DOCTORAL THESIS

Discovering Mental Models for the Enhancement of Mental Health Risk Formulation and Clinical Decision Making

Ifeoluwa Ibidunni Agboola

Doctor of Philosophy

ASTON UNIVERSITY

JULY 2022

Abstract

The uncertain nature of mental health and the complexities in delivering mental healthcare has brought immense pressure on healthcare professionals to use risk assessment and formulation tools that can accommodate the complexities of mental health risk assessment and clinical decision-making processes. The domain of this research is enhancing risk assessment and formulation process in mental health using mental modelling techniques to gaining an understanding of clinical decision-making process and clinical workflow. Enhancing risk formulation requires an examination of the clinical decision-making model of the risk formulation tool used and the users' perceived mental model of the tool based on actual clinical workflow.

An elicitation of users' mental model was carried out with data on users' interactions with the Galatean Risk and Safety Technology (GRiST); a web risk assessment tool with a view of identifying patterns, behaviours and preferred options of the user which may however not synchronise with the conceptual model of the system causing a mismatch which impacts on performance of the end users. The elicited users' mental model showed common pattern of data collected and questions ignored when answers are expected. Missing data, incomplete tasks/data and data inconsistencies were common issues identified.

This showed the different approach of risk assessment the user has taken; the underlying reasons behind the chosen approach of the user could be lack of understanding of the system and its expectations, confusion arising from the set of questions, non-relevance of the required data or task, time pressure with too many questions, the overriding factor of the clinician's skills, experience and intuition.

This thesis develops a framework aimed at aligning the users' mental model with the GRIST model is designed to address the shortcomings identified which include omission of data, unanswered questions, incomplete task and or data, non-relevant questions/data, differences in workflow and users' mental model with GRIST suggested workflow and model is proposed.

Keywords: GRiST, Clinical Decision Support System, Clinical Decision Making, Mental Models, Risk Formulation

Dedication

This thesis is dedicated to my late dad; Dr Raphael Adeniran Agboola, my ever-supporting mum; Mrs Victoria Funmilayo Agboola and to my children yet unborn.

Eyin t'oluwa shey ni....ko le baje lailai. Amin

Acknowledgement

My sincere appreciation goes to Dr Chris Buckingham, for his supervision. This thesis would not have been possible if not for his unlimited patience, support and encouragement from the day one of the PhD journey.

I am indebted to Dr Austin Briggs for needed support and advise in trying times along this journey and also to my fellow researchers for supporting one way or the other. To my family for the indirect push to get me going, thank you for all you do and have done.

Last but not the least, to my children yet unborn, this PhD in Computer Science is for you; the sky will never be your limit but the starting point. Also a pinpoint to always remember…What God cannot do does not exist.

Table of Contents

List of Abbreviations

AC - Affirmation of the Consequent

AT - Answer Tree

CAT - Client Answer Tree

CBT - Cognitive Behavioural Theory

CDSS - Clinical Decision Support System

CDM - Clinical Decision Making

CM - Concept Mapping

CMM - Concept Mapping Modelling

CSIP - Care Services Improvement Programme

CSV - Comma Separated Value file

CompTMAP - Computerized Texas Medication Algorithm Project

DA - Denial of the Antecedent

DCP - Division of Clinical Psychology

DSS - Decision Support System

ADHD - Attention Deficit Hyperactivity Disorder

GRiST - Galatean Risk and Safety Technology

HCI - Human Computer Interaction

HQIP - Healthcare Quality Improvement Partnership

IOM - The Institute of Medicine

MG - Membership Grades

MP - Modus Ponens

MT - Modus Tollens

NHS - National Health Service

NPfIT - National Programme for Information Technology

PhD - Doctor of Philosophy

QT - Question Tree

RAMAS - Risk Assessment, Management and Audit Systems

RIT - Relative Influence Tree

RI - Relative Influence

SPJ - Structured Professional Judgement

SST - Super Structure Tree

ST - Structure Tree

UK - United Kingdom

UI - User Interface

WHO - World Health Organisation

XML - eXtensible Markup Language

XLSX: Excel Microsoft Office Open XML Format Spreadsheet file

List of Tables

List of Figures

Chapter 1 Problem Domain and Research Background

1.1 Introduction

The chapter introduces the challenges in mental healthcare delivery due to the complexities in the nature of mental health and the issues in effective risk assessment and formulation. It highlights the need to address the issues in order to enhance risk formulation. The chapter provides the research background and focus underlined in the research motivation and in the definition of the problem domain which leads to defining of the research question. The research aims and objectives based on the research focus are identified to provide the scope of the research.

1.2 Research Motivation

Achieving quality and cost-effective mental healthcare delivery has increasingly become a concern due to the rise in mental health cases in the United Kingdom (UK) and across the globe. Statistics shows that one person in five living in an area affected by conflict is living with some form of mental disorder, from mild depression or anxiety to psychosis worldwide. Around 1-in-7 people in the UK have one or more mental disorder [171] Statistics show that one in four persons in the UK and about 450 million individuals worldwide suffer from neuropsychiatric disorders in their lifetime [202]. Early diagnosis and intervention plans have been suggested for effective management of mental health but the rising cases of wrong diagnoses and errors in clinical judgements due to the complex and uncertain nature of mental health and the risk assessment approach used have brought some challenges to healthcare managers [144]. This suggests the need to have a good understanding of the risk assessment process and how it accommodates the complexities of mental health diagnoses. This has also raised concerns on the clinical decision-making process and the risk assessment approach or tools applied in making appropriate clinical decisions for intervention. Decision support systems (DSS) are used to support decision-making in clinical settings. This is often with the assumption that the decision-making process in the clinical setting such as mental health assessment is well understood.

However, outputs of such decision support systems may not always support decision-making in the way that was intended if clinical assessment is not done properly. This situation usually implies some discrepancy between the decision-making process that is being modelled and done in practice or as perceived by the user. This suggests the need to examine the clinical decision-making model of the decision support system used for the risk formulation. The delivery of quality mental healthcare therefore may be very much dependent on the clinical assessments and judgements that are based on the adopted clinical decision-making process and the perception of the user. This shows the intimate and critical role of users' perception and clinical decision-making process in risk formulation and the quality of care that clinicians provide to patients as poor decision-making can lead to adverse events with negative consequences [55]. Clinical practice is aimed at providing effective and accurate solutions to clinical problems of individual patients and could be described as an act of continual decision-making. The best clinical decision practice therefore demands making a choice that maximizes effectiveness and minimizes harm [98]. Kerrigan [114] describes decision making as the choosing of options directed toward the resolution of problems and the achievement of goals. The choice of options sometimes may be on the subjective intuition of the clinician especially where the supporting evidences were scant which further makes decision making unpredictable and non-reproducible [12]. This implies that the decision process in the real world may be complex, ill-defined, and lack structure which requires a good understanding. Clinical decision making has therefore been described as a contextual, continuous, and evolving process. It is a process that includes clinical reasoning as part of the decision-making process in which information is collected and evaluated and then an action is taken or decision is made [102, 41, 46, 155, 133]. The process may include antecedents such as considering information, gathering information, and other activities such as weighing the risks and consequences which may be a challenge to carrying out effective risk formulation.

1.3 Defining Problem Domain – Research Background

The domain of this research is the problem of enhancing risk assessment and formulation process in mental health using mental modelling techniques to gaining an understanding of clinical decision-making process and clinical workflow. Risk formulation in mental health involves steps determined by the clinical decision-making process adopted in the chosen risk formulation tools based on accepted clinical workflow. Enhancing risk formulation may therefore require an examination of the clinical decision making (CDM) model of the risk formulation tool used and the users' perceived mental model of the tool based on actual clinical workflow.

The need to enhance risk formulation is borne out of the increasing rate of mental health cases, especially deaths by suicide which has made mental health a major social and public health problem [202]. The lack of clarity on how to assess individual cases for mental health risk is becoming a major concern for clinicians and mental health professionals [120].

The need to provide quality mental healthcare intervention through quality risk formulation has prompted the formulation and establishment of policies and tools on how to effectively assess mental health risks and reach decisions on formulating intervention programmes [51, 35]. Different CDM models targeting structured, simplistic and systematic approaches have also been applied in the various risk formulation tools that relate with the workflow of the clinician with effective clinical support.

The problem domain will thus be focused on enhancing risk formulation through having a good evaluation and understanding of the clinical decision-making model of the risk formulation process/tool and a good evaluation and understanding of the users' perspective of risk formulation. The research therefore examines the challenges and issues in risk assessment and formulation, examination of clinical decision-making model of the risk formulation tool; and evaluation of users' perspective of risk formulation.

1.3.1 Risk Assessment and Formulation in Mental Health

A major concern in mental health is the increasing rate of mental health cases and the number of patients who never got the treatment they needed due to late or wrong detection [180]. Adult Psychiatric Morbidity Survey [134] highlights the predicaments of one in six adults with diagnosable mental health problems, yet only a third received a diagnosis. This situation calls for early detection and prevention of mental health cases requiring effective identification of risks such as suicide, self-harm, harm to others and self-neglect risks. It also highlights the importance of risk assessment/formulation and the need to address the challenges of carrying out the process successfully.

Risk is described as the probability of an event taking place with the potential of being harmful or with beneficial outcomes for self and others which affects the mental health of the individual. The presence of risk factors indicates the vulnerability of a person to or is at an increased probability of developing a mental health condition. Risk assessment is therefore a part of a comprehensive review of the mental health of an individual and considers a combination of psychological factors such as current mental health conditions, and social factors such as relationship problems, and employment status, to assess risk level and identify the care needs of the patient. Risk Assessment as a clinical practice in mental health targets the collection of relevant individual information and analysis of the potential outcomes of different identified risk behaviours on the individuals [51, 35].

The three main domains in determining the level of risk are the assessment of current mental state including specific suicidal thoughts, assessment of empirically supported risk factors and assessment of protective factors [101, 100]. The process of information collection on the various aspects, what is to be recorded and the integration of the information to formulate intervention have become issues in risk assessment.

