and outcome, if available	
8. Identification of the potential associated error	
9. Extraction of if the consequence could be predicted	

** Stages in grey required direct data extraction. Stages in blue required categorisation and interpretation.*

Figure 34: The analysis approach using the weak signals in healthcare framework (version 3) adopted in Case Study 3: A Systems Perspective of Sepsis Cases.

The Ombudsman report, 'A Time to Act' (Parliamentary and Health Service Ombudsman, 2013), and the survivor and tribute stories from the UK Sepsis Trust website were used in the weak signals analysis. The 'Just Say Sepsis' report (A. Goodwin et al., 2015) was excluded in this analysis as the nine patient cases described in this report contained minimal information and consisted only of a brief paragraph that supported the key findings of the report.

7.3.4 Validity and Reliability

Validity and reliability were improved through reflexivity. Similar, to Case Study 2, this case study also applied two analyses at different time points. The first was in preparation for the conference papers submitted in 2017 and then again in 2019 in preparation for this thesis. This provided the researcher an opportunity for reflexivity by looking at the data and its initial

interpretation again for alternative conclusions (Malterud, 2001). The objectivity and intersubjectivity of the results were also enhanced as the theoretical standpoints and frame of reference of the researcher were clearly stated (Malterud, 2001). Through document triangulation and by including quotes from the data, the credibility was enhanced.

7.3.5 Ethical Considerations

All documents included in this case study were open access and readily available on the internet. The anonymity of the stories was also ensured by not including any names of the individuals if they were included in the stories published on the Sepsis Trust website.

7.4 Results

The results include a description of the work system, which provides the context, a brief comparison of the system elements in the survivor and tribute stories, and the weak signals associated with the identification and treatment of sepsis. This case study focused on the initial phase of the identification, diagnosis and treatment of sepsis and not the required follow-up care once the sepsis had been treated. The data sources provide information predominantly for this initial phase. Identification, as described in this case study, differed from diagnosis as this included the suspicion of sepsis. The focus of this case study was not to comment or contribute information on clinical aspects of sepsis but rather explore how human factors can contribute to the identification and treatment of sepsis through understanding the work system and weak signals that may be associated with sepsis.

7.4.1 The Work System for the Identification and Treatment of Sepsis

All three document types were used to generate the work system configuration, which aimed to depict the different system components that featured in the documents analysed. The configural diagram and the work system components for this case study are depicted in Figure 35. The work system wherein the identification and treatment of sepsis occurs is described as well as including a comparison between system elements identified in the survivor and tribute stories. As the identification and treatment of sepsis is complex and a patient can present in numerous healthcare subsystems, it needs to be stated that the work system configuration is a high-level depiction of system factors involved and as a result, not an exhaustive list of all

the influencing factors. The purpose of this diagram is to provide an overview of the potential extent of this system, as this may have implications regarding the design of processes and tasks that are dependent on other subsystem areas within the larger system.

The documents analysed highlighted that sepsis can present in a variety of healthcare settings and as a result the active agents in the work system include healthcare staff (e.g. doctors, nurses, therapists, paramedics, GPs) in a variety of healthcare settings (e.g. hospital, different departments and wards, community setting). In addition to this, the patient, their family and friends are also active agents in this work system. Consequently, the person factors that influence work in this work system configuration include patient-related, family-related and staff-related aspects. The patient-related aspects identified as influencing the treatment of sepsis included the patient's history, their general health, behaviour (e.g. refusing help), the underlying infection, and the physical and physiological signs and symptoms they experience (e.g. pain, fever, breathing problems, confusion, feeling unwell). Additional patient-related elements identified in only the survivor stories included the patient recognising the symptoms of sepsis themselves due to previous experience as well as the patient pleading for treatment, which is highlighted in the following excerpt: 'It was there that I collapsed after trying to convince the GP that there was something terribly, terribly wrong with me' (Survivor Story 5).

The family-related aspects identified in both survivor and tribute stories included either rationalising away the symptoms (e.g. 'all… girls caught chickenpox consecutively', Survivor Story 24) or intercepting and seeking medical attention on behalf of the patient (e.g. 'my wife wanted to call 999', Survivor Story 17). A family-related element identified in the survivor stories included advocating for the patient. This is highlighted in the following excerpt: 'my *fiancé turned and said to the doctor* – "but he can't even walk, this can't be right"' (Survivor Story 13).

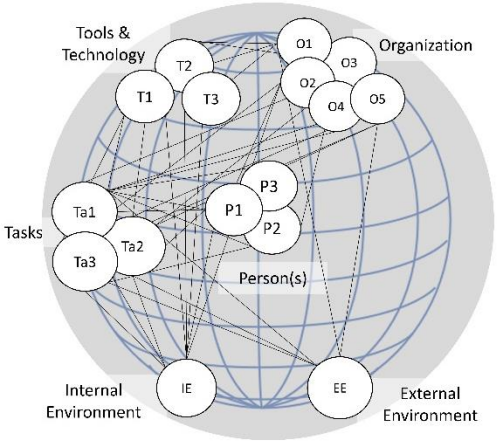
Work System Factors involved in the Identification and Treatment of Sepsis	
Active Agent(s): Numerous healthcare staff will be involved in the patient's journey in the identification and treatment of sepsis. Examples include healthcare staff (e.g. doctors, nurses, therapists, paramedics, GPs, microbiologists) in a variety of healthcare settings (e.g. hospital, different departments and wards, community), patient, their family and friends.	
Performance is shaped by a combination of the following factors:	
Person(s) Factors: - **P1 - Healthcare staff:** Staff's knowledge and awareness of sepsis, the position within the department and ability to speak up in instances of uncertainty regarding severity and diagnosis thereby advocating for the patient, willingness to defer to one another and other members of the care team. - **P2.1 - Patient current condition:** The patient's current health condition may affect sepsis identification and diagnosis as the signs and symptoms may be misinterpreted (e.g. sepsis in the presence of chickenpox). The patient's current condition and stability will influence if certain diagnostic tests and medical procedures can be performed (e.g. being stable enough for scans, inserting cannulas and lines). - **P2.2 - Patient co-morbidities and history:** This may influence identification as symptoms and signs may be ascribed to other causes. - **P2.2 - Patient behaviour:** This may influence the speed at which help is sought (e.g. rationalising the symptoms away) and the interactions with staff that may affect identification. - **P3 - Patient's family:** Family may be able to provide a reference for the change in state of the patient or their behaviour. They may also be advocate for the patient or the reason a patient seeks medical attention.	
Task Factors: - **Ta1 - Task complexity:** Tasks may become very complex as a patient may respond differently to treatments. - **Ta2 - Task significance:** Simple tasks may have important implications for sepsis (e.g. regular observations). - **Ta3 - Time restrictions:** Some tasks will need to be done in parallel, whereas others need to occur in a specific order (e.g. blood drawn for diagnostic tests prior to administering antimicrobial medication).	
Tools and Technology Factors: - **T1 - Required time for diagnostic tests:** This refers to the turnaround time to receive diagnostic results. Samples for certain diagnostic tests need to be taken prior to administering medication (e.g. blood for blood cultures) - **T2 - Use of scores and track and trigger systems:** The timely and consistent use of these types of scores (e.g. National Early Warning Score-NEWS, Glasgow Coma Scale, SOFA, qSOFA) and systems. - **T3 - Tools to access online information:** Tools to access and layout of online information (e.g. protocols and policies)	
Organization of Work Factors: - **O1 - Policies and treatment protocols:** Availability, access to information on and usability of policies and protocols (e.g. antimicrobial policies, NICE clinical guidelines, Surviving Sepsis Campaign guidelines, local policies). Certain protocols will specify time restrictions. - **O2 - Transfer between subsystems:** This will include the transfer of the patient and communication of the patient's condition along the pathway of care. Duration of the transfer may have implications for the time implications associated with treating sepsis. - **O3 - Multidisciplinary teamwork and cross team collaboration:** Additional team support or other departmental support and communication may be required (e.g. critical care outreach team, rapid response team, orthopaedic team). Furthermore, different groups of staff and departments will be involved in the patient's care pathway. - **O4 - Collaboration with specialists:** Identification and treatment may be affected by the access and dynamic of collaborating with specialists on and off site (e.g. infectious disease specialist). - **O5 - Availability of appointments, beds and specialized personal:** This may influence the time to diagnosis and treatment (e.g. availability of GP appointments, space in accident and emergency department (A&E), availability of specialized surgeons)	
Internal Environment Factor (IE): The internal environment may change frequently as the patient is moved between departments, organisations and possibly hospitals. Furthermore, different internal environments will have access to different resources which will affect diagnostic and treatment options. Some examples of the environments the patient may require care in include the local general practice, ambulance, A&E, intensive care, high dependency unit, other wards (e.g. surgical, maternity, paediatrics).	
External Environment Factor (EE): Day of the week, season, out of hours, public holidays (effects access to healthcare resources), national and international guidelines should inform local antimicrobial and sepsis policies, and culture associated with antibiotic prescription.	
This work system configuration is a high-level depiction of the complex elements associated with the identification and treatment of sepsis in the healthcare system and as a result is not an exhaustive list of all the influencing factors.	

Figure 35: The configural work system for the identification and treatment of sepsis.

Staff-related factors included staff's knowledge on sepsis, their ability to challenge a decision and willingness to defer to other staff. Similarly, to the family-related aspect, a staff-related element identified in both survivor and tribute stories included medical staff advocating for the patient. This is highlighted in the following excerpt: 'I was so fortunate that the Junior *Doctor pushed and pushed for me to be taken to the ICU in spite of others who wanted me to* stay put' (Survivor Story 14). Unfortunately, this element was identified in both stories, highlighting this alone is not enough to ensure the successful and efficient treatment of sepsis and that the system needs to be designed to support staff with this. An additional staff-related element that had a negative effect identified in the tribute stories included not recognising the urgency of the patient's situation. Positive elements identified from the survivor stories included staff trying to ensure shorter waiting times at the emergency department as they knew the severity of the patient's condition, staff being aware of sepsis, and quick reactions of staff (e.g. immediate surgery, antibiotics being administered by paramedics).

The tasks identified included those associated with the initial assessment, diagnosis, continuous assessment, transfer and handover of the patient, treatment, as well as the follow up care for the patient. The factors that influence these tasks include task complexity, task significance as simple tasks may have important implications for sepsis (e.g. frequency of observations) and time restrictions of tasks. Some of the task categories described above may occur in parallel whereas others need to be performed sequentially (e.g. taking blood for diagnostic tests prior to administering antimicrobials). With regards to task complexity, the signs and symptom of sepsis may be similar to many more common medical conditions, adding to task complexity. In both story types, the task components identified as hindering the treatment of sepsis included a fixation on the preliminary diagnosis. This is highlighted in the following excerpt from one of the survivor stories 'the GP put down to being muscular. I kept returning with the pain and was just given stronger painkillers and told to rest' (Survivor Story 10). The negative task components identified in the tribute stories included delays in receiving scans, being diagnosed, administration of antibiotics, and lack of availability of services (e.g. GP appointments). Additional negative task components identified included being misdiagnosed (e.g. viral versus bacterial infection), antibiotics not being prescribed and being inappropriately triaged either by the accident and emergency department (A&E) or the general practitioner (GP). The positive task components identified in the survivor stories

included receiving scans early and in a timely manner, early administration of antibiotics specifically intravenous (IV) antibiotics, and immediate medical treatment such as surgery. This is highlighted in the following excerpt: 'whilst I apparently didn't initially score too high *for sepsis, they treated me with IV fluids and antibiotics, painkillers and various X-rays and* scans' (Survivor Story 5). The negative task components identified in the survivor stories included not monitoring the patient's vital signs and despite the need for antibiotics being identified early, they were not administered for several hours. The tools and technology component includes diagnostic tests, documentation, scoring tools (e.g. National Early Warning Score), other online systems (e.g. pre-alert systems), protocols to support the diagnosis and treatment of sepsis (e.g. care bundles, Sepsis Six) and in addition to this, generic tools and technology needed to access these sepsis specific support tools.

Majority of the stories analysed highlighted that numerous services and wards were involved in the treatment as well as in the diagnosis of sepsis (e.g. GP, Emergency medics, NHS helpline, emergency numbers such as 111 and 999). This would increase the complexity of the organisation of work elements. Negative organisation of work components identified across both survivor and tribute stories included the effect of organisational pressures (e.g. bed availability), a lack of availability of services, and poor response times (e.g. GP appointments). Elements identified in the tribute stories included miscommunication between services due to a lack of understanding of the severity of the condition. In the survivor stories, quick response time by ambulance staff, liaising between systems to reduce waiting times for the patient to receive medical care, and an organisational awareness of sepsis were identified as aiding the treatment of sepsis. An example of the different systems liaising with each other to reduce waiting times is highlighted in the following excerpt: 'The nurse liaised with [the] *hospital and arran*ged for me to … get to A&E – armed with a letter saying I wasn't to wait in reception to be seen and had to go straight through' (Survivor Story 7).

External environment elements identified in the tribute stories included assigning the symptoms to flu due to the time of year (i.e. 'flu season'). The external environment elements identified in the survivor stories included the negative effects of the holiday season on access and availability to healthcare services and the misconceptions and concern regarding seeking healthcare treatment whilst in a foreign country.

7.4.2 Weak Signals

This section of the results presents the weak signals identified, the source, inferred form and behavioural elements including the identifier of the weak signal and if the weak signal was acted upon. Text extracts were used to highlight some examples of weak signals identified. The Ombudsman report, 'A Time to Act' (Parliamentary and Health Service Ombudsman, 2013) and the survivor and tribute stories from the UK Sepsis Trust website were used in the weak signals analysis. As in the narratives by the patient and their families, weak signals were often repeated and deeply interwoven into the description of events, the number of signals were not quantified in this case study. These results rather aimed to present the weak signal in a meaningful way without decontextualising them and making as few assumptions as possible regarding the data. Furthermore, following Case Study 2 (Chapter 6), the quantification of the number of weak signals presented did not contribute extensively to the understanding of weak signals. In this case study, not every medical sign and symptom was classified as a weak signal, rather the weak signals extracted from the stories were ones that the narrator explicitly referred to and were the ones where the narrator implied an association with sepsis. As these stories are not extensive accounts of what occurred, it is very possible that additional weak signals may have been present in each story and might not be documented.

7.4.2.1 Structural Elements of Weak Signals for Sepsis

All 10 cases described in the Ombudsman report, 'A Time to Act' (Parliamentary and Health Service Ombudsman, 2013), contained examples of weak signals. Of the 55 survivor stories, 48 stories contained weak signals and of the 44 tribute stories, 39 stories contained weak signals. Eleven different types of signal categories were identified from three of the six work system components, including 'person(s)', 'tool' and 'task' elements. The signal types, examples, and forms identified across for the SEIPS 2.0 work system components have been presented in Table 25. Extracts from the survivor and tribute stories, for the work system categories of signals has been included in *Appendix D1*.

Table 25: The weak signal types, examples, and the forms identified across for the SEIPS 2.0 work system components.

Source	Signal Types	Examples	Forms
Person - Patient	Medical and physiological signs and symptoms*	Cold or flu symptoms, shivering, abnormal vital signs (e.g. fever, abnormal blood pressure, heart rate), swelling, nausea and vomiting, changes in consciousness, breathlessness	Verbal, visual and cognitive
	Continuation of signs and symptoms	Patient signs and symptoms do not appear to improve with time as expected	Cognitive
	Patient condition progression	Rapid deterioration following an initial improvement, lack of response to medication or recuperation, not the expected progression of a 'simple' infection or illness	Cognitive
	Patient symptoms	Feel like 'you are dying', pain, general fatigue and malaise	Verbal
	Behaviour	Unable to drink and eat, confusion, disorientation, behaving peculiarly, talking 'nonsense' and communication problems, unexpected mobility problems, lethargy, not passing urine, relatively abnormal behaviour	Visual and verbal
	Physical appearance	Looking 'unwell', visibly infected wounds, rash and mottled skin, pale appearance, blue lips, jaundice	Visual
	Knowing something is wrong – in numerous cases, the narrator (patient) described a feeling of just knowing something was wrong.		Cognitive
Person - Family	Knowing something is wrong – in numerous cases, the narrator (friend or family) described a feeling of just knowing something was wrong. This may have been as a result of the physical appearance of the patient, the patient's behaviour in comparison to how they are 'normally'.		Cognitive
Task	Diagnostic tests and medical observations	Blood tests indicating infection; assessment of temperature, blood pressure, oxygen levels, respiration rate and heart rate; scans	Cognitive
	Frequently accessing the healthcare system	Numerous GP visits in a short period of time, accessing different healthcare subsystems (e.g. GP, NHS111)	Cognitive
Tools and Technology	Scores	National Early Warning Score, Paediatric Early Warning Score	Cognitive

*The list of medical and physiological signs and symptoms that may be associated with sepsis is not exhaustive.

The person-related sources included weak signals originating from the patient or their family. The weak signals originating from the patient included medical and physiological signs and symptoms, unexpected continuation of the signs and symptoms, the unexpected progression of the health condition, subjective patient symptoms, patient behaviour and appearance. The most frequently cited weak signal was that of medical and physiological signs and symptoms, which were varied and, in the majority of the cases analysed, non-specific (e.g. 'feeling unwell', nausea, fever). These medical and physiological signs and symptoms can be considered as weak signals as they may be indicative of various different health conditions and can be described as 'imprecise, ambiguous and incomplete', a key component of the

weak signals definition. An example of the weak signal associated with the unexpected progression of the health condition is highlighted in the following extract: '[The doctors] *prescribed me antibiotics, two weeks later nothing had changed and doctors were baffled* what was making this infection stay' (Survivor Story 36).

Signals that originated both from the patient and their family was the vague feeling of 'knowing something was wrong'. This may be as the patient and family have subconsciously identified and interpreted various weak signals, potentially the symptoms, unusual severity experienced and not fitting the expected perceived condition, to arrive at an evaluation of the situation. This is highlighted in the following extract: 'I eventually realised that I seriously *needed to get help as I lay there in bed shivering violently with what I now know was the* rigors' (Survivor Story 5).

The signals that originated from tasks included diagnostic tests (e.g. blood tests, scans), medical observations (e.g. assessment of blood pressure) and the frequency the patient accesses the healthcare system within a short period of time for this specific episode. An example of this last type of signal is highlighted in this extract: 'I knew something was very *wrong but three different GPs told me she was fine. 3 days later [she] was incoherent, very* thirsty but not weeing and a rash was rising up her tummy.' (Survivor Story 10)

The tool elements identified associated with weak signals were the formal tools that compile a variety of medical signs and symptoms. These tools could be seen as means of compiling several weak signals to provide more clear indication of the patient's condition. One example of this was the Early Warning Score which is calculated using physiological parameters collected during observations performed during patient monitoring (Parliamentary and Health Service Ombudsman, 2013). This tool was only mentioned as a reference point in the Ombudsman report (Parliamentary and Health Service Ombudsman, 2013). However, this tool was also mentioned in the 'Just Say Sepsis' report, not included in this analysis, where it was mentioned that there was no evidence that this tool was used to assess and monitor physiological parameters in the cases reviewed (Goodwin et al., 2015).

Similar to Case Study 2, some examples included combination signals. These included a discrepancy between test results and the patient's physical appearance (e.g. tests indicate the patient is unwell although they appear visually not as ill), documentation and presentation of the patient (e.g. odour of wound not documented in the patient file), and discrepancies between vital signs (e.g. no fever but abnormal heart rhythm and low blood pressure).

The forms of the weak signals included verbal, visual and cognitive forms. Visual weak signals referred to weak signals that were objective in nature, and therefore were relatively independent of the person identifying them. Examples of this for sepsis included a visible wound that looked infected, and the patient having blue lips and shivering. Verbal weak signals included the patient describing their symptoms which are subjective and only apparent to the patient, and communication problems with the patient due to their disorientation, which would be objective. Cognitive weak signals require interpretation and included knowing abnormal values for vital signs, being aware of the expected progression of a health condition and knowing when the patient's behaviour was abnormal.

7.4.2.2 Behavioural Elements of Weak Signals for Sepsis

The behavioural elements identified in this case study included who identified the weak signal, aspects of interpretation and the response to the weak signal. An example of how the information associated with the weak signals identified was used to determine behavioural elements is presented for one example in Table 26. A new behavioural element of weak signals was identified in this case study, namely the rationalisation of why the signal was not acted upon. The information on behavioural elements was categorised into three key elements, namely the aspects associated with weak signal detection, interpretation and response or action. Additional examples highlighting the analysis approach taken for the behavioural elements of weak signals have been included in *Appendix D2*.

Table 26: An example of the approach adopted for the identification of the behavioural elements associated with the detection, interpretation and action or response for weak signals.

Story	Example	Detection, Interpretation, and Action or Response
Survivor Story 7	'[it was] easily the **worst pain** I've ever known - so I went to the GP on the Wednesday who said he was ***worried and predicted that I'd end up in A&E***. He did take my **temperature, but it was normal**... I'd also had a **slight sore throat** a few days earlier. The doctor gave me penicillin and pain killers, and I went home, but spent the next 2 days feeling really ill… the contra-indications of the medicines I was on seemed to be the same, so I just put how I felt down [to] the strong drugs.	**Detected by:** Patient **Transmission:** GP ***Interpretation - Prediction:*** Potential serious nature (predicted by the GP) **Signals:** Contradicting signals – pain (subjective) and no temperature (objective) **Action:** Provided treatment **Rationalisation:** Ascribed symptoms to medication side effects
	Come the Friday I really felt **horrendous**, so went to the local walk-in clinic by taxi. They instantly noticed my **blood pressure was up, my breathing was shallow and fast, my temperature was high, my skin was pale and sticky** - they couldn't even get blood out of me to do the usual testing. The nurse liaised with Kingston Hospital… [and provided] a ***letter saying I wasn't to wait in reception to be seen, and had to go straight through…*** We did have a long wait to be seen once inside (many hours), but when the doctors came over, they arrived in their many, **telling me my blood test results were those of someone really very critically ill, and none of them believing how normal I looked**'	**Signals:** Patient feeling unwell (subjective), vital signs and patient appearance (objective) **Action:** Referral to hospital ***Interpretation and action:*** Provided a letter to prevent potential delays at A&E – Action was unsuccessful. **Signals:** Contradicting signals – patient appearance (objective) and diagnostic tests (objective)

7.4.2.2.1 Detection and Identification

The detection aspect of weak signals was inferred by extracting the identifier of the signal. In majority of the cases, unlike in Case Study 2 on hospital discharge, the weak signal was identified by the patient and their family and friends. This may be because many weak signals in this context start to present in the home environment, and result in the action of seeking medical attention. Certain weak signals were only identified by healthcare professionals, namely some of the medical and physiological signs and symptoms, diagnostic tests, medical observations and scores from tools such as NEWS. A weak signal that featured and was picked up on by patients and their families was the frequency of accessing the healthcare system. This is a weak signal that may be beneficial to healthcare providers but currently does not appear to be used. A potential reason for this, may be the lack of a central database of patient information across the subsystems that patients may go to for care within the NHS.

7.4.2.2.2 Interpretation

Similar to Case study 2, extracting and identifying interpretation elements was challenging as these mechanisms are often not discussed or described. This is highlighted in the following extract*:* 'at that point I knew we needed help. I can't even say what it was that made me think that' (Survivor Story 2). However, in some examples, the narratives described several interpretation elements, namely how previous experience enhanced the interpretation of weak signals, how two contradicting weak signals could be presented in the same situation and in one example an outcome was predicted. The sample contained several survivors that had experienced more than one episode of sepsis. Their stories highlighted how their initial experience exposed them to the weak signals of sepsis, and when they experienced another episode were able to recognise these much sooner. The following extract highlights this phenomenon:

> '*I just knew that something was now terribly wrong, once more! I started feeling extremely cold inside and yet hot and very feverish and shivery at the same time as my breathing began to* get more and more difficult… I had now begun to recognise *the all too familiar feelings that had struck me previously and I just knew that I needed medical help!*' (Survivor Story 5)

For the cases of two contradicting weak signals presented in the same situation, these included the patient's appearance or behaviour not 'correlating' with medical test results and discrepancies between vital signs (e.g. no fever but low blood pressure and abnormal heart rhythm). For the instance of the predicted consequence (described in Table 26), the patient described how the GP that initially treated her predicted that she may need to go to the emergency department. However, despite this prediction the patient was not sent to the emergency department at that time and was instead provided medication and sent home.

7.4.2.2.3 Action, Responses and Rationalisations

The actions or responses initiated due to identified weak signals included seeking medical assistance, no action being taken, and the weak signals being rationalised away. As most weak signals were identified or detected in the home environment and indicated a health concern, one of the main responses, following self-medication and rest, was to seek medical advice and attention. This was sought from a variety of providers depending on time of day and

severity of the symptoms experienced. Examples included the GP, NHS 111 telephone service, and emergency department. This highlights the need for awareness of sepsis to span across the entire healthcare system and not just in acute settings. If weak signals persisted, numerous narratives described several attempts at seeking medical advice and attention. This is highlighted in the following excerpt: 'we got him seen twice by two separate GP 's due to him still remaining poorly days after' (Tribute Story 20).

In the narratives where the severity of the patient's condition was not necessarily perceived when medical attention was sought, a response of family and some staff was to advocate for the patient. This can be described as a facilitator for the treatment of sepsis, as the patient's appearance may not always reflect the current health status, especially as numerous narratives described an initial improvement prior to deteriorating. The following extract details an example of this: '*As the day went on, it was clear the antibiotics were not helping the way they should have. I was so fortunate that the Junior Doctor pushed and pushed for me to be taken to the ICU in spite of others who wanted me to stay put*' (Survivor Story 14).

In many cases, once the severity of the patient's condition was identified, the patient was transferred to another healthcare subsystem. This then ties to the work system configuration (depicted in Figure 35) as the influencing factors of the different subsystems may affect task performance. The example described in Table 22, highlights how a healthcare provider understanding the constraints in the emergency department and how this might affect treatment for this patient, attempted to mitigate the delay by providing the patient with a letter so they could transition between healthcare subsystems quicker. This raises the question of can 'formal' structures and processes be created to aid the transition of suspected sepsis patients between healthcare subsystems to prevent delays. In one narrative, a patient describes a form of this: 'My medical records are now apparently "flagged" on [the] computer *at my GP practice so that I can be se*en urgently, if needed, and so I wouldn't have to wait as I did before' (Survivor Story 5).

A theme that stands in contrast to the response of seeking medical attention identified across several narratives was also a reluctance to seek medical advice. The reasons given for this included waiting for a more convenient time and not wanting to burden healthcare

professionals with something that appeared to be flu. An extract that highlights this is: 'I thought I had flu and I don't want to bother the Drs or A&E, they're busy enough!' (Survivor Story 4). This highlights the need for public awareness regarding sepsis as the patient themselves may cause delays which will ultimately influence the effectiveness of treatment received later. In some instances, family and friends were able to mitigate this barrier by insisting the patient seek medical attention.

