Swiss Cheese, Butterflies and Algebra: Looking Ahead at an Innovative Approach for Researching Culture and Safety

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This paper presents fuzzy set qualitative comparative analysis (fsQCA), a configurational comparative method (CCM), as an innovative research method that may be used to conduct research in the area of safety climate. Data obtained from using the method to research safety climate and views of error reporting in a health care study will be used to demonstrate how the method may be useful for future maritime research.

Results suggest the presence of some non-positive safety climate factors may be more consistent at producing a view that an error would always be reported than if positive all safety climate factors are positive. Hence a view that a positive safety climate is a means of improving error reporting may not be accurate. Results also indicate clear differences in relation to between managers and clinicians in relation to safety climate and views of reporting error.

Keywords: methodology, configurational comparative methods, safety climate, error reporting, complexity

1. Introduction

This paper will outline results from a health care study investigating how rural nurses' attitude to safety climate influences their views of reporting and disclosure of a hypothetical medication error. The results consider safety climate and teamwork factors and views of reporting severe and near miss error amongst management and clinicians in rural clinical settings.

The study adopted a Configurational Comparative Methods (CCM) research design [1]. Results of the fuzzy set qualitative comparative analysis (fsQCA) suggest that a positive attitude across all factors is not related to an outcome of a view that an error would "always" be reported. There are also differences between managers and clinicians in this area.

The results of this study have potential implications for other industries. Whilst maritime and health care settings may not be identical enough is known about disasters and their cause(s) for similarities to be considered. Similar research using CCM could be undertaken with a focus within maritime safety.

2. Background

On 16 April 2014 the South Korean vessel *MV Sewol* capsized and sank. In the days following the incident information was inconsistent regarding passenger numbers and potential causes. By 21 May it became clear that 288 lives were lost with 16 still missing, the Captain and several crew members had been arrested and charged and the world looked on wondering how so many regulations could potentially have been breached and a century following the sinking of *Titanic* (and the more recent events relating to *MS Costa Concordia*) that another maritime disaster could have occurred.

On 6 February 2013 the final report of the *Mid-Staffordshire NHS Foundation Trust Public Enquiry* [2] was released. This followed a similar report and enquiry conducted in 2010. The report found a culture of acceptance of poor standards of care that adversely affected patient outcomes. The world

also looked on at these events and wondered such things could occur following numerous enquiries into other incidents such as the *Bristol Infirmary* and other major incidents in health care settings.

Whilst some elements have been identified as unique to health care there are many similarities that lead to events such as those mentioned above [3]. How disasters occur has been examined for some time and whilst human factors are attributed to their cause organisational factors are also now considered to contribute.

Three elements have informed the design of this research. "Swiss cheese" refers to error and error management, "butterflies" refers to complexity science, the complexity of organisations and organisational culture and "algebra" relates to the Boolean expressions obtained through the use of a configurational comparative method.

2.1 Swiss cheese

Safety and error are complex areas. The "Swiss Cheese Model" acknowledged that multiple factors could lead to a major accident [4]. This model also acknowledged two forms of error – active and latent error. The latter is often undetected within organisations and is perhaps less well understood. Organisations are complex in terms of how they operate hence understanding what should be done to ensure safety is maintained is difficult to research.

It has been suggested that a shift in focus is needed away from concentrating on what has gone wrong in a few cases (Safety I) to what has gone right in most cases (Safety II) [5]. This notion of resilience requires determining "what should happen" for things to go right.

It is also known that a large amount of error, particularly near miss error, goes unreported. Near miss error is regarded as a learning opportunity whilst failure to report and/or manage error may be regarded a precursor to a major organisational accident [4]. Indeed, in his remarks regarding the Mid-Staffordshire Trust Enquiry, James Reason highlighted the importance of culture and its contribution to the acceptance of a poor standard of care amongst health care staff in that particular organisation [3]. Near miss error occurs where things go wrong but no harm occurs and/or something goes right to prevent a major event. A better understanding of near miss error could perhaps assist in understanding 'what should happen' in some cases. However, without an adequate level of reporting that level of understanding cannot be achieved.