The process is complex involving a large number of factors to be considered and integrated and it is not a well understood process either as a clinical activity or a probabilistic science [57]. Various

pragmatic approaches have been described for integrating these components effectively, but there is little agreement over how the components might be integrated [192], and even on what cues that should be collected, recorded, and the process of collection [87]. Moreover, the fact that mental illness is characterised by uncertainty and unpredictability makes the conduct of risk assessment and the use of a more structured and easily understood risk assessment approach / tools [61] very important and more appealing to improve the decision-making of mental-health professionals [130].

This explains why a plethora of different risk assessment tools which are mostly paper-based are in use [89] while the search for and efforts to develop a common approach to risk assessment for all mental-health professionals continues [167]. Risk assessment is thus an intrinsic part of mental health care which provides the bases for effective formulation of intervention programmes. The concept of risk assessment within the field of clinical risk assessment and management has also been acknowledged as an important part of mental health care [138].

A key clinical practice guideline defines risk formulation as a part of decision-making model process in which the practitioner decides how the risk might become acute or triggered. This highlights the importance of a clear effective decision-making process model to aid the risk formulation process. Risk formulation process has also been described as an organised framework based on a clinical decision-making model to produce a narrative explaining the underlying mechanism and proposed hypotheses regarding action to facilitating change. It has become central to the process of risk assessment in recent years.

An understanding of the process of assessment and the framework for formulation of intervention programme based on a chosen clinical decision-making model is needed to improve decision making and enhance risk formulation in mental healthcare [130].

1.3.2 Overview of Clinical Decision-Making Models in Risk Formulation

Risk assessment and formulation has also been described as an inexact science which raises questions on the accuracy of the clinical judgement particularly when there appears to be little consistency or

convention on how risks are classified and reported in practice [59]. The process involves the integration of potentially complex and often ambiguous information from inherently complex patients requiring a clear and simple clinical decision-making process to facilitate the methods of combining, scaling, or otherwise actuarially integrating risk factors into some sort of formula for judging level of risk [173]. The essence is to provide patients with non-biased, evidence based clinical recommendations that take into consideration objective assessment of risk. However, the challenges in the integration of the large mass of data collected during the assessment process precisely and with empirical certainty highlight the importance of a clinical decision-making process/model [178, 131]. This leaves the clinician to rely on clinical experience and inductive reasoning which further corroborates the argument that clinical formulation of risk is based on a cognitive understanding of data gathered about risk, ideation, and protective factors [178].

Risk formulation adopts a process of conceptualising the problems with the view of specifying necessary interventions by endeavouring to statistically model the decision rules that would enhance the accuracy of clinical judgements [192].

The use of some sort of formula based on the clinical decision-making model for judging level of risk have been shown to have poor specificity [173]. A new alternative approach is the use of a clinical decision support system which adopts unique models of clinical decision-making process and structured classification model. The different theoretical interpretations of decision-making process show the need for a general framework to facilitate the description of clinical decisions which is able to relate the data and their interpretations and is also reflective of clinical workflow.

The challenge remains to provide clinicians and patients with non-biased, evidence based clinical recommendations that take into consideration objective assessment of risk using standard clinical practice/workflow as perceived by the user.

1.3.3 Gaining Users' Perspectives through Users' Mental Model

The use of clinical decision tools in mental health risk formulation has played key role in the provision of quality decisions for quality health care. However, the essence and effectiveness of a clinical decision tool lies in its ability to effectively mimic expert knowledge of the human expertise and the clinical workflow in practice which has been a major challenge. Its impact in facilitating important clinical tasks including risk assessment and enhancing quality health care is also dependent on understanding and accommodation of the clinician's cognitive workflow which is formalised in the clinician's mental model of the system; this makes it easy for its acceptance and effective utilisation by the clinicians.

The impracticality of many clinical decision tools may be due to the failure of developers to deal adequately with the logistical, mechanical, and psychological aspects of system use. Research shows that a better understanding of these factors that impact on the success such as poor usability or integration of the system into the workflow of the user, is very much required [146]. Understanding how users think, workflow is a start point which makes the development of user's mental model a necessity in building a better focused clinical decision tool.

The complexity of clinical tasks and experts' behaviour necessitate a comprehensive awareness of the relationship between user information needs and functional requirements for CDSS systems. The importance of the interpersonal, cultural, and organizational aspects of the clinical decision tool in practice highlights the focus on the human dimension in understanding the user and in meeting his needs with a successful design.

Mental models are regarded as important cornerstones for building knowledge and defining some of the cognitive processes that support change and learning. Examining and extracting the model provides a good platform for understanding the biases, beliefs, experiences, and values of individuals incorporated in the model that are constantly interacting with patterns of perception, thought, and action.

The challenge is therefore capturing of users' evaluative view and perception of the system using the users' mental model. This will help to provide better understanding of the system's functionalities and how it is fit for purpose and meets users' requirements. This is necessary for the enhancement of users' interactions and effectiveness of the system. The concept of mental model and the building of user' mental model has been widely applied in human computer interface to enhance better user interface design.

The concept is a psychological representation of some domain or situation which facilitates understanding, reasoning, and prediction [106, 105]. Mental models have been described as knowledge structures employed by users to represent, make sense of, and interact with the external world [77, 105]. Mental models may therefore be used to understand user's behaviour, predict their actions on the system and guide their use of the system.

The construction of models which reflect the decision structure has been described as one major tool for dealing with decision making under uncertain conditions and to gain an understanding for better decisions because it allows decision experimentation with hypothetical consequences [139].

1.4 Research Focus

The research is focused on three main issues necessary for enhancing clinical decision making in the mental health domain focusing on risk assessment, formulation and management. These issues are based on the motivation of research to guide the process of risk formulation in order to reduce or eliminate errors in clinical decisions:

1) examining the risk assessment and formulation process and tools

2) evaluation of the clinical decision-making model to facilitate the enhancement of risk formulation and

3) evaluation of mental health clinicians' perspective of how assessments are taken for a better understanding of assessors' behaviour, prediction of activities and enhancement of the overall clinical decision making.

1.4.1 Enhancing Risk Assessment and Formulation Process\Tools

Formal risk assessment involves complex processes with different mental illnesses and conditions which carry with them different prognoses and risks to the patient. An examination of the complex processes and the different components, levels and interactions will enhance a better understanding.

Research shows that there is little agreement over what information should be collected and what cues should be recorded and how they might be considered in combination [192]. The main challenging issues include the collection of relevant individualised information of the patient in the midst of available mass of information, and the difficulties in integrating and applying this information to individuals and producing a comprehensive assessment report to facilitate effective risk formulation and consequent clinical decisions [183]. An understanding of how clinicians collect required relevant information and the process followed may be vital to the enhancement of the risk assessment/formulation process.

In the midst of the disagreements and the uncertainty and unpredictability of mental illness a plethora of different risk assessment tools which are often paper based are in use [89] with doubt about the scope of improving the decision-making of mental-health professionals. It has also been noted that users are sceptical about the risk assessment tools they use [57]. Efforts are therefore ongoing to develop a common approach to risk assessment for all mental-health professionals [167].

Suggestions have been made that risk assessment tool should be capable of incorporating crucial transient, dynamic, qualitative, and idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement [85, 184, 93, 128, 129]. This has prompted the NHS National Programme for Information Technology (NPfIT) and other suggested framework to come up with a standardised minimum data set and the data structure that needs to be collected.

An examination of the risk formulation tool to determine its capabilities of incorporating relevant standardised data set and with a clearly defined data structure to enable efficient data collection is required for the enhancement of risk formulation. This shows the need to examine how risk assessment and formulation is carried out to determine how the process and sequence of data collection adopted in the clinical decision-making tool used affect the clinical practice workflow or have an impact on the clinical decision-making process and clinical decisions made.

1.4.2 Evaluation of Clinical Decision Making

Process The different theoretical interpretations of decision-making process show the need for a general framework to facilitate the description of clinical decisions which is able to relate the data and their interpretations. Gaining a better understanding of the decision-making processes is considered to bring some important benefits to the clinicians and their patients as it enhances clinical effectiveness and provides a platform to consolidate those elements that lead correctly to predicted outcomes while others are re-evaluated.

Risk formulation is described as a clinical decision practice that demands the making of a choice that maximizes effectiveness and minimizes harm [98]. Kerrigan [114] describes decision making as the choosing of options directed toward the resolution of problems and the achievement of goals. The choice of options depends on the supporting evidences collected and sometimes may be on the subjective intuition of the clinician especially where the supporting evidences were scant which further makes decision making unpredictable and non-reproducible [12].

Identifying how good clinical practices and decisions may be achieved and where improvements can be made is therefore an issue and can be problematic undermining clinical and organizational effectiveness. Achieving a better understanding of clinical decision making has been enabled by the representation of the process in different theories and models with the aim of understanding the process, elements involved and how changes can be evolved to enhance effectiveness in decision making. The need for the evaluation of the underlying model of the clinical decision-making tool

adopted to identify how the decision-making process may be enhanced and to accommodate the requirements of risk assessment and formulation is important. A user's congruent corresponding mental models are developed which in turn facilitate the enhancement of functionalities and user's interactions.

1.4.3 Evaluation and Understanding of the Users' Perspective of Risk Formulation

A user's mental model described as knowledge structures representing their cognitive process provides an evaluative view of the system from the user's perspective. The mental model captures the cognitive thinking and behaviour of the user during the use of a system. It therefore shows the aspects and features of the system that facilitate the accomplishment of a functional task during interaction with the system. The model also projects users' expectations of the system, guides expected usage and how feedback is interpreted. These features of user mental model make it useful in providing an understanding of the features and functions of the system considered as critical and most useful by users [106]. This will help in identifying important user-based system criteria to be considered in the evaluation and update of the system's functionalities.

User's mental models are usually constructed during user interaction with the system and will generally include how the user perceives the system's functionalities which are described as the system aspect of the mental model. This may provide the user's evaluative view of the system which will be indicative of the aspects and features that facilitate the accomplishment of tasks carried out through interaction with the system. Zhang [207] suggests that user's perceptions of a system are usually in four components namely system, content, information organization, and interface which may be exploited to make the system more effective and useful.

Researches on mental models are however limited with focus on the wide varieties of the definition and characteristics of mental model such as the accuracy and completeness. Few studies have also been made on the impact of mental model on user's navigational behaviour and interaction with system for a better understanding of user's perception of the system [207]. Research on the use of

mental model is aimed at having a better understanding of the cognitive process of the user in the decision-making process and in the effective use of clinical decision support systems.