In the narratives, examples of weak signals that appeared to be missed and not acted upon could be identified. Moreover, in numerous instances the rationalisation of why the signals were not acted upon was provided. Rationalisations included assigning the symptoms to other forms of illness (e.g. flu, cold, general virus) and exhaustion, side effects of medications, expected symptoms associated with a recent medical procedure (e.g. after effects of the general anaesthetic and surgery), the patient had similar symptoms previously that were not associated with sepsis and complications associated with chronic conditions. This phenomenon is illustrated in the extract below, describing how weak signals may be rationalised away: 'the contra-*indications of the medicines I was on seemed to be the same,* so I just put how I felt down to some strong drugs' (Survivor Story 7). An example of an external environment factor contributing to one example of a rationalisation is highlighted in the following quote: '*This was the height of the flu epidemic of 2010/2011 and her symptoms were quickly assessed to be another case of seasonal flu. She was immediately dismissed, receiving no treatment, and with the standard advice to rest and take plenty of fluids*' (Tribute Story 27).

7.5 Discussion

This case study, in this series on weak signals in healthcare, identified the work system context in which weak signals present in association with the identification and treatment of sepsis. Through the depiction of a generalised work system configuration for the identification and treatment of sepsis, different influencing system factors that might affect work associated with this clinical syndrome were identified. Following this, the weak signals present in 99 survivor and tribute stories and 10 cases described in the Ombudsman report (Parliamentary and Health Service Ombudsman, 2013), and the associated structural and behavioural

elements were identified. The discussion will include the implications of adopting a systems perspective to identifying influencing factors, the potential application of weak signals for processes associated with identifying and treating sepsis and how the results were used to expand and modify the weak signals in healthcare framework and analysis approach. This section will conclude with a description of the limitations of this case study.

The work system configuration highlighted the breadth of different people, departments and potentially subsystems that may be involved in processes associated with the identification and treatment of sepsis. This complexity revealed several barriers that may arise because of the structure of this work system configuration. These included people's awareness of sepsis including healthcare professionals, the patient and their families; the effect of numerous patient-related elements that may make diagnosing and identifying sepsis challenging; transmitting information across boundaries; and tasks and processes involved that may span several subsystems or departments. Considering the time sensitivity associated with sepsis, the work system configuration can have additional implications for the performance of tasks and processes that span several subsystems. For example, this raises the question for treatment protocols that require input from several departments or subsystems (e.g. antimicrobial advice from the microbiology team, specific medication from the pharmacy department), namely have the processes been designed to span these subsystems so the tasks can occur in the predefined time limit? Does the environment and organisation of work allow for the administration of broad-spectrum antibiotics within three hours from emergency department (ED) triage, as recommended by the Surviving Sepsis Campaign (SSC) guidelines (Dellinger et al., 2013)? This raises several work system considerations such as who needs to prescribe the medication, where is the medication stored, who will deliver it and who can administer the medication. In addition to these, a key consideration is: are there means available to escalate these tasks, so they do not become delayed? This starts to reveal how human factors may be able to support clinical work on sepsis by considering the effect of the system on clinicians' ability to complete their clinical tasks. If structures have not been put in place to expedite these tasks and ensure the time limitations suggested by treatment guidelines can be achieved, it should not be surprising that delays occur. Another example of how considering the work system may be beneficial for the design of processes and pathways for sepsis treatment, is that, as nurses are usually the first clinicians to evaluate patients, this

staff group may have the opportunity to initiate the appropriate clinical pathway more quickly than other staff groups (Burney et al., 2012).

The work system configuration identified several tools that are associated with some of the weak signals identified, for example scores (e.g. NEWS, SOFA, qSOFA) calculated from the observation of vital signs used in patient monitoring (Alam et al., 2014; Weldon et al., 2018). These tools can be considered as compiling the weak signals of medical and physiological signs and symptoms, which due to the predominantly objective nature, may be considered as being relatively strong signals indicating the patient is unwell, however due to the low specificity may still be weak with regards to being indicative of sepsis. Furthermore, as acknowledged medical signs of sepsis include confusion and altered mental status, family and friends may be able to provide information on the change in the patient that reflects this. Although healthcare has the Glasgow Coma Scale which is an objective tool used to assess impaired consciousness (Jain & Iverson, 2020), the family of a patient may be able to provide additional information that may be of use to healthcare providers regarding these types of weak signals (e.g. first onset of impaired consciousness). Similarly for some of the more subjective weak signals that may only be identified by the patient and their family, the importance of some of these weak signals has been acknowledged in that they feature in the advice for the general public on how to spot sepsis in adults from the Sepsis Trust (The UK Sepsis Trust, 2020), for example the weak signal of 'it feels like you're going to die'.

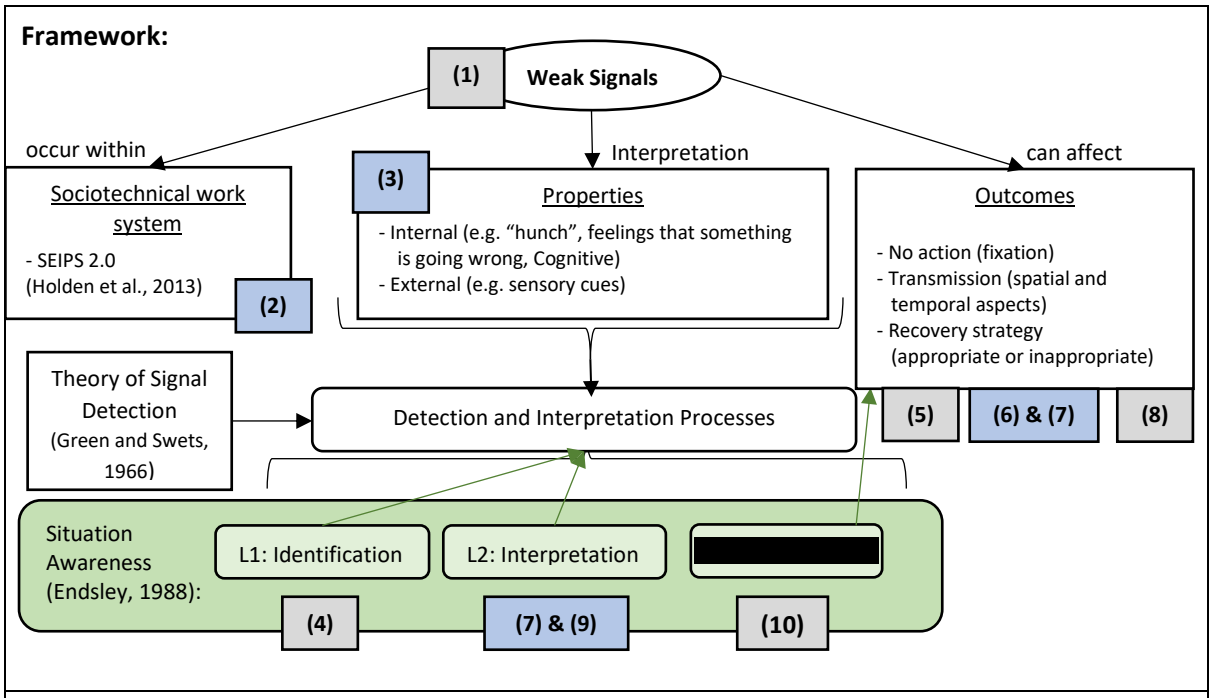
The weak signals identified in this case study predominantly originate from the patient indicating a medical concern. However, several sources were identified that although they draw on information from the patient to provide an indication that 'something is not right' with the patient, the weak signal source was not the patient themselves. Although this study, did not go into detail on the weak signals associated with the physical and physiological signs and symptoms of sepsis, as in the study by Patterson et al. (2016), it did aim to identify additional weak signals that may assist in the identification and treatment of sepsis and the functioning of the work system. These included the weak signals originating from the family, the family or patient repeatedly accessing the healthcare system as well as the weak signals that when compiled indicated contradictory outcomes. As with most research, more questions are raised than answered, and this raises the question of what can these other non-

clinical weak signals offer healthcare staff? Possible answers include the information the family may have on the patient (e.g. has the patient's behaviour changed that might suggest confusion, were they unwell prior to their change in behaviour) and if a patient is frequently accessing the healthcare system being potentially indicative of an underlying problem.

A unique contribution of this case study was the identification of rationalisations on why weak signals were not acted upon. These rationalisations provide several insights. The first is that they provide information on the interpretation stage of weak signals and secondly, they provide information on why weak signals may not be acted upon. With regards to the weak signal interpretation, rationalisations provide insight to the potential alternative indications of that weak signal. Consequently signal detection theory (Green & Swets, 1966) can provide some insight into some of the underlying mechanisms of why a weak signal may be rationalised away or not detected. This theory describes the probability of detecting a signal (Luce, 2003) and suggests that it is influenced by the sensitivity of the receiver (Swets et al., 1978) and individual's bias (Anderson, 2015; McLeod, 2015). An example that illustrates the above principle is described in the following extract: 'I thought I had flu and I don't want to bother the Drs or A&E, they're busy enough! Sepsis won't happen to me' (Survivor Story 4). This example highlights how the receiver (the patient) was sensitive to the weak signal (she had identified she was unwell), however because of individual bias (she did not believe it was likely she had sepsis), the weak signal was incorrectly rejected. Rationalisations also provide information on why a signal may be rejected, which has practical implications. If one can understand why people misinterpret or do not respond to weak signals, interventions targeting these reasons can be developed to support the use of weak signals. An example of a means of preventing the rationalisation of weak signals that was extracted from the results is the role of the advocate for patients with sepsis in the presence of non-specific signs, symptoms, and contradicting weak signals. In several narratives, the narrator described 'speaking out' against the interpretation of the weak signal, for example a family member insisting the patient seek medical care or a staff member challenging the decision regarding the planned changes of care due to an initial improvement in the patient's health.

7.5.1 The Weak Signals in Healthcare Framework (Version 4)

The weak signals in healthcare framework (Version 3) provided 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. Based on the results of this case study, the framework and analysis approach were expanded and Version 4 is depicted in Figure 36.



Analysis Stages	
1. Extraction of the examples of weak signals from the data source	*Refers to structural elements of weak signals*
2. Categorisation of the weak signals according to its source	
3. Identification of the form of the weak signal	
4. Extraction of who identified the weak signal	*Refers to behavioural elements of weak signals*
5. Extraction of if the weak signal was transmitted, to whom and by whom	
6. Identification if the weak signal was missed or not acted upon	
7. Identification of rationalisations if the weak signal was not acted upon	
8. Extraction of the response and outcome, if available	
9. Identification of the potential associated error	
10. Extraction of if the consequence could be predicted	

** Stages in grey required direct data extraction. The stages in blue required categorisation and interpretation. Yellow indicates the recently added element.*

Figure 36: The analysis approach using the weak signals in healthcare framework (Version 4), showing the modification adopted from the results of Case Study 3.

The existing structural elements of the framework were confirmed, and no additional structural elements were established in this case study. For the behavioural elements, although no detailed information was identified for the transmission component and for the

potential associated error, these elements were retained in the framework as this may have been as a result of the type of data that was analysed in this case study. A new behavioural element not previously included in this version of the framework or analysis approach was identified, namely the rationalisations associated with missed signals, which include weak signals not acted upon. As rationalisations can be considered as revealing information on the interpretation element of weak signals as well as being the potential reason for no action in response to the weak signal, this element was incorporated into the analysis approach instead of the framework itself.

7.5.2 Limitations

The limitations of this study included those associated with the self-reported data, and the limited variety of data sources and perspectives included in this case study's sample. With regards to the limitations associated with self-report data, these are similar to those of incident reports, namely that these accounts may be incomplete, selective (Brown et al., 2008c), affected by bias, and cannot be considered as a 'true' and complete record of the event (Andrews et al., 1997; Boxwala et al., 2004). Although the survivor and tribute stories, will have less rigor and objectivity than incident reports or official reports on adverse events (e.g. Ombudsman reports), they did provide a unique perspective, namely that of the patient and their family's experience. Although these stories may have been written using a specific template with the aim to increase the public's awareness of sepsis, because they were not written with this specific research topic in mind, these accounts were not influenced by the researcher and consequentially, were not affected by a potential lack of reflexivity (Bowen, 2009). These stories are an unconventional data source that allowed for access to a much larger sample of patients that had experienced sepsis than otherwise may have been possible within the parameters of this research. Additional key limitations of this case study included a lack of data variety and the lack of direct input from medical staff. Future work on this case study, if possible, would be to have healthcare professionals evaluate the work system configuration and weak signals identified, either using focus groups or interviews, with the aims of exploring how this information could be used to inform system design and the development of support tools and processes.

7.6 Conclusion

This case study explored the work system context, the influencing work system factors and weak signals associated with the identification and treatment of sepsis, using the third version of the weak signals in healthcare framework. A unique feature of this case study, compared to others included in this thesis, was the inclusion of the patient and their family's perspective through the analysis of stories they narrated on their experience with sepsis. As with Case Study 2, to provide the context of the system wherein these weak signals occur, this case study created a work system configuration for the work system associated with the identification and treatment of sepsis from the analysis of both formal and informal documents including a clinical report, Ombudsman report and 99 survivor and tribute stories.

Eleven different types of signal categories were identified from three of the six work system components, including 'person(s)', 'tool' and 'task' elements. The weak signals identified in this case study predominantly originate from the patient indicating a medical concern. However, several sources were identified that although they draw on information from the patient to provide an indication that 'something is not right' with the patient, the weak signal source was not the patient themselves. This case study confirmed the majority of existing structural and behavioural elements of the framework, in addition to identifying a new behavioural element not previously included in the framework or analysis approach. This element was the rationalisations associated with missed signals, including weak signals not acted upon. Rationalisations can be considered as revealing information on the interpretation element of signals as well as the potential cause for no action. Consequently, this element was incorporated into the analysis approach instead of the framework itself. The next case study will apply the fourth version of the weak signals in healthcare framework and analysis approach that emerged from this case study to a different healthcare context.

Chapter 8: Case Study 4 – The Case Study of the Mid Staffordshire NHS Foundation Trust

8.1 Introduction

The research on weak signals in healthcare, as has been highlighted in Chapter 3, is limited. Studies have either concentrated on the more traditional retrospective use of weak signals in the context of healthcare disasters or understanding how staff use weak signals informally. This case study will focus on the former application of weak signals and apply the weak signals in healthcare framework to one organisational disaster. Examples of the studies on the role of weak signals in organisational failures within healthcare include the failures of care discovered in the Mid Staffordshire case (Macrae, 2014b), the Bristol Royal Infirmary case (Walshe & Shortell, 2004; Weick & Sutcliffe, 2003) and at the Morecambe Bay NHS Foundation Trust (Kirkup, 2015).

The work for this case study has been presented by the author at the 20th Congress of the International Ergonomics Association (IEA 2018) held in Florence, Italy on the 26th to the 30th August 2018. The paper is reproduced here, with minor modifications, with permission from Springer Nature Customer Service Centre GmbH: Springer Nature Springer eBook – Weak Signals in Healthcare: The Case Study of the Mid Staffordshire NHS Foundation Trust (Carman, Fray, & Waterson, 2018).

8.2 Aims and Objectives

This chapter aimed to explore the application of the weak signals in healthcare framework and analysis approach (version 4) to a unique healthcare context in comparison to the previous three case studies, namely, to support the analyse of the presence of weak signals in an organisational failure in healthcare. The healthcare context explored in this chapter was the organisational failings of the Mid Staffordshire NHS Foundation Trust. To achieve this aim, the case study addressed the following objectives:

- Identify the weak signals documented in the independent (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010a) and public (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a) reports on the failings of the Mid Staffordshire NHS Foundation Trust. This included identifying the source and type of weak signal.
- Extract from the data the rationalisations of why the weak signal was not acted, which underpins behavioural elements of the framework as it affects action and response to weak signals.
- Determine the timeline for the appearance of these weak signals for this case study.
- Identify the characteristics of weak signals for this context.

8.3 The Context – Organisational Disasters

An organisational disaster can be defined as a low-probability, high impact event with the potential to threaten an organisation's survival (Duncan, Yeager, Rucks, & Ginter, 2011). Most organisational disasters have warning signals prior to the event occurring (Wei Choo, 2008). These type of signals are increasingly appearing and receiving progressively more attention in accident reports. These warning signals are sensed information regarding emerging events (Ansoff & Mcdonnell, 1990), and include indicators or cues from the environment (Rasmussen, 1983) which require interpretation and sensemaking (Weick, 1995). Many of these warning signals are often also referred to as weak signals, as the information they contain is frequently imprecise and vague in nature (Ansoff & Mcdonnell, 1990).

These weak signals are gaining increasing interest in the research community as they may provide an opportunity to achieve pro-activeness and promote effective risk management, as they provide an opportunity 'sooner-rather-than-later' for identifying problems that threaten safety (Macrae, 2014a). Furthermore, by using weak signals, unexpected events may be addressed in a more cost-effective and timely manner (Vogus & Sutcliffe, 2007). In healthcare, this could result in significant benefits particularly with regards to patient health. Furthermore, weak signals may provide an opportunity to render a system more resilient (Hollnagel, 2014) as they provide insight regarding the status of the system and areas of risk (Macrae, 2014b). By identifying where these weak signals originate from and understanding how they are identified and interpreted, possible changes to work structure and management

could be developed to encourage weak signal identification for promoting patient safety. Despite their potential for improving safety, research exploring weak signals, especially in healthcare, is limited.

8.3.1 Case Description

This case focused on the failings surrounding the Mid Staffordshire NHS Foundation Trust, which resulted in unacceptable standards of care for patients between the years of 2004 and 2009 (Roberts, 2013). During this time, there was a noted rise in patient mortality and complaints relating to clinical care, with an estimate of between 400 and 1200 excess deaths occurring during this time period (Roberts, 2013). As a result of the substandard care, many patients were left struggling to care for themselves (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010a). The investigation into this organisational disaster found that the system failed to protect patients from unacceptable risk, and in several cases inhumane treatment (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). The systemic failings were so pronounced, that this event has been described as: 'the worst crisis any district general hospital in the NHS can ever have known' (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b, p. 47).

Events contributing to the failings that resulted in unacceptable standards of care at this Trust have been dated back to about 2001 (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a). Initial concerns regarding the Trust were reported in August of 2001 and January 2002 to the NHS Executive West Midlands. These were related to staffing levels, leadership and management problems (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a). Over the period from 2004 to 2009, several key events or changes occurred within the organisation, that could be seen as contributing towards the downward spiral the Trust experienced. Some of these included the suspension of reporting patient complaints to the hospital trust board from 2003 to 2006 (Thomé, 2009), a financial recovery plan that was put in place in 2005, the modification of the ward structure to include two new units, reconfiguration of the clinical floors and at the end of 2005, the replacement of the Chief Executive (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a). Moreover, the director of Nursing was replaced at the end of 2006, the Mid Staffordshire General Hospital NHS Trust requested £1 million for redundancies twice in 2006, and received foundation trust

status beginning of 2008 (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). Over this period, numerous reviews, audits and reports were conducted, of which many suggested problems regarding staffing, managerial and other concerns.

In 2008, the Health Care Commission (HCC) were approached based on above average mortality rates to investigate the Trust. The investigation found that the staffing shortages, operational problems and a lack of leadership meant that despite the best efforts of staff, the quality of care was compromised and patient safety was at risk (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a). In response to the HCC investigation, the above-average mortality rates and the persistent complaints made by a group of patients, named 'Cure the NHS', an independent inquiry was launched (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a).

The independent inquiry, concluded in 2010 (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010a) and resulted in the publication that has become known as the Francis Report, described detailed accounts of inadequate care and incidents of unexpected risks that patients experienced. These included malnutrition and dehydration (Vincent & Amalberti, 2016). Due to the extensive public outcry, the independent inquiry was followed by a public inquiry which concluded in 2013 (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). An overview of the events including the different inquiries that occurred during the period for this event, complied from the documents analysed, has been presented in the timeline depicted in Figure 37.

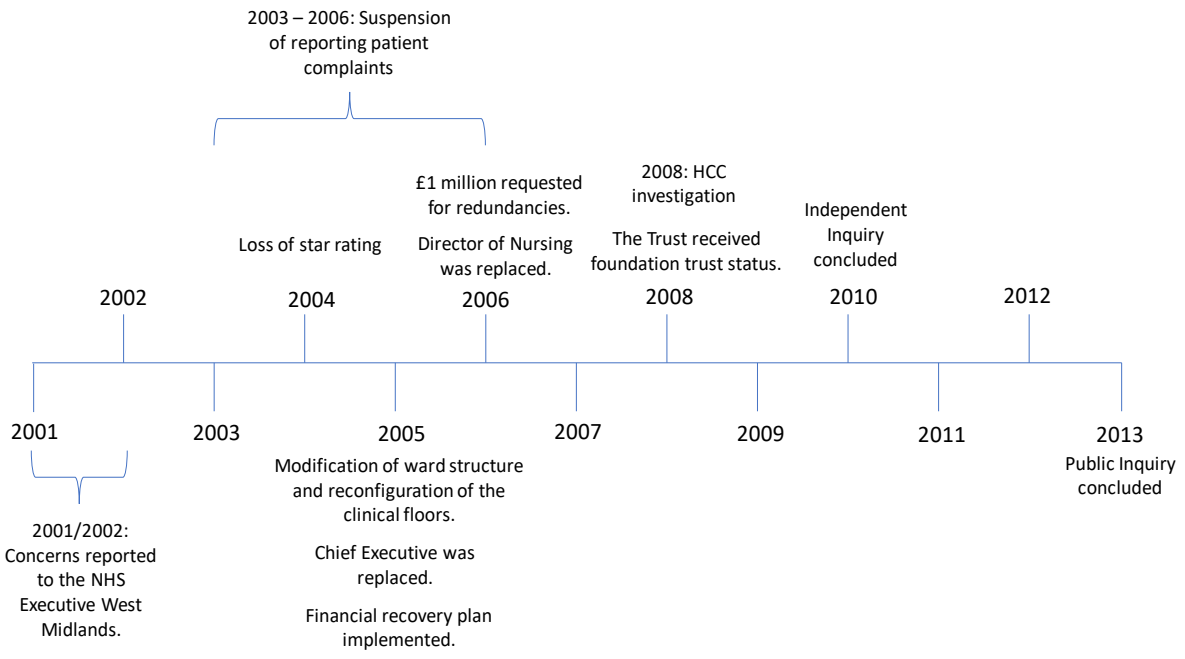


Figure 37: An overview of the events associated with the failings surrounding the Mid Staffordshire NHS Foundation Trust (2004 – 2009) including the different inquiries that followed this period.

Numerous system factors were identified as contributing to the appalling standards of care patients received (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). Examples of these included inadequate staffing, negative culture, professional disengagement regarding reporting concerns, poor governance, a lack of focus on standards of service, inadequate risk assessments, and incorrect priorities (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010b).

The above description of the events surrounding the Mid Staffordshire NHS Foundation Trust is a brief summary and not an exhaustive description of the events and occurrences. The purpose of this summary is to provide the context for the results included below. Additional events will be mentioned in the results as they directly relate to weak signals.

8.4 Method and Analysis

Weak signals and their relation to organisational disasters are gaining increasing interest and traction among the research community. They are increasingly mentioned in accident reports, with an entire section of the Public Inquiry report (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a) of the Mid Staffordshire NHS Foundation Trust dedicated to them. In the report they are referred to as warning signs. This case study aimed to analyse the weak signals identified in the 2013 report using a systems approach as well as other weak signals that could be extracted from the event descriptions included in both reports for this example of a healthcare-related organisational disaster. An explorative qualitative method was adopted to investigate these aspects due to the fuzzy nature of weak signals. The two reports generated by the independent (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010a) and public (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a) inquiries into the Mid Staffordshire Disaster were selected for analysis. The weak signals and related events leading up to the May 2009 were included in the analysis.

The two models selected for the analysis were the SEIPS 2.0 model (Holden et al., 2013) and the weak signals in healthcare framework (Carman, Fray, & Waterson, 2017). The SEIPS 2.0 model was selected as it a systems model that has not only been used to understand healthcare processes better to improve patient safety (Gurses et al., 2012; Rivera et al., 2008) but also to understand infection outbreaks within acute care settings to identify the larger system contributing factors of the outbreaks (Waterson, 2009). The weak signals in healthcare framework provides a structure for the analysis of weak signals in the context of the system in which they occur specific for the healthcare environment. The framework provided a point of reference for the analysis of related and key information relating to weak signals. By analysing the weak signals from this perspective, one identifies the sources and the related rationalisations. This together provides a greater understanding on the context in which these weak signals occur. The analysis was initial performed using the second version of the weak signals in healthcare framework, followed by verifying the analysis using the fourth version of the framework. The weak signals were identified and grouped according to the elements in the sociotechnical work system, as described in the SEIPS 2.0 model, from which they originated, the types, and the associated rationalisations. All data were analysed using NVivo

11 (QSR International Pty Ltd, 2015) using a thematic analysis approach (Braun & Clarke, 2006).

8.5 Results

From the analysis, an extensive list of weak signals, categorised according to the system levels from which they originated was created. In addition to the examples of weak signals collected, corresponding rationalisations were included where available for the weak signals (a key component of the weak signals in healthcare framework, version 4). Numerous weak signals, some possibly stronger than others, were extracted from the official reports. A collection of examples of weak signals originating from the different system levels, the year they were presented and the rationalisations for why no action was taken is included in Table 27. As is clear from the table, numerous weak signals were present over the time period, though many were rationalised away. From the analysis, it is also clear that many different factors contributed to this disaster and numerous weak signals were present, but for brevity, only a few key examples are included here. The majority of the weak signals were identified from the person, organisation and external environment levels of the work-system element of the SEIPS 2.0 model.

Person-level weak signals identified included patient complaints, staff complaints and behaviours, whistleblowing by staff and management staff voicing concerns. Highlighted in both the first and second inquiry reports, was that senior management was not made aware of the concerns of patients and frontline staff (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). This is highlighted by the following extract:

> 'Incidences of poor care were not formally fed through the system and they were not supplied to commissioners or regulators…' (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 47).

However, staff did speak up which was visible in several different types of weak signals. Examples of these include the person-level signals relating to staff whistleblowing on senior staff's conduct and staff voicing their complaints regarding the reconfiguration of certain wards. Furthermore, based on the Barry Report, published in 2005, which was a report generated as a result of a whistle blowing complaint, staff were trying to make management

aware of the current situation, which contradicts the above statement (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 69). With regards to staff voicing concerns regarding the reconfiguration of wards, this weak signal was met with the rationalisation that the staff had already given input. Another example of a weak signal related to the concerns of staff, which was identified though an internal staff survey conducted in 2007, which could be considered an organisation-level weak signal, is highlighted by the following extract:

> 'Concern was expr*essed at the percentage of staff who said they would not want to* be treated at the hospital, nor wish a relative to be either' (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 98).