This raises questions in relation to both latent error and how near miss error is dealt with if it is not routinely reported. What elements need to be present in an organisation for near miss error to be reported? If it is not routinely reported then how do workers in organisations handle such situations? Are there approaches to near miss error that we are unaware of? How can we better understand how organisations should work for 'what should happen' to actually occur?

The culture of an organisation is often cited as an important factor in building resilience and the prevention of major disaster. However, there is still much that is unknown about how complex organisations work.

2.2 Butterflies

Complexity science is emerging as a paradigm for a better understanding of how organisations work in respect to organisational culture and safety. Rather than focussing on macro level approaches, complexity science acknowledges the need for micro level understanding and recognises that different things work in different settings and situations. As organisations adapt to complex environments they move closer to working at the "edge of chaos". Subsequently small changes can lead to big differences in outcomes, often referred to as 'the butterfly effect' [6].

This concept of complexity science has been applied to organisational theory and management and some of the key elements will be outlined here now. Complexity science postulates that organisations are complex and self-organising resulting in the "emergence" of properties that may not reflect the elements from which they form [7]. Lewin [8] outlines as an example how hydrogen and oxygen separately bear little resemblance to water.

These small changes can sometimes lead to big disasters or alternatively help prevent them. These relationships are also non-linear in their progression. Just as water has a 'tipping point' where it can become solid from liquid (at zero degrees Celsius) it has another "tipping point" at which it becomes vapour (one hundred degrees Celsius) [8]. Organisations that operate at the "edge of chaos" have been described as "drifting" towards the "tipping point" that results in a disastrous event [9].

Safety climate is an element of safety culture that has been present in the literature for some time. There is a suggestion in health care research that as safety climate increases the reporting of error also increases [10]. However, other research contradicts this with one study that considered one hospital where various measures were put in place that increased safety climate that whilst one hospital unit achieved increased reporting of mediation error the overall institutional reporting of medication error decreased [11]. These types of conflicting results are examples of the limitations of the dominant focus of cause and effect approaches to research that are present in health care which have been described as inadequate [12]. As a result there have been suggestions that a greater focus on new methods be undertaken [12] and the need to explore how better to understand complexity as a means of reducing harm to patients [13]. This includes the suggestion that CCM be applied to research hospital error [14].

2.3 Algebra

Configurational comparative methods offer an innovative means for the future research of organisational complexity. These methods have their foundations in mathematics and fuzzy set theory. A key concept of CCM is an acceptance of multiple means of causality (or conjectural causality). That is that multiple factors across a number of cases may result in a particular outcome and that these factors may be present or absent in a variety of different configurations. Schneider and Wagemann [15] describe this allowance for '… different, mutually exclusive sufficient conditions or paths for the outcome' as "equifinality". Boolean algebra is applied in the analysis and results are presented as "logical equations" [16].

Two recent publications indicate the growing number of studies where a CCM research design has been applied [17, 18]. Recently the first application of this type was published in a high ranking journal [19]. One of the CCM approaches is fuzzy set Qualitative Comparative Analysis (fsQCA). There is growing consensus that fsQCA is considered the more rigorous approach to use and it is certainly evident that its use is growing.

Charles Ragin [20] recognised as the "founder" of the QCA approach, argues that approaches to research have been variable based and that case based methods offer an alternative. Rather than deciding between quantitative or qualitative approaches, he suggests the choice should be between variable or case based approaches.

He argues that in quantitative research the focus is upon the comparison of different variables and how they interact with each other (whether it be single cause and effect randomised control trials or multi-variable analysis). That is, the primary consideration is upon diversity. Qualitative research by comparison is focussed upon the identification of variables through considering data in terms of thematic or discourse analysis. The primary consideration here is upon considering sameness. With QCA the focus is upon the presence or absence of conditions across cases against the presence or absence of a particular outcome. The primary consideration is upon understanding complexity [16].