This research is aimed at understanding the processes of risk assessment in mental health care delivery and how the building of users' mental models can help enhance users' effective decision making. The study will investigate the construction of mental models as a way of dynamically extracting new requirements and understanding the mind-set of users as they interact with the system. This is aimed at developing effective risk assessment process and enhancing the user friendliness of the system using mental model theories.

1.5 Research Questions

Can clinicians' mental models be extracted from system interactions with the aim of improving clinical decision process for mental health risk assessment and management? The overall goal of the research questions is sub divided as follows:

Can mental models provide an understanding of users' behaviour?

Can mental models be elicited from clinicians' use of Decision Support System?

Can the Decision Support encapsulate beneficial mental models?

1.6 Research Aims

The problem domain highlights that the research is focused on enhancing risk formulation with a good evaluation and understanding of the clinical decision-making model of the risk formulation process/tool and a good evaluation and understanding of the users' perspective of risk formulation.

The research is aimed at determining how risk formulation fits with the mental model of clinical decision making and the users' mental model with a view of enhancing the clinical decision making process of risk assessments and formulation to reduce or eliminate errors in clinical decisions; evaluating the clinical decision making process of risk assessments and formulation to gain a better

understanding of the process, the approaches and tools used with a view of identifying the challenges and how to ensure effective clinical decisions and judgements and how it supports the clinical decision making process of the user. The evaluation is aimed at identifying how it impacts the clinical workflow and enhancing the clinical effectiveness of the Clinical Decision Support System (CDSS) and provides a platform of consolidating those elements that lead correctly to predicted outcomes while others are re-evaluated.

The research is also aimed at evaluating user's mental model to identify any mismatch with the Clinical Decision Making (CDM) model of the CDSS and how the models may enhance the software functionality and user's interactions. The construction of the user's mental model is with the view of gaining an inner depth to the user's experience of the Galatea Risk Safety Technology (GRiST) and its challenges facilitating the development of a user's congruent corresponding mental model. It is expected that conceptual models of a system such as GRiST; a mental decision support system and user's mental models must be similar in order for the interaction to prove successful [187].

1.7 Research Objectives

1.7.1 A critical examination of risk assessment and formulation approaches and tools

Clinical risk assessment in mental health is noted to be a complex clinical decision-making process that is not a well understood process. There are different approaches and tools which have been tried and used for the process with varied advantages and limitations. The mental health industry has also established best practice guidelines for risk assessment to guide the approaches to risk formulation in order to enhance the process.

An examination of the different approaches will be carried out to identify the impact on the process of collecting information on risk factors and the sequence of collection and integration, and the resulting intervention decisions. The examination of the approaches will also be aimed at determining the capability of the approach in incorporating crucial transient, dynamic, qualitative, and

idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement. The examination will also determine the impact of the approach on the clinical practice workflow and how it supports clinical risk assessment practice in real life.

1.7.2 Understanding the clinical decision-making process of risk formulation

Incomplete diagnoses and errors in clinical judgements in risk assessment and management can be based on incomplete or inconsistent clinical decision making. This may imply some discrepancies between the decision-making process that is being modelled and the way decision-making occurs in practice.

An examination of the clinical decision-making tool adopted for risk formulation will be carried out to determine how the clinical decision model of the adopted CDSS meets the requirements of the standard best practice guideline on risk assessment/formulation, how it supports and facilitates decision making in risk formulation and how it meets the workflow requirements of the clinicians. The clinical decision-making tool that will be used as a case study for the research is the GRiST, a web based clinical decision support system.

This will require the understanding of GRiST's ontology which represents its conceptual model, to provide a platform for an understanding of the kind of interactions undertaken with GRiST and how these can be tracked to determine how well the system is engaging with the human user in their shared journey.

The research will identify the static and dynamic relationships between GRiST's functionalities with a high-level description of how the system is organized and operates. This will help to specify and describe the major design metaphors and analogies employed in the concept of GRiST. The concepts used in the system which the users should know, including the task domain data-objects users create and manipulate, their attributes, and the operations that can be performed on them will also be highlighted. The relationships between these concepts will be highlighted and evaluated while the mappings between the concepts and the task domain the system is designed to support will be drawn.

1.7.3 A critical evaluation of user's interactions with GRiST through the elicitation of users' mental models

The research will be focused on building a users' mental model of GRiST which gives an evaluative view of the system from the user's perspective. This will help to capture and explain the human mind and human behaviour in the use of the system. This stage of the research is aimed at capturing the end user's experience of the system, and to show the internal abstraction of what the user thinks the system is supposed to be doing. The building of user's mental model will require the examination of users' interactions with the system, how they navigate the system in carrying out risk assessment, the processes followed, sequential steps taken and the general workflow. This is with a view of identifying patterns, behaviours and preferred options or paths of the user which may however not synchronise with the conceptual model of the system causing a mismatch which impacts on performance of the end users.

1.7.4 Identify any mismatch between the CDM model of GRiST and the user's mental model

The construction of the model using the deposit of clinicians' interaction with the system (data); illustrating the steps in which assessments were done; the type questions were answered or unanswered and how these are done (pathway). The data will be cleaned and the different pathways extracted to identify patterns of user's interaction and behaviour. A comparison of the CDM model of GRiST with the user's mental model will be made to determine any mismatch and identify any different mental model being pursued by the user.

1.7.5 To determine how risk formulation fits with the mental model of clinical decision-making process of GRiST

The study will identify elements of the sequential workflow relevant to the requirements of risk formulation and the expected mental-model behaviour based on best practices and guidelines for risk

formulation. The study will also identify the relevant features of the CDM of GRiST and the provisions to accommodate the requirements for effective risk formulation process.

An analysis of the user's mental model will help in the identification of unique patterns and the sequential work flow in accordance to current medical practice in risk formulation different from mental model of GRiST. This is with the view of identifying how the GRiST functionalities may be enhanced with the incorporation of relevant work flow patterns to enhance risk formulation process.

1.7.6 Providing a new framework of risk assessment and formulation approach

A new proposed framework will be developed to enhance the risk assessment and formulation process and the decision-making process to enable quality and reliable risk formulation decisions. The proposed framework will be focused on ensuring that the CDM model of GRiST accommodates the requirements of effective risk formulation process. The proposed framework focuses on rearranging the process and arrangement of collecting the predisposing, precipitating, perpetuating and protective data on the risk in question and relating the factors to determine their interrelationships and impact on the mental health of the patient.

1.8 Expected Contributions

The research focus is in three main areas namely an examination of risk assessment and formulation process; a critical examination of GRiST as a Clinical Decision Support System (CDSS) and how its risk formulation supports the decision-making model; and the elicitation of user's mental model of GRiST and evaluation of users' interaction with the system.

The main objectives focus of the research are carried out with the view of identifying how risk assessment and formulation can be supported and improved using an enhanced CDSS tool that is aligned with users' mental model.

The research contributes to knowledge in the area of risk assessment and formulation as it provides a deeper understanding of the challenges and complexities of the risk assessment process, and the

appropriate structure to guide effective risk assessment and formulation. The research also contributes to knowledge in the area of clinical decision-making process of a CDSS tool as it provides a deeper understanding of the decision-making process, different approaches to risk formulation, and how the functionalities can be enhanced.

The research also contributes to knowledge in the area of eliciting users' mental model to have the user's perception of a system and identify unique patterns and areas for improvement in the system. The main expected contribution is the proposed new framework for risk assessment and formulation that will guide the enhancements of GRiST for good usability features and quality and reliable clinical decisions.

1.9 Thesis Structure

Chapter one provides the introductory and background view of the research issues presented in different sessions such as motivation for the research, research focus, research aims and objectives and expected contributions. The motivation for research provided an overview of the general research areas which include the enhancement of risk assessment tools, enhancement of the decision-making process of CDSS, and the assessment of user's mental model. The research focus presents the problem areas to investigate in the research which will focus of identifying how risk assessment approach can be made effective, how the CDM model of the CDSS can be enhanced to support effective risk assessment and formulation, and how the CDSS can accommodate the cognitive workflow of the clinician and be aligned with the user's mental model. The chapter also presents the research aims and objectives and the expected contributions.

Chapter two presents the research background and literature on the state of mental health in the UK, its complex nature, challenges for effective risk assessment and formulation of evidence-based intervention programmes using a structured clinical decision-making process. The chapter also provided a critical examination of risk assessments and formulation in mental healthcare with a focus

on definitions, important role in risk assessment in mental healthcare, requirements in risk assessment / formulation process and the different approaches to risk assessment. It highlights the complex nature of the process and what is required for a reliable and quality assessment and formulation of risk judgements and intervention plans. The chapter also examined tools used in the risk assessment/formulation process, best practices guidelines, the impact of clinical decision-making process and the issues to consider in the evaluation of the risk process.

Chapter three examines clinical decision support systems (CDSS) and decision making. It examines CDSS in mental health and the challenges of CDSS. it also examines the need for an appropriate clinical decision-making tool and clinical decision-making process for effective risk formulation was also discussed with an examination of clinical decision support systems, their designs, types, challenges and how they have improved the clinical decision-making process in risk formulation with positive impact on intervention decisions.

Chapter four presents the concepts of mental modelling highlighting definitions and underlying theories. The chapter examines the usage of mental models in the development and effective use of clinical systems. The important role played by the concept as a psychological representation of some domain or situation which facilitates understanding, reasoning, and prediction was highlighted. The use of mental model as important cornerstones for building knowledge and defining some of the cognitive processes that support change and learning is exploited in enhancing risk formulation. The chapter examined mental modelling in clinical decision making in mental health and in gaining understanding of clinical decision-making process. It also presents the elicitation of mental models and how it may enable the understanding of users' cognitive behaviour with the view of enhancing risk formulation. The different methods of eliciting mental models will be reviewed with a comparison of the methods and processes involved using case studies.

Chapter five presents an overview of the Galatean Risk and Safety Tool (GRIST) – the clinical decision support system that is used as the case study system for investigation. The chapter provides an

examination and analysis of the design of GRIST with description of the underlying classification theory and the processes required. It also presents highlights of the driving ontology that defines the operational functionalities of GRIST. The chapter describes the use of nodes, the attributes, data types and the XML knowledge tree, and how these facilitate the risk formulation process. The chapter describes the major design metaphors and analogies employed in the concept of GRIST

Chapter six presents the research design adopted for the research. It examines the data mining tool for the data analysis. The chapter also presents the construction of the proposed framework to address the shortcomings of the mental model.