Table 27: A selection of weak signals, the year they occurred, and their corresponding rationalisations identified in the two reports.

System Component	Weak Signal	Examples (Year of occurrence)	Rationalisation
Person	Patient complaints	Patients reported inappropriate attitudes of staff (2002).	Patient's feared repercussions.
	Staff behaviour and complaints	Staff voiced concerns regarding reconfiguration of wards (2005).	Staff were told their input had been considered.
	Whistleblowing	Whistleblowing regarding conduct of senior staff (2005, 2007).	She was advised to 'keep her head down'.
	Management voiced concerns	The medical director voiced concerns about the surgical department (2007).	
Organisation	Loss of star rating	Loss of star rating due to breaches in waiting times and financial deficit (2004).	The tool was criticized for being a blunt assessment tool.
	Financial recovery plan	Despite staffing levels concerns, a plan containing redundancy was implemented (2005).	Staff reductions seemed to be consistent with proposed reduction in beds.
	Negative statistics	Mortality statistics were above average.	There were concerns with the coding.
Internal Environment	Outbreaks	Outbreaks of *Clostridium difficile* (2008, 2009).	It was claimed an action plan was underway.
External Environment	Findings in reviews, audits and surveys	Reviews included Children's Service Review (2003, 2004, 2006, 2008), National Review of Medicines Management (2006), National Cancer Review (2005, 2006), Royal College of Surgeons Review (2007).	Rationalisations included it was thought action was being taken prior to the reports being published, the complaints were limited to one ward and not reflective of wider concerns, and not all data had been submitted for consideration.
	Findings in official reports	Reports included Commission of Health Improvement Report (2002), Barry Report (2005), Dr Foster Report (2007).	
	HCC investigation	HCC investigation highlighted concerns regarding basic nursing care and medication (2008).	Other regulation bodies decided to await the outcome of the investigation.

An example of a weak signal that was identified where management staff voiced concern was that the medical director reported concerns about the surgical department. Elements of the strength of this signal and the response to this signal is indicated in the extract below:

> 'From the time of her appointment as Medical Director, … had harboured concerns about the Surgical Department. … She had a number of audits and other reviews *undertaken but these came up with no evidence of concern. She approached the National Clinical Assessment Service (NCAS) who agreed with her proposal to invite* the Royal College of Surgeons (RCS) to conduct a review…' (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 111)

This is a prime example of a weak signal, as the staff member was convinced that there was a problem despite evidence contradicting this. With hindsight, it has been confirmed that there were reasons for concern.

Organisation-level weak signals identified included the loss of the Trust's star rating; implementation of a financial recovery plan that included redundancies despite staffing level concerns; and negative organisation statistics such as above average mortality statistics. The 'loss of stars' signal was rationalised away in questioning the validity of the assessment tool. The rationalisation for the financial recovery plan was that the proposed staff reductions were in-line with the proposed reduction in beds. The signal of the above average mortality rates appears to be one of the strongest signals in this case study. Despite the rationalisation of the metric being subject to concerns regarding the coding of the data, this signal, possibly in addition to several weaker ones, initiated the greatest response, namely the HCC investigation and the first inquiry. This signal was identified by several sources and can be considered as an organisation-level signal. However, this signal also featured in the external environment signal the 'Dr Foster report'. The strength of the signal is highlighted by the extract below:

> 'it has to be concluded that this was a clear alarm bell requiring urgent action to find out whether this result could be explained by a review of the care provided' (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 100).

Internal environment level signals identified included two outbreaks of *Clostridium difficile*, one in 2008 and 2009. These weak signals directly reflect the concerns relating to the key

areas identified by the independent inquiry of continence, bladder and bowel care; safety; personal and oral hygiene; as well as cleanliness and infection control (The Mid Staffordshire NHS Foundation Trust Inquiry, 2010a). Furthermore, following the outbreak in 2008, senior staff raised concerns, which should have been a signal to management, as they felt unhappy about the Trust's reaction to outbreak as there had been an insufficient sense of urgency.

External environment level signals included the findings of external and peer reviews, audits and surveys; findings from official reports and the HCC investigation. Several reviews, investigations, audits and surveys were repeated over the time period in question whereby on numerous occasions similar results were found. Figure 38, complied from the documents analysed, depicts numerous examples of weak signals including repeated weak signals (orange), the reports (grey) and the reviews that signalled specific concerns (purple).

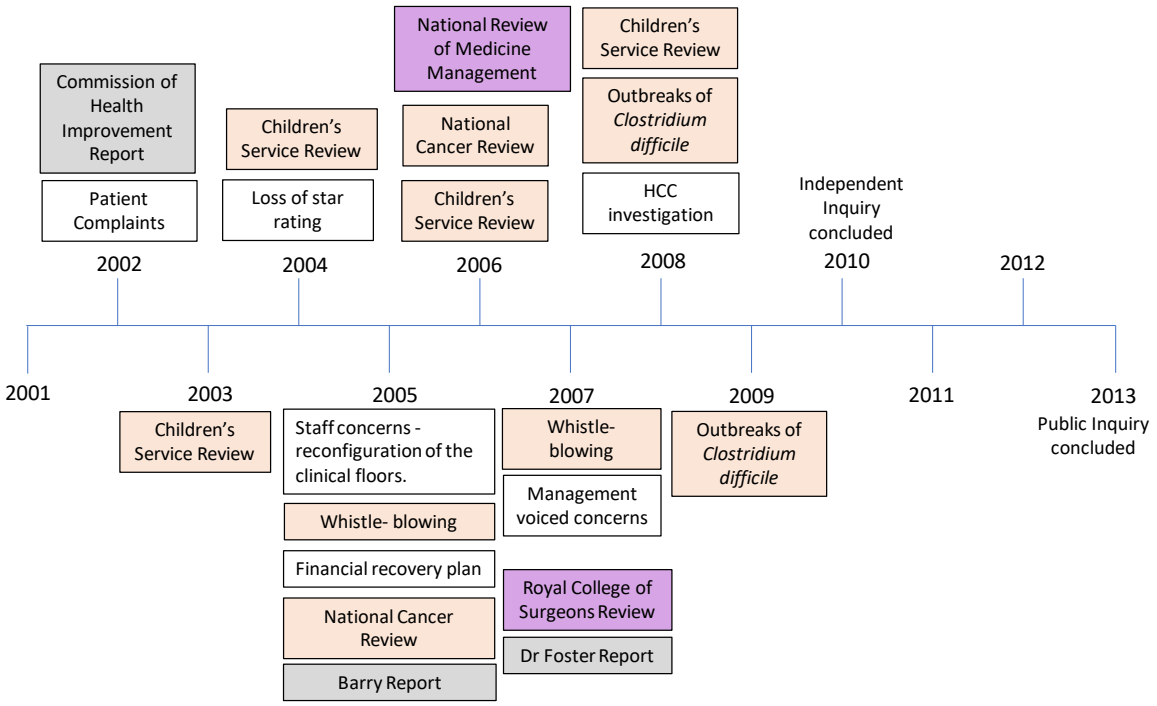


Figure 38: A timeline of some of the weak signals that presented during this organisational failure including repeated signals (orange), as well as the reports (grey) and the reviews that signalled specific concerns (purple).

Numerous concerns highlighted in the report published in 2010 were concerns that had been mentioned in earlier reports, for example the Barry Report in 2005 highlighted inadequate handovers, deficient note keeping, poor standards of care, inappropriate management style and inappropriate behaviour by staff (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013a, p. 64). The HCC investigation was an unusual event and should have been considered as a signal to other regulatory bodies that there was a need for concern regarding this Trust's performance. Other oversight and regulation bodies decided to await the outcome of the investigation, which is a form of rationalisation. The weak signals identified spanned several years and were repeated over this time period, as depicted in Figure 38.

8.6 Discussion

The events surrounding the Mid Staffordshire NHS Foundation Trust can be qualified as an organisational disaster by the definition provided in the *Section 8.3* (p. 214), as in its entirety it was a high impact event that threatened the survival of the organisation, in this case this specific Trust. As a result of this organisational failure, numerous patients lost their lives, others experienced unacceptable standards of care and undignified treatment, and in addition to this, the inquiries into this event have cost approximately £19 million and ultimately have led to the trust being dissolved in 2014 and services being relocated to other centres.

In this case study, the drift into failure through ignoring precursory signals, some of which were weak signals, is quite evident. This is visible in that as system components and safety processes were failing, the weak signals indicating this were rationalised away or the response was too weak to prevent the failures from still occurring. This is visible from the results above, specifically with regards to the numerous signals available over the time period, repetition of various signals and the rationalisations associated with not acting upon these signals. Through the analysis of weak signals and their rationalisations in this case study, insights into the characteristics of weak signals can be extracted. The characteristics included the repetition of signals and the accumulative effect of weak signals. One would expect the extent and severity of what was occurring, to have been derivable from some individual signals if they were clear and strong enough, for example signals associated with the higher system levels such as

Commission of Health Improvement Report in 2002 or the loss of the star rating in 2004. But also, a combination of slightly weaker signals, repetition or the accumulation of these signals should have notified management of what was occurring. Examples of repeated signals included the outbreak of Clostridium difficile and external peer reviews.

Furthermore, the clarity of the information regarding what was occurring at this Trust should have become more apparent with the repetition or accumulation of weak signals (Hiltunen, 2010). The findings in official investigations and reports, which provide evidence-based information, and as a result may be considered as relatively strong higher system level signals, can also be considered as an accumulation of signals differing strengths. The reports usually comprised of an accumulation of lower system level and potentially weaker signals, including person level signals, for example patient complaints and staff behaviours, task level signals and internal environment level signals. But in this case, the majority of the signals, irrespective of the strength, both lower and higher system level signals, were rationalised away, and then occurred later in the timeline again.

A common theme among the rationalisations was that the Trust assured external and regulatory bodies that progress had been made in correcting perceived deficiencies at numerous different time points. There also appeared to have been a lack of follow up on the previously generated reports. Additional system factors that prevented weak signals from being noticed and responded may have included a negative culture, professional disengagement regarding reporting concerns, poor governance, a lack of focus on standards of service, inadequate risk assessment of staff reduction, and incorrect priorities (The Mid Staffordshire NHS Foundation Trust Public Inquiry, 2013b). Rationalisations, which may result in a lack of action, can also impede comprehension of the event that is occurring. This is as action, which in a crisis is an epistemological issue, is a means for building an understanding of unknown environments and providing feedback (Weick, 1988).

This case study also highlights how rationalisations from one signal may impact the 'face-value' of other weak signals. An example of this was that if the severe staff cutting to meet the needs of the cost improvement plan had negative effects, this would have been highlighted in other performance measures. But unfortunately, the Trust's performance

measures had been highlighted as unreliable and the systems for collecting and coding for these measures were seen as inadequate.

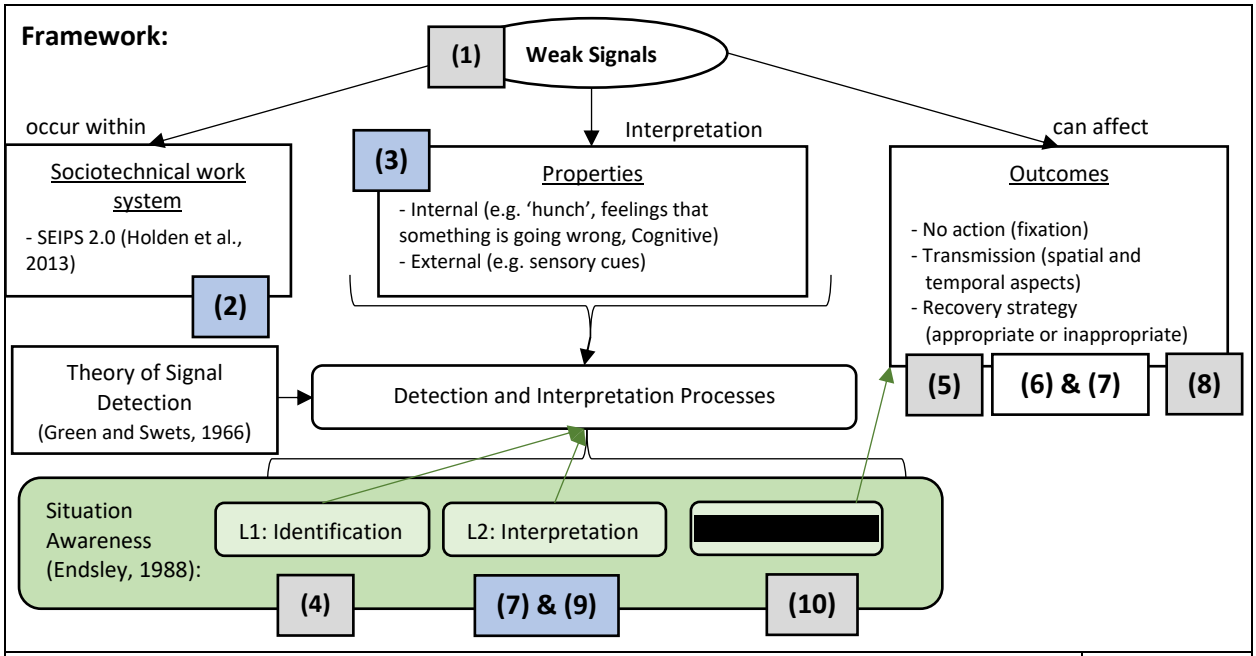
The weak signals identified in this case study and event can be described in the context of the pre-crisis signal detection model proposed by Hensgen et al. (2003) described in Chapter 3. Although over the years the weak signals were detected, it appears that there was a lack of suitable responses generated. This may have been because the organisation may not have had a system with a triggering mechanism, and therefore the appropriate response could not be generated (Hensgen et al., 2003). As described by this model and seen in the description of events, no-action was taken resulting in inflexibility and chaos. The organisation never self-corrected and as a result did not learn from the signals, strong or weak.

8.6.1 Framework Application

This case study explored the presence of weak signals in an organisational failure in healthcare, specifically for the case of the organisational failings of the Mid Staffordshire NHS Foundation Trust, using the weak signals in healthcare framework and analysis approach (version 4). The framework was used to guide the analysis and although not all elements of the framework were applied in this case study, the framework provided a structure for the analysis and identification of numerous elements. The framework and analysis aspects applied in this case study have been depicted in Figure 39.

Although the results of this case study focused on specific elements of the framework, namely the examples identified (analysis stage 1), their sources (analysis stage 2), and the rationalisation of why the weak signal was not acted upon (analysis stage 5), the data sources did provide additional information and other elements of the framework could be inferred. These included who identified the weak signal (analysis stage 4); if the weak signal was transmitted, to whom and by whom (analysis stage 8); if the weak signal was missed or not acted upon (analysis stage 9) and if there was a response or outcome (analysis stage 10). For the identifier of the weak signal in this case study, examples include the receiver of complaints for the weak signals of patient and staff complaints or the teams that conducted the reviews and audits for the weak signals of the findings in reviews and audits. Both of these examples also include transmission of the weak signals as the complaints and reports on the reviews

and audits would have been transmitted to potentially numerous different individuals as well as the Mid Staffordshire NHS Foundation Trust. For the analysis stages 8 and 9, the rationalisations provide indications of if the weak signal was acted upon and in this case most likely missed by being rationalised away or in that most actions were insufficient to prevent the drift into failure.



Analysis Stages			Application
Structural elements of weak signals		1. Extraction of the examples of weak signals from the data source	* Results
		2. Categorisation of the weak signals according to its source	*Inferred*
		3. Identification of the form of the weak signal	
Behavioural elements of weak signals		4. Extraction of who identified the weak signal	*
	Interpretation	5. Rationalisation for why the weak signal was not acted upon	*Results
		6. Extraction of if the consequence could be predicted	
	Action	7. Identification of the potential associated error	
		8. Extraction of if the weak signal was transmitted, to whom and by whom	*
		9. Identification if the weak signal was missed or not acted upon	*
		10. Extraction of the response and outcome	*

Stages in grey required direct data extraction. Stages in blue required categorisation and interpretation.
** Indicates the elements explored in this application.*

Figure 39: The analysis approach using the weak signals in healthcare framework (Version 4) applied to Case Study 4.

8.6.2 Limitations

The limitations of this case study included those associated with document analysis, the limited variety of data sources and limited perspectives included in this sample. The limitations of document analysis specific to this case include that they are social constructions of reality and therefore may be biased (Bowen, 2009; Bowling, 2002). It is essential to consider the process of construction in addition to the content, along with the authenticity, completeness and representativeness of the documents (Bowling, 2002) with regards to the results. However, as these documents were created independent of this research, the generation of these reports were not influenced by the researcher and consequentially, were not affected by a potential lack of reflexivity and may improve the reliability of the data (Bowen, 2009). Furthermore, these documents provided a unique perspective and information on an event that spanned approximately 10 years. Additional key limitations of this case study included a lack of data variety and the lack of perspectives on this event. Future work on this case study, if possible, would be to analyse additional documents available on this organisational disaster to identify additional and verify the current weak signals and associated elements identified. Through the use of data triangulation this would then improve the validity and reliability of the results (Barbour, 2001; Bowling, 2002).

8.7 Conclusion

Weak signals provide an opportunity for insight regarding the status of the system and areas of risk (Macrae, 2014b). But unfortunately, these signals are often rationalised away. As with many organisational disasters, this one also highlights the difficulty of recognising and accurately acting upon signals of imminent failure (Wei Choo, 2008). This case study explored the application of weak signals in healthcare framework for an example of an organisational failure in healthcare, namely the organisational failings of the Mid Staffordshire NHS Foundation Trust. Inquiries have estimated that between 400 and 1200 patients died as a result of poor care between 2004 and 2009 in this organisational failure. This application analysed the independent and public inquiry reports to identify the precursory weak signals and their rationalizations that occurred during this event. The framework was developed to support the research and understanding of weak signals in healthcare, and in this case study the framework was employed to a novel application in comparison to the previous case

studies. Although not all elements of the weak signals in healthcare framework were identified in the application, the framework provided sufficient structure without limiting the analysis.

The results highlighted examples of numerous types of weak signals, their source and associated rationalisations. Signals were present on numerous system levels. At a person level, there were cases of staff trying to make management aware of the problems, as well as the campaign 'Cure the NHS' started by bereaved relatives. At an organisational level, examples of missed signals included the decrease in the trust's star rating due to failure to meet targets, the NHS care regulator voicing concern regarding the unusually high death rates and auditors' reports highlighting concerns regarding risk management. At an external level, examples included negative peer reviews from various external organizations. The source of the weak signals was a focus of this case study as incorporating signals in risk management requires being able to identify where these signals originate, namely 'knowing where to look for them'. The second key focus of this case study was that of the rationalisations of signals. One needs to know the rationalisations for weak signals to better understand the factors that hinder acting upon them when identified.

It is the hope of this research that by understanding why weak signals were dismissed previously and the responses taken in the past, a better action plan may be developed for future situations. One needs experience or cases to create precedents, which one requires to assist in creating operational policy. This case study is an example of how healthcare can suffer from an organisational failure. It is essential that one learns as much as possible to inform policy and procedure so that safeguards for this kind of failure can be developed and put in place.

Chapter 9: Final Synthesis and Discussion

This chapter provides a discussion of the results relative to the literature on weak signals and safety. To achieve this, the discussion will first consider how the findings relate to the gaps identified in the literature and the research problem this thesis aims to address. Following this, a synthesis of the findings from across the four case studies (Chapters 5 to 8) that contribute to the general weak signal knowledge is presented and then related to the literature on weak signals that was presented in Chapter 3. The weak signals are then placed in the larger context of current concepts driving safety improvements, reviewed in Chapter 2. This chapter also aims to explore the practical implications of this research and weak signals in general for the healthcare context. This will be achieved by addressing the following objectives:

- Provide recommendations to support the use of the weak signals in healthcare framework. (*Section 9.4.2*, p. 246)
- Identify how the different elements of the weak signals in general may support improvement work in the healthcare environment. (*Section 9.4.3.3*, p. 251)

This chapter will also highlight the relevance of this research and discuss operationalising weak signals, in particular in the healthcare domain. This chapter concludes with a discussion of the methodology applied and the implications of this on investigating weak signals in healthcare.

9.1 Addressing the Gap and Research Problem

This research aimed to address a gap in a concept that spans several theories and paradigms currently driving safety improvements, namely weak signals. Chapter 2 highlights that to achieve a proactive approach to safety, the aim of the current concepts driving safety improvements (Lekka, 2011; Rankin et al., 2013), one needs an awareness of the current status of the system and to address problems as they arise. Weak signals may provide an indication of the system status and therefore provide an opportunity to address problems as they arise. As highlighted in Chapter 3, the knowledge on weak signals is largely distributed across numerous fields and an integrated conceptual representation of weak signals, the

processes underlying them and the factors that affect them is still largely undefined. This may be one reason why the application of weak signals to enhance task performance and system safety is still underdeveloped.

To address the above-described gap, the research question posed in this thesis was:

What are the weak signals in healthcare that may identify that a task or process may not be completed successfully?

This research question was answered by providing a theoretical basis and approach to guide research into weak signals that are present in healthcare work systems. This was achieved through the meeting the following objectives:

- Identification of the key weak signal elements and development of a definition of weak signals for the healthcare context based on a review of literature on weak signals. (Chapter 3)
- Development and evaluation of a framework of the key elements of weak signals to guide weak signal research in different healthcare contexts that function at different system levels, including at a micro (i.e. task), meso (i.e. process) and macro (i.e. organisational) level. (Chapters 5-8)
- Development of an analysis approach to support the application of the weak signals in healthcare framework to different healthcare contexts. (Chapters 6-8)

As weak signals are entangled and dependant on the context, to understand weak signals with an aim to operationalise them within the context they present, the following objective was also met:

- Depiction of the work systems for the different healthcare contexts in which weak signals were explored. (Chapter 5-7)

The following section will compile the knowledge acquired from addressing these objectives across the case studies investigated in this thesis. This will provide an overview of the answer to the research question posed. This will then be discussed relative to the available literature on weak signals and the implications of these findings.

9.2 Weak Signals in Healthcare

The main contribution of this research was to the knowledge on weak signals in healthcare. To explore weak signals in healthcare, a theoretical foundation was generated and then applied to four exploratory qualitative case studies on different healthcare themes. The theoretical foundation, developed from the literature described in Chapter 3, consisted of specifying and justifying the term 'weak signal', generating a definition for the term, identifying the key elements of weak signals (e.g. attributes, behaviours and influencing factors) and generating a framework for the analysis of weak signals in healthcare. The theoretical foundation and framework were applied to four case studies on different healthcare themes to explore the presence of weak signals. This section of the discussion will compile the results from across the case studies to identify the key elements of weak signals and how they relate to the literature available on weak signals. Case Study 1 investigated patient handling, Case Studies 2 investigated the context of patient discharge from hospital care to community care, and Case Study 3 investigated the care processes relating to sepsis. Case Study 4 investigated the presence of weak signals in an example of a healthcare system failure, namely the failings at the Mid Staffordshire NHS Foundation Trust.

9.2.1. Synthesis of the Findings

The term 'weak signals' was selected to represent the concept investigated in this thesis irrespective of the actual strength of the signal, as it was felt that in the healthcare context, the majority of signals could be considered weak, based on the criteria that affect strength and descriptions of signal strength found within the literature. Reasons for this include the complexity of work in healthcare and the uncertainty often associated with patient care. Furthermore, the identified criteria that affect signal strength (e.g. discriminability (Kaivo-oja, 2012; Nevin, 1969), precision (Turner, 1978) and interpretability (Hiltunen, 2010)) can be assigned to the two variables of signal detection theory (Green & Swets, 1966), namely an individual's sensitivity to the signal or their internal decision-making criteria. Moreover, the description of Mcleod (2015) that states weak signals are tasks and situations where staff need to manually monitor and integrate information over time to determine normal operating boundaries, describes numerous examples identified across the case studies, further highlighting how most signals in healthcare can be described as 'weak'.

Elements of the strength of the signals did not emerge from the results, and as the implications of labelling signals as either weak or strong is not practical, trying to define signal strength can be seen as a 'red herring'. Even strong signals have the potential to be weak. This is as signal strength is affected by the individual and their current state, elements described by signal detection theory, as well as the context in which signals present. With regards to the latter, if one considers the results from Case Study 4 (Chapter 8) on the organisational failings of the Mid Staffordshire NHS Foundation Trust, even though strong signals were present, they still did not yield an adequate response. This research chose to retain the adjective of 'weak' for the term 'weak signals', as interpretation is an essential element for generating an action in this context and even with strong signals there appeared to be problems with accurate projections, as seen in Case Study 4. This essential element was captured in the definition for weak signals generated for this research:

> *Weak signals are information that provide an indication of upcoming or emerging events that may have significant implications, whereby the information provided is often imprecise, ambiguous and incomplete, which requires active identification and processing.*

The ambiguity regarding both the concept, term and synonyms, highlights the need to clearly state the definition and justification of the term, especially to provide a common ground off which future research can build.

A key element of weak signals is the ultimate event or situation they indicate. The research in this thesis identified five key indications weak signals provide. That is, the weak signals indicated problems or concerns regarding patient safety and health, staff safety, task elements, process elements and organisational functioning. As QI aims to enhance patient experience and outcomes through the modification of working processes (Øvretveit, 2009), and HFE aims to improve worker well-being, efficiency and performance (Hignett et al., 2015), this highlights why weak signals may be of interest to both QI and HFE. The practical applications of weak signals from a HFE and QI perspective will be discussed later in this chapter (*Section 9.4.3.3*, p. 251).

Across the four case studies, a large number of weak signal examples were extracted. These were then categorised according to the source. By comparing the different case studies,

which explored healthcare themes that traversed different levels of the system, the results highlight how these themes result in weak signals emerging from different system level sources. The more system levels spanned in the case studies; usually the more elements of the work system produced weak signals. A summary of the different system levels explored, the indication the weak signals provided, the system level and the weak signal sources identified across the case studies is presented in Table 28. This highlights that by defining the healthcare theme one wants to investigate or apply improvement projects to, this already provides insight into where weak signals may originate from. If the task or process spans several subsystems, these could provide weak signals and furthermore provide insight into where the weak signal may need to 'travel' so the appropriate action can be taken.

Table 28: The different system levels explored, the indication the weak signals provided, the system level and the weak signal sources identified across the case studies.