3. Research Method

A CCM research design was adopted for PhD research considering how rural nurses' views attitude to safety climate influences their views of reporting and disclosure of a hypothetical medication error. The data obtained for this research has been used for this paper, although only one element of the analysis and results will be presented: configurations of factors of teamwork and safety climate relating to the outcome of views of reporting severe and near miss error.

3.1 Data collection

Following receipt of the appropriate ethics approval data for this study was collected in the form of a survey. The survey consisted of three sections. The first was the Safety Attitudes Questionnaire (SAQ) [21, 22], a highly validated tool used in health care settings [23] that was developed from the Flight Management Attitudes Questionnaire (FMAQ) which is used in the airline industry. The SAQ adopts a 5-point Likert Scale with responses of *agree strongly, agree slightly, neither agree or disagree, disagree slightly and disagree strongly* [21]. The option of *not applicable* was also included.

The second section included an error vignette that contained three different outcome levels of harm: severe, moderate and near miss [24]. Respondents were asked the likelihood that the error would be formally reported in their workplace. Respondents were also asked the likelihood that the patient and/or family would be informed of the error but this element will not be considered for this paper.

The final section of the survey contained demographic questions. The demographic area that is the focus of this paper is that of workplace role where respondents indicated their role as either "Management", "Clinical" or "Other".

The survey was distributed directly to nurses in rural clinical worksites via mailing an invitation to participate and the invitation was also emailed to members of relevant nursing unions. The invitation to participate contained a link to an online survey. The period of data collection was from mid-April until end of May 2012.

3.2 Data analysis

Figure 1 outlines the process of analysis relating to this paper. A total of 116 surveys were returned. Following principal components analysis (PCA) four factors were identified. Missing data resulted in a total of 93 responses being included for the teamwork factor analysis and 104 responses included in the analysis of safety climate factors.

The four factors identified from principal components analysis [25] are listed in Table 1. Also included in this table are the outcome sets and Boolean expression for each. Factor scores were then calculated using Sexton's approach [21] where a score of 75 or higher is deemed as positive for the relevant factor.

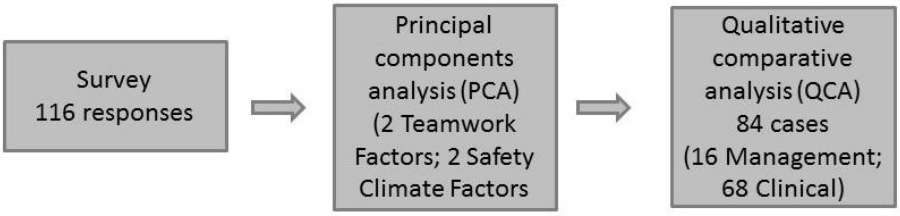

Figure 1: The process of data analysis

In order to undertake QCA research it is necessary to have diversity (heterogeneity) in the cases being studied. The diversity needs to be present across both the conditions and the outcome sets. All the "Management" cases viewed the severe error scenario would be reported so this lack of diversity meant a comparative analysis using QCA was not possible. The view of reporting near miss error amongst the "Management" cases exhibited diversity allowing analysis as did the views of reporting both severe and near miss error amongst the "Clinician" cases. In each case the outcome set was the view that the error would "Always" or "Not always" be reported.

Factor	Description
Teamwork factor 1	Teamwork and patient safety at the bedside
Teamwork factor 2	Workplace relationships and communication
Safety climate factor 1	leadership and management of error
Safety climate factor 2	safety culture in the workplace

Table 1 Teamwork and safety climate factors identified through PCA

The two groups of responses (managers, clinicians) were considered as separate sets of data. Thus a fuzzy set analysis was conducted on the "Management" set (16 cases) and a separate analysis conducted on the "Clinical" set (68 cases). One respondent who indicated their work role as "Other" was not included in the fuzzy set analysis for the purpose of this paper.