Chapter seven presents the data analysis, results and discussion. It provides the data in the different categories, and the implications to the overall data collection process and risk judgements.

Chapter eight presents the elicitation of users' mental model based on the data analysis from chapter seven. It provided the identified pattern of users' interaction representing their mind set and current clinical practise.

Chapter nine presents a discussion comparing GRiST mental model and the elicited users' mental model.

Chapter ten presents the proposed framework formulated based on users' behaviour and the identified issues of incomplete data and non-aligned models.

Chapter eleven presents the research recommendations, conclusion, research contributions and further research.

1.10 Chapter Conclusion

The increasing rate of mental health cases and the failure of the medical profession to deliver quality healthcare due to errors in diagnosis have highlighted issues in risk assessment and formulation that need to be addressed. The chapter highlights the need to have a better understanding of risk assessment and formulation approaches with a view of finding better ways of deciding interventions.

The chapter also identified the need to examine the CDSS used as risk assessment and formulation tools in order to enhance its decision-making process and ensure it is aligned with the clinician practical workflow obtained from the construction of user's mental model, and that it meets the requirements for risk assessment.

Chapter 2 Risk Assessment and Formulation in Mental Health

2.1 Introduction

Chapter one highlighted the research motivation and the research aims based on the increasing rate of mental health cases and the failure of the medical profession to deliver quality healthcare due to errors in diagnosis and poor decision judgements in risk formulation. The research focus has thus been established to examine risk assessment and formulation approaches with a view identifying the challenges, impact of the clinical decision-making process/model, users' evaluative mental model and ways of enhancing the process for quality interventions.

This chapter provides a detailed background of the research starting with a discussion on mental issues, its complex nature, challenges for effective risk assessment and formulation of evidence-based intervention programmes using a structured clinical decision-making process. This will be followed by a critical examination of risk assessments and formulation in mental healthcare. The process which is in two parts will be discussed separately starting with risk assessment followed by risk formulation. The section will focus on definitions, important role in mental healthcare, the requirements in risk assessment / formulation process and the different approaches to risk assessment. The section will also examine tools used in the process, best practices guidelines, the impact of clinical decision-making process and the issues to consider in the evaluation of the process.

2.2 Mental Health Problems

Mental health is described as a state of well-being in which an individual is able to realise his or her own potential, cope with the normal stresses of life, work productively and fruitfully, and is able to make a contribution to her or his community [202]. Mental health problems which affect one in six (17%) of people over the age of 16 had a common mental health problem in the week prior to being interviewed. This is an increase from the 2007 survey, which found that 16.2% had a common mental

health problem a week [73]. The Adult Psychiatric Morbidity Survey of 2014 which examines the mental health and wellbeing of people in England shows that one in six adults had a common mental disorder (CMD) [134].

The survey also shows that one in five women and one in eight men were diagnosed of CMD. There has also been an increase in the reported rates of self-harming across age groups since 2007 and the trend shows that most mental disorders were more common in people living alone in poor physical health, and unemployed.

The high prevalence of mental health disorders is thus raising increasing public health concern on how to effectively deliver mental health care. This growing concern is based on the acknowledgement that mental health care requires attention to detail, which can be difficult within busy practice areas [95]. The practice also requires good understanding of the experiences and the social context of patients' inner worlds which most health care delivery systems have failed to do effectively [95].

This makes the understanding of the cultural and social background of the patient an important issue in the treatment and management of mental health. Effective mental health care aimed at improving the outcomes for people with mental health problems therefore presents a core public health issue in the UK and worldwide. Achieving effective mental health care has however been challenged by a number of barriers which limit doctors' ability, and that of the mental health sector resulting in a vast amount of unmet need among people with mental health problems. Statistics show that three in four people with a mental health problem in England receive little or no treatment for their condition while one in three NHS patients with depression and other mental health problems in England receives poor treatment [72].

Statistics also show that 75% of people in England experiencing mental health problems receive no treatment at all while between 2002 and 2012 in England, 72% of people who died from suicide had not been in contact with their GP or any other health professional a year before their death [91]. The dimension of mental health cases is also changing as one in three adults in their life time, will be

diagnosed with common mental disorders ranging from depression, suicidal thoughts, anxiety disorders etc. [134].

There has also been an increase in the reported rates of self-harming across different age groups since 2007 till date and the trend shows that most mental disorders were more common in people living alone, in poor physical health, and unemployed [134]. It is said that the World Health Organisation (WHO) predicted that by 2020 mental health cases would account for 15% of the total world diseases [201]. This highlights the importance of the management and early detection of mental health and associated risks which rely on effective and successful risk assessment.

There are a range of mental health conditions; from common problems such as mild depression and anxiety disorders, to more severe mental health problems, such as schizophrenia and bipolar affective disorder which require different levels of care. Effective mental health care therefore is a function of many factors such as complete assessment, understanding the socio-cultural background of service users and medical procedures and policies.

The gathering of information on the patient and the analysis of the potential outcomes of identified behaviours of patients using effective medical procedures, policies and practices are also important. These factors are related in ensuring adequate health care management. Diagnostic criteria have been developed, and continue to evolve over time, to help identify mental health problems such as the WHO (World Health Organization) 'ICD-10 Classification of Mental and Behavioural Disorders' and the American Psychiatric Association's 'Diagnostic and Statistical Manual of Mental Disorders [153].

2.3 Mental Health Diagnosis and Assessment

The alarming increasing rate of mental health statistics around the world highlights the need for effective diagnosis and early prevention of mental health aimed at identifying the risks associated with suicide, self-harm, harm to others and self-neglect. The Psychiatric Morbidity survey of 2003 shows the alarming rate of increase in people suffering from a neurotic (16.4%), personality (4.4%) or

psychotic disorder (0.5%) unfortunately never got the treatment they needed due to late or wrong detection [180].

There is a growing concern for effective delivery of mental health care services based on accurate risk assessment and current medical knowledge and clinical procedures. This concern is founded on the increasing rate of mental health cases, symptoms and risk factors, and the continuous changes in medical knowledge and research outcomes. The increasing rate of mental health cases, symptoms and risk factors is brought to light in various medical reports such as the National Service Framework for Mental Health which highlights the need for effective diagnoses and assessment [134].

Mental Health disorders today are usually diagnosed based on symptoms that are largely self-reported through subjective interviews and administration of partial sets of subjective questionnaires. This has made diagnosing mental health disorders a challenge as it should be carried out using a combined consideration of psychological (e.g. current mental health) and social factors (e.g. relationship problems, employment status) to capture the care needs of the patients and enhance the assessment of their risk of harm to themselves or other people [160]. Every patient presents with an array of physical, behavioural, cognitive, emotional and social symptoms which need to be collated together and then diagnosed into a “best fit” strategy that will ultimately determine treatment [160].

Research also indicates that not all the cases investigated received the needed treatment [181] which may be due to wrong assessment, lack of adequate assessment, wrong medical procedures/policies or lack of medical expertise. The need to understand individuals holistically taking into account cultural beliefs, values and attitudes, and social context is gaining importance due to the complexity of mental health problems and the increased need for services for different ethnic groups and for individuals.

There has also been the concern that there is disconnect of mental health diagnosis with underlying physiological processes. This indicates that current clinical boundaries do not reflect distinct underlying pathogenic processes, at least on the genetic level. It also suggests a deeply interconnected nature for psychiatric disorders, in contrast to neurological disorders, and underscores the need to

refine psychiatric diagnostics. Trying to force fit patients into a specific diagnosis is therefore misaligned with the biological underpinnings of mental health disorders.

There are diverse arrays of clinical and research-focused questionnaires which have been developed to review the symptoms of individual disorders. There are four fundamental challenges in the current state of mental health diagnosis which include asking the right questions; ability of subjective questionnaires to carry out effective assessment; carrying out partial views of symptoms; and a disconnect with underlying physiological processes [145]. Carrying out clinical interviews designed to map out the symptoms of the patient in order to classify them towards a particular diagnosis depends very much on asking the right questions. The questions should have some basic neutral questions and also to focus on the presence or absence of particular negative symptoms. Secondly, there are a range of screening questionnaires that are used to provide subjective assessments of a patient's behaviour, either from a self-report perspective, or from the perspective of the clinician or caregiver.

Although these may be critical to providing a holistic impression about the symptomatology of the patient, subjective assessments of behaviour are open to bias and can only do little. Thirdly, most of the questionnaires are designed to focus on one or two disorder types (or really categories of symptoms) which implies that symptoms outside the category may be missed and therefore accentuate the channelling of a patient towards a single disorder type, rather than providing the "bigger picture" of a patient's mental and emotional prognosis where relevant. The practice of arriving at a single score from these questionnaires poses a significant problem. Fourthly, mental disorders don't fit neatly within predefined boundaries but there is considerable overlap between different psychiatric disorders. Clinical boundaries do not reflect distinct underlying pathogenic processes. Attempts to force-fit patients into a specific diagnosis therefore may be misaligned with the biological underpinnings of mental health disorders.

Putting patients into a particular diagnosis is fraught with problems, and fails to reflect the interconnected and overlapping spectrum of cognitive, emotional and social changes and their

relationship. In addition, the use of subjective assessments which are influenced by individual, social and cultural norms and are overly-focused towards the negative side of human nature are important notes of caution to consider within the realm of mental health diagnosis. A complete overhaul of the diagnosis of mental health disorders has been suggested to understand and treat patients at more physiological levels [145]. In this vein, objective measures, computerised tasks and more sophisticated analytical approaches have been recommended to avoid the partial subjective categorization into mental disorders but to provide the platform to understand broader symptom clusters, both negative and positive that will help to determine a course of treatment.

2.4 Importance of Risk Assessment and Formulation

The high prevalence of medical errors in clinical decision making to effectively deliver mental health care are growing public health concerns [72]. The mounting complexity of clinical decision making in healthcare delivery systems with consequent risk to patients has also highlighted the need to have an effective mental health assessment. The need to reduce the suicidal rates has prompted the formulation and establishment of policies and tools on how to effectively assess mental health risks and reach decisions on formulating intervention programmes [167, 51, 35].