Case Study	Healthcare theme	Weak Signal Indications	System Level	Weak Signal System Sources
Case Study 1 – Patient Handling (Chapter 5)	Healthcare task	Problems with patient safety.	Task level	Person, Task, and Internal Environment
Case Study 2 – The Hospital Discharge Process (Chapter 6)	Healthcare process	Problems with patient safety, staff safety, tasks elements and process elements.	Cross subsystem levels	Person, Task, Tools and Technology, Organisation of Work and Internal Environment.
Case Study 3 – Sepsis Cases (Chapter 7)	Health condition	Problems with patient health.	Cross subsystem levels	Person, Task, and Tools and Technology
Case Study 4 – Mid Staffordshire NHS Foundation Trust Disaster (Chapter 8)	Organisational failure/ System concern	Problems with organisational functioning.	Cross subsystem levels	Person, Organisation of Work, Internal Environment, and External Environment

A source of weak signals that featured across all the case studies was the person work system component. A common example of weak signals from this system element present in all four case studies were weak signals associated with patient behaviour. This underscores how most work in healthcare is centred around patient work, as described in Chapter 2, and emphasizes the importance of adopting a patient-centred approach. The patient may not only provide information about their own health condition, but also how well a healthcare task is proceeding, the functioning of a healthcare process and when the patient population is seen as a whole, may provide an indication of how well a healthcare system is functioning.

9.2.2. Development of the Weak Signals in Healthcare Framework

A key outcome of this research was the development of the weak signals in healthcare framework to provide a conceptual representation of weak signals in healthcare and a means of applying the theory and guide research on weak signals in healthcare. The developed framework provided a unified structure for the elements of weak signals that emerged from data and available literature on the topic. This section will discuss the core elements of the framework and the process applied to the development of the framework. The final version of the weak signals in healthcare framework is depicted in Figure 40.

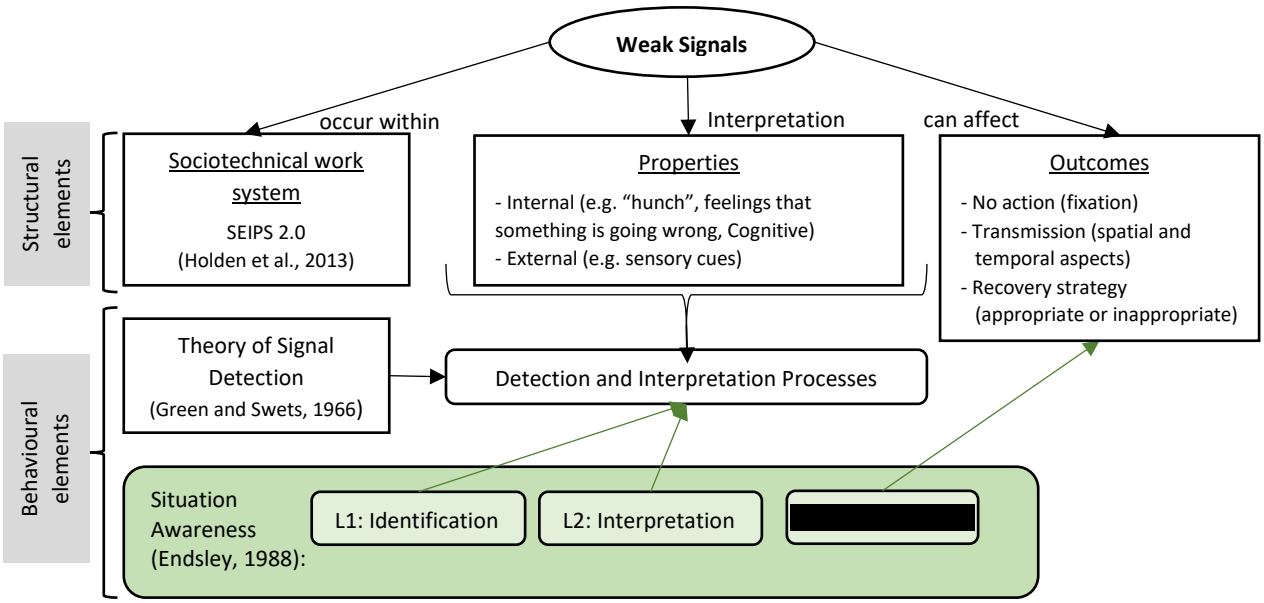


Figure 40: The weak signals in healthcare framework (Version 4).

The weak signals in healthcare framework (Version 4) provided 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. The framework was developed using the available literature on weak signals, not just related to weak signals in healthcare, and explored numerous theories that may have been applicable to the underlying mechanisms associated with weak signals. Although the aim was to develop a specific framework for weak signals in healthcare, the researcher did not want to exclude any supporting theories during the development phase. To enhance the generalisation of the findings, the framework was evaluated and modified using different healthcare contexts. This was to develop a general

weak signals framework relevant to healthcare work and not restrict it to a specific healthcare context.

The framework, which consists of structural and behavioural elements, initially had a more basic structure to allow the development to be data driven. The structural elements of the framework refer to the more easily detectable elements of weak signals as often they were easier to 'observe', whereas the behavioural elements, which were more difficult to 'access' refer to the processing components of weak signals and therefore may not be observable. Each element has been constructed using different theories and models, specifically the system structure was extracted from the SEIPS 2.0 model (Holden et al., 2013), detection factors were extracted from the Signal Detection Theory (Green & Swets, 1966), and the underlying structure for the detection and interpretation processes was extracted from the Aircrew Decision Model (Endsley, 1988) from the paradigm of Situation Awareness. Following each case study, the data was used with theory matching to modify and expand the framework. A summary of the modifications to the framework per case study have been included in Table 29.

Table 29: The contribution of each case study to the framework developments and additional theories used in conjunction with the framework.

	Framework Developments
Case Study 1 – Patient Handling (Chapter 5)	– Differentiation between forms of weak signals – General behavioural element added
	Other theories applied: – Reason's taxonomy of errors based on the SRK model (Reason, 2001)
Case Study 2 – The Hospital Discharge Process (Chapter 6)	– Refinement of structural elements – Behavioural element refined – Situation awareness (Endsley, 1988) incorporated as the key behavioural model – Development of an accompanying analysis approach
Case Study 3 – Sepsis Cases (Chapter 7)	– Confirmed the structural and behavioural elements – Addition of rationalisations to the analysis approach – Example of use of signal detection theory (Green & Swets, 1966)
Case Study 4 – Mid Staffordshire NHS Foundation Trust Disaster (Chapter 8)	– The framework and analysis approach were applied to an organisational system level failure
	Other theories applied: – Pre-Crisis Signal Detection Model (Hensgen et al., 2003)

Communication was identified as a common theme across the four case studies and, as a key action to weak signals may be the transmission of the signal, the relevance of Communication

theory (Shannon & Weaver, 1964) was made evident. Unsurprisingly, the framework and analysis approach (discussed later in this chapter) contains element that refer to four of the ten elements described in the schematic representation of a simple communication transmission as described by Shannon and Weaver (1964) in Figure 8 (Chapter 3). These include the source, signal, receiver, and message (referred to as indications in this research). Communication theory also provides a description of potential problems with weak signals as these align with the three levels of communication problems (Shannon & Weaver, 1964), namely the technical problem, concerned with the accuracy of transference of weak signals, the semantic problem, involving the interpretation of the meaning of the weak signal and the effectiveness problem, referring to the degree of success in the weak signal being interpreted and a resultant action taken based on this interpretation (Shannon & Weaver, 1964).

Additional theories were used in conjunction with the weak signals in healthcare framework, which enhanced the analysis and made the results more practical (e.g. Reason's taxonomy of errors (2001) based on the SRK model and Pre-Crisis Signal Detection Model (Hensgen et al., 2003)). In Case Study 3, a specific example was provided to explain the use of the Signal Detection Theory (Green & Swets, 1966) that describes two determining factors for signal detection, namely the sensitivity of the receiver (Swets et al., 1978) and individual's bias (Anderson, 2015; McLeod, 2015). The choice of the specific structural and behavioural elements of the framework will now be considered in the following sections.

9.2.2.1. Structural Elements of Weak signals

Based on the compiled literature in Chapter 3, the weak signals identified in this research could be evaluated against the identified attributes associated with weak signals (compiled in Table 8, p. 73). A total of five attributes were identified, one of which is signal strength. Six sub-attributes were identified for signal strength, and included interpretability (Hiltunen, 2010), discriminability or perceptibility (Coffman, 1997b), precision (Vaughan, 1996), perceived significance of the future event(McLeod, 2015), the subjective or objective nature of the information contained in the signal and whether it was context specific (Hiltunen, 2008; Tarasti, 2001). Although across the case studies, examples of weak signals depicting several of these sub-attributes were identified, these sub-attributes did not assist in identifying a scale for signal strength. Based on these results, it was decided not to include this element in

the framework. The other attributes identified in the review of literature included outcome type, event, source and frequency. All identified weak signals were associated with one outcome type as described by Stolper et al. (2009), in that all weak signals indicated a negative outcome or event, as this was the specified focus of this research. As highlighted in Case Study 2, the examples of weak signals identified that were associated with barriers highlights the point made by Hiltunen (2010) that weak signals may be signs of emerging issues or be the emerging issues themselves.

The source of weak signals specified by Eco (1976), McLeod (2015), and Tarasti (2001) were identified across the case studies. Eco (1976) identified two types of weak signals, which the author referred to as signs, based upon the source; specifically, natural signs that originate from physical events from natural sources, and non-intentional signs that originate unintentionally from human behaviour. Weak signals that could be described as non-intentional signs were identified across all case studies and related to those associated with the patient's, their family's or staff's behaviour. McLeod (2015) identified type A signals, given off by equipment or instrumentation indicating the current state of the system, and type B signals originating from the behaviour and actions of individuals in the system that indicate the system's defences are being eroded. From the results, the examples of weak signals associated with results from equipment (e.g. blood pressure, temperature), especially in Case Study 3, could be classified as type A indicating the health state of the patient. Numerous examples of type B signals, namely the patient's, their family's and staff's behaviour were identified across all the case studies. Moreover, examples of weak signals identified across all of the case studies, were also classified as either originating externally or created internally, which aligns with the endo- and exosigns described by Tarasti (2001). This refers to signs present in the outside world (exosigns) and signs created in the mind (endosigns). Examples of mixed weak signals as described by Vaughan (1996) were also found across the different case studies, especially in weak signals described in this research as combined and reflected as a discrepancy between two pieces of information or two different weak signals.

Although the typologies of other authors could be applied to some of the results from this research (e.g. Eco, McLeod, Tarasti and Vaughan), this offered little practical insight with regards to operationalising weak signals. This research chose a system-based source typology

as this provides practical implications, in that if 'one knows where to look for weak signals', one might be able to identify them. This is as the detection of signals is often dependent on knowing what to look for, in addition to the ability to perceive them (Gaba et al., 1995). By identifying the source, potential targets for interventions or support tools can been identified.

9.2.2.2. Behavioural Elements of Weak signals

Although the behaviours associated with weak signals were more difficult to investigate, elements associated with these processes emerged from the data. The participants from focus groups (Case Studies 1 and 2) felt that the processes related to detection and interpretation may be related to intuition, 'you somehow unwittingly subconsciously refer to a similar incident' and use a 'catalogue of experiences' which indicates the first component of the RPD model (Klein, 1993) and the rule-based behaviour of the SRK model (Rasmussen, 1983). However, these elements were mentioned with an air of uncertainty and posed in the form of a question which highlights how the mechanisms behind weak signals are predominantly invisible to the user. This phenomenon may be the reason behind the difficulty in explaining decisions made using weak signals (Benner & Tanner, 1987). Furthermore, several weak signals specifically described a discrepancy between the situation and the expected situation, which caused the participant to redirect their attention. This discrepancy is thought to explicitly cause sensemaking (Louis, 1980; Weick et al., 2005). Several influencing factors on the processes associated with weak signals were also identified in the case studies that were described in the literature (Chapter 3, Table 9, p. 76). These aspects included external pressures and drivers that may suppress weak signals (Hensgen et al., 2003), the ability to question the situation (Carrillo & Samuels, 2015) and the predicted consequences of the situation (Klein, 2003).

Although the results from several case studies hinted at several other theories to describe the mechanisms underlying the behavioural aspects of weak signals (e.g. intuition, RPD model), the data that can be collected regarding behavioural elements is best supported by the paradigm of situation awareness. This paradigm provides a theoretical basis from which practical implications can be drawn. For example, if one knows who is most likely to identify a weak signal, support tools and interventions can be developed with this stakeholder in mind. The behaviour elements of the framework were expanded to incorporate the three

levels of situation awareness, as described in the Aircrew decision model by Endsley (1988). However, when trying to describe the underlying processes of weak signals in specific contexts, the unique elements of the context should be taken into account and the most suitable theory of human cognition (e.g. Information processing, RPD, heuristics) applied to understand how the weak signals may be processed.

The aggregated results from the case studies revealed some additional insight into the underlying connections between behavioural elements associated with weak signals, as described in the framework. These included the types of responses selected once the weak signals were identified, that certain weak signals need to be compiled (i.e. combined signals), the reason why weak signals generated no response (rationalisations), the types of factors that influence weak signal detection and the barriers to identifying and responding to weak signals. The connection between these behavioural elements has been depicted relative to the weak signals in healthcare framework in Figure 41.

A variety of responses to weak signals were identified. These include several ones that resulted in no action, namely adopting a 'wait and see' response and not responding as a result of rationalisations regarding the interpretation of the signal. Rationalisations were also seen to have an affect on the interpretation of other weak signals, as described in Case Study 4. Other actions included initiating a response which included searching for more information, initiating a corrective action, and transmitting the weak signal as one was unable to respond directly. The search for more information may result in the identification of additional weak signals, which may result in the generation of a combined signal that then provides greater information about the indication. All of the outcomes will be influenced by the context and the system within which the weak signals are located. As shown in Case Study 2 and Case Study 4, if the system is not designed to support a response or transmission of the weak signal, this may hinder the action.

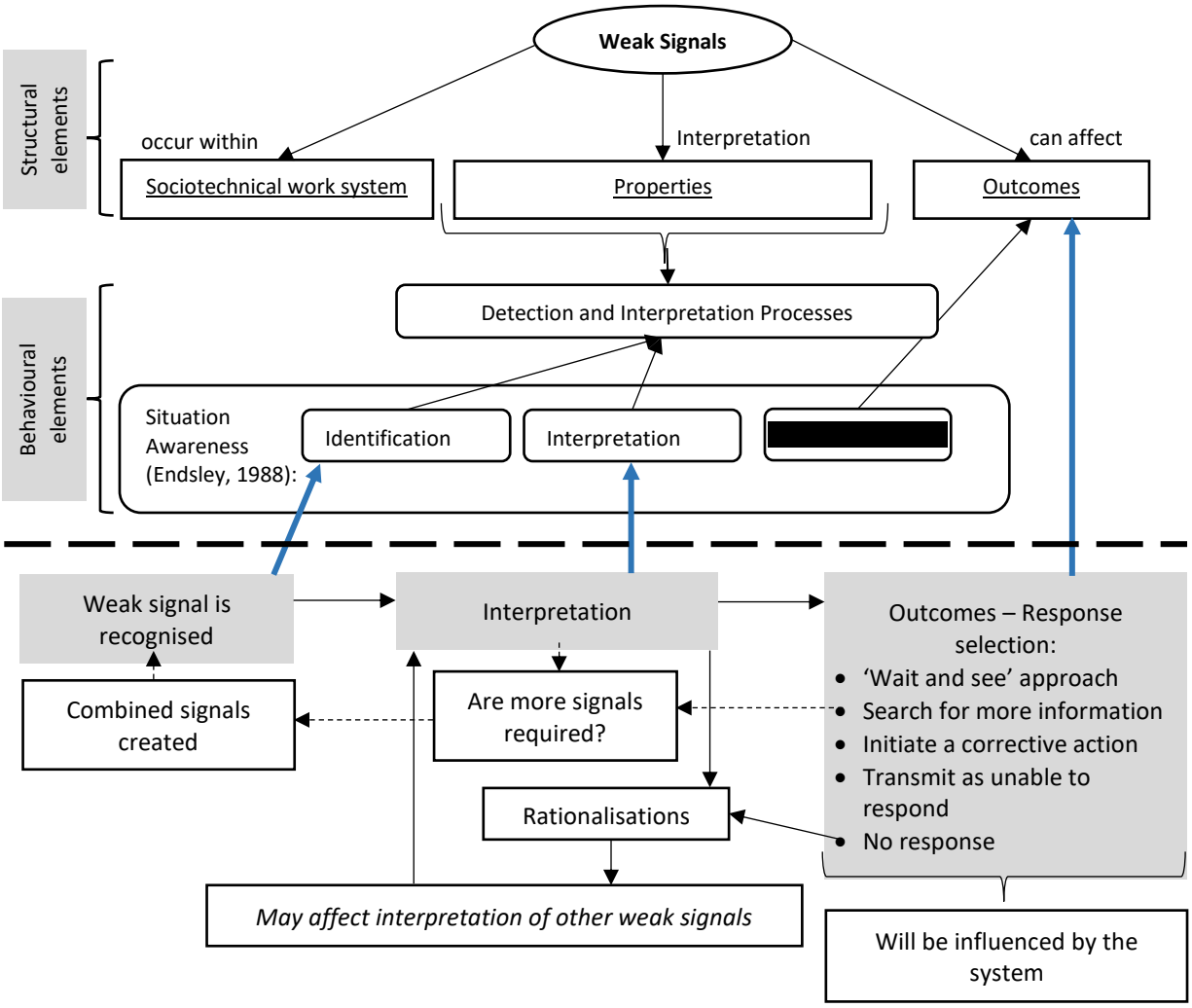


Figure 41: The connection between behavioural elements identified across the case studies depicted relative to the weak signals in healthcare framework (Version 4).

The factors identified as affecting weak signal detection (identified in Case Study 1 and 2) include the familiarity of the action and situation, underlying assumptions regarding the nature of work, the effect of habit, the ability to question the situation and the consequences of the situation. The barriers to identifying weak signals included individual barriers (e.g. being too task-orientated, a lack of experience), organisation of work barriers (e.g. time constraints, work pressures), task barriers (e.g. limited information poor communication) and external environment factors (e.g. external pressures and drivers which might suppress signals). The barriers to responding to weak signals identified included individual barriers (e.g. complacency, insufficient knowledge and experience) and organisation of work barriers (e.g. time constraints, management pressures, poor teamwork).

9.3 Weak Signals in Safety

The literature review presented in Chapter 2 highlighted that most of the current concepts driving safety improvements have a degree of overlap in that they advocate a proactive approach to safety by addressing problems as they arise (Lekka, 2011; Rankin et al., 2013). One means of addressing problems as they arise involves the use of weak signals, as these may provide an indication of deviations in the task or system, and allow for sufficient time to facilitate swift and flexible action (Vogus & Hilligoss, 2016; Weick et al., 1999). This section of the discussion places the results from across the case studies and the concept of weak signals relative to the current concepts driving safety improvements.

9.3.1 Safety Culture

Safety culture can be defined as the beliefs, values and norms shared by organisational members in terms of what is considered important (Sorra & Nieva, 2004). Furthermore, this includes how organisational structures and systems operate and interact, which influences the attitudes, behaviours and social norms that promote safety (Singer et al., 2009). The literature specifically highlighted signals as an element of the social processes of patient safety culture (Reiman et al., 2010) that may assist in guiding behaviour. In addition to this, the results highlighted several elements of safety culture that are associated with weak signals. As signal detection is influenced by the sensitivity of the receiver (Swets et al., 1978) and individual's bias (Anderson, 2015; McLeod, 2015), it is conceivable that the beliefs, norms and values that comprise safety culture will also affect weak signal detection.

As weak signals may appear in the form of errors or the emerging event themselves, as is specifically highted with weak signals in Case Study 2, this ties directly to safety culture as described by Reason (1997). The ability to point out errors, which may be the weak signal itself, is essential to be able to respond to the weak signal and falls within the component of safety culture referred to as a reporting culture (Reason, 1997). Similarly as reporting culture is influenced by whether a 'blame culture' exists in the organisation (Waring, 2005), it is conceivable that a 'blame culture' may also suppress the reporting of weak signals. Likewise if a flexible culture, which is management's trust in the front-line staff's knowledge to respond

to situations (Reason, 1997) is present, staff may use weak signals to guide their response to emerging situations.

As a good safety culture is associated with open communication that allows staff to freely raise issues and questions (Kirk, Parker, Claridge, Esmail, & Marshall, 2007; Olive et al., 2006), this would suggest environments with this type of culture would assist the transfer and discussion of weak signals. Moreover to sustain a good safety culture, communication between and among levels of an organisation are necessary (Olive et al., 2006). This would also aid weak signal use as the case studies showed that especially for processes that span several subsystems (e.g. hospital discharge and sepsis), these weak signals may need to span subsystem boundaries. Resilience as described within the concept of safety culture, as the ability to process small incidents or errors and maintain system functioning (Olive et al., 2006), ties to weak signals in that weak signals may be in the form of small incidents or errors, as described in Case Study 1 and 2. The theme of vigilance from good safety culture, would also allow for an increased likelihood in the detection of weak signals. In Case Study 2, almost all the participants mentioned a barrier to identifying weak signals was time pressure and workload, both of which would affect vigilance.

9.3.2 HRO Theory

HRO theory aims to understand the conditions under which high reliability organisations achieve high safety performance levels (Lekka, 2011). Of the five unique characteristics of HROs that enhance reliability (Weick, 1987), two can be specifically related to weak signals. The literature specifically highlights the connection to weak signals with regards to the characteristic of a 'preoccupation with failure' as the organisation is always alert for the smallest signal of a new developing safety threat despite their current safety record (Chassin & Loeb, 2013; Cochrane et al., 2017). In addition to this, weak signals may also provide a mechanism for achieving the characteristic of sensitivity to operations. HROs may also use weak signals more frequently than other types of organisations, without specifically referring to the indicators as weak signals. These organisations experience errors, however the errors do not disable the organisation (Sutcliffe, 2011), which is generally achieved through dynamic organising principles (Weick et al., 1999). These include mechanisms to monitor and report signals indicating a breakdown of the system (Barton & Sutcliffe, 2009; Sutcliffe, 2011), as well

as having the flexibility and capability to respond to these indicators and events (Weick & Sutcliffe, 2007). Both elements are essential for utilising weak signals to enhance safety.

9.3.3 Resilience Engineering

Resilience engineering aims to understand how success is obtained as well as how individuals learn and adapt in an environment containing faults and hazards (Hollnagel & Woods, 2006). Everyday adaption is required to address the fluctuations and unexpected events that occur while working in complex systems, which can be referred to as performance variability (Rankin et al., 2013). Weak signals may be an indicator of fluctuations in the system, signifying staff need to adapt their performance. Furthermore the literature specifically describes that resilient organisations are better able to identify signals as forms of up-to-date information regarding ongoing operations and alterations in the system, allowing an organisation to anticipate changes (Hollnagel, 2012; Hollnagel & Woods, 2006; Vogus & Sutcliffe, 2007). This would include weak signals.

The key principles of resilience include top management commitment, flexibility, learning, awareness (Hollnagel, 2006), open communication and a non-punitive approach towards error reporting (Vogus & Sutcliffe, 2007). Some of these principles overlap with safety culture and HROs, and as such the principles relating to weak signals described previously would apply to resilience engineering too. The four capabilities of resilience are the ability to anticipate what may potentially happen, monitor the current state through vigilance, respond effectively when something occurs and learn from past experiences (Hollnagel, 2009). Furthermore, the process of vigilance specifically ties resilience engineering to weak signals, as vigilance is 'the ability of a system to detect and interpret weak signals' (Brizon & Wybo, 2006). Such signals assist in detecting deviations and facilitate swift and flexible action (Vogus & Hilligoss, 2016; Weick et al., 1999). The mechanisms staff mentioned in Case Study 1 that they use to prevent the task from going wrong are related to resilience. These included building in individual checks into one's own behaviour, being less task orientated, more situation aware, continuous assessment of the situation and questioning actions. These behaviours relate to the resilience capabilities of monitoring the current state through vigilance and responding effectively when something occurs (Hollnagel, 2009).

In relation to the CARE model (Anderson et al., 2016) depicted in Figure 6, p. 34, described in Chapter 2, weak signals can also be positioned relative to this model. Weak signals may provide information regarding the lack of alignment of demand and capacity within the system. An example of a weak signal indicating this, described in Case Study 2, would be staff's behaviour indicating their stress level as a result of the imbalance of demand and capacity. Furthermore, weak signals may result in staff making adjustments and adapting their work, as described by the work-as-done component of the CARE model. Several examples throughout the four case studies described the misalignment between work-as-done and work-as-imagined, as highlighted in the example below, with weak signals being used to guide and inform the work-as-done component.

> 'You have had a referral for a wound dressing. You walk in and you don't go in and *do that wound and walk out. You just know. You are looking around and you know some*thing is not right, and as much as you have had the referral for that task… you restructure your time.' (Case Study 2, Community Focus Group 6)

9.3.4 Safety-I and Safety-II

Although Safety-I and Safety-II was the only paradigm of the current safety concepts not to explicitly mention weak signals in the associated literature, the position of this researcher is that weak signals can aid this concept. Safety-II is defined as 'the ability to succeed under varying conditions, so that the number of intended and acceptable outcomes is as high as possible' (Hollnagel, 2014, p. 179). Similar to the CARE model, key principles and theories underpinning Safety-II are the concepts of performance adjustments, performance variability, and work-as-done as opposed to work-as-imagined (Hollnagel et al., 2015). Several of these concepts have already been discussed relative to weak signals. Furthermore, it is the position of the researcher that to be able to succeed under varying conditions, one needs to be aware of weak signals indicating 'drift' or performance variability, so that performance can be adjusted to ensure a successful outcome.

9.4 Practical Implications and Recommendations

9.4.1 Relevance of this Research

The problem addressed in this research, identified in the literature, is the lacking conceptual representation of weak signals from which to research and operationalise weak signals. This is relevant as weak signals provide an opportunity to enhance system functioning and safety. Weak signals may present an opportunity to address problems as they arise. This may promote safety in that, when problems are small, there may be more ways to solve them, whereas if these problems develop, they tend to become entangled with other problems, resulting in fewer options for solutions (Sutcliffe, 2011). Furthermore weak signals can provide the opportunity to prevent incidents if their potential significance is identified and individuals respond to them (McLeod, 2015). By addressing weak signals and system drift, a proactive approach to improved safety performance can be established (Carrillo & Samuels, 2015; Dekker, 2011). Furthermore, if weak signals could be operationalised, they may be able to contribute to developing a positive safety culture, promoting reliability and resilience. Considering the nature of work, the patient-centred element and the unique characteristics of healthcare systems, adopting a proactive approach to safety and operationalising weak signals will have many benefits for this domain.