Full terminology	Role	Boolean expression
Teamwork factor 1	Condition	tf1
Teamwork factor 2	Condition	tf2
Safety climate factor 1	Condition	scf1
Safety climate factor 2	Condition	scf2
Overall teamwork factor	Condition	tf
Overall safety climate factor	Condition	scf
View of reporting severe error	Outcome	sr
View of reporting near miss error	Outcome	mmr
Negated set (ie not 'in' the set)	Expression	~ (before set expression)
Logical 'OR'	Expression	+
Logical 'AND'	Expression	*

Table 2 Terminology and Boolean expressions

3.3 Set calibration and analysis

In order to conduct fsQCA it is necessary to prepare the data in the form of sets. For each condition and outcome it is necessary to 'calibrate' the data to illustrate whether it is in or out of the particular set of interest [15]. The calibration also considers the degree to which the data is in or out of the set. The calibration results in a figure between 0 and 1 indicating the degree to which the condition or outcome is in or outside of the set. The calibrations applied in this analysis are listed in Table 3 and Table 4.

	Outside the set (factor not positive)			In the set (factor positive)	
SAQ factor score	0	0-74.99	74.999	75-100	100
Calibration	0.05 minimum value (fully out)	0.05 - 0.49 Out of the set of positive factor	0.5 point of indifference	0.51-0.95 In the set of positive factor	0.95 maximum value (fully in)

Table 3 Data calibration of the conditions (factors)

The score of 75 is the point at which SAQ scores are viewed as positive so the point of indifference was set so that cases with a score of 75 or higher were included in the set of "positive" factor. The outcome set 'point of indifference' was set so that cases which view the error would "Always" be reported were in the "Always" set and cases with responses of "Usually", "Sometimes", "Rarely" or "Never" were not included (ie they were in the set "Not Always").

	Outside the set (view error not always reported)					**In the set (view error always reported)**
Response	Never	Rarely	Sometimes	Usually		Always
Calibration	0 minimum value (fully out)	0.15 (almost fully out)	0.3	0.45 (almost fully in)	0.5 point of indifference	1.00 maximum value (fully in)

Table 4 Data calibration of the outcome sets

3.4 Use of software

Two software platforms have been used for analysis. *fsQCA 2.5* [26] was used for the analysis. *Kirq* [27] was used for the identification of contradictory rows (although these have not been reported in this paper). Contradictory rows (or configurations) occur when cases displaying a particular combination have examples of both the presence and the absence of the desired outcome [16].

4. Results

Figure 2 illustrates the frequency of each of the teamwork and safety climate factors. Overall each of the factors had more responses that were positive than not positive with *workplace relationships and communication* exhibiting the highest rate of 79.6% (n=74). The factor with the lowest rate of positive scores at 66.3% (n=69) was *leadership and management of error.* The remaining two factors *teamwork and safety at the bedside* and *safety culture in the workplace* had positive scores at rates of 75.3% (n=70) and 73.1% (n=76) respectively.

Those in a clinical role accounted for 80.7% of responses (n=92) with 19.3% (n=22) indicating they worked in a management role. Scores for overall teamwork factor and overall safety climate factor were also calculated. Chi squared analysis indicated that those in a management role were more likely to have a positive overall teamwork score (p=0.016) and positive overall safety climate score (p=0.002) when compared to those in a clinical role.

For the purposes of this paper the responses relating to views of reporting severe and near miss error were subject to the QCA analysis. This was considered sufficient to provide an example of what is possible through the use of this methodological approach. In addition, the views of reporting moderate error contained some contradictory rows that made the analysis more complex.