Different policies, guidelines and medical procedures have been established and implemented to facilitate effective mental health assessment and early detection and prevention of risk factors associated with suicide, self-harm, harm to others and self-neglect [167, 51, 35]. Health policies, guidelines and medical procedures on mental health assessment have also evolved over the past decade based on medical research outcomes and government regulations. This implies that mental health assessment needs to be based and guided by policies and medical guidelines.

Formal risk screening and assessment involve complex processes with different mental illnesses and conditions which carry with them different prognoses and risks to the patient. Assessing and formulating the likely future course of events involves the consideration of a large number of factors.

The process is highly individualized and context specific and the focus in a suicide risk assessment and formulation is to understand how the risk and protective factors play out and balance themselves in the socio-cultural milieu of the patient to render him/her at a certain level of risk for harming themselves.

The diagnostic process of mental health assessment has key psychological dimensions which need to be fully considered to produce the right intervention. The dimensions include diagnostic reasoning, acknowledging and learning from mistakes, workplace culture, teamwork relationships, and physician-patient-family communications. The Institute of Medicine (IOM) report [151] makes a strong case for devoting more attention to these crucial issues in order to improve the diagnostic process and also to avoid the challenges of cognitive bias, missed diagnosis and misdiagnosis which leads to errors of clinical reasoning, resulting in inappropriate action. These challenges have an impact on patient care, inform research on diagnostic errors in psychiatry, and point toward areas where improvements might be made. Improving the diagnostic process is a public health imperative and also represents a moral and professional duty.

2.5 Risk Assessment in Mental Healthcare

Mental healthcare is focused on the identification of risk based on some psychological, economic and social factors, the potential impact on the patients and formulation of intervention programmes. Risk assessment aimed at identifying specific risk factors of relevance to an individual and the context in which they can occur thus forms an intrinsic part of mental health care and provides an opportunity to engage with patients, their carers and families in order to gather relevant information and promote the patient's safety, recovery and wellbeing [58, 89].

Risk assessment is a clinical practice that combines the consideration of psychological factors such as current mental health conditions, and social factors such as relationship problems, employment status, as part of a comprehensive review aimed at capturing the care needs of the patient, and

assessing their risk of harm to themselves or others [183]. The process of risk assessment and formulation is a twofold process where the first set of processes is used by mental health professionals to focus essentially on gathering all relevant information regarding patient risk factors by recreating the attempt in order to understand the psychiatric history surrounding the attempt.

The second set of processes is concerned with weighing factors against each in order to reach a clinical judgement regarding the risk of suicide in an individual patient [88]. Specialist mental health training, skills and experience of the clinicians play a major role in risk assessment but often times the complexity of the processes and uncertainty of risks makes the formulation and determination of best clinical decisions difficult to achieve in spite of the clinicians' experiences and skills.

The core process of risk assessment involving the collection of relevant individualised information of the patient in the midst of available mass of information, and the difficulties in integrating and applying this information to individuals and how to produce a comprehensive assessment report to facilitate effective risk formulation and consequent clinical decisions is a daunting task [107]. Risk assessment in mental health is challenging due to the number of considerations that need to be made to effectively promote the patient's safety and wellbeing [206].

A good and useful risk assessment tool is required to carry out a comprehensive review of the patient and potential risk factors. Carrying out effective risk assessment requires an easy, quick and effective system of managing the collection of relevant information from multiple sources and identification of empirically supported risk and protective factors. It also requires a system that enables a focus on the factors that are modifiable in order to try and bring down the risk of future attempts. The expectations of the outcome of the risk assessment process therefore include predicting a patient's behaviour; assessment of the probability of a particular behaviour; or making a prognostic statement about the patient [88].

The use of risk assessment tools based on tick boxes which allows users to tick boxes of questions and required answers as a way of confirming and providing information on the individual patient, is

comparatively common in most mental health services in the UK. Some services use risk assessment tools based on risk scales which is aimed at scoring or classifying patients according to their risk of future self-harm or suicide based on the presence or absence of a specified set of characteristics.

Examples of risk assessment tools using risk scales are SAD PERSONS, PATHOS, Beck hopelessness scale and the Columbia suicide severity rating scale (C-SSRS) which are usually used in conjunction with the main tool. These types of risk assessment tools are focused on prediction, however the categorisation of risks using the scales may have poor predictive value [40]. Furthermore, the predictive ability of risk scales in risk assessment tools have wide variations [189].

The tools themselves varied in length and some were accompanied by supporting guidance [144]. The emphasis which has been on prediction using the predictive approach based on forensic psychiatry where the potential for committing a violent act is assessed [137], is gradually shifting to that of prevention with the emphasis on identifying and modifying factors that may reduce probability of such an occurrence [86]. This identifies the importance and role of risk formulation in the overall process of mental risk assessment and healthcare provision. Approaches to risk assessment have evolved from unstructured risk assessment and actuarial risk assessment to structured professional judgement (SPJ) which incorporates formulation and treatment planning, to the current focus on the formulation. This shift in focus of the risk formulation has been described as the “fourth era” of risk assessment [43].

The issues in risk assessment and formulation are tied to the approaches and tools used. There are three main approaches with different advantages and disadvantages namely clinical, actuarial and structured professional judgement approaches.

2.5.1 Clinical approach to risk assessment

The clinical approach to risk assessment is the gathering of information from the patient and the evaluation of risk on the basis of the clinical expertise and judgement of the clinician. The approach lays importance on the clinician’s judgement in arriving at a decision which can be described as subjective and intuitive. The main criticism of the clinical approach is its informal, unstructured format

which makes it subjective and based on the impressions of the clinicians [80]. Furthermore, it's high dependence on interviewing, observation and self-report makes it more susceptible to various sources of bias and error [113].

The major weaknesses and criticisms of the unstructured clinical judgement include the lack of consistency or agreement across assessors with low inter-rater reliability; the difficulty of assessors to specify why or how they reach a decision that makes it difficult for others to question it. There is also little evidence of the accuracy of decisions made using this approach. The general agreement has also been that clinical risk predictions are only slightly above chance and the competence varies greatly between clinicians [121].

A number of errors clinicians make during assessment using the clinical approach have been traced to the resulting inaccurate predictions. The issues of lack of specificity or unclear definition of what is being assessed, reliance on illusory correlations, ignoring and non-incorporation of situational or environmental information in the approach and ignoring statistical base rate information have been raised as challenges of the clinical approach [192]. These issues could be improved with the incorporation of research evidence into the assessment process and statistical information on valid predictive relationships integrated into clinical practice.

The attempts to improve the clinical approach of risk assessment have warranted the introduction of a 'second generation' of theory and policy aimed at identifying a valid array of actuarial risk markers for risk assessment. The aim is to integrate statistical evidence into risk prediction which is referred to as the actuarial approach. The integration of statistical / research evidence into the process implies a shift of focus from the clinicians' experience/ expertise and intuition to the reliance of statistical evidence but at the same time giving some place to clinicians' judgement. The clinical implication is that clinical practices and clinical decisions in risk assessment should be based on clinicians' experience, expertise, intuition and research evidence and statistical information.

2.5.2 Actuarial Approach in Risk Assessment

Assessment of risk in the actuarial approach is founded on empirical population-based research highlighting various static and historical variables that are likely to predict the risk of a particular outcome. The approach enables decisions to be made based on statistical information according to fixed and explicit rules. The application of these rules is primarily to provide a structure or format lacking in the clinical approach and to overcome methodological and conceptual problems. The overall design of the actuarial approach is to make the process of risk assessment scientific in order to disengage clinicians as much as possible and to reduce their input or professional judgement to the minimum thereby improving its predictive accuracy [192]. The scientific based actuarial approach process involves the compilation of a checklist of a number of predictors or factors with allocation of scores to each factor.

The summation of the scores of all the risk factors gives the 'actuarial' graduated probability measure which represents the amount of risk attributed to the individual. Furthermore, actuarial judgements are based on specific empirically proven assessment data which makes the actuarial approach more statistically superior than the clinical approach [115, 86]. The use of the actuarial approach of risk assessment have also demonstrated the shift in the focus on the concept of risk and clinical practice being shifted from assessing the inherent 'quality' of dangerousness to a focus on individual 'actions'; namely violent behaviour [136, 81]. Grove and Meehl [80] meta-analysis of 136 studies showed that 64 cases showed more accurate prediction for the actuarial method. Although actuarial risk assessment has more predictive capability it has some limitations such as focusing the assessment on a limited number of factors, thus ignoring potentially crucial case specific, idiosyncratic factors.

The actuarial approach also has the propensity of focusing on relatively static factors that are immutable which encourages passive predictions. There is also the chance that actuarial approaches may exclude crucial logical risk factors because they have not been proven empirically [86]. The use of actuarial approach in risk assessment may also be improved leading to the prediction of a specific

outcome, over a specific time period in a specific population, producing non-optimal, even bizarre decisions when applied in different settings [78]. It has also been argued that disengaging clinicians from the clinical process is a limiting factor as that minimises the role of professional judgement which might be crucial in the decision-making process [86].

Both clinical and actuarial approaches have definite advantages and disadvantages which has made the choice of which approach is most relevant to clinical practice a complex one requiring the consideration of combining both the clinical and actuarial approaches. The use of a combined approach provides an alternative approach aimed at exploiting the benefits of both the clinical approach and the actuarial approach while eliminating the drawbacks of the individual approaches. This alternative approach is designed to bridge the gap between the scientific (actuarial) approach and the clinical practice of risk assessment. It is referred to as the empirically validated, structured decision making [53] or structured clinical judgement [86].

2.5.3 Structured Clinical Judgement Approach

Structured clinical judgement approach places emphasis on developing evidence-based guidelines or frameworks that promote systemization and consistency yet are flexible enough to account for case-specific influences and the contexts in which assessments are conducted. Structured clinical judgement involves a broad assessment approach using well-defined published schema (structure) that is rooted in evidence that has been validated by research aimed at improving the clinical practice of risk assessment [20, 53].