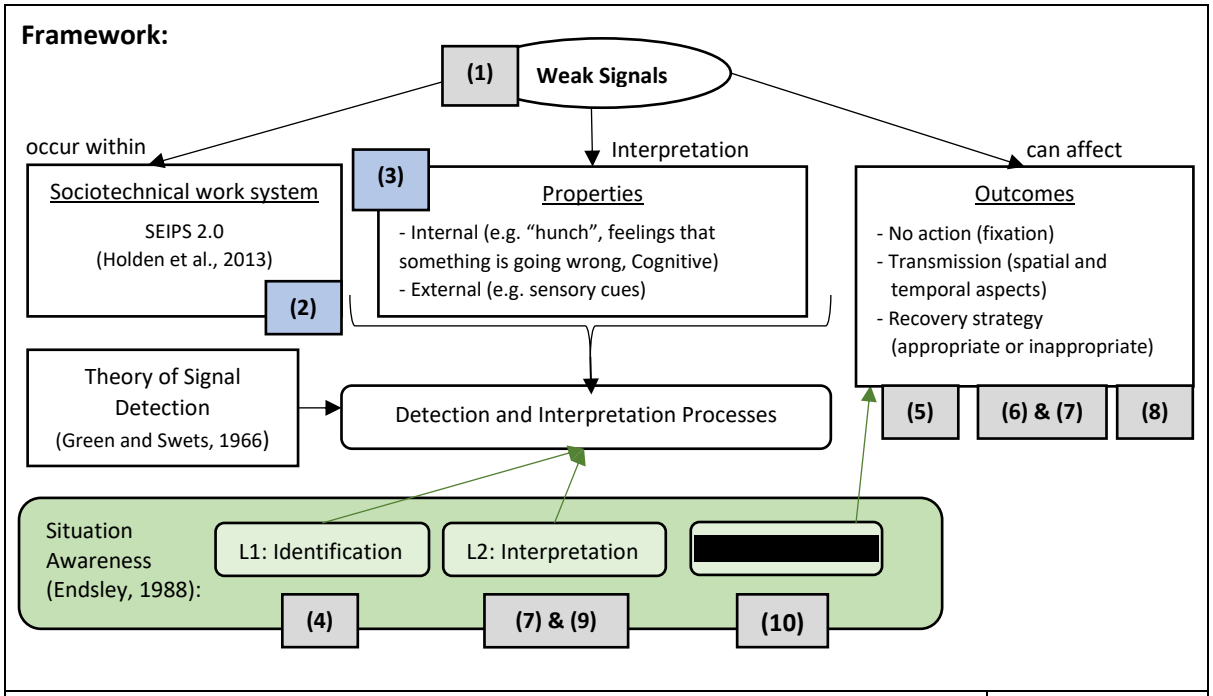
This research developed a theoretical basis and approach to guide research into weak signals that present in healthcare work systems. The two key outcomes of this piece of work were a contribution to knowledge on weak signals in healthcare and an approach to investigate weak signals in healthcare. Both of these outcomes have practical implications, which will be discussed in this section. The developed framework provides a structure and language for the investigation of weak signals experienced within the healthcare environment and consequently, has two key practical implications. The first is to provide a conceptual structure to support further research on this topic and the second is to support using weak signals to enhance task performance and patient safety. The framework provides not only a structured approach to investigating weak signals in healthcare, but also based on the results of this research, key elements and considerations were identified for use of weak signals on an individual level, other system applications and for design of intervention or improvement projects. The recommendations and applications for the framework and analysis approach

developed in this thesis will be discussed first. Following this, the general implications of weak signals in healthcare will be discussed.

9.4.2 Recommendations and Application of the Weak Signals in Healthcare Framework

The aim of the framework was to provide a structure and language for the investigation and discussion of weak signals experienced within the healthcare environment. Based on the lessons learnt across the four case studies in this thesis, this section will describe the need for and function of the framework, outline the analysis approach developed to support the application of the framework and provide recommendations for the application of the framework. This section describes the recommendations and the first practical element of the framework from the perspective of supporting research into weak signals in healthcare.

The literature on weak signals in healthcare to date has adopted a variety of approaches and perspectives and consequently, this makes comparison of the results and building upon past research difficult. The framework was designed to provide structure, allowing future work to be compared more easily, while still providing a degree of flexibility that may be required for the investigation of weak signals. The accompanying analysis approach provides additional transparency to the framework and a potential guide for future research into weak signals. Furthermore, the case studies highlighted that alternative theories and models (e.g. work system configurations (Holden et al., 2013), Reason's taxonomy of errors (2001)) can be used in conjunction with the weak signals in healthcare framework. This highlights the importance of flexibility and transparency, as healthcare is a complex system with complex challenges, numerous models and theories may need to be used in conjunction with each other to develop research that will result in sustainable improvements. The final version of the framework and accompanying analysis approach developed in this research are depicted in Figure 42.



Analysis Stages			Data Sources
Structural elements of weak signals		1. Extraction of the examples of weak signals from the data source	All
		2. Categorization of the weak signals according to its source	*Inferred*
		3. Identification of the form of the weak signal	*Inferred*
Behavioural elements of weak signals	Identification	4. Extraction of who identified the weak signal	Incident reports, patient stories
	Interpretation	5. Rationalisations for why the weak signal was not acted upon.	Patient stories, official reports
		6. Extraction of if the consequence could be predicted	Focus groups, interviews
	Action	7. Identification of the potential associated error	*Inferred*, incident reports
		8. Extraction of if the weak signal was transmitted, to whom and by whom.	Incident reports, patient stories
		9. Identification if the weak signal was missed or not acted upon	Patient stories, official reports
		10. Extraction of the response and outcome	Patient stories, incident reports

** Stages in grey required direct data extraction. Stages in blue required categorisation and interpretation.*

Figure 42: The weak signals in healthcare framework and analysis approach (Version 4).

This framework functions to provide something between a model and a method that contains a structure for the understanding of weak signals that can affect performance and patient safety. The structure includes an understanding of the key elements of weak signals and a means for analysing these elements, ultimately providing a basis for working towards operationalising weak signals for improved safety in healthcare. The framework intends to achieve this aim by providing an understanding of where weak signals may be found, what

might affect them, the information they may contain, which outcomes they may indicate, the context in which they may appear and the factors that may influence them.

As described earlier in this chapter, the framework consists of two key components, specifically the structural and behavioural elements. For each element, a series of analysis questions to support the assessment of data associated with that element have been developed. This research also identified that different data sources provided different information types associated with weak signals. The different analysis questions and the data sources that provided information on these aspects have been included in Figure 42. The data sources listed for each element in Figure 42 are not meant to be seen as prescriptive, but rather as a potential starting point and consideration for the research design process. As the framework provides a structure to the available literature on weak signals, the framework and analysis approach could be used to develop alternative questions to explore weak signals in healthcare. Furthermore, each element of the framework provides insight into a different element of weak signals, which can support the research design process. This information is not only relevant for understanding weak signals but also offers insight for improvement work in the healthcare environment, discussed later in this chapter.

Some key recommendations specific to conducting research into weak signals could be extracted from the lessons learnt from the four case studies. These have been listed in Table 30 and the relevance for each recommendation has been included. The recommendations include apply a systems approach to the research design and analysis, including qualitative data, including multiple and different types of data sources and avoid 'becoming stuck' trying to define and assign signal strength if it is not necessary.

Table 30: Key recommendations relevant to conducting research into weak signals.

Recommendation	Relevance
• It is essential to apply a systems approach to the research design and analysis.	• The theme being investigated will determine the extent of the system and as experienced in this research, the more systems spanned; the more elements of the work system produce weak signals.
	• The system will provide the context from which weak signals emerge.
	• A systems approach will be required if the research is to contribute to interventions and changes in the system.
• Qualitative data sources should form an essential component of the research design	• Due to the unobservable nature of some of the processing mechanisms of weak signals, these may need to be explored directly with participants.
• Multiple and different types of data sources should be considered for inclusion in the sample	• This allows for data triangulation and increases the likelihood of identifying additional examples of weak signals.
	• As found in this research, the different data sources provide different levels of detail and information on weak signals.
• Depending on the focus of the research, one should avoid 'becoming stuck' trying to define and assign signal strength if it is not necessary	• As weak signals may be stronger to some individuals and weaker to others (Hiltunen, 2008, 2010), this attribute of weak signals may not provide practical or additional insight.

A key emphasis of human factors is on practical implications of research (Vincent, Moorthy, Sarker, Chang, & Darzi, 2004). The framework's practical implications are enhanced as it has incorporated a system's perspective, which is essential for understanding safety in complex systems such as healthcare (Waterson et al., 2015). The framework, as shown in the case studies in this research, can assist in identifying key stakeholders, barriers to using signals, and system considerations regarding the transmission of the signal. The framework selected the system source as the categorisation scheme for weak signals, which has a practical benefit as this categorisation scheme would promote 'knowing where to look for' signals. This is essential as to improve safety, one needs to consider weak signals from all sources, especially the voices of patients and carers, as highlighted in the Berwick report (National Advisory Group on the Safety of Patient in England, 2013), which emerged in light of the failings surrounding the Mid Staffordshire disaster. The framework also assists with identifying rationalisations associated with not acting on signals. This is an important component for enhancing weak signal use as if one can identify why staff do not respond to them, interventions and support tools can be designed to alter this behaviour.

9.4.3 Practical Implications: Operationalising Weak Signals

The second practical element of this framework is that it can support enhancing weak signal use to improve task performance and patient safety. Examples of current studies exploring weak signal use include the use of verbal and non-verbal cues to gather information on the patient's status risk of developing depression before and during IFN-a treatment (Hepgul et al., 2012), cues for early recognition of sepsis (Patterson et al., 2016), situational cues in anaesthesiology (Gaba et al., 1995) and cues that form part of neonatal intensive care unit (NICU) nurses' patient assessment skills (Crandall & Getchell-Reiter, 1993; Militello, 1995). Examples of literature aimed at promoting weak signal use as a healthcare quality element or intervention include educating patients on 'red flags' to self-identify worsening conditions in a study on a care transition intervention (Coleman et al., 2006), and 'red flag' warnings of patients at high risk of readmission following discharge (Katikireddi & Cloud, 2008). As discussed earlier, as previous research has approached this topic from a variety of perspectives, building upon this is difficult. The framework and results of this research thus provide key elements and considerations for use of weak signals on an individual level, other system applications and for design of intervention or improvement projects.

9.4.3.1 Use of Weak Signals on an Individual Level

As highlighted in the literature above and from the results of several of the case studies in this thesis, the use of weak signals on an individual level, appears to be already incorporated in some everyday work elements. The results, especially from Case Study 1 and 2, highlight that weak signals are being used as informal strategies to guide work-as-done. This is described in the quote earlier in this chapter (p. 244). This research also identified elements to enhance this form of local weak signal use, by determining the elements that support detecting, identifying and responding to weak signals. Facilitators for the detection and identification of weak signals included communication and information elements (e.g. cross-system collaboration, patient-specific information), individual behaviour elements (e.g. being less task-oriented and more situation-aware), training elements (e.g. provide opportunities reflection, review and discussion of incidents, trained memory cues) as well as organisation of work elements (e.g. good management support and teamwork). In addition to the above, as highlighted in Section 9.2.2.2 (p. 239), the larger system also needs to support the response and transmission of weak signals. The framework can provide support in determining the

system elements in place that support weak signal use and identify the prerequisites for weak signal use in a specific healthcare context.

9.4.3.2 Other System Applications of Weak Signals

The results from the case studies highlighted some of the other system applications of weak signals. These included tools compiling weak signals, organisation of work elements that allowed for the identification of weak signals and the external environment example of raising awareness of weak signals. Two examples of tools that compile various weak signals were tools that calculate scores (e.g. NEWS, SOFA, qSOFA) from the observation of vital signs used in patient monitoring described in Case Study 3, and audit or review reports that presented an accumulation of weak signals indicating system functioning as described in Case Study 4. The organisation of work element that supported the identification and response to weak signals was the roles of staff positioned to respond flexibly to weak signals as described in Case study 2 (e.g. 48hr discharge coordinator, responder role). The external environment example of raising awareness of weak signals, featured in Case Study 3, was through advice for the general public on weak signals of sepsis (e.g. 'it feels like you're going to die') to support patients accessing healthcare more timely for this condition. As with the use of weak signals on an individual level, other system applications of weak signals also require support from the work system as a whole in order to be utilised. This includes systems for monitoring, identifying and the structure and resources to generate an appropriate response (Hensgen et al., 2003).

9.4.3.3 Applications of Weak Signals for Improvement Work in Healthcare

In addition to the above, the results generated from the framework can provide an indication of which areas in the system to target for improvement projects. As weak signals provide insight regarding the status of the system and areas of risk (Macrae, 2014b), so too the indication the weak signal provides can assist in identifying targets for improvement strategies and system redesign. The research in this thesis identified five key indications weak signals provide, namely problems or concerns regarding patient safety and health, staff safety, task elements, process elements and organisational functioning. Figure 43 depicts potential improvement strategies derived from each of the indicated outcome or event types for weak signals in healthcare.

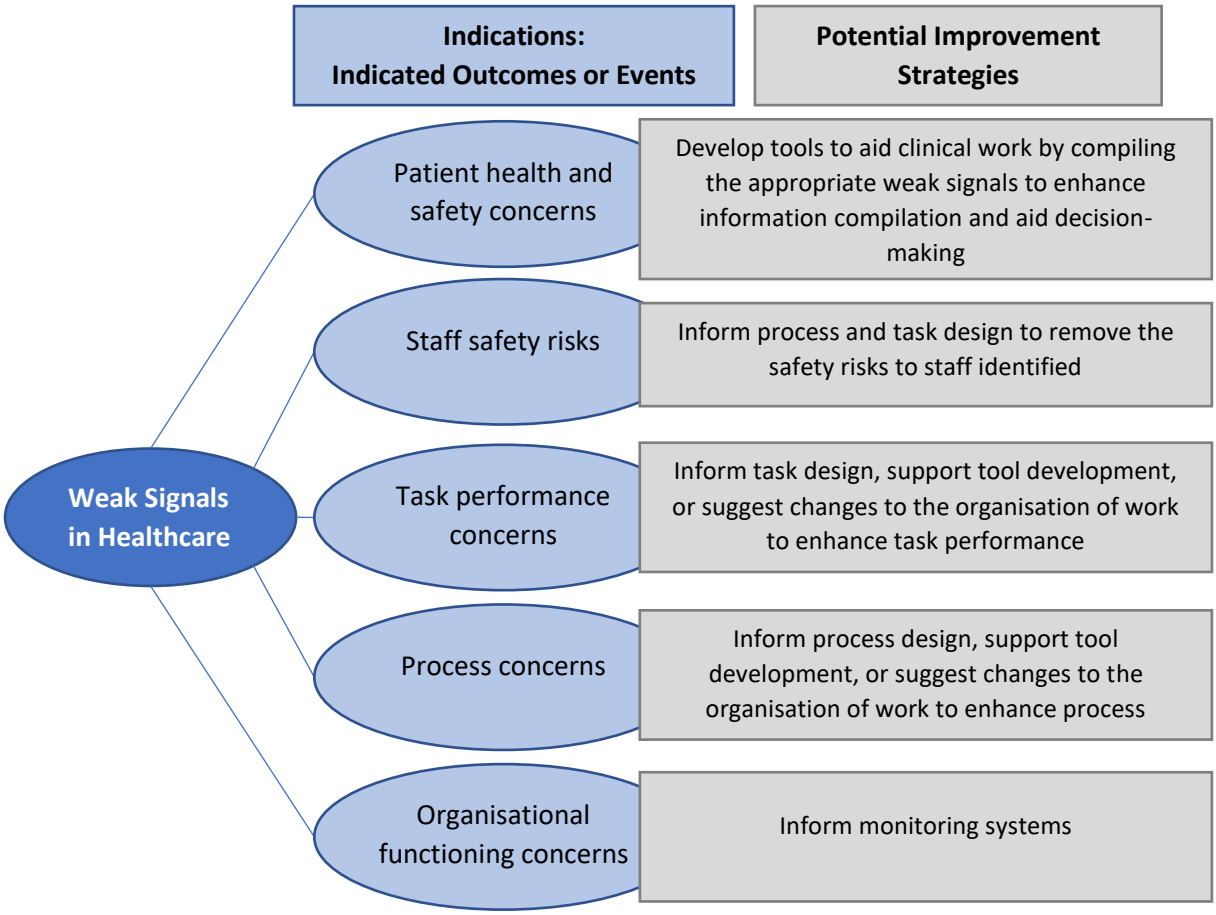


Figure 43: Potential improvement strategies derived from the indicated outcome or event types for weak signals in healthcare.

For the indicated outcome of patient health and safety concerns, the weak signals associated with this can provide a starting point to develop tools with clinicians, using a participatory approach, that can enhance information compilation and decision-making to aid clinical work. In addition to this, these types of weak signals could also be used to inform training. As some weak signals may appear weaker than others due to their dependency on context (Hiltunen, 2008), highlighted by examples of the weak signals identified in Case Study 1, staff may require specific information or knowledge regarding the context to interpret them. By using weak signals that indicate patient health and safety concerns to inform educational materials and development of assessment tools, this can assist in transferring the specific knowledge needed to interpret these weak signals. This can include either making the required information more readily available or providing means of identifying the additional information needed for their interpretation.

Weak signals that indicated staff risks can suggest certain processes, protocols and tasks may need to be redesigned to remove or reduce the risk to staff. An example of this, highlighted in Case Study 2 (p. 171), was where the procedure associated with visiting a patient at home was modified to ensure staff safety.

The weak signals that indicate task performance concerns can provide insight to inform task design, support tool development, or suggest changes to the organisation of work to enhance task performance. Similarly, for process concerns, weak signals can highlight problematic components of a healthcare process that may require redesign or tools to support staff in this process. Quality improvement, which focuses on improving and modifying healthcare processes (Hignett et al., 2015), may find the information that weak signals can provide on the functioning of a healthcare process beneficial to identify specific areas to target.

The final indicated outcome identified was that of organisational functioning concerns. If one is aware of the weak signals that indicate an organisation is not functioning well, for example the case of the Mid Staffordshire NHS Trust, this information can used to inform the design of monitoring systems that indicate the 'health' of an organisation.

9.5. Methodological Considerations

Although the real findings of this thesis pertain to the weak signal results, a brief discussion of the methods applied in this thesis has been included in this chapter. This is necessary as these elements influenced how the knowledge on weak signals was developed. First the general strengths and limitations of this work as a whole will be described. This will be followed by a discussion on the progression of the method adopted across the case studies and the validity and reliability of the findings.

9.5.1 Strengths and Limitations

While the strengths and limitations of the individual case studies have been discussed in detail in their respective chapters (Chapter 6 to 8), the focus of this section is on the collective strengths and limitations of this research. The strengths of this research include the key outputs of this work, namely the framework and analysis approach, the use of a systems

approach and the generalisability of the overall findings. The weak signals in healthcare framework not only provides a conceptual overview of weak signals, but also provides a structure for research and the means for operationalising weak signals. This as the framework and analysis approach have been developed from both data and theory. By encompassing a systems approach, in this research and the framework, the practical applications are further enhanced. Finally, as the framework was developed using three different types of healthcare themes and successfully applied to a fourth, the generalisation of the findings and therefore the potential applications of the framework were enhanced.

The limitations include a lack of specific guidance on the analysis of individual framework components, limited depth of the framework components and the limited application of the framework. Although the framework is descriptive, not prescriptive which enhances the potential applications of it, this may be considered a limitation as it does not provide specific guidance on the individual components. Attempts were made to mitigate this, in the form of the analysis approach developed to support the framework and the general recommendations for using this framework in research (discussed in *Section 9.4.2,* p. 246). Future work would include refining and specifying an analysis approach for each framework component, before developing a comprehensive method for the framework as a whole. The limited depth of the framework components may be seen as a limitation; however, this was unavoidable. The focus and resources in this research were used to establish an initial structure, something that has been missing from the literature. This offers an overview and a broader approach to start guiding research into weak signals. Future work would include exploring the individual framework elements in more detail (e.g. explore rationalisations and why one does not respond to weak signals). A final limitation of this research was, of the three practical applications of this framework discussed in *Section 9.4* (p. 245), only one was applied in this research, namely to use the framework for research into weak signals in healthcare. As the resources of the PhD were used to develop the framework, it was not possible to apply the framework to further cases. Future work on this framework would include exploring not only the other practical applications of this framework mentioned in this thesis but also the consideration of new practical applications.

9.5.2. Overview and Progression of the Method

As models, tools and methods on weak signals are limited, especially in healthcare, a predominantly qualitative approach was adopted. The exploratory nature of this approach allowed for the identification of a variety of themes relating to this phenomenon. Furthermore, as the healthcare environment is complex, contains elements that may be sensitive, and in some instances, certain aspects can be challenging to study (e.g. occurrence of sepsis), appropriate methods need to be selected that are suited to the context. The philosophy of pragmatism allowed for this (Hignett & McDermott, 2015), as well as considering the importance of the practical implications of the findings (Creswell et al., 2011; Saunders et al., 2009).

This study had a multiphase research design, with each case study building sequentially on the former one, both from a knowledge perspective as well as the approach applied. Each case study employed a different research design to best address the aims of that case study. Weak signals were explored in one healthcare context, key features of weak signals were extracted and then the updated framework was applied to the next healthcare context. The main type of data collected in this research was qualitative data, as this allowed elements of the context to be captured, and was particularly useful as this type of data is known for eliciting a deeper understanding of the phenomenon under investigation (Jick, 1979). The methods adopted throughout this research included focus groups, interviews, observation sessions, incident report analysis and other document type analyses (i.e. Ombudsman reports, survivor and tribute stories). A summary of the methods and progression of the approach adopted in this thesis is presented in Table 31.

The method for each case study considered the limitations identified in the previous case study. Case Study 1 used focus groups with expert staff to explore weak signals. The questions used in these focus groups were limited to discussions on errors and did not consider the wider context and aspects that worked well. Consequently, the discussion guide for the focus groups used in the second case study was expanded to include aspects that work well and improve patient safety. Additionally, Case Study 1 only adopted one method and although this provided a rich data source, it was identified that it would be beneficial to identify weak signals from other data sources. Consequently, the variety and number of data sources for

Case Study 2 was expanded to include observations, analysis of incident reports and other documents in addition to employing focus group methods. This increase in sample size and data variety facilitated the identification of additional weak signals. Case Study 2 also aimed to refine the analysis approach for the weak signals in healthcare framework to enhance the transparency of the analysis. To enhance the description of the context in which weak signals present, work system configurations were generated using the format and method described by Holden and colleagues (2013).

Table 31: Summary of the research design employed for each case study.

	Methods (Sample Size)	**Analysis Focus**
Case Study 1 – Patient Handling (Chapter 5)	Focus Groups (n=2)	Framework Development
Case Study 2 – The Hospital Discharge Process (Chapter 6)	Observations (n=5)	Testing the second version of the framework
	Focus Groups (n=9)	Development of an analysis approach to support the framework
	Incident reports (n=348)	
	Document Analysis (n=1)	Depiction of the work system (work system configuration)
	Interviews (n=10)	Verification and validation of the weak signal results
Case Study 3 – Sepsis (Chapter 7)	Document analysis: – Survivor and Tribute Stories (n=99) – Formal documents (n=2)	Testing the third version of the framework
		Testing the analysis approach that supports the framework
		Depiction of the work system (work system configuration)
Case Study 4 – Mid Staffordshire NHS Foundation Trust Disaster (Chapter 8)	Document Analysis (n=2)	Applying the fourth version of the framework and analysis approach to the analysis of an healthcare system failure.

Case Study 3 adopted document analysis due to the nature of the healthcare theme explored, namely sepsis. Although this case study had the limitations of a restricted sample size, data variety and a lack of direct input from healthcare professionals, as sepsis is a medical condition that can occur in any population type and therefore will present in numerous healthcare settings, the advantage of using document analysis was that a larger sample size could be accumulated over a shorter time period. Furthermore, by including narratives by the patient and their family, this unique perspective was included in the analysis, a distinguishing element of this case study. This case study also included the depiction of the work system using the work system configuration and tested the analysis approach developed to support the use of the framework. Case Study 4 applied the weak signals in healthcare framework

(Version 4) to a completely different healthcare theme, namely to explore the presence of weak signals in the organisational failure for one healthcare example, namely the failings of the Mid Staffordshire NHS Foundation Trust.

Abductive reasoning was applied across the case studies to generate knowledge on weak signals. This process started with prior theoretical knowledge (Peirce, 1931 as cited by Kovács & Spens, 2005), presented and compiled in Chapter 3. In each case study, data was collected and then underwent theory matching to determine the aspects that contradicted or fitted the existing theory (Dubois & Gadde, 2002; Saunders et al., 2009). The abductive reasoning process and how this was applied to this research is depicted in Figure 44.

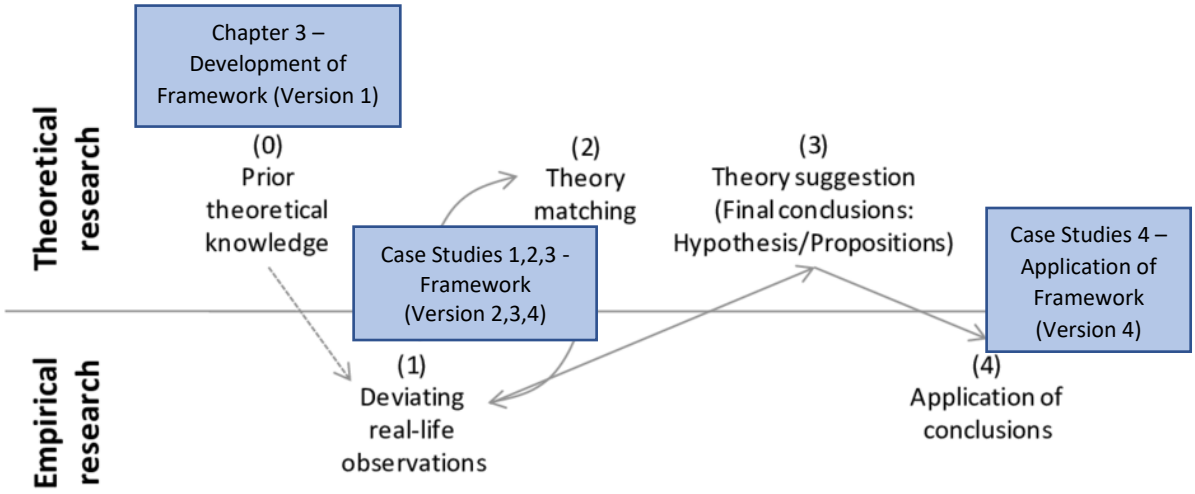


Figure 44: The abductive reasoning process and its relation to theoretical and empirical research by Kovács & Spens (2005) overlaid with how this was applied in this research.

In Chapter 3, theories from a variety of scientific fields were presented to develop a new conceptual framework on signals, which was then evaluated against the empirical research from Case Studies 1, 2 and 3. Case Study 4 then applied the newly developed theory, namely the weak signals in healthcare framework (Version 4) and analysis approach to a different type of healthcare theme compared to the previous case studies.