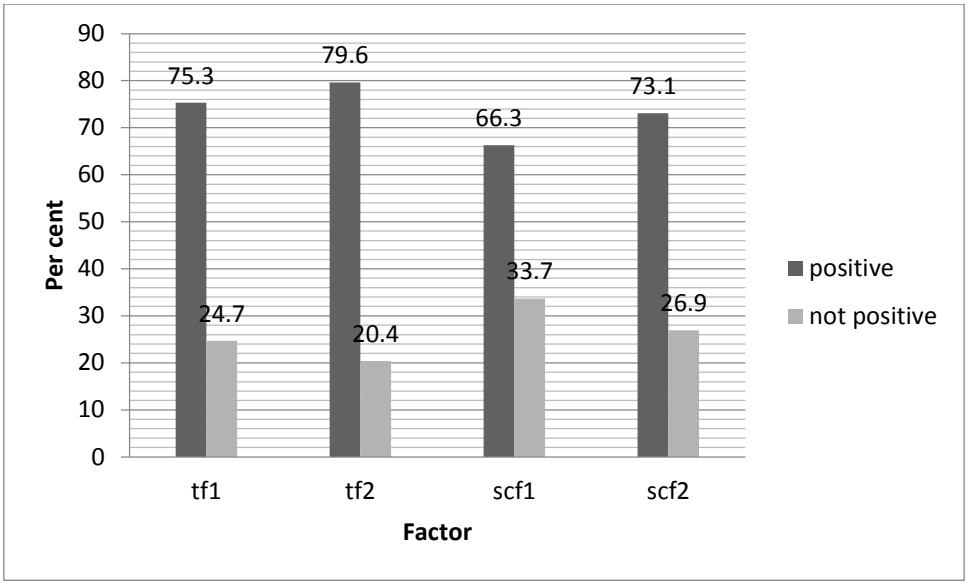

Figure 2 Frequency of teamwork and safety climate factors

Table 5 provides a brief explanation of how to interpret the results tables for QCA. This table should be referred to in conjunction with Table 2 which assists in interpreting the logical equations. When interpreting values the key elements in to take note of are "Consistency" and "Solution consistency" whereby the closer this figure is to "1" the more consistent the equation is in relation to the outcome.

Outcome	**Logical Equations**
Consistency	Expression of percentage of cases' set membership scores in two sets that is in line with the statement that one of the sets is a subset of the other [15]
Raw coverage	Percentage of cases' set membership in outcome covered by a single sufficient path of the equifinal solution term [15]
Unique coverage	Percentage of all cases' set membership in the outcome that is uniquely covered by a single path of an equifinal solution term [15]
Solution consistency	Expression of consistency of the complete solution term
Solution coverage	Percentage of all cases' set membership in the outcome covered by the solution term [15]

Table 5 How to interpret QCA results tables

For this analysis the four factors were considered as conditions for the analysis with the outcome the views of reporting of near miss or severe error. In undertaking QCA there are 2^k possible combinations of conditions [16] thus with four factors there are 2^4 or sixteen possible configurations. The sixteen configurations can be seen in Table 9.

Other terms that are used in CCM relate to different types of solution terms. In considering Table 9 it is evident that there is a row of conditions where no cases were present in amongst clinicians and several rows of conditions where no cases were present amongst management. These are referred to as 'logical remainders' and analysis may be undertaken where they are included or excluded in the analysis [16].

Different terms are used for solution terms depending upon if and how logical remainders are incorporated [16]. Where logical remainders do not aid analysis the solution term is referred to as complex. Where logical remainders are considered in the analysis (although plausibility of the remainder is not considered) the solution terms are referred to as parsimonious. Where the plausibility of the logical remainder is considered the solution term is referred to as intermediate. The latter solution terms have not been listed in this paper as the plausibility of the remainders have not been considered (and thus the intermediate and complex solution terms produced were identical).

Severe Error "Always" Reported (Clinicians)	tf1*tf2*~scf2	+	tf1*tf2*scf1	+	~tf1*~tf2*scf1*scf2
Consistency	0.880992		0.872500		0.872776
Raw coverage	0.280035		0.550087		0.171804
Unique coverage	0.025569		0.280911		0.019440
Solution consistency	0.880996				
Solution coverage	0.595096				

Table 6 Solution terms for factors and views of reporting severe error (clinicians)

Table 6 presents three solution terms that indicate the outcome view amongst clinical nurses that a severe error would always be reported. Positive teamwork factors and a not positive view of workplace safety culture is the most consistent of the three. Positive teamwork factors and a positive view of leadership and management of error (safety climate factor 2) is another configuration which results in the outcome. If both safety climate factors are positive and yet both teamwork factors are not positive then the outcome will also be present. These results suggest that not all factors of safety climate and/or teamwork need to be positive for the outcome to be present.