The approach therefore has the ability to promote transparency and accountability but at the same time encourages the use of professional discretion based on sound scientific knowledge, yet practically relevant [86, 53]. The approach is thus based on national guidance involving the use of clinical judgment that is guided by a standardised format, and taking into account actuarial risk factors. The approach combines actuarial and clinical risk factors in considering a number of factors relating to past history using an objective measure(s) integrated with the assessment of current presentation,

protective and contextual factors. One important factor of note about the approach is that it shifts the emphasis from one of prediction to risk management with much consideration on prevention and treatment issues while highlighting the conditions under which the risk will increase and decrease.

This approach also recognizes the reality that the process of clinical risk assessment is a dynamic and continuous process that is mediated by changing conditions [57]. The focus is on developing a personalized account of the individual's problems using a combination of functional analysis and model development through hypothesis testing. This represents a shift of focus away from simply identifying risk factors to thinking about how the key variables that are unique to the individual interact to cause them to act in a violent way. The key variables are categorised into five factors using the psychology of formulation to understand a problem and need of the patient. The five categories of factors are presenting problem factors, predisposing factors, precipitating factors, and protective factors [103]. The risk formulation should, therefore, inform management interventions that are developed into a risk management plan.

The five-step Structured Professional Judgment framework [57, 61] shows a guideline of five set of activities of collection and analysis of relevant information. The first step is to build a case information of past history of Psychiatric, Forensic, Personal, Family, Mental state, Personality assessments, Current functioning & behaviour, Past and current substance use. The second step involves collection of information on Presence of Risk Factors and Past history of violence highlighting recency, Severity, Frequency, Pattern, Dispositional factors, Anger regulation problems, Stressful life events, etc. The third step collects information on presence of protective factors such as responding to treatment, compliance with treatment, good insight, etc, while the fourth step guides the risk formulation stage involving predisposing (Historical information), precipitating (current information), protective (Risk reducing factors or circumstances), and prolonging (Risk enhancing factors or circumstances). The fifth step involves formulating a management plan highlighting treatment plan, monitoring, supervision, crisis intervention, etc [57, 61].

Within the five-step model, developing a formulation of the information obtained from review of history, information from clients, and observation sources is regarded as a key step in the process, which follows on to inform care planning, treatment and management decisions in a logical sequence that enables the reasons for clinical decision making to be transparently observed. This mirrors approaches that conceptualize risk behaviours for treatment purposes [122, 149, 96]. An idiosyncratic and individualized risk formulation of this type promotes better understanding of the presenting problems and risks and provides a framework for subsequent interventions [163].

2.6 Risk Formulation

Risk formulation, defined as an organization framework for producing a narrative explaining the underlying mechanism and proposed hypotheses regarding action to facilitating change, has become central to the process of risk assessment in recent years [88].

Risk formulation can therefore be described as the preparation of an evidence-based explanation of a service user's difficulties: their form, their origins, and their development and maintenance over time [107]. The process of formulation usually based on either one or many theories and practices, is aimed at generating an idiographic treatment plan that will provide an appropriate and unique response to the peculiar difficulties of the patient as presented that is both effective and proportionate [49]. The process weaves together the most important relevant strands of the harm potential of the patient into an explanation for why that potential exists. In combination with scenario planning, risk formulation process makes for the most potent driver of individualised and meaningful risk management plans. Risk formulation which is an important concept in mental health [190] is sometimes described as a process or a product of gathering and integrating diverse information to develop a concise account of the nature and etiology of the problems affecting a person's mental health to guide idiographic treatment design and other decision-making.

Describing risk formulation as a process highlights the importance of the set of linked or interrelated activities involved in preparing or developing something in a precise, systematic manner. The arrangement of the set of activities in the process is to enhance the quality of the outcome or product of the process which could be in the form of linguistic or conceptual in nature, such as a statement, account, or explanation. This emphasises the need for the application of an appropriate clinical decision-making process that fully considers the complexities of risk assessment, the component features and the interrelationships of all factors. Furthermore, it also suggests that risk formulation must be precise, systematic and abstracted.

Risk formulation described as a product also highlights the importance of the quality of the product and its ability to guide decision-making to have positive impact on quality mental health care. This emphasises the role of risk formulation in clinical decision making and the need to apply a clinical decision support system to ensure the quality of the outcome/product. It is also pertinent to note that the risk formulation product is a function of the clinical decision-making risk formulation process which can also be enhanced by a clinical decision support system.

The emphasis on risk formulation is therefore of being precise and systematic which puts the focus on how best to collect and organize the most relevant information available about the problem to be prevented. The requirements for an effective risk formulation thus bring to light the need to identify key risk factors and the determination of an organisational framework. There are a number of organizational frameworks available to guide the process and shape the product [88]. Each organisational framework has different advantages and disadvantages or limitations and as such may not be useful in all situations. Most mental health service centres in the UK use two or more combinations of the framework to cover all the requirements of successful risk formulation. Risk formulation processes are an intrinsic part of mental health care but need to be consistent across mental health services [144].

It has also been argued that identifying the key features of the risk formulation and how a formulation is developed are the essential steps towards an effective managed risk with enhanced understanding of the patient's risk potentials and clarity of objectives [124]. Skipping these critical steps, carrying them out too briefly or superficially or overdoing these steps is likely to limit the usefulness of the resultant product to the task of intervention [86, 190, 88]. Managing risk with focus, clarity of objectives, or confidence, and restrictive interventions may only be achieved through a better understanding of the individual patients. The process of formulation offers a means by which such an understanding may be acquired. Indeed, until there is such clarity about the task required, formulation may remain more science fiction than science fact [18].

Risk formulation especially the process, has a number of functions [88]. First, it is a process intended to organize information in order to create a platform from which an understanding of risk potential may be generated. Second, it is intended as an opportunity to create an understanding that is agreed and communicated between the evaluator and the client. The process adopted by most organisational framework begins with the most relevant risk factors and arrange the information in accordance with the 5Ps model which consists of the problem (that is, risk of what?), predisposing (or vulnerability) factors, precipitating factors (or triggers to harm), perpetuating (or maintenance) factors, and protective factors [200].

Risk formulation is thus a structured approach involving a thorough process of information gathering, followed by an analysis of that information and development of hypotheses or ideas about what caused and maintained the problems. Through the process of the assessment, hypotheses are tested where possible to improve the accuracy of the formulation.

2.7 Theoretical Base of Risk Formulation and Frameworks

Risk formulation was first introduced in the clinical psychology domain as case formulation and has been described and interpreted in various terms based on different theoretical perspectives and

therapeutic models. Earlier definitions are mostly rooted in the cognitive behavioural theory (CBT) approach which emphasises that formulations are theory driven and require a hypothesis testing approach to enhance a good understanding of a patient's problems and how to approach treatment. Division of Clinical Psychology (DCP) [150] also describes formulation as the summation and integration of knowledge that is retrieved through the assessment process, drawing on psychological theory and research.

This highlights the importance of the risk assessment process as part of the overall risk formulation activity which relies heavily on reliable facts. Risk formulation is thus a core clinical skill that links assessment information and treatment planning and may be described as a hypothesis about the mechanisms that cause and maintain the problem. It can also be best understood as a tool that applies psychological theory in an effort to develop a number of hypotheses offering explanations of the development and maintenance of a client's difficulties [150].

Formulation thus synthesizes a client's presenting issues and experiences with theory and research to form a new understanding that is original and unique to the client [117]. It provides a framework based on theory and research to describe the nature of a client's problem, how it developed and how it is maintained. This implies that the theoretical orientation of the risk formulation tool provides the framework the clinician will use to condense and synthesize multiple pieces of information into a coherent and well-developed narrative. This makes the theoretical orientation and how it is utilised to guide the risk formulation process of a paramount importance in risk formulation.

Risk formulation seeks to derive meaning and understanding through the integration of empirical knowledge and the perspectives/experiences of the clinician and client. It is thus individual based making the collection of relevant accurate information on pressing issues and prevailing circumstances from the client of paramount importance, and the experiences and knowledge of the clinician very relevant to the success of risk formulation. It draws on the experiences that made an individual prone

to developing the difficulties, the events that prompted the onset of the problems and the factors that maintain the symptoms.

Formulation process can therefore be seen as the foundation for understanding an individual's difficulties through a collaborative empiricism between the client and the clinician [15, 66]. It also represents a bridge between the assessment and intervention based on the understanding of the issues it provides in such a way that it becomes a means of informing the best possible treatment plan for the individual.

In another dimension, formulation can be regarded as a structured approach used as a framework to understanding the factors underlying distressing states of clients. The structured approach used as a framework in risk formulation is based on a theoretical orientation as defined by the biological, psychological, and social contexts of the client which describes the underlying factors. Cognitive behavioural theory-based formulation emphasises the importance and identification of factors that have influenced the origins, development, and maintenance of the client's problems [117].

The key task on beginning the process of formulation is organizing the most relevant available information about the problem to be managed in simple clear structure to provide relevant meaning. There are different organizational frameworks that can possibly be used to provide a structure to facilitate easy collection and assimilation of information [88].

A popular organisational framework in risk formulation is the five Ps framework which describes five levels of factors, which help structure the formulation process [107] the framework allows information to be arranged in accordance with the 5Ps model [200] and thus provides a suitable guide to demonstrate the potential utility of case formulation [88]. The first level factor is the presenting or problem factor which focuses on getting to have an understanding of the problem in terms of the risk factor, risk of what.

This level provides an opportunity to have a description of the clients' presenting problems, in terms of emotions, cognitions, and behaviours. It focusses on identifying difficulties the client is facing, how the client's life is affected and when a particular difficulty should be targeted for intervention. It enables clarity about the answer to the question of what is the risk, the risk of what is the client in danger of.

This has been described as the essential first step requiring specific answers to specific questions on present problems. This first step determines and guides other questions in the level and how other levels will go and how comprehensive the assessment will be. The second level factor in the framework is the Predisposing (or vulnerability) factors which focuses on the factors that increase the person's vulnerability to their current problems or led to the problems starting. It enables the identification of possible contributing factors that may put the client at risk in terms of biological or genetic / vulnerability, environmental, psychological and personality.

Efforts will be made at this level to identify the most relevant historical items, relevant clinical and risk management items. The third level which is Precipitating Factors level is focused on identifying the factors that may have triggered the clients' problems. It provides the opportunity of identifying significant events preceding the onset of the episode / disorder / illness. The focus of the fourth level of investigation is the identification of perpetuating factors that maintain the problem. Perpetuating factors are regarded as the subset of predisposing factors that have to be worked around in a risk management plan. It highlights the characteristics of the individual client or the situation that may not easily or is not likely to change in the short- or even medium-term.