9.5.3 Validity and Reliability of the Findings

This research used triangulation as a strategy to enhance the validity of the results through the convergence of information from different data sources (Carter et al., 2014). Triangulation, especially in qualitative research, can assist in illuminating the context, examining the phenomenon from numerous perspectives and also provides a deeper understanding of the concept (Jick, 1979; Malterud, 2001). By utilising several sources and methods, this allowed the results from one data source to be corroborated through the results of a different data source (Bowen, 2009; Brown et al., 2008a). Additionally it also assisted in reducing the impact of potential biases (Bowen, 2009), improving the internal validity of the research (Barbour, 2001) and allowing for the capture of a more holistic view of the element being studied (Jick, 1979). More specifically in this research, data triangulation, methodological triangulation and theory triangulation were applied. Triangulation assists with validity in that it ensures the variance in results are not as a result of the method, and reflects a degree of external validity (Jick, 1979). Across all of the case studies, theory triangulation was applied through using different theories on a common theme to analyse and interpret the data (Carter et al., 2014; Jick, 1979).

One means to ensure reliability includes extensive member checking (Mays & Pope, 2000). However, due to the nature of a doctoral study, the data capturing and coding were done by one person, which will make the influence of the researcher's bias prominent. In an attempt to mitigate this effect, the results common across all the case studies were subsequently discussed with the supervisors and the development of framework was presented at numerous academic conferences.

To enhance the rigour and quality of research reproducibility, replicability and transparency need to be considered. Although reproducibility is not feasible for qualitative research, forms of replicability are. Some may argue replicability is not meaningful in qualitative research, but there is still a need for transparency (Aguinis & Solarino, 2019). As replicability is more difficult to achieve in qualitative research, there are different forms of replicability that may be applicable (Aguinis & Solarino, 2019). This thesis aimed to provide sufficient transparency for empirical replication, namely replicating a study using the same procedures on a different population (Aguinis & Solarino, 2019). To achieve this, the methods and analysis approach

require transparency (Aguinis, Ramani, & Alabduljader, 2018). This thesis aimed to provide as much transparency as possible at each stage of the process, namely the theory, design, measurement, analysis and reporting of the results. The analysis approach that was developed in Case Study 2 and extended in Case Study 3 was created to support the framework and enhance the transparency of using the framework. The simplicity of the analysis approach aims to increase the applicability and enhance the use while still maintain transparency regarding use of the framework.

9.6. Conclusion

This chapter provided an overview of how the research question was addressed from a synthesis of the findings from the four case studies. Furthermore, the compiled knowledge on weak signals was evaluated against the available literature on weak signals and situated in the broader theoretical concepts associated with safety. The practical implications of both the framework and weak signals in general were explored. The chapter concluded with a discussion of the methodological considerations and the validity and reliability of the results.

Chapter 10: Conclusion and Future Work

This final chapter provides a conclusion by summarising the research design and approach adopted, the key findings and outputs of this research, as well as highlighting the contribution of this thesis. The chapter and thesis are concluded with a brief description of future work.

10.1 Summary of Research Design and Approach

The aim of this thesis was to provide a theoretical basis and an approach to guide research into weak signals that present in healthcare work systems. This aim was broken down into two sub-aims. Firstly, to explore the system context from which weak signals emerge, and second to develop a theoretical framework to investigate weak signals in healthcare. To address these sub-aims, the research design, developed against a philosophical backdrop of pragmatism, adopted an exploratory sequential qualitative approach incorporating a systems approach both in the framework and analysis adopted. An initial framework was generated from a synthesis of literature on weak signals, in Chapter 3. The framework was then applied to four explorative and descriptive case studies, that featured different healthcare themes (Chapters 5 to 8). Case Study 1 investigated patient handling, Case Study 2 investigated the context of patient discharge from hospital care to community care, and Case Study 3 investigated the care processes relating to sepsis. The results from these three case studies were used to drive the development of the weak signals in healthcare framework and analysis approach. The fourth and final case study applied the framework to a different context and investigated the presence of weak signals in an example of a healthcare organizational failure, namely the failings at the Mid Staffordshire NHS Foundation Trust. The main data type collected was qualitative data obtained through focus groups, observations, interviews and document analysis. The data was analysed using a thematic analysis approach applying both inductive and abductive reasoning.

10.2. Summary of Key Findings: Weak Signals in Healthcare

Several key conclusions can be summarised from the findings of this research. Namely although weak signals and similar concepts have been studied in healthcare, an underlying

structure and skeleton for this concept was missing. To address this, a functional framework was created to provide the conceptual representation of weak signals that provides means of applying the theory compiled. This framework was developed using data and information on weak signals successfully collected in the four case studies on different healthcare themes. The framework was then successfully applied to a healthcare context different from those used to develop it. The framework allows for the differentiation of key elements of weak signals that will assist to operationalise them.

The key outcomes of this research included generating a conceptual structure for the knowledge on weak signals, the means of applying this theory through the development of the weak signals in healthcare framework and analysis approach, as well as contributing to the knowledge on weak signals that present in the healthcare context. The conceptual structure for the knowledge on weak signals included specifying the term 'weak signals', identify relevant synonyms, generating a definition for weak signals in healthcare, and identifying the properties and characteristics of weak signals. The theories and paradigms that explain the underlying processes involved in detecting, interpreting and responding to weak signals were also compiled. The conceptual structure for the knowledge on weak signals and the contribution to weak signal knowledge obtained in this research can be summarised through five key questions on weak signals the results from this research can answer. These questions and the summarised answers, with references to sections in this thesis, have been included in Table 32.

The five key questions included: what are weak signals; why are they weak; why are they important; why is understanding them important; and how might we start to understand them and operationalise them? The first two questions relate to defining this concept clearly. Questions three and four highlight the relevance of this concept, and therefore this research. Question five is associated with the final key outcome of this work, namely an approach to understanding and operationalising weak signals, the weak signals in healthcare framework and analysis approach.

Table 32: The five key questions on weak signals the results from this research can answer.

Key Weak Signal Questions	Summarised Answers (relevant chapters)
1. What are weak signals?	Weak signals are information that provide an indication of upcoming or emerging events that may have significant implications, whereby the information provided is often imprecise, ambiguous and incomplete, which requires active identification and processing. (Chapter 9, *Section 9.2.1*, p.231)
2. Why are they weak?	Due to the healthcare context and that signals require interpretation, which may contain many subjective elements, even strong signals may appear weak. (Chapter 9, *Section 9.2.1*, p.232)
3. Why are they important?	Weak signals are important as they may indicate problems or concerns regarding patient safety and health, staff safety, task elements, process elements and organisational functioning. (Chapter 9, *Section 9.2.1*, p. 232)
4. Why is understanding them important?	It is essential to understand weak signals as they can be indicators of risk. By understanding weak signals, one can move towards designing systems that utilise this underused resource. They may contribute to making systems more resilient, efficient, and safer. (Chapter 9, *Section 9.4.1*, p. 245)
5. How might we start to understand them and operationalise them?	The weak signals in healthcare framework and analysis approach provides a structure for research to explore and understand weak signals in healthcare, a necessary prerequisite for operationalising them. (Chapter 9, *Section 9.4.2*, p. 246)

The weak signals in healthcare framework and analysis approach brings together the elements of weak signals identified in the literature and provides a structure for future research into weak signals in healthcare. The function of this framework is to describe weak signals, their attributes, and behaviours with the overall goal of improving safety by supporting learning from experience. An integrated framework on weak signals was necessary because, although the information and research on this concept have been approached from numerous perspectives, it is distributed across a range of fields, and the theoretical basis is to some degree incoherent and unstructured. The framework and results from this research have also identified key elements and considerations for use of weak signals on an individual level, other system applications and for design of intervention or improvement projects.

10.3 Knowledge contribution

At the time this research began, there was no clear compilation nor structure for the theoretical concepts associated with weak signals in healthcare. Furthermore, guidance on how to explore weak signals in healthcare with the aim to work towards operationalising them was limited, with weak signals having been only explored in a limited number of specific healthcare contexts. As the work presented in this thesis addresses both of these deficits, this

work provides an original and fundamental contribution to the knowledge on weak signals, and due to its relevance to proactive safety concepts, contributes to the wider safety literature.

The key contributions of this work are not only examples and an understanding of weak signal use in specific healthcare contexts, but more importantly a conceptual structure for the knowledge on weak signals and a means of applying this theory through the weak signals in healthcare framework and analysis approach. Support for the originality and contribution of this research is demonstrated in that to date one case study has already been converted into peer-reviewed publication (Case Study 2) and this research received recognition at the ODAM 2017 conference by being awarded the Ted Brown & Hal W. Hendrick Young Investigator Award from the HFES Macroergonomics Technical Group. Future publications on the remaining case studies are planned.

10.4 Future Work

Although the framework has undergone numerous iterations and has been presented on several occasions to academic staff, additional review of the framework, both from a healthcare and academic perspective, would be advised. Following the submission of this research, the aim is to submit a journal publication on this framework, for further academic input and review. Moreover, this framework would benefit from additional input and feedback from healthcare staff, as one limitation of this framework has been a lack of direct feedback on the final version of the framework from different groups of healthcare staff. Although this framework was constructed using a variety of healthcare case studies, it would be beneficial to introduce this framework to staff responsible for improvement and HFE projects that are employed within a healthcare system. This would provide an opportunity to see how this framework may work in conjunction with current improvement work in this sector and identify potential modifications to enhance the practical applications of this framework. The next step in this research would be to use the framework alongside a HFE or improvement project to determine, how weak signals may support the redesign process

10.5 Conclusion

This research revealed that healthcare staff employ numerous weak signals, to perform their daily work. By better understanding the weak signals that healthcare staff use in their work to ensure task success and patient safety, the healthcare system can be designed to support the use of weak signals and thereby improve resilience and achieve proactive safety. The research contained in this thesis explored and compiled the elements of weak signals in healthcare that may be used to promote task success and patient safety. This was achieved through compilation of relevant literature on weak signals to form a framework that was then expanded and modified through a series of four case studies on different healthcare aspects. The knowledge contribution of this research was to provide a common theoretical basis for weak signals in healthcare that could be applied to several different types of research, including research associated with broadening the understanding of weak signals as well as enhancing the use of weak signals in practice.

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Appendices

Appendix A – Chapter 4: Methodology

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D1. Additional Results – Examples of weak signals extracted from the survivor and tribute stories from Case Study 3.

D2. Additional Results – Analysis Approach Adopted for the Behavioural Elements of Weak Signals in Case Study 3

Appendix A – Chapter 4: Methodology

Appendix A1. SEIPS 2.0 Coding Structure

Table 33: The coding structure for the systems analysis of the qualitative data, based on the SEIPS 2.0 model including description of the components as described by Carayon et al., (2006) and Holden et al., (Holden et al., 2013).

SEIPS 2.0 Aspects	Components	Description and Examples
Sociotechnical work system	Person	This includes the patient, their family and healthcare professionals in the system. This component includes education, skills, knowledge, motivation, needs, physical and psychological characteristics of these individuals.
	Tasks	This refers to the specific tasks within work processes. This also includes task characteristics, job content, job demands and control, task sequence, utilization of skills, autonomy and participation.
	Tools and Technology	This refers to the objects used to do the work and includes information technologies, medical devices, physical tools and equipment. Included in this component is also the usability, level of automation and functionality.
	Organization	This refers to the external structures that organize the space, resources and activity. This includes coordination, collaboration, communication, teamwork, organizational culture, patient safety culture, work schedules, management style, social relationships and performance evaluation approach.
	Internal Environment	This includes the layout, noise, lighting, temperature, humidity, air quality and workstation design.
	External Environment	This refers to the societal, economic, ecological and policy factors outside the organization.
Work Processes	Continuum of Engagement	Professional work – This refers to the work process that those employed in healthcare need to undertake. This includes minimal involvement from the patient and their family.
		Patient work – This involves the engagement of patient, family and care givers, as patients are now seen as not just passive recipients of care. Healthcare professionals are minimally involved in these processes. This can include medication taking, symptom monitoring, activities that affect health as well as logistical and coordination activities.
		Collaborative professional-patient work – This refers to the collaborative work that requires input from both professionals and patients.
Outcomes	Patient	This includes patient experience, patient safety and quality of care.
	Professional	This includes job satisfaction, stress, burnout, employee safety and health.
	Organization	This includes organizational health as in profitability, staff turnover, staffing levels, public appearance and cultural changes.

Appendix B1. Data Capturing Documents – Focus Groups

Adult Participant Information Sheet

What is the purpose of the study?
The purpose of this study is to identify key elements, behaviours and process which contribute to the task being completed successfully and which contribute towards safe behaviour. Through a focus group format and by discussing specific types of tasks and the possible outcomes, it is aimed to explore the strategies individuals use to detect, interpret or respond to variations in the work environment. Specifically the following will be discussed in the group: what could go wrong with a set task, which external factors would influence this task, how one knows the task is going wrong and how one would correct one's behaviour to ensure success of the task.

Who is doing this research and why?
This study is part of a PhD dissertation supported by Loughborough University, supervised by Dr P. Waterson and Dr M.J. Fray.

What will I be asked to do?
You will be required to attend and participate in a one-hour focus group session. Prior to the focus group, you will be provided with the project information and asked to provide written informed consent. Following this, basic demographic information comprising of your age, educational degree, number of years involved in patient care, the current position you hold, your current responsibilities in this position and number of years in this current position will be collected using the demographic information form. Following this the focus group will commence, whereby a set task will be presented for you to consider and the discussion will be lead and directed through a series of questions by one of the investigators.

The discussions of the focus group will be recorded using two audio recorders and a second investigator will record field notes.

Once I take part, can I change my mind?
Yes. After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

However, once the results of the study are aggregated, have been published (expected to be by April 2016) or the dissertation has been submitted (expected to be by April 2017), it will not be possible to withdraw your individual data from the research.

How many sessions will I be required to attend and where will these be?
You will be required to attend one session which is the focus group session. Detailed information regarding the session will be provided in advance.

How long will it take?
The total time required will be 80 minutes. The focus group will be one hour and an additional 20 minutes will be required to discuss the project information and informed consent, as well as collect the demographic information.

What personal information will be required from me?
The personal information that will be required is limited to your age, educational degree, number of years involved in patient care, the current position you hold (this does not include within which organisation you work), your current responsibilities in this position and number of years in this current position.

Are there any risks in participating?
As no specific cases will be discussed at any point, the research is interested in general behaviour and no feedback will be given to your superiors, no direct risks are associated with participating. In addition to this, all data will be kept confidential and only aggregated results with no specific references to individuals will be presented.

Will my taking part in this study be kept confidential?
Your anonymity will be ensured and all information will be stored confidentially by ensuring that there is no link between the data and your name. The researcher will use codes to store all the data as opposed to your name. None of your individual results will be made available at any time, and only the aggregated data will be included in the thesis, the presentation of the final results and published for academic purposes. This data will be kept to allow sufficient time for the completion of this project and will solely be used for academic purposes. The data collected will be archived by the student Eva-Maria Burford in the form of the field notes, the demographic information form, audio data and transcribed data from the focus groups. They will be archived till the completion of the PhD programme.

I have some more questions; who should I contact?
For additional information please contact Eva-Maria Burford at Loughborough Design School, Loughborough University, Epinal Way, Loughborough LE11 3TU.

What will happen to the results of the study?
The results of the study will be included in the thesis, the presentation of the final results and published for academic purposes. The results will only be presented in an aggregated form and none of your individual results will be made available at any time.

INFORMED CONSENT FORM

(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee.	Yes ☐	No ☐
I have read and understood the information sheet and this consent form.	Yes ☐	No ☐
I have had an opportunity to ask questions about my participation.	Yes ☐	No ☐
I understand that I am under no obligation to take part in the study.	Yes ☐	No ☐
I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.	Yes ☐	No ☐
I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.	Yes ☐	No ☐
I agree to participate in this study.	Yes ☐	No ☐

Your name _____

Your signature _____

Signature of investigator _____

Date _____

Demographic Information Sheet

Age:	
Level of Education/Educational degree:	
Total number of years involved in patient care:	
Current position/role held:	
Current responsibilities in position held:	
Number of years in current position:	

Appendix B2. Focus Groups Discussion Guide

Outline of focus group session	1. Introduction 2. Description of the scenario 3. Discussion questions
Introduction	An introduction to the project was presented, the aim of the focus group described, and written consent was obtained from all the participants. Following this the demographic information of the focus group participants was collected.
Scenario	***Scenario 1: Transfer Type: Lying to lying*** *Using a slide sheet (0:20:00 DVD 1)* o *Moving a client up the bed with two carers using slide sheets (Chapter 8 DVD2)* o *Moving up the bed with three carers using slide sheets (Chapter 9 DVD2)* o *Move with a transfer board and slide sheet (Chapter 10 DVD2)* ***Degree of assistance:*** o *Hands on (some help): giving assistance using manual techniques and/or equipment with the patient assisting the movement, transfer, care or repositioning task* o *Hands On (a lot of help): moving dependent patients who are assessed as mostly unable or unsuitable to give assistance (e.g. non-weight-bearing and/or uncooperative).* ***Suggestions from professional guidelines:*** *Lying to lying:* o Hands on (some help): lateral-transfer boards, bed ladder/pull, overhead lifting pole, manual assistance o Hands on (a lot of help): lateral-transfer boards/rollers, hoist (sling or stretcher), powered lateral-transfer devices, manual techniques e.g. lifting sheet from floor at least six carers ***Scenario 2: Transfer type: Lateral Transfer*** *Degree of assistance:* o *Hands on (some help): giving assistance using manual techniques and/or equipment with the patient assisting the movement, transfer, care or repositioning task* o *Hands On (a lot of help): moving dependent patients who are assessed as mostly unable or unsuitable to give assistance (e.g. non-weight-bearing and/or uncooperative).* For the focus group held in Edinburgh, a video of the scenario was present. Due to technical problems, the video would not play for the focus group held in Loughborough and therefore the second investigator (M. Fray) described the scenario.
Discussion questions	1. What could go wrong with this task? (Error) 2. What external factors would influence this task? E.g. staff shortages, time pressure, and other activities (External Factors) 3. How do you know the task is going wrong? (Signals) 4. Cues - What were you seeing, hearing or smelling that helped in formulating your action plans? (Gary A. Klein et al., 1989) Example tasks discussed included brakes not applied and non-compliance of patient for a sit-to-stand mobilisation where patient co-operation is needed. 5. Do you use this knowledge next time you do this task? (Learning)
Outputs	The audio from the focus groups were recorded and a summary of the key points was made on a flip chart during the discussion. The transcribed notes were analysed with the flipchart summaries.

Appendix B3. Additional Results – Weak Signals Identified per Patient Handling Task

Table 34: The weak signals identified in the focus groups with patient handling experts for the scenarios involving the errors of not applying the brakes and for the task of accomplishing a sit-to-stand mobilisation for a non-compliant patient where patient cooperation was needed.

Task	Signal	Source	Manifestation and Form
Not applying the brakes	Visual cues e.g. pedals in wrong position (both focus groups)	Environment or Task	Visual, external
	Do not see team members performing the checks (both focus groups)	Task	Visual, internal
	Communication (Focus Group 2)		Auditory, external
Non-compliance of patient: Sit-to-stand mobilising. Patient co-operation is needed.	Patient body language (Focus Group 1)	Patient	Visual, external
	Patient not following instruction (Focus Group 1)	Patient	Visual, external
	Previous experience with the patient (Focus Group 1)	Internal - Previous experience and expectations	Cognitive, internal
	Recognised pre-conditions not met (Focus Group 1)	Internal - Previous experience and expectations	Cognitive, internal
	Visual cues (Focus Group 1)	Environment or Task	Visual, external
	Communication (Focus Group 1)		Auditory, external
	Application force (Focus Group 1)	Internal – proprioception	Proprioception, internal
	Sensory feedback from patient (both focus groups)	Internal - proprioception	Proprioception, internal
	Awareness of own movement (proprioception) (Focus Group 1)	Internal – proprioception	Proprioception, internal
	Degree of dissonance (Focus Group 2)	Internal – Previous experience and expectations	Cognitive, internal

Appendix C – Chapter 6: Case Study 2 – The Discharge Process

Appendix C1. Sample Characteristics

Observation Sessions – Sample Characteristics

A total of five of the weekly TAG meetings were observed within the hospital environment for the Health Care of the Older Person (HCOP) wards whereby the upcoming discharge plans were discussed among staff. The meetings held between the 02 August 2016 and the 13 September 2016 were unobtrusively observed. A minimum of five and a maximum of seven wards took part in the weekly discharge meetings, and over the five meetings observed, the discharge plans for 777 patients were discussed (mean = 155.4 patients discussed per meeting, SD = ± 26.77). An overview of the number of wards that were observed and the total number of patients discussed for each session is presented in Table 35.

Table 35:The number of wards observed, and the number of patients discussed per TAG meeting observed.

TAG Meeting Number	1	2	3	4	5
Number of Wards Observed in Meeting	7	7	5	5	6
Number of Patients Discussed	182	182	130	127	156

Incident Report Analysis – Sample and Directorate Characteristics

The incident reports included in this analysis were all reported incidents associated with the discharge process for adult patients, filed by community healthcare staff from April 2014 to March 2016 for three directorates in Nottingham. The directorates involved in this case study included Nottingham West, Nottingham North and East and Rushcliffe. Nottingham West directorate covers a total registered population of approximately 111,000 patients, 14.05% of the registered population of Nottinghamshire. The health of the people in this area is varied compared with the national average and the life expectancy for men and woman is higher than the national average. Nottingham North and East directorate covers a total registered population of approximately 150,000 patients, 16.6% of the registered population of Nottinghamshire. The health of the people in this area is varied compared with the national average and the life expectancy for woman is lower than the national average. Rushcliffe directorate covers a total registered population of approximately 112,000 patients, 14.18%

of the registered population of Nottinghamshire. The health of the people in this area is generally better than the national average and the life expectancy for both men and woman is higher than the national average. This information has been obtained from the 2014 health profiles for the Broxtowe district (Nottingham West), Gedling district (Nottingham North and East) and the Rushcliffe district from the website: www.healthprofiles.info.

Appendix C2. Quantitative Method Development for the Observation Sessions

The method for the observation phase of the TAG meetings observed in August and September 2016 was developed following the attendance of two high-level meetings in January 2016 aimed at rapidly reducing delayed transfers of care of patients currently requiring discharge. Observation of the two meetings titled 'SuperTAG - busting transfer of care delays', held at Nottingham University Hospitals NHS Trust (NUH) aimed at reducing delayed transfers of care – the backlog of patients within the hospital requiring discharge, was used to develop a method and model for collating potential risks to the discharge process. The meetings were chaired by the community lead and attended by senior staff from the system partners which included Social Services, Community Health partnerships and matrons and ward managers (key managerial staff from both Trust A and Trust C). During these meetings all medically safe patients on discharge pathways and all patients on end of life pathways were reviewed. The aim of these meetings was to focus and prioritise areas of pressure for the discharge process, so that as many patients as possible could be discharged over the next days as possible.

Based on the 161 patient cases discussed at the preliminary meeting held on 06/01/2016, a general model of the discharge process and potential influencing factors was generated. This was done by categorising the content of the notes taken during the observation of the meeting into the type of content it represented. Three main categories were identified, namely:

- whether the staff were discussing a failed discharge,
- whether the information was a consideration for the discharge process (*affected discharge process and planning*),
- or whether the information was regarding why a delay in the discharge process had occurred (*reason for delay in the discharge*)

Following this initial categorisation, the aspects identified as affecting the discharge process and planning were recategorized. The categories and associated subcategories have been described in Table 36.

Table 36: The categories of factors affecting the discharge process and planning based on the data from the observation of the 'SuperTAG' meetings held in January 2016.

Aspects affecting the discharge process and planning	**Patient-related factors**	Underlying condition (level of need, reversibility), Behaviour (Alcohol, self-neglect), Compliance, Independence, Mobility, Psychological issues (mental health, aggression)
	Other	Financial support, Home environment, Family/Partner support, Legal (Power of attorney)
Reason for delay in the discharge	**Patient-related factors**	Psychological issues (mental health, aggression), Independence, Health, Compliance/ Believed needs, Home environment/living situation, Treatment plan
	Family-related factors	Family/Partner support system, Family training, Influence on discharge process
	Process-related factors	Decision-making process (e.g. pathway not selected)
		Bottlenecks/Prerequisites. Awaiting: Documents, Assessments, Bed/Placement, Equipment, Package of Care, Pathway, Procedure/Treatment, Social worker, Services
		Coordination between services
	Other factors	Home environment (e.g. hoarders), Legal issues, Safety-related issues (Safeguarding issues), Decision-making issues (e.g. incorrect plan selected), Timing, Unavailable resources, Previous home care will not accept patient back

This was then confirmed at the follow-up meeting based on the 204 patient cases discussed. Based on the two meetings, influencing factors for determining if the patient was ready for discharge and possible reasons for delay were identified. Additionally, based on the available system, the seven different types of discharge plan categories were noted. These included "return to the same care home", "supported Integrated Health and Social Care Team (IHSCT) referral", "repatriation", "End of Life", "simple", "Fast Track" and "restart of package".

Appendix C3. Data Capturing Documents – Observations

Observation Participant Information Sheet

Adult Participant Information Sheet

What is the purpose of the study?
The purpose of this study is to undertake Human Factors and Ergonomics analyses of patient safety incidents arising from the handover of cases between Nottingham University Hospitals NHS Trust (NUH) and Nottinghamshire Health Care NHS Trust Health Partnerships Division (HP). It is aimed to identify key elements, behaviours and processes which contribute to the discharge process being completed successfully as well as identifying factors resulting in a delay in the discharge process or a failed discharge. It is aimed that based on reviewing reported incidents and analysing the discharge process through a Human Factors and Ergonomics lens to design informed solutions to improve safety, efficacy and efficiency to the care process.

Who is doing this research?
This project is being jointly conducted by the NHS Health partnerships division, NUH and Loughborough University. The data will be collected by Eva-Maria Burford and additionally will be part of a PhD dissertation supported by Loughborough University, supervised by Dr P. Waterson and Dr M.J. Fray.

What will I be asked to do?
Observation of Discharge Meetings
You will be observed for several concurrent discharge meetings or TAG meetings (a maximum of 6 consecutive sessions). During the meetings, the researcher will make notes and collect information regarding the discharge process such as the type of discharge plan selected, considerations that will influence the type of discharge plan selected, and possible reasons for a delay. Additionally, the researcher will note any other items related to the discharge process, that may affect the outcome or complexity of the task. No information pertaining to the identity of the patients discussed will be collected. The only patient information that will be collect is that of the patient's health status as well as their available support system as it is related to how the discharge process will be completed. The researcher will not interrupt the discharge meeting at any point.

Follow-up Interview of Discharge Meetings
Following the observation of the discharge meeting, you may be asked to participate in a brief follow-up interview regarding the discharge meeting that had taken place. During the interview, the researcher will ask some questions regarding they types of factors influencing the discharge plans discussed that day. Additionally, discharge plans that have been described as particularly complex or where there is the potential for the discharge to fail will be discussed in more detail. The discussions during the interview will be recorded using an audio recorder and the researcher will record field notes.