Near Miss Error "Always" Reported (Clinicians)	~tf1*~tf2*~scf2	+	~tf1*~tf2*scf1	+	tf1*scf1*~scf2
Consistency	0.852405		0.858103		0.848361
Raw coverage	0.246523		0.245084		0.347482
Unique coverage	0.037410		0.035971		0.146523
Solution consistency	0.830934				
Solution coverage	0.429017				

Table 7 Solution terms for factors and views of reporting near miss error (clinicians)

Table 7 reflects different configurations in relation to the outcome of a view amongst clinical nurses that a near miss error would always be reported. Once again there are three solutions terms, although the overall solution consistency and the consistency of each solution term are slightly lower.

If teamwork factors are not positive and the workplace safety culture is also not positive then the outcome is present. If both teamwork factors are not positive yet leadership and management of error is positive then the outcome is also present. If teamwork and patient safety at the bedside a positive, along with a positive score for leadership and management of error yet the safety culture in the workplace is not positive then once again the outcome is likely to be present. Once again, not all factors of safety climate and/or teamwork need to be positive for the outcome to be present.

Near Miss Error "Always" Reported (Management)	Complex solution tf1*~tf2*~scf1*scf2	Parsimonious solution ~tf2*~scf1
Consistency	0.988142	0.988930
Raw coverage	0.204082	0..218776
Unique coverage	0.204082	0.218776
Solution consistency	0.988142	0.988930
Solution coverage	0.204082	0.218776

Table 8 Solution terms for factors and views of reporting near miss (management)

Table 8 displays the solution terms for respondents indicating their role is a management one. As indicated earlier only the views of near miss reporting amongst these respondents could be analysed with fsQCA. The complex and parsimonious terms are also different in this instance (due to the larger number of logical remainders in this group). The complex solution term indicates that if teamwork and patient safety at the bedside along with safety culture in the workplace are both positive and workplace relationships and communication and leadership and management of error are not positive then the outcome of a view that a near miss error would always be reported is present.

The parsimonious solution term is simpler and suggest that the outcome may be present if only the workplace relationships and communication and leadership and management of error are not positive then the outcome will be present.

These solution terms here have a higher consistency than the solution terms from the respondents in clinical roles. However, once again there is an indication that not all factors need to be present for the outcome to be present also.

Teamwork and patient safety at the bedside	Leadership and management of error	Workplace relationships and communication	Safety culture in the workplace	Cases (Clinicians)	Complex and Parsimonious		Cases (Management)	Complex	Parsimonious
					Severe	Near Miss		Near Miss	
1	**1**	**1**	**1**	**31**	x		**10**		
0	1	0	0	5			1		
0	1	1	1	4	x		0		
1	1	0	1	4			1		
0	**0**	**0**	**0**	**4**			**0**		x
1	1	0	0	3	x	x	0		
1	1	1	0	3	x		1		
1	0	1	1	3	x		1	x	x
0	1	0	1	3			1		
0	0	1	1	2	x		0		
1	0	1	0	2			0		
0	1	1	0	1			0		
1	0	0	1	1			1		
1	0	0	0	1			0		x
0	0	1	0	1		x	0		
0	0	0	1	0			0		x

Table 9 Solution coverage

Table 9 indicates the configurations covered by the solution terms amongst clinicians in relation to views of reporting severe and near miss error. This table also displays the rows covered by the solution terms amongst both clinicians and managers in relation to views of reporting near miss error. Complex and parsimonious solution terms have been presented.

It is clear when viewing this table that the configuration of all positive factors results in an outcome view that error would always be reported in severe error only amongst clinicians. It is not however, the only configuration that results in that outcome.

If all factors except the second teamwork factor (workplace relationships and teamwork) are positive then amongst management there is a view that a severe error would always be reported, yet clinicians with the same configuration of factors view that a near miss error would always be reported.

Clinicians view that both severe and near miss error is always reported when both teamwork factors are positive and both safety climate factors are not positive. There were no cases in the management set with this configuration. However, the analysis utilising logical remainders indicated that this configuration was not likely in the parsimonious solution.