Examples of perpetuating factors may include the client's severe personality disorder or intellectual disability, both of which would be major considerations in the design of a risk management plan. The fifth level of investigation focuses on identifying protective factors which shows the positive assets and strengths the client demonstrates. It provides the opportunity to identify strengths or supports that may mitigate the impact of the disorder / illness such as social supports, skills, interests, and

personal characteristics [64]. The 5Ps model has been described as an attractive and efficient way of organizing risk relevant information. It provides an empirical base which is used to examine risk factors in terms of their role as predisposing factors leading to precipitating, perpetuating and finally, protective factors.

The inclusion and emphasis on protective factors is consistent with the recovery model which focuses on building safeguards and change [63]. This model has been applied in many risk formulation tools and approaches to enhance quality intervention programmes. A notable example is the Five-Step Structured Professional Judgment Framework [61, 59, 60] which provides a guideline of five set of activities of collection and analysis of relevant information. Another alternative to the 5Ps model is the 3Ds model which examines the Drivers, Destabilizers and Dis-inhibitors [88]. This organisational framework emphasises on identifying the driving factors of the clients' actions, what the client is expected to achieve. This is in an attempt to understand the psychological needs of the client in order to establish an empirical base. The destabilizers are similar to precipitating factors in the 5Ps model which examines triggers and significant events preceding the problem.

2.8 Best Practice Guidelines in Risk Formulation

The concept of risk formulation within the field of clinical risk assessment and management has been acknowledged as an important part of mental health care [138]. Different policies and guidelines based on some principles have been formulated at different times to inform best practices in mental health care and assessment.

The primary aim of the policies and guidelines is to help establish what could be regarded as the best practice for conducting risk management. A key clinical practice guideline defines formulation as a process in which the practitioner decides how the risk might become acute or triggered, it also identifies and describes predisposing, precipitating, perpetuating and protective factors, and also how these interact to produce risk which will lead to an individual risk management plan [152].

The guideline proposed some helpful structure for clinical risk formulations, particularly in terms of specifying what questions should be posed and answered, drawing attention to a context of "evidence-based practice," which required the risk assessment endeavour to be approached in a "systematic fashion". This places emphasis on the gathering of relevant information based on evidence-based practice and the importance of using an appropriate structure that is able to effectively collect information for assessment and to "make sense out of complex interactions between different factors" and assist clinicians in identifying "possible causal mechanisms".

Risk formulation therefore provides a crucial link between assessment and management and should be a practical solution to the task at hand [57]. Best Practice in Managing Risk [167] has thus been designed and prepared in the UK by the Department of Health within the National Health Risk Management Programme to serve as a guide to service providers in constructing policies and procedures relating to the management of risk.

The framework particularly guides the conduct of risk assessment in three main areas of clinical risk violence (including antisocial and offending behaviour), self-harm/suicide, and self-neglect. The use of risk formulation has therefore been endorsed as a method of analysing, understanding, and communicating an individual's risk. Formulation is seen as crucial in clinical practice, especially psychological therapies, for understanding individuals' problems and behaviours, explaining factors that maintain problems, linking thoughts, feelings and behaviours, providing a framework for interventions, helping service users to understand their problems and helping them to develop ways of helping themselves [163, 19, 116].

Psychological case formulations involve functional analysis of possible causal relationships [90], often using simple ABC analysis (i.e., antecedent–behaviour– consequence) or revisions to encompass the influence of cognitions on behaviour where ABCs represent antecedents, beliefs and consequences [39]. The recommended best practice guideline uses tools that adopt the structured clinical (or

professional) judgment approach [51] which combines the strengths of actuarial methods with clinical judgement [57].

Clinical judgement in this approach will be based on an assessment of clearly defined static (historical) and dynamic (changeable) factors derived from research, clinical experience, and knowledge of the service user, and the service users' own view of their experience [167].

Enhancing the decision-making of mental-health professionals therefore may depend on using a risk assessment tool that is capable of incorporating crucial transient, dynamic, qualitative, and idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement [184, 85, 93, 128] [184, 85, 93, 128]. A common observed theme across the different approaches to formulation is the application of a systematic method to organize information and hypothesize about possible causal mechanisms underlying a problem.

2.9 Risk Formulation Tools in Mental Health

Some of the assessment / formulation tools focused on prediction include the HCR-20 clinical risk management tool which is a broad instrument with potential applicability to a variety of different settings [54]. It is focused on historical violence appraisal and takes into account individual/ client's current mental, emotional and behavioural functioning but at the same time seeks to integrate information from different sources such as face to face interviews, observation, clinical notes, ward notes and psychological and neurological testing. The HCR-20 which is more popular in the forensic domain incorporates different ways of enhancing prediction accuracy which yields a summary risk statement allowing easy monitoring of current clinical status and the development of risk management strategies [125].

Another popular risk assessment tool is the Risk Assessment, Management and Audit Systems (RAMAS) developed by psychologists; O'Rourke and Hammond [156] to incorporate 'lessons learned' from public inquiries with what works principles in public safety, risk management and clinical care.

RAMAS proposes a cumulative model of risk for mental health risk assessment and management while providing structured professional judgement and measures for risk to others, mental instability, self-harm and vulnerability. It provides an objective and comprehensive approach aimed at giving professional judgement as possible. Its provision of the profile of an individual's risk factor together with demographics, specific risk indicators and needs assessment makes it useful and effective for easy risk formulation and management. It is designed to be flexible in accommodating information from other sources and acknowledges that there may be highly individual-specific case sensitive situation or set of conditions that undermine the objective measurement of the risk assessment.

The tool applies a risk indicator with scales scores indicating the position of the individual in which helps the assessor to make a clinical judgement of the best action for managing that individual. The tool supports both the content and process of risk need and responsivity assessment and management by providing the four main risk and communication protocols such as the Risk Identification, Crisis Alert, Risk and Care manager and the supervision review.

Another common risk tool is GRiST; a web based clinical decision support system for risk formulation [27]. It is designed to encapsulate clinical and personal risk expertise of suicide, self-harm, harm to others, self-neglect and vulnerability in mental health. It is made to be universally accessible to people without specialist training to use by anyone. It is designed using cognitive computing models of structuring knowledge and reasoning which is applied to clinical decision making and mental health informatics. GRiST represents human knowledge and knowledge reasoning processes based on a universal model of classification used by everyone as it is easy to elicit and to understand when interacting with the end user. The classification model helps to organise how the knowledge of people and how they think and reason. The input data are generated from a hierarchy or tree of knowledge which helps to identify relevant serviceuser data. The tree relates data to risk concepts and top-level risks to provide the information profile for service user. Meanwhile output risks are explained by the tree of knowledge of which data is structured.

2.10 Evaluation of Risk Formulation Process

There is a general consensus in mental health professions that formulation is a core competence and a critical aspect of daily practice. However, there is no common agreement on how the process of formulation, which is usually covert or implicit, should be carried out. Literature however agrees on the common features of formulation in mental health which include inferential, action-oriented, theory driven, individualised, narrative, diachronic, testable, and ampliative features [44, 164, 82, 165]. These features describe the character of the formulation process and provide a basis for evaluation.

The action-oriented feature of risk formulation process highlights the characterisation of risk formulation to assist the mental health professional to develop an overall understanding of a patient's problems, prioritize treatment issues and problems, plan general treatment strategies and select specific interventions, anticipate the patient's responses to strategies and interventions, evaluate treatment progress, and enhance the therapeutic relationship [44].

The theory-driven feature of risk formulation suggests that the determination of which facts are noteworthy or identifying which explanations are legitimate requires some a priori guidance based on a theory. Formulation is therefore guided by or embedded in a particular theory of problem cause or solution. Each different theoretical approach predetermines which target behaviours, variables, and treatments are legitimate, as well what constitutes a valid explanation [164].

The individualised feature of risk formulation also suggests that the process is not only driven by theory but also by each person's detailed life history data. A formulation that is not individualized is merely a restatement of the nature, etiology, and solution of the problems experienced by the (non-existent) average patient. The narrative feature of risk formulation suggests that formulation requires narrative cognition, as opposed to paradigmatic cognition [44]. Narrative cognition "configures the diverse elements of a particular action in a unified whole in which each element is connected to the central purpose of the action" [165].

Narrative cognition therefore is an inherently qualitative approach to understanding the world. It defies quantification and is especially suited to the analysis of human behaviour, being "uniquely suited for displaying human existence as situated action. The diachronic feature of risk formulation suggests that formulation spans time and is anchored in information about the past, the present, and possible futures, problems arise when it is synchronic.

A set of evaluative criteria for judging the adequacy of formulations in mental health include external coherence, factual foundation, internal coherence, explanatory breadth, diachronicity, simplicity, reliability, generativity, accuracy and acceptability [157]. External coherence shows the degree to which a formulation is consistent with theory which implies that the formulation has a plot that is familiar or of a type that is commonly encountered. Factual foundation shows the extent to which a formulation is based on information about the case that is adequate in terms of quantity and quality.

This implies that an abundance of information elements makes it easier to develop a good plot. Internal coherence shows the degree to which a formulation rests on propositions or makes assumptions that are compatible or non-contradictory. This implies that the formulation has a plot that is cogent and consistent. Explanatory breadth shows the degree to which a formulation accounts for critical evidence. It implies that the formulation has a plot that ties together as many information anchors as possible.

Diachronicity is another evaluative measure of the extent to which the formulation ties together information about the past, present, and future of the case. Formulation process is also evaluated by examining its simplicity which considers the degree to which a formulation is free from unnecessary details, propositions, and assumptions. In a survey where clinical risk tools were assessed by Healthcare Quality Improvement Partnership (HQIP) [160], the opinion of most clinicians centred on the length of the risk assessment tool/process and the time taken to complete it.

Other challenges with risk assessment tools include the difficulty in finding relevant information; Information may not always be accessible if updated incorrectly; Difficulty in the inputting of

information and tracking back, leading to details being lost; The use of tools may prevent staff from using experience and clinical judgement and provide false reassurance; tables and tick boxes are not always read by clinicians. The general conclusion is that risk assessment tools are only as effective as the individual carrying them out and can create a false sense of safety.