Prior to the observation session and follow-up interview, you will be provided with the project information and asked to provide written informed consent. Following this, basic demographic information comprising of your age, educational degree, number of years involved in patient care, the current position you hold, your current responsibilities in this position and number of years in this current position will be collected using the demographic information form.

Once I take part, can I change my mind?
Yes. After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you

wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

However, once the results of the study are aggregated, have been published (expected to be by September 2016) or the dissertation has been submitted (expected to be by December 2017), it will not be possible to withdraw your individual data from the research.

How many sessions will I be required to attend and where will these be?
You will be required to attend approximately 6 sessions which includes both the observation session and the follow-up interview. Detailed information regarding the session will be provided in advance.

How long will it take?
The observation session will occur during the usual planned discharge meeting for your ward and will not disrupt your discharge meeting at any point. The follow-up interview will take a maximum of 30 minutes. An additional 20 minutes will be required to discuss the project information and informed consent, as well as collect the demographic information which may be collected on a day prior to the discharge meeting.

What personal information will be required from me?
The personal information that will be required is limited to your age, educational degree, number of years involved in patient care, the current position you hold (this does not include within which organisation you work), your current responsibilities in this position and number of years in this current position.

Are there any risks in participating?
As the research is interested in general behaviour and no feedback will be given to your superiors, no direct risks are associated with participating. In addition to this, all data will be kept confidential and only aggregated results with no specific references to individuals will be presented.

Will my taking part in this study be kept confidential?
Your anonymity will be ensured and all information will be stored confidentially by ensuring that there is no link between the data and your name. The researcher will use codes to store all the data as opposed to your name. None of your individual results will be made available at any time, and only the aggregated data will be included in the thesis, the presentation of the final results and published for academic purposes. This data will be kept to allow sufficient time for the completion of this project and will solely be used for academic purposes. The data collected will be archived by the student Eva-Maria Burford in the form of the field notes, the demographic information form, audio data and transcribed data from the interviews. They will be archived till the completion of the PhD programme.

I have some more questions; who should I contact?
For additional information please contact Eva-Maria Burford at Loughborough Design School, Loughborough University, Epinal Way, Loughborough LE11 3TU.

What will happen to the results of the study?
The results of the study will be included in the thesis, the presentation of the final results, published for academic purposes as well as appearing in a report generated by NHS Health partnerships division. The results will only be presented in an aggregated form and none of your individual results will be made available at any time.

Observation Informed Consent Form

Pre-Discharge Analysis

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

Taking Part	**Please initial box**
The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and NHS Health Partnerships as part of Nottinghamshire Healthcare NHS Foundation.	☐
I have read and understood the information sheet and this consent form.	☐
I have had an opportunity to ask questions about my participation.	☐
I understand that I am under no obligation to take part in the study, have the right to withdraw from this study at any stage for any reason, and will not be required to explain my reasons for withdrawing.	☐
I agree to take part in this study. Taking part in the project will include being interviewed and recorded (audio).	☐
Use of Information	
I understand that all the personal information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others or for audit by regulatory authorities.	☐
I understand that anonymised quotes may be used in publications, reports, web pages, and other research outputs.	☐
I agree for the data I provide to be securely archived at the end of the project.	☐

_____	_____	_____
Name of participant [printed]	Signature	Date
_____	_____	_____
Researcher [printed]	Signature	Date

Observation Demographic Information Sheet

Phase: Pre-Discharge Analysis

Demographic Information:

Age:	
Level of Education/Educational degree:	
Total number of years involved in patient care:	
Current position/role held:	
Current responsibilities in position held:	
Number of years in current position:	

Data Capturing Sheet for the Observation Sessions in the Pre-Discharge Analysis

Ward Identifier			Tally
Number of patients discussed			
Discharge Plan:	1. Return to same care home		
	2. Supported IHSCT referral		
	3. Repatriation		
	4. End of life		
	5. Simple		
	6. Fast track		
	7. Restart of package		
Considerations	Patient-related factors	Underlying condition (level of need, reversibility)	
		Behaviour (Alcohol, self-neglect)	
		Compliance	
		Independence	
		Mobility	
		Psychological issues (mental health, aggression)	
	Other	Financial support	
		Home environment	
		Family/Partner support	
		Legal (Power of attorney)	
Reasons for delay	Patient-related factors	Psychological issues (mental health, aggression)	
		Independence	
		Health	
		Compliance/ Believed needs	
		Home environment/living situation	
		Treatment plan	
	Family-related factors	Family/Partner support system	
		Family training	
		Influence on discharge process	
	Process-related factors	Decision-making process (e.g. pathway not selected)	
		Bottlenecks/Prerequisites. Awaiting:	
		Documents	
		Assessments	
		Bed/Placement	
		Equipment	
		Package of Care	
		Pathway	
		Procedure/Treatment	
		Social worker	
		Services	
		Coordination between services	
	Other Factors	Home environment (e.g. hoarders)	
		Legal issues	
		Safety-related issues (Safeguarding issues)	
		Decision-making issues (e.g. incorrect plan selected).	
		Timing	
		Unavailable resources	
		Previous home care will not accept patient back	

Notes regarding patient discharge cases where it was stated they “knew the discharge would fail”:

Appendix C4. Data Capturing Documents – Focus Groups

Pre-Discharge and Post-Discharge Analysis: Focus Groups

Adult Participant Information Sheet

What is the purpose of the study?
The purpose of this study is to undertake Human Factors and Ergonomics analyses of patient safety incidents arising from the handover of cases between Nottingham University Hospitals NHS Trust (NUH) and Nottinghamshire Health Care NHS Trust Health Partnerships Division (HP). It is aimed to identify key elements, behaviours and processes which contribute to the discharge process being completed successfully as well as identifying factors resulting in a delay in the discharge process or a failed discharge. It is aimed that based on reviewing reported incidents and analysing the discharge process through a Human Factors and Ergonomics lens to design informed solutions to improve safety, efficacy and efficiency to the care process.

Who is doing this research?
This project is being jointly conducted by the NHS Health partnerships division, NUH and Loughborough University. The data will be collected by Eva-Maria Burford and additionally will be part of a PhD dissertation supported by Loughborough University, supervised by Dr P. Waterson and Dr M.J. Fray.

What will I be asked to do?
You will be required to attend and participate in two 45-minute sessions of one focus group on one day. Prior to the focus group, you will be provided with an introduction to the project, an opportunity to ask any questions as well as a document containing the project information. Following this you will be asked to provide written informed consent and basic demographic information comprising of your age, educational degree, number of years involved in patient care, the current position you hold, your current responsibilities in this position and number of years in this current position. This information will be collected using the demographic information form. Following this the first session in the focus group will commence which will centre on the elements of the discharge process that work well and improve patient safety. Following a break, the second session in the focus group will commence which will concentrate on potential elements for error recovery and weak signals. The discussions of the focus group will be recorded using two audio recorders and a second researcher will record field notes.

Once I take part, can I change my mind?
Yes. After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

However, once the results of the study are aggregated, have been published (expected to be by September 2016) or the dissertation has been submitted (expected to be by December 2017), it will not be possible to withdraw your individual data from the research.

How many sessions will I be required to attend and where will these be? How long will it take?
You will be required to attend one data capturing session with a total time of one hour and 50 minutes. The introduction (10 - 30 minutes), 2 focus group sessions (each 45 minutes) with a break (10 - 30 minutes) in-between will occur on the same morning. Detailed information regarding the session will be provided in advance.

What personal information will be required from me?
The personal information that will be required is limited to your age, educational degree, number of years involved in patient care, the current position you hold (this does not include within which

organisation you work), your current responsibilities in this position and number of years in this current position.

Are there any risks in participating?
As the research is interested in general behaviour and no feedback will be given to your superiors, no direct risks are associated with participating. In addition to this, all data will be kept confidential and only aggregated results with no specific references to individuals will be presented.

Will my taking part in this study be kept confidential?
Your anonymity will be ensured and all information will be stored confidentially by ensuring that there is no link between the data and your name. The researcher will use codes to store all the data as opposed to your name. None of your individual results will be made available at any time, and only the aggregated data will be included in the thesis, the presentation of the final results and published for academic purposes. This data will be kept to allow sufficient time for the completion of this project and will solely be used for academic purposes. The data collected will be archived by the student Eva-Maria Burford in the form of the field notes, the demographic information form, audio data and transcribed data from the interviews. They will be archived till the completion of the PhD programme.

I have some more questions; who should I contact?
For additional information please contact Eva-Maria Burford at Loughborough Design School, Loughborough University, Epinal Way, Loughborough LE11 3TU

What will happen to the results of the study?
The results of the study will be included in the thesis, the presentation of the final results, published for academic purposes as well as appearing in a report generated by NHS Health partnerships division. The results will only be presented in an aggregated form and none of your individual results will be made available at any time.

Focus Group Informed Consent Form

Pre-Discharge and Post-Discharge Analysis

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

Taking Part	**Please initial box**
The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and NHS Health Partnerships as part of Nottinghamshire Healthcare NHS Foundation.	☐
I have read and understood the information sheet and this consent form.	☐
I have had an opportunity to ask questions about my participation.	☐
I understand that I am under no obligation to take part in the study, have the right to withdraw from this study at any stage for any reason, and will not be required to explain my reasons for withdrawing.	☐
I agree to take part in this study. Taking part in the project will include being interviewed and recorded (audio).	☐
Use of Information	
I understand that all the personal information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others or for audit by regulatory authorities.	☐
I understand that anonymised quotes may be used in publications, reports, web pages, and other research outputs.	☐
I agree for the data I provide to be securely archived at the end of the project.	☐

_____	_____	_____
Name of participant [printed]	Signature	Date
_____	_____	_____
Researcher [printed]	Signature	Date

Focus Group Demographic Information Sheet

Phase: Pre-Discharge and Post-Discharge Analysis

Demographic Information:

Age:	
Level of Education/Educational degree:	
Total number of years involved in patient care:	
Current position/role held:	
Current responsibilities in position held:	
Number of years in current position:	

Focus Group Discussion Guide

Outline of focus Group session	1. Introduction 2. Discussion questions – Component 1 3. Discussion questions – Component 2
Introduction	An introduction to the project was presented, the aim of the focus group described, and written consent was obtained from all the participants. Following this the demographic information of the focus group participants was collected.
Discussion questions - Component 1	The emphasis of the first component in the focus group was on the elements of the discharge process that work well and improve patient safety, both of which can be described as proactive safety. • First the group should develop a definition of a good discharge from the perspective of the staff as well as that of the patient. • Following the development of the definition, the discussion should be guided by one of the researchers through the following series of questions: 1. What is the best way or optimal way to perform your work? What personal elements ensure a good discharge? *(Person-related)* What needs to be in place (requirements)? 2. What can happen unexpectedly during the task and how do you prepare for it? *(Task-related)* 3. Are tools in place that assist with this? *(Tool-related)* 4. What do you require for the discharge to be a success from your team/unit? *(Team/group/unit/department)* 5. What organizational elements assist in ensuring the discharge is a success? *(Organisational factors)*
Discussion questions - Component 2	This component focuses on the things that go wrong and possible error recovery strategies, including the identification of weak signals that indicate that a discharge may fail. Staff should be asked to consider all types of things that could go wrong, not only failed discharges, which in this context was defined as a patient requiring readmittance to acute care within 48 hours after being discharged. The main discussion should be guide through the following series of questions by one of the researchers: 1. What could go wrong with this task? *(Error)* 2. What external factors would influence this task? *(External Factors)* 3. How do you know the task is going wrong? *(Trigger)* 4. When you know it is going wrong how do you correct yourself? Can you pre-empt the task? *(Reaction/Monitoring)* 5. Do you use this knowledge next time you do this task? *(Learning)*
Outputs	The audio from the focus groups were recorded and a summary of the key points was made on a flip chart during the discussion. The transcribed notes were analysed with the flipchart summaries.

Appendix C5. Data Capturing Documents – Interviews

Interview Participant Information Sheet

Staff Group: Community healthcare staff involved in the discharge process

Adult Participant Information Sheet

What is the purpose of the study?
The purpose of this study is to evaluate the results from the project 'Human Factors Analysis of Patient *Handover: Nottingham University Hospitals NHS Trust and Nottinghamshire Healthcare NHS Trust,* Health Partnerships Division'. This project analysed patient safety incidents arising from the handover of cases between acute and community staff with the focus of identifying behaviours and processes which contribute to the discharge process being completed successfully as well as indicators that a discharge may be delayed or fail. You have been contacted as you participated in one of the focus groups held last year for this project.

Who is doing this research?
This evaluation analysis is part of a project that is being jointly conducted by NHS Health partnerships division and Loughborough University. The data will be collected by Eva-Maria Carman and additionally will be part of a PhD dissertation supported by Loughborough University, supervised by Dr P. Waterson and Dr M.J. Fray.

What will I be asked to do?
You will be required to participate in one interview, approximately 45-minutes in duration. Prior to the interview, you will be provided with an introduction to this phase of the project, an opportunity to ask any questions as well as a document containing the project information. Following this, you will be asked to provide written informed consent and basic demographic information comprising of your age, educational degree, number of years involved in patient care, the current position you hold, your current responsibilities in this position and number of years in this current position. This information will be collected using the demographic information form. Following this, you will be contacted to arrange a time for the interview, which can be in person or over the phone. The interview will be recorded as well field notes being generated from the interview.

Once I take part, can I change my mind?
Yes. After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the session you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

However, once the results of the study are aggregated, have been published (expected to be by September 2018) or the dissertation has been submitted (expected to be by April 2018), it will not be possible to withdraw your individual data from the research.

How many sessions will I be required to attend and where will these be? How long will it take?
You will be required to participate in one interview, that will be approximately 45-minutes in duration. The interview can be conducted over the telephone. Alternatively, the interview can be conducted at one of the Nottinghamshire Healthcare NHS Trust, Health Partnerships Division Offices. Detailed information regarding the interview will be provided in advance.

What personal information will be required from me?
The personal information that will be required is limited to your age, educational degree, number of years involved in patient care, the current position you hold (this does not include within which

organisation you work), your current responsibilities in this position and number of years in this current position.

Are there any risks in participating?
As the research is interested in general behaviour and no feedback will be given to your superiors, no direct risks are associated with participating. In addition to this, all data will be kept confidential and only aggregated results with no specific references to individuals will be presented.

Will my taking part in this study be kept confidential?
Your anonymity will be ensured and all information will be stored confidentially by ensuring that there is no link between the data and your name. The researcher will use codes to store all the data as opposed to your name. None of your individual results will be made available at any time, and only the aggregated data will be included in the thesis, the presentation of the final results, the project report and published for academic purposes. This data will be kept to allow sufficient time for the completion of this project and will solely be used for academic purposes. The data collected will be archived by the student Eva-Maria Carman in the form of the interview notes, the demographic information form, audio data and transcribed data from the interview. These will be archived till the completion of the PhD programme.

I have some more questions; who should I contact?
For additional information please contact Eva-Maria Carman at Loughborough Design School, Loughborough University, Epinal Way, Loughborough LE11 3TU.

What will happen to the results of the study?
The results of the study will be included in the thesis, the presentation of the final results, published for academic purposes as well as appearing in a report generated for the NHS Health partnerships division. The results will only be presented in an aggregated form and none of your individual results will be made available at any time.

Interview Informed Consent Form

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

Taking Part	**Please initial box**
The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and NHS Health Partnerships as part of Nottinghamshire Healthcare NHS Foundation.	☐
I have read and understood the information sheet and this consent form.	☐
I have had an opportunity to ask questions about my participation.	☐
I understand that I am under no obligation to take part in the study, have the right to withdraw from this study at any stage for any reason, and will not be required to explain my reasons for withdrawing.	☐
I agree to take part in this study. Taking part in the project will include being interviewed and recorded (audio).	☐
Use of Information	
I understand that all the personal information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others or for audit by regulatory authorities.	☐
I understand that anonymised quotes may be used in publications, reports, web pages, and other research outputs.	☐
I agree for the data I provide to be securely archived at the end of the project.	☐

_____	_____	_____
Name of participant [printed]	Signature	Date
_____	_____	_____
Researcher [printed]	Signature	Date

Phase: Project Evaluation

Demographic Information:

Age:	
Level of Education/Educational degree:	
Total number of years involved in patient care:	
Current position/role held:	
Current responsibilities in position held:	
Number of years in current position:	

Appendix C6. Additional Results – Observation Data

Across the five meetings observed, the discharge plans and information for a total of 777 patients was discussed. The hospital has the policy that as soon as a patient is admitted the discharge planning process is started. Across all the patients discussed, 385 were described as not being medically fit yet and 169 (21.75%) as being medically fit and ready for discharge from a health perspective. Across all five meetings, the mean number of patients discussed that were described as not being medically fit was 77 patients (±11.66) and those described as being medically fit was 33.80 patients (±14.91). For the cases described as the patient being medically fit, it was not possible to differentiate between patients that were ready for discharge, that would be discharged that day and those that would be classified medically fit but as having a delayed discharge. The frequency count per meeting of patients described as being medically fit and not medically fit are included in Table 37.

Table 37: The number of patients classified as medically fit or not medically fit per meeting observed and the mean and standard deviation (SD) across the five meetings.

Meeting Number	1	2	3	4	5	Total	Mean	SD
Patient not medically fit	66	86	64	79	90	385	77.00	±11.66
Patient medically fit	12	42	33	30	52	169	33.80	±14.91

Based on the pilot and through discussions with the management running the TAG meetings, seven possible discharge plan types were identified. These included “return to the same care home”, “supported Integrated Health and Social Care Team (IHSCT) referral”, “repatriation”, “End of Life”, “simple”, “Fast Track” and “restart of package”. The most frequently discussed discharge plan was for the return to the same care home, which was cited in 83 patient cases. This was followed by a restart of the package plan, cited in 63 cases, supported IHSCT referral, cited in 59 cases, and a simple plan cited in 57 cases. Table 38 lists the frequency counts of the discussed discharge plans for the five observed TAG meetings.

Table 38: The frequency count of the number of patient cases per discharge plans discussed in the observation of the TAG meetings.

Number of patients discussed		777
Patient not medically fit		385
Patient medically fit		169
Discharge Plan	Return to same care home	83
	Restart of package	63
	Supported IHSCT referral	59
	Simple	57
	Fast track	42
	End of life	19
	Repatriation	1
	No discharge plan in place/Plan no longer suitable	51

For the model components of the contributing factors and possible reasons for delaying the discharge of the patient, a frequency count was performed for each category with the possibility of more than one category occurring per patient case. As based on the model, the contributing factors were divided into two categories, namely patient-related factors and other. Figure 45 depicts the frequency counts of the influencing factors discussed in regard to discharge planning for the five observed TAG meetings.

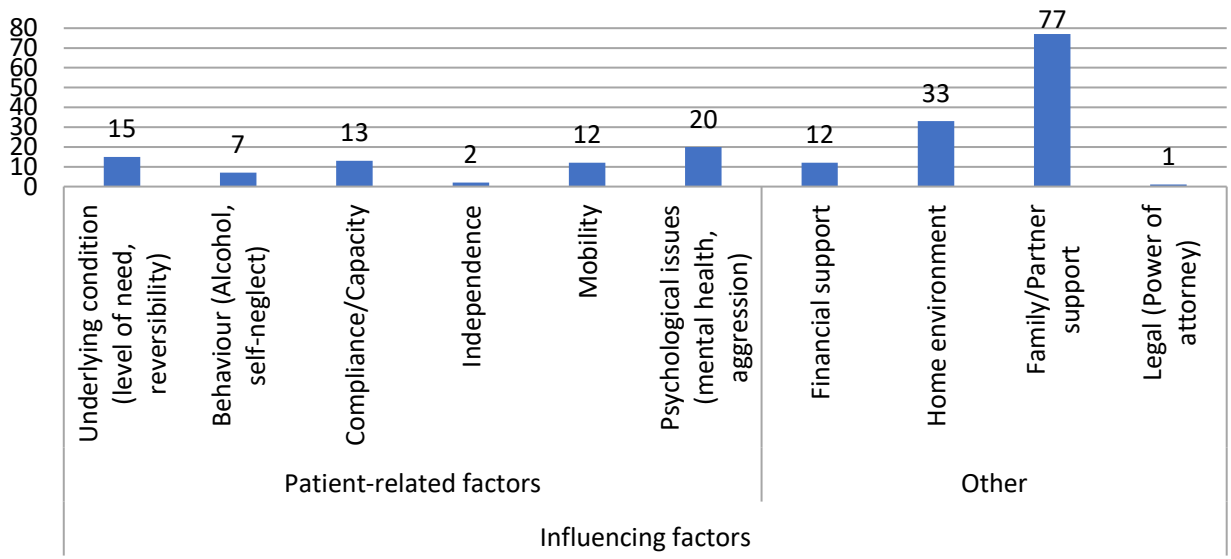

Figure 45: The frequency counts of the influencing factors, classified as patient-related factors or other, discussed in regard to discharge planning for the observed TAG meetings.

Possible reasons for delays were categorised into four main categories, namely patient-related, family-related, process-related and other factors. Patient-related factors included psychological factors, the patient's independence, change in the patient's health, the

patient's treatment plan, for example the patient's medication regime, and the patient's compliance and believed needs. The most frequently cited factor for causing a delay across all categories was the process-related factor of awaiting assessments or reviews, cited 155 times. This was followed by the patient-related factor of a change in the patient's health, which was cited 121 times. The third and fourth most frequently cited factors were both from the process-related category and were awaiting a bed or placement and awaiting services such as therapy or mental health services, cited in 71 cases and 68 cases respectively. Family-related factors included the patient's support system, either their family or partner, family training and the influence the family has on the discharge process. The most frequently cited family-related factor was family or partner support, which was cited 54 times. Figure 46 depicts the frequency counts for the four categories of factors that result in a delay discussed in regard to discharge planning for the five observed TAG meetings.

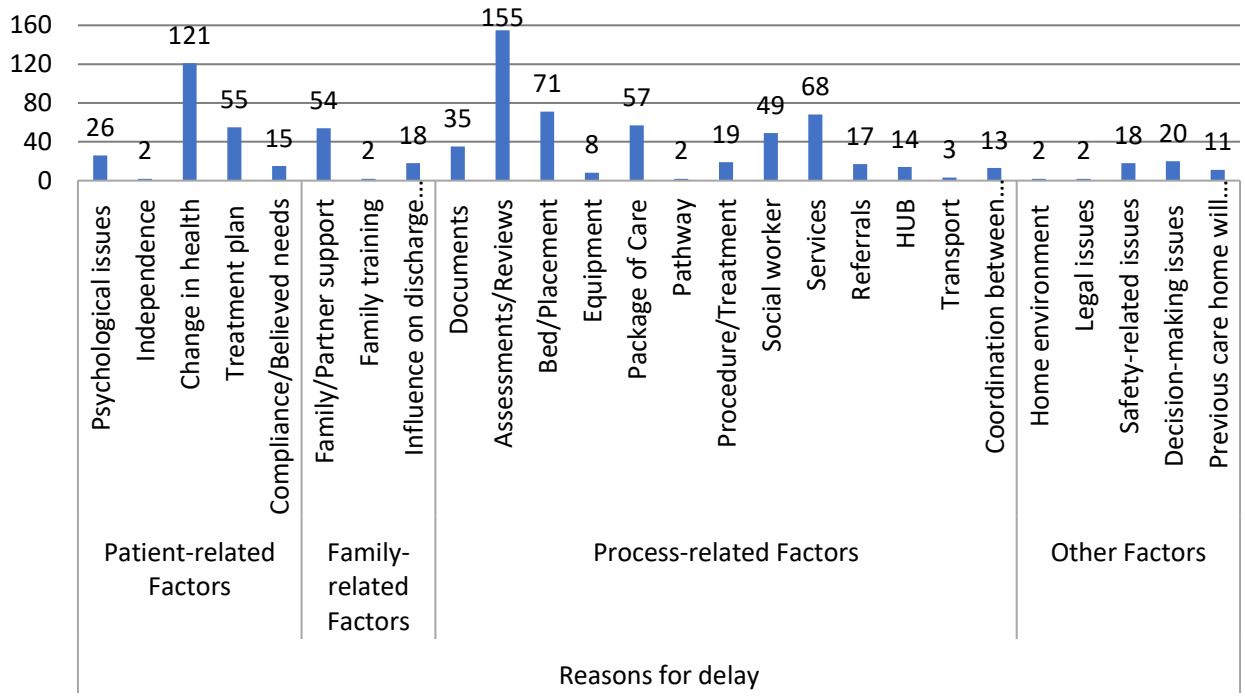

Figure 46: The frequency count of the reasons for delay for the categories of patient-related, family-related, process-related and other factors discussed in regard to discharge planning.

Process-related factors included delays due to missing documents, outstanding assessments and reviews, awaiting a bed or placement, awaiting equipment or package of care, delay as a result of the discharge pathway the patient is on, awaiting a procedure or treatment, awaiting input from other internal services such as therapy and mental health, awaiting allocation of a

social worker, referrals, feedback from the hub, transport or a delay due to coordination between services. The most frequently cited process-related factor for causing a delay was awaiting assessments or reviews, which was cited 155 times. Other factors included the patient's home environment, for example if the patient is a hoarder the home environment may require alteration prior to the patient being discharged; legal matters; safety-related concerns, for example cases of safeguarding; decision-making problems, which include an inappropriate discharge plan being selected; and that the previous care home would not accept the patient back. The most frequently cited factor categorised as other for causing a delay was due to a problem with the decision-making process in that either no or an inappropriate discharge plan was selected, which was cited 20 times. The frequency count of the model components discussed in the observation of the five TAG meetings is listed in Table 39.

Table 39: The frequency count of the model components discussed in the observation of the five TAG meetings. This includes the contributing factors for the patient being ready for discharge and potential reasons for the discharge being delayed.

Model Component	Categories	Themes	Frequency Count
Contributing factors to the patient being ready for discharge	Patient-related factors	Underlying condition (level of need, reversibility)	15
		Behaviour (Alcohol, self-neglect)	7
		Compliance/Capacity	13
		Independence	2
		Mobility	12
		Psychological issues (mental health, aggression)	20
	Other	Financial support	12
		Home environment	33
		Family/Partner support	77
		Legal (Power of attorney)	1
Reasons for delay	Patient-related Factors	Psychological issues	26
		Independence	2
		Change in health	121
		Treatment plan	55
		Compliance/Believed needs	15
	Family-related Factors	Family/Partner support system	54
		Family training	2
		Influence on discharge process	18
	Process-related Factors	Bottlenecks/Prerequisites. Awaiting:	
		Documents	35
		Assessments/Reviews	155
		Bed/Placement	71
		Equipment	8
		Package of Care	57
		Pathway	2
		Procedure/Treatment	19
		Social worker	49
		Services	68
		Referrals	17
		HUB	14
		Transport	3
		Coordination between services	13
	Other Factors	Home environment	2
		Legal issues	2
		Safety-related issues	18
		Decision-making issues	20
		Previous care home will not accept patient	11

Appendix C7. Additional Results – Barriers and Facilitators of the Discharge Process

Barriers to the Discharge Process

The work systems analysis and the work system configurations highlighted several of barriers that originate as a result of these two subsystems functioning spatially and temporally apart. In addition to the focus groups, the observation sessions and analysis of the incident reports were used to identify themes relating to barriers to the discharge process. The observation sessions assisted in identifying barriers to the discharge process from hospital staffs' perspective and the barriers identified usually affected the process before the patient had left the hospital. The results from the incident reports identified barriers that were experienced by community healthcare staff but may have originated in the hospital work system.