The parsimonious solution term for the management respondents indicated that if all factors were not positive then there may be a view that near miss error would always be reported. However, with four clinicians indicating this configuration the outcome that the near miss error would always be reported was not present. The other configurations also indicate differences between clinicians and management in relation to the configurations for positive/not positive safety climate and teamwork factors and the outcome of a view that the error (severe or near miss) would always be reported.

5. Discussion

The inferential statistics presented here indicate there are differences between managers and clinicians in relation to safety climate and teamwork. The fsQCA results provide some insight into how the factors safety climate and views of reporting error differ between management and clinicians. How such differences impact upon the management of error in clinical settings cannot be determined but further research may be warranted in this area.

Perhaps one of the most pertinent results from this research is from the analysis that could not be undertaken. The responses from nurses in a management role all indicated that the viewed the severe error would always be reported. This suggests a limited diversity [15] with regards to the outcome (views of reporting severe error) amongst managers.

Closer inspection of Table 9 also shows that there are less configurations of safety climate and teamwork factors amongst managers (7 of the possible sixteen are present) compared to clinicians (15 of sixteen). This suggests there may also be less diversity amongst managers with respect to safety climate and teamwork factors.

There are also less configurations amongst both management and clinical nurses that result in a view that near miss error would always be reported when compared to the number configurations present that lead to a view that severe error would always be reported. However, when considering the parsimonious solution, there are potentially more configurations amongst managers compared to clinicians with respect to the view that a near miss error would always be reported. More research is therefore needed in relation to safety climate and teamwork.

The fsQCA results also suggest that whilst fully positive safety climate and teamwork may result in a view amongst nurses in a clinical role that severe error is always reported, it is not the only configuration of factors that leads to that outcome. Some configurations where teamwork and/or safety climate factors are not positive still result in a view that severe error would always be reported.

The vignette for this study for the severe harm outcome from the hypothetical error referred to a patient who had a severe reaction to a medication, was resuscitated but remained unresponsive twelve months after the event [24]. If clinicians do not feel that severe error is always reported yet those in a management role do then there an indication that those in management may be overly confident of what may be reported in their workplace. Such a difference in views should be concerning for anyone in a management role, regardless of their industry.

If such differences are suggested from data in health care settings then it is also possible that similar results exist in other industries. With the recent events in the maritime sector it is also possible that those in management roles may have very different views of what could be happening at the coalface of their workplaces.

6. Limitations

The fsQCA undertaken for this paper used the "Standard Analysis" in fsQCA software. Contradictory rows were identified using Kirq and were included in the analysis. It is recognised that an analysis using "Specify Analysis" may have yielded different results. However, the purpose of this paper is to explore the use of CCM and hence the more simplified process of analysis has been applied. Further exploration of the cases, making use of demographic data may also provide further insight into the results.

7. Conclusion

The fsQCA results presented here suggest that whilst teamwork and safety climate factors may be positive it does not necessarily result in a view that error would always be reported, regardless of whether it is severe error or a near miss. Indeed, factor scores that are not positive may play a role in such outcomes.

There is also a suggestion that those in clinical and management roles may think differently in relation to safety climate and views of error reporting. This raises a question in relation to how error is managed in clinical settings.

Clearly the relationship between safety climate and views of error reporting is complex. What is potentially gained from the use of CCM and fsQCA is an improved understanding of what this relationship may look like.

In releasing his report, Robert Francis QC [2] reflected on the number of times the term 'benefit of hindsight' had been used in his enquiry. James Reason has since commented in relation to this report that the term 'culture' is perhaps more relevant [3]. Whether further investigations into the *MV Sewol* results in similar dialogue is yet to be determined but it is likely that some will acknowledge known issues that contributed to the disaster.

Using methods that recognise complexity may make it possible to improve understanding of what needs to happen to ensure organisations are enhancing safety outcomes. Similar research could be undertaken in maritime organisations and workplaces. Through combining Swiss cheese, butterflies and algebra it is possible to look ahead at future maritime research aimed at understanding the complexity of organisational culture and safety. Innovative approaches such as CCM should therefore be considered for future research in other industries, including maritime safety.

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