Five main themes were extracted that represented the barriers to the discharge process from the perspective of both hospital and community healthcare staff. The main themes consisted of barriers associated with hospital discharge-related tasks; a lack of cross system interaction, communication and capacity; patient's health and capacity; organisation-related barriers and the family's expectations and lack of support for the process. The key differentiation between the hospital and community healthcare themes was in some of the subthemes identified.

Themes associated with hospital discharge related tasks included the pre-requisite tasks for the discharge process not being completed on time or accurately. These barriers originate as a result of events in the hospital work system and included poor, missing or insufficient assessments, documentation and information; discharge planning, delayed transport; poor time of day the discharge occurs; the home environment is not prepared; insufficient equipment, medical supplies (e.g. dressings) and medications have been provided and medical devices have been left in situ (e.g. cannulas).

Themes associated with cross system interaction, communication and capacity limitations included communication and information transfer problems, limited capacity of external service providers, a lack of understanding of the subsystems, a lack of ownership of the patient, cut off times of services missed, and not having access to the patient. Communication and information transfer were related to the task of sending referrals (work system

component Ta2, Figure 26) as this is a form of formal cross system communication and these barriers result in the necessary information not being transmitted. The problems with referrals, which were mentioned in all six focus groups held with community staff (Trust C), included no referral being sent, being sent late, being inaccurate or inappropriate and the template for the referral being inappropriate. This last point refers to the prompts for hospital staff on the referral form being insufficient for the information required by community healthcare staff. The subtheme of a lack of understanding of the subsystems involved a lack of understanding of procedures, the services offered, and a lack of trust between systems. An example of a lack of awareness of the services offered in the community is highlighted in the following excerpt:

> "I think that goes back to … what the hospital knows of our role, as I don't think they've got a clear definition of what we do sometimes and what we don't do …" (Community focus group 4)

Themes associated with the patient's health and capacity related barriers included the intrinsic factors of the patient such as their expectations, knowledge, medical condition, behaviour and ability. Regarding the patient's medical condition, this may result in time pressure for the discharge to occur such is the case for End of Life patients. This also included the funding status of the patient as this may affect the types of services a patient can access.

The theme of organisation-related barriers included the effect of organisational pressures, adopting a risk adverse culture, certain policies and procedures, and a lack of capacity of services. Organisational pressures related to meeting targets and having enough beds available in the hospital. An example of one of the comments by participants relating to the effect of meeting targets and how the problem may be linked to inappropriate admissions was:

> "You get them upstairs constantly shouting … for beds. People being schlepped out *inappropriately because people have been admitted inappropriately*" (Hospital focus group 3)

The above comment also related to the subtheme of adopting a risk adverse culture whereby healthcare staff err of the side of caution, particularly with patients that are admitted to HCOP wards. Policies and procedures that provide barriers to the discharge process include an

incompatibility of the services offered during different days of the week across the system, delays as a result of the discharge pathway the patient is on, and a lack of consideration of supporting services' cut off times for accepting new patients. An example of the incompatibility of the services offered during different days of the week and a resulting effect of this is highlighted by the following quote.

> "it's about wider organisational issue on both sides, so we talk about a seven-*day* service ... But it's not a true seven-day service... the*re is availability of the service over* the weekend ... the other services don't do that in tandem so we can't access all the services we need ... subsequently we will have reduced capacity in week." (Community focus group 2)

The family related aspects included family having unrealistic demands and expectations with regards to the care and support the patient requires or is entitled to as well as not cooperating with the staff regarding the discharge. An example of this would be the family changing their minds on the day of the discharge regarding the plans.

Facilitators for the discharge process

Four main themes were extracted that represented the facilitators both hospital and community healthcare staff use, with the key differentiation being in some of the subthemes identified. The four main themes consisted of good information availability, accuracy and collection methods; good cross system coordination, communication and interaction; successful and timely completion of pre-discharge tasks and good organisation of work at a subsystem level.

Key information sources that were considered as facilitators from both perspectives included online systems, key documents and utilising the family and patient as an information source. For community staff, the transmission of specific information was a key facilitator. This included information on the patient, their home environment, key contact information, current medication and risks and safety concerns staff need to know.

The theme of good cross system coordination, communication and interaction referred to good communication and interaction across all the involved system elements including the

patient, their family, and between the different services and subsystems. The importance of coordination and teamwork across subsystems with regards to preventing a readmission is described in the excerpt below:

> "… sending them back into hospital is always going to be the last resort. It would be *a case of what can we get into place, what equipment can we get, who [staff] can we* get involved to try keep them at home." (Community focus group 3)

The theme of successful and timely completion of pre-discharge tasks refers to tasks that need to be done prior to the patient being discharged from hospital. These include ensuring the patient is ready for discharge, accurate assessments, having access and having considered the patient's home in discharge planning, ordering equipment, dispensing medication, booking follow-up appointments and sending the necessary referrals.

The theme of good organisation of work at a subsystem level refers to how the subsystem level organises their work to meet the needs of the system and ensure a successful outcome for this process. This includes individual behaviours, time the discharge takes place, good teamwork and sharing of information, specific organisational aspects such as policies, procedures and roles as well as understanding how to work within this complex process. Specific job roles that are facilitators included discharge coordinators and the triage role. An additional subtheme identified only by community healthcare staff included creating capacity through triaging referrals, work scheduling and being aware and using alternative resources to provide unplanned care. The alternative resources included same-day delivery of equipment and external services that can provide quick short-term care. An example of how the community service has organized their work to support anticipation and the flexibility required for the discharge process is described below:

> "We usually have our second responder, but we also have got somebody that triages … you can ring them, and … it's [ordering equipment] not something extra you got to *do when you get back. So, I think as a service we have changed quite a lot how we* run to allow for the crises." (Community Focus group 2)

This example describes several system levels, namely the person, task and organization, that have adapted to promote safety and learn how to cope with the pressures within the system.

Connections between Barriers and Facilitators

Based on the results presented above, several conclusions can be drawn regarding the connection between barriers, facilitators and the two different subsystems included in this study. Examples of the barriers and facilitators that are connected for the discharge process across the hospital and community healthcare setting have been presented in

Table 40. Several of the main themes for the barriers and facilitators identified can be considered "two sides of the same coin". These include the barrier of hospital discharge related tasks not completed and the facilitator of successful and timely completion of pre-discharge tasks, and the barrier of cross system interaction, communication and capacity and the facilitator of good cross system coordination, communication and interaction. The absence of the facilitator would suggest the presence of the barrier.

Table 40: Examples of how barriers and facilitators and local strategies may be connected for the discharge process across the hospital and community healthcare setting.

Barrier	**Facilitator**
Hospital discharge related tasks not completed	Successful and timely completion of pre-discharge tasks
Barriers associated with cross system interaction, communication and capacity	Good cross system coordination, communication and interaction
Family's expectations and lack of support	Good family communication and involvement
- Missing and inaccurate information (Community) - A lack of trust between systems (Community)	Independent information gathering (Community)
- Missing equipment (Community) - Insufficient support planned (Community)	Use of alternative resources to provide missing equipment and unplanned care (Community)
Capacity of external services (Hospital)	Create capacity through triage and work scheduling (Community)
Cut off times (Hospital)	Cut off times (Community)

* The subsystem that identified this theme is printed in brackets.

Some facilitators have arisen as a result of barriers within the subsystem or the other subsystem. An example of this was the barrier of missing and inaccurate information for which community staff have developed the facilitator of independently gathering information. This may also have developed as a result of the barrier of a lack of trust between systems. For the barriers of missing equipment and insufficient support, although these were identified in the community healthcare subsystem, they originate as a result of tasks in the hospital subsystem. Community healthcare staff have developed the facilitator of using alternative resources to provide unplanned care and for same day delivery of equipment. The

final example in the table is that of a barrier for the hospital subsystem that is a facilitator for the community healthcare subsystem. Whereas care home cut-off times are seen as a barrier for hospital staff as it may result in the patient being readmitted if not adhered to, it is a facilitator in the community healthcare subsystem as it links to work scheduling and ensures patient safety.

Appendix C8. Additional Results – Weak Signal Examples

Table 41: The signal types, examples, and the forms identified across all the data sources grouped according to the different SEIPS 2.0 work system components. Signal types in yellow cells were additional types identified only in the incident report and the Ombudsman report data.

Source		Signal Types	Examples	Forms	Count
Person – Patient	Both	Patient type	Bariatric, End of Life.	Cognitive	1
		Patient's appearance	Patient hygiene, patient looks unwell, distressed, anxious and unkept, visible wounds, wounds leaking, signs of infection or sepsis.	Visual, cognitive	19
		Patient's behaviour	Behaves confused and unclear, has problems with activities of daily living, poor appetite, and resists assistance. It may be through speaking to patient, includes expectations, and the "wants and needs" of patient.	Visual, verbal	10
		Patient's capabilities	Mobility and immobility, including history of falls.	Visual, verbal, cognitive	17
		Patient's current health condition	Information on recent infection, addiction problems, mental health concerns (e.g. dementia diagnosis) and effect of medication on patient's behaviour. Also, the potential for rapid deterioration.	Verbal, cognitive	4
	Post-discharge	Smell	Odour of wound	Smell	1
		Verbal cues	Regarding undocumented treatment, wounds, medication, and catheter; patient's symptoms and the patient states they do not feel safe at home, unwell or that they are not coping.	Verbal, cognitive	21
		Unexpected contact	SOS call, out of hours call, self-referral, and regarding care that has not been planned or referred for.	Verbal	11
		Patient's symptoms	Patient describes pain, feeling unwell, or discomfort.	Verbal, cognitive	4
		Physiological and physical signs	Unresponsiveness, laboured breathing or breathlessness, temperature, fainting, appears unwell.	Cognitive, visual	8
		Wound appearance	Leaking wound, and undocumented wound identified.	Visual	6
Person – Family	Both	Appearance and Behaviour	Interaction with family; they appear or act distressed, anxious, or frustrated; tone of voice (sounds distressed); they are on holiday and a lack of compliance regarding planned care.	Visual, Verbal	10
	Post-discharge	Expectations	Unrealistic expectations from healthcare staff.	Verbal	0
		Unexpected calls or contact	Family/friends/partner contacted services. This may be in the form of an SOS call, informal referral or regarding care although this has not been planned or referred for (including to inform services that patient is home). This may also be regarding specific concerns (e.g. catheter, patient's health or condition, patient's safety at home, regarding coping).	Verbal	33
		Verbal cues	This could be on expectations or concerns regarding safety, medication, not coping and raising concerns about the patient's ability to care for themselves. This may occur prior to discharge.	Verbal	17
Person – Staff	Pre-discharge	Behaviour	Staff's language and they appear stressed.	Verbal, visual, cognitive	0
		Experience	Experience level of staff relative to decisions made and confidence level when making decisions.	Cognitive	0
	Post-discharge	Unexpected contact from other staff	Contact from carers, residential home, care home, GPs, and therapy staff. This may be in the form of an SOS call or informal or alternative referral.	Verbal	32
		Previous experience with this patient (their usual behaviour or state).		Cognitive	2
		Staff voiced specific concerns	Regarding level of care and safety, safeguarding, inadequacy of current package of care, and the family not coping.	Verbal	6
		Specific information transmitted	Informed that patient was discharged by the GP, regarding medication or leaking wound.	Verbal	4

Source		Signal Types	Examples	Forms	Count
Task	Pre-discharge	Waiting on pre-requisite tasks	These include waiting on tests, medical reviews, assessments, or allocation of social worker.	Cognitive	0
		Previous home will not accept patient back.			
		Planned care relative to the patient's needs (i.e. support not planned).		Cognitive	1
		Medication procedure for discharge not followed.		Cognitive	1
	Post-discharge	Holistic Assessment	Visual assessments and observations indicating sepsis.	Cognitive	5
		Time of task	Late in the evening, on a public holiday, or over the weekend.	Verbal, cognitive	9
		Additional unplanned medical requests		Cognitive	0
		Tests indicating physiological signs. This includes early warning scores, low blood sugar, chesty and pitting oedema.		Visual, cognitive	6
		Medical tests	Blood tests indicating a problem or infection.	Cognitive, verbal	3
		Type of discharge	Self-discharge	Visual, cognitive	1
Tools and Technology	Both	Documentation of patient specific information	Patient history (e.g. previous failed or unsafe discharges, multiple admissions, repeat readmissions, patient's mental health and behaviour), documentation that highlights other risks or previous problems, safeguarding concerns, patient situation details, underlying health conditions, changes in weight, certain medications i.e. warfarin, mental health diagnosis, patient is from out of area, and documentation discrepancies (e.g. discrepancy between the discharge letter and the referral).	Cognitive, Visual	13
	Pre-discharge	Documentation of treatment plan	Seen numerous professionals before they have seen staff involved in the discharge, and medical test results (i.e. sepsis and contribute to picture of patient's health).	Cognitive	1
	Post-discharge	Documentation – Missing or contradicting information	Information sparse on referral, inconsistencies on referral, missing documentation for medication (TTOs), and missing information found when cross comparing documents.	Cognitive, Visual	3
		Documentation – Discharge summary or referrals	Vague referral and missing information on referral form (e.g. location of wound), concerns highlighted by referral, referral identifies patient as inappropriate for the service, poor discharge summary, missing information regarding medication type and dose, documentation indicates referral was needed but not done or received, or information indicating other information was missing.	Cognitive, visual	8
		Discrepancies between documentation and equipment provided.		Cognitive	2
		Medical device in situ (e.g. subcutaneous needle, cannula, clips, sutures, PICC line, Venflon) including presence of unreported medical devices (e.g. indwelling catheter).		Visual	29
Organisation of Work	Pre-discharge	Awareness of the current status of other services or departments.		Cognitive	0
		Lack of clear planning by the medical team.		Cognitive	0
		Patient's out lied to other areas.		Cognitive	1
Internal Environment	Post-discharge	Home environment untidy	Hospital bags still visible, bottles of alcohol visible and home environment is cluttered.	Visual	2
		Home not prepared	Missing equipment visible, heating not on, or no food is in the home.	Visual	2
		Exterior of patient's home		Visual	2
		Smell	Gas	Smell	0
		State of the pets		Cognitive	0
		Untouched medications		Visual	0

Appendix C9. Additional Results – Behavioural Elements of Weak Signals

Table 42: Signal examples, their sources and the identification of the behavioural elements associated with the detection, interpretation and action or response to these signals.

Source	Examples	Quotes	Detection, Interpretation, and Action or Response
Person - Patient	Patient symptoms	'[The patient], who was in her late 90s, fell ill at home. Her granddaughter called a GP to see her, who diagnosed a bladder infection and also noticed that Mrs T's stomach was *swollen. She became unwell overnight, so her granddaughter called an ambulance who* took Mrs T to hospital.' (Ombudsman report, p.9)	**Detected by:** Patient **Transmission:** Patient – Family – GP, Patient – Family – Ambulance **Action:** Contacted health services, hospitalised patient
Person - Family	Behaviour and interaction with staff	'we *had a patient that had very very advanced dementia and she was very mobile, no aids. So, the plan was home QS package of care. The family was saying no she wanted to* go home. And I said well you know there is a high chance it's going to go wrong in the fi*rst day or two so is somebody going to be there or can please somebody be there overnight just for the first one or two nights just so you mum settles in or your grandma settles in.* And they said yes but you knew they were playing lip service to it.' (Hospital focus group 2)	**Detected by:** Hospital staff **Action:** Pre-emptively advise family **Interpretation - Predicted consequence:** Something may go wrong
Tools and Technology	Documentation – Information missing on referral	'Alarm bells have rung for me before w*hen an end of life patient has been discharged and you have never heard of them. And you just get a paper referral that just says fast track – to die at home. You know nothing about that patient, not even a diagnosis, not even what the prognosis is... As s*oon as you read something like that you think 'oh no, it is going to be awful'. And it is usually on a Friday afternoon.' (Community focus group 4)	**Detected by:** Community staff **Interpretation:** Combing information on patient type and missing information from referral **Interpretation – Predicted consequence:** Discharge may proceed poorly and may be difficult from the staff's perspective.
	Documentation – Inconsistencies on referral	'On one breath they are saying they are mobile, and on the other page they are saying they need bedrails. So, you think hang on a minute that can't be right. It just doesn't quite add up, so that often gives you a sign to ask further questions.' (Community Focus Group 4)	**Detected by:** Community staff **Interpretation:** Comparing information **Action:** Seek additional information
Organisation of Work	Patient has been out lied to other areas	'a day where you are being pushed by the site manager and ED, there are people on *trolleys in corridors, and somebody saying you need to outlie that patient to City hospital and you know in the back of your head when that patient goes to [there] that they are not* going to get the same treatment as they would here. And its knowing when to say I don't think that's not a good idea.' (Hospital focus group 2)	**Detected by:** Hospital staff **Action:** Potentially speaking up **Interpretation – Predicted consequence:** Patient may receive inadequate care

Source	Examples	Quotes	Detection, Interpretation, and Action or Response
Combination	Discrepancies - Between information received and visual signals	'I suppose from the anticipation point of view, what we do…, that is why we do what we do in therapy… like I said about having that cut-*off period, so we know that if they need* more equipment than what they've been given we can arrange that on that day. So *that* same lady we were told that she could do the stairs and she couldn't. And so we had to *arrange for her to have a downstairs existence that same day. So because we allow* ourselves that time we could do that. I suppose that's our contingency.' (Community focus group 1)	**Detected by:** Community staff **Action:** Ordering same day equipment.
	Patients health status and appearance	Participant 1 – 'where people talk about end of life, but they are still physically quite good that's a weak signal for me. *Because you just think well, they are going to go off the cliff* at some point.' Participant 2 – 'all it will take is one day and they will wake up and never get out of bed again' Participant 1 – 'Yeah, that's it. It's making sure that people know, let's get the OT on board, let's get the social worker on board, let's get the paperwork done. Because if we leave it to late and they want to die at home, and they end up… we miss the boat, and they die in hospital. Then that's… you know, umm, a dignified death we have missed.' (Hospital focus group 2)	**Detected by:** Hospital staff **Interpretation - Predicted consequence:** Rapid deterioration of the patient. Staff may know the plan will change even before the decision has been made. **Action:** Pre-emptively advice and coordinate staff

Appendix C10. Additional Results – Verification and Validation Component - Behavioural Elements of Weak Signals

Table 43: Behavioural elements of signals for the examples originating from the person and environment components as well as signals that were an unspecified feeling staff got that something was wrong.

	Person	Environment	Unspecified feeling staff got that something was wrong
Examples	These included family contact, patient's physiological signs, patient type (End of Life), patient behaviour, family obstructive and not engaging with community staff.	These included missing equipment, the set up and state of the home environment, not having access to the home environment, and the area the patient lives.	These were described by staff as hunches and gut feelings.
Signal identification means	These included interaction with family, full assessment, first visit, visual assessment of the patient, through previous experience with the patient,	These signals were identified through the initial visit of the home environment.	These included seeing the change in a more junior colleagues body language indicating stress, safeguarding concerns identified during initial visit, the visual appearance of a patient's wound, families behaviour and the home environment indicating they are not coping with the discharge, the patient or their family member's body language, the appearance of the home environment that included bags of medication and unpacked clothing bags from the hospital visit, and the patient appeared in a worse condition than prior to being admitted to hospital.
Information provided by the signal	These included discharge planning, missed essential aspects, highlighted missing information, how the patient was coping at home, that the discharge will be difficult, and a potential upcoming crisis.	These included problems associated with the discharge process (e.g. incorrect equipment ordered), concerns regarding the patient's capacity to make decisions, and that the patient was not coping at home.	These included staff workload and stress, health concerns for the patient, as well as family and patient not coping with the discharge.
Reaction to the signal	These included seeking additional information, completing missing tasks, providing additional care and support, and transmitting the information to the hospital.	These included ordering equipment, seeking additional information, communicating with the patient to ease the transition, and providing emergency support.	These included providing junior staff with advice and support to reduce their stress, obtaining more information from various sources, conducting patient observations, arranging medical support, exploring support options with the family and patient as well as readmitting the patient.
Prompt for reaction	This was not explicitly described by the participants as they felt that if the signal was identified, that alone was sufficient to prompt a response as part of the duty of care.		

Appendix D1. Additional Results – Examples of weak signals extracted from the survivor and tribute stories from Case Study 3.

Table 44: Exemplar extracts from the survivor and tribute stories indicating signals that originate from the different work system categories that were identified.

Source	Signal Types	Illustrative Examples/Extracts
Person - Patient	Medical and physiological signs and symptoms	'I started to have temps of 40.1, rigors – uncontrollably shaking and blue lips and nail beds.' (Survivor Story 4) 'That night the high temperature and shivering continued, plus nausea; by mid-morning she was affected by severe diarrhoea and was becoming drowsy.' (Tribute Story 40)
	Continuation of signs and symptoms	'[I] continued to have incredible back pain that the GP put down to being muscular. I kept returning with the pain and was just given stronger painkillers and told to rest.' (Survivor Story 10) 'the Thursday morning he awoke complaining of pain in his elbow. Throughout the day he complained of having a headache and went to bed; this continued into Friday and we just thought he had flu.' (Tribute Story 35)
	Patient condition progression	***Deterioration following initial improvement –*** 'Then, really quite strangely, I felt better, just for one day. But the next day, I became unwell again,' (Survivor Story 1) 'They were about to discharge him as there were no visible signs of anything and he was "stable". At 6:20 he went floppy at which point the doctors moved him to a side room' (Tribute Story 44)
	Patient symptom	'I started to feel nauseous, and drowsy. I went really cold, even with a blanket wrapped around me, and my skin went pale, and had almost no colour to it at all' (Survivor Story 1) 'Following being unwell for 10 days with no specific symptoms other than a slight irritating cough and pain in left side of her chest, which reduced her to tears on one occasion' (Tribute Story 8)
	Behaviour	'When it was finally my turn to be seen, they tried to perform routine tests on me... But, soon realised that I couldn't even sit up to have any tests done, as my body was flopping sideways.' (Survivor Story 1) 'When he woke up on the Tuesday, he was talking an absolute load of rubbish' (Tribute story 17)
	Physical appearance	'I had already fainted on the bathroom floor and my lips and nose turned blue.' (Survivor Story 6) 'The redness around her wound had now spread to cover a massive area of her body and was travelling down her legs. She was in severe pain' (Tribute Story 10)
	Knowing something is wrong	'I just knew that something was now terribly wrong, once more! I started feeling extremely cold inside and yet hot and very feverish and shivery at the same time as my breathing began to get more and more difficult.' (Survivor Story 5)
Person - Family	Knowing something is wrong	'I remember as we were leaving the hospital my fiancé turned and said to the doctor – "but he can't even walk, this can't be right".' (Survivor Story 13) 'We knew that things weren't right, she was our Mum and we knew instinctively that we were losing her, but still we placed our faith in those treating her who were telling us she was getting better' (Tribute Story 36)
Task	Diagnostic tests and medical observations	'They instantly noticed my blood pressure was up, my breathing was shallow and fast, my temperature was high, my skin was pale and sticky – they couldn't even get blood out of me to do the usual testing.' (Survivor Story 7) 'I got him to the doctors and they done his bloods ….they rang about 3-30 and said that [he] had a serious infection and had to go to hospital immediately and a team would be waiting for him.' (Tribute story 17)
	Frequently assessing the healthcare system	'My next visit to A&E just 24hrs later, now unable to walk, triggered a more thorough investigation into my symptoms which intensified once they received the blood test results back.' (Survivor Story 13) 'She saw a local GP twice in the first 48 hours – and was told her vomiting, shivering, and leg pain was a gastric bug.' (Tribute Story 14)

Appendix D2. Additional Results – Analysis Approach Adopted for the Behavioural Elements of Weak Signals in Case Study 3

Table 45: Examples of the approach adopted for the identification of the behavioural elements associated with the detection, interpretation and action or response for signals in Case Study 3.

Story	Example	Detection, Interpretation, and Action or Response
Survivor Story 4	On Boxing Day, I started to have **temps of 40.1, rigors - uncontrollably shaking and blue lips and nail beds.** I took some paracetamol, slept A LOT and carried on… On the 28th Dec I went to see my friend, **I was crying for 4 hours, couldn't stop shaking and was telling her I felt like I was going to die. I hadn't passed urine, and I was confused!** She said she would take me to hospital, but I said no, and that it was flu and I was just feeling sorry for myself - my body was screaming to me to get help. I went to my GP on the 29th who wasn't sure, and gave me antibiotics and sent me for a blood test, he said he could send me to A&E if I wanted, but I said no, I thought, I'll start these and soon be better. I am a stubborn nurse. On the 30th of Dec **I woke up feeling like there was something really wrong, my legs were mottled, and I started to feel short of breath**… when my friend saw me she admitted me to A&E. **My surgeon was baffled and could not believe how I had carried on for so long considering what was going on inside me**.	**Detected by:** Patient **Signals:** Physiological signs and symptoms **Action:** Self medicated and rested **Signals:** Patient behaviour and subjective patient symptoms and feelings **Action:** Friend insisting patient seek medical attention **Rationalisation:** Ascribed symptoms to other illness (flu) **Action:** Patient sought medical attention **Transmission:** GP **Rationalisation:** Medication will work **Signals:** Physiological signs and patient knowing something is wrong **Action:** Friend admitted patient to A&E **Signals:** Discrepancy between patient appearance, behaviour and health
Tribute Story 5	**Within 24 hours of being released from hospital, Kirsty was rushed to Accident and Emergency.** On the morning after her release, **she felt nauseous and started being very sick, and the stoma bag kept leaking**. We phoned the stoma nurse as instructed to if there were any problems. We were told that leakage can be normal and to try and eat something more substantial, as this might be contributing to the problem. **However, as the day progressed, nothing would settle in her stomach. By late afternoon, things were getting worse.** We phoned the ward she had been in and NHS 111 for advice. Her symptoms were explained to the NHS 111 operator - especially that she was around a week post-op. We were informed that a doctor would be sent out for a home visit to assess her condition. However, there was a delay in being seen, and so a second phone call was made to NHS 111. We were told that the doctor was nearly there. Just as the doctor arrived, her breathing started to become laboured. He sent for an ambulance which arrived rapidly.	**Signals:** Recent frequent attempts to access healthcare subsystems, physiological signs and symptoms **Action:** Sought medical advice **Rationalisation:** Signals assigned to symptoms of chronic condition and recent medical procedure **Signals:** Continuation and progression of symptoms **Action:** Sought medical advice