2.11 Enhancing the Risk Assessment and Formulation Process

Based on the identified challenges, some suggestions on enhancing risk formulation tools have been highlighted. The suggestions include improving consistency, making tools shorter, clearer and easier to complete. Making tools accessible to patients and carers, with explanations of specialist vocabulary; Removing scoring/rating systems; Providing sufficient training on the risk assessment process using case vignettes which are relevant to all staff; Promoting staff confidence through ongoing training and supervision on how to record information and manage identified risks; Staff training on understanding risk and not just tool completion. [160].

The enhancements highlight the importance of usability issues in making the risk tools more useful and acceptable. However, the features of the risk tools and the evaluative criteria discussed above highlights the importance of making the risk tools more functional and focused on meeting users' clinical requirements and clinical workflow practice. The need for a theory driven risk tool guided by the theoretical concepts is well appreciated in most tools like GRiST. The risk formulation process in GRiST is consistent with theory which guarantees its external coherence. The process in GRiST also ensures a good factual foundation with adequate information in terms of quantity and quality which makes it easier to develop a good plot. The organisation of the process in collecting factual information on the five Ps may however be improved to explore the interrelationships between the factors. An appropriate arrangement will ensure that the formulation ties together information about the past, present, and future of the case thereby guarantying the diachronicity evaluative criteria of GRiST.

2.12 Chapter Conclusion

The examination of the state of mental health in the UK shows a high prevalence of mental health cases and the increasing rate of incomplete diagnoses due to the complexities in mental health diagnoses and lack of a good understanding of the risk assessment process and tools in use and the understanding of the experiences and the psychological and social context of patients' inner worlds which most health care delivery systems have failed to do effectively.

The delivery of quality mental healthcare provision is faced with the challenges of early detection of the risk factors of patients and the determination of evidence-based intervention programme. Identification of the possible risk factors requires the collection of information from multiple sources based on the psychological, environmental and social context of the patient. This also requires an effective framework to enable the easy and fast collection and organisation of relevant individual information for easy analysis and integration to determine and provide evidence-based intervention decisions for the patient.

Different approaches can be adopted from the actuarial approach which is focused more on prediction of risk factors to the structured approach for the risk assessment and formulation process. Each of the approaches have different focuses and benefits and the chosen approach may determine the clinical decision-making process of the risk assessment and formulation which has a significant impact on the decision support given to the clinicians using the tool. Risk formulation is simply an organised framework for effective intervention decisions which rely on clinical decision-making process of the chosen tool. The next chapter examines clinical decision making in risk assessment, decision making process and the use of clinical decision support system in mental health risk assessment. The chapter will also examine clinical decision support systems, their designs, types, challenges and how they have improved the clinical decision-making process in risk formulation to have positive impact on intervention decisions.

Chapter 3 Clinical Decision Support Systems and Decision Making

3.1 Chapter Introduction

Chapter two provided a critical examination of mental health in the UK with highlights of its complex nature and challenges for effective risk assessment and formulation. The chapter also provided a critical examination of risk assessments and formulation in mental healthcare. It highlighted the need to collect information from multiple sources based on the psychological, environmental and social context of the patient in order to effectively identify possible risk factors. This requires an effective framework to enable the easy and fast collection and organisation of relevant individual information for easy analysis and integration to determine and provide evidence-based intervention decisions for the patient. The chapter thus established the need for an appropriate clinical decision-making tool for risk formulation to enhance the risk formulation process and a positive intervention decision.

On the background of the need for an appropriate clinical decision-making tool for the risk formulation process, this chapter examines clinical decision support systems, their designs, types, challenges and how they have improved the clinical decision-making process in risk formulation to have positive impact on intervention decisions. The last section of the chapter examines clinical decision making in risk formulation and the clinical decision-making models appropriate for the risk formulation process.

3.2 An Overview of Clinical Decision Support Systems

The development of Decision Support Systems (DSS) aims to reduce the reliance on human experts by mimicking how a human handles problem situations in a particular domain [38]. An expert system/decision support system can be described as a computerized human expert comprising of; the expert knowledge of a particular area of expertise in the knowledge base, a memory and an inference engine that searches through the knowledge base in delivering the right advice, services or conclusion to the user [203].

Decision Support Systems (DSS) have been applied in different domain such as business domain, airline systems domain, financial services and health services domain with some degree of acceptance and importance. The health care sector in particular, has notably experienced the increased need and use of DSS in the provision of quality and safe health for the people [99, 199].

Intelligent expert medical systems are designed to support healthcare workers with tasks that rely on the effective acquisition and manipulation of expert data and knowledge. Most of the expert medical systems are presently applied in acute care settings, clinical laboratories, and incorporated into electronic medical record systems.

These expert medical systems are known as Clinical Decision Support Systems (CDSS) containing medical knowledge in routine medical use such as diagnostic assistance, therapy critiquing and planning, image recognition and interpretation and risk assessment and management. An early CDSS developed to analyse chemical compounds was the DENDRAL expert system developed in the 1970s by Edward Feigenbaum.

The expertise of chemists and their knowledge of chemicals and their compositions made up the knowledge base and the domain while the tasks included the determination of the structure of organic molecules in an instrument based on the interpretation of its mass spectrum. Another early medical expert system is the MYCIN system, which is regarded as the first medical expert system to provide diagnostic and medical advice about an infected patient. It is composed of an explanation subsystem that explains the reasoning of the system [50] and also capable of using both clinical data and judgemental decisions regarding infectious disease therapy.

The development of the system in 1990s is based on the representation of the expert knowledge using production rules and statements – "if..then statement; 'if' is followed by a set of conditions and 'then' followed by the conclusion preceding the conditions that has been earlier stated [70]. MYCIN is a large project incorporating many rules making it essential for an appropriate representation rule to be used. The best methodology in representing the rules was however adopted being the use of production

rules. MYCIN as a rule-based system, helped in the efficient development of the knowledge base as the cluster of rules are minimal which kept it simple.

The medical expert system MYCIN was focused on the severity of the infection to patients, the type of organism and its common features and helped to identify any drug that has the capabilities to kill microscopic living organism or hinder them from growing [24]. The system was also able to identify and evaluate the useful drugs that can be used for the patients, which can be narrowed down to the best drug that can be administered to the patients after the consideration of many factors. The developmental approach adopted a very detailed structured flow in the knowledge acquisition and representation in the development of the system, which can be extremely, time consuming but worth the while as MYCIN's success was thorough.

The inference engine uses the backward mechanism, inferring the knowledge base of the system. The backward chaining goes from the statement of the goal and then go through the inference rules in the system. The research problem was divided into different sections and it is noted that it helped in development of the system in making it very easy to approach or start in the user or developer's view.

Other web based CDSS such as the tuberculosis diagnostic system, use the forward chaining mechanism to navigate through various prompted questions relevant to the preclinical screening and finally arrive at a conclusion that defines the infectious or non-infectious status of tuberculosis [158].

The adoption of CDSS in medicine is widely accepted and has increasingly become a crucial component in the evaluation and improvement of patient treatment. This is attributed to its provision of expert knowledge and specific information to assist clinicians and patients with patient-related decision making. CDSS is therefore useful for both patients and clinicians to provide guidance or a reference relating to an appropriate context for an enhanced decisionmaking process. CDSS has a wide variety of uses in clinical practice including determining optimal treatment strategies for individual patients, aiding general health policies by estimating the clinical and economic outcomes of different treatment methods, and estimating treatment outcomes under circumstances where methods like randomized

trials are either impossible or infeasible. CDSS have thus be designed to minimize analytical errors and improve both patient outcomes and cost of care.

Clinical decision support systems (CDSSs) play a pivotal role in improving patient care and enhancing practitioner performance [25]. Nevertheless, adaption of CDSSs in an actual healthcare workflow setup is challenging. Despite a long history of CDSS development, most of the systems evaluated in academia have not been realized in a real clinical practice environment. The concerns for a mismatch between the functionality of most CDSSs and their organisational requirements have led to the issue of CDDS not fit for purpose. Effective evaluation using a user-centred approach uncovers emergent concepts and themes that may be transformed into functional requirements for solutions capable of addressing unmet user needs.

It has been noted that the impracticality of many clinical decision tools may be due to the failure of developers to deal adequately with the logistical, mechanical, and psychological aspects of system use. Research shows that a better understanding of these factors that impact on the success of CDSS, especially factors that are barriers to CDSS implementation such as poor usability or integration of the system into the workflow of the user, is very much required [1]. Any deficiencies in the completeness, timeliness, appropriateness of the knowledge base, and the quality or relevance of the evidence captured through the user interface, may affect the usefulness and effectiveness of the CDSS. The design and effectiveness of the CDSS is therefore based on its knowledge base made up of the expert knowledge of an expert in the chosen area of expertise.

Most CDSS are designed as machine learning systems with the capacity to learn. This is useful in the development of the knowledge bases used by expert systems and the creation of medical knowledge, and in the development of pathophysiological models from experimental data. The CDSS systems are aimed at improved patient safety, improved quality of care, and improved efficiency in health care delivery. Department of Health [167] document on Best Practice in Managing Risk, ‘safety is at the centre of all good healthcare’ (p.3), an effective risk assessment and management is required. This is

due to the complex nature of health care, particularly mental health described as a state of well-being in which an individual is able to realise his or her own potential, cope with the normal stresses of life, work productively and fruitfully, and is able to make a contribution to her or his community.

CDSS has been defined as software designed to be "a direct aid to clinical decision-making, in which the characteristics of an individual patient are matched to a computerized clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician or the patient for a decision". It provides "clinicians, staff, patients and other individuals with knowledge and person-specific information, intelligently filtered and presented at appropriate times, to enhance health and health care" [42]. This definition implies that CDSS has three key components namely Knowledge, Intelligent filters and presentation which must work together to provide the underlying evidence base of the system. This shows the importance of the knowledge base of the CDSS, the logic/inference system, and the user interface for user's interaction with the system. Any deficiencies in the completeness, timeliness, appropriateness of the knowledge base, and the quality or relevance of the evidence captured through the user interface, may affect the usefulness and effectiveness of the CDSS. Therefore, CDSS is only as effective as the strength of the underlying knowledge/evidence base. The development of more effective CDSSs may be to generate more high-quality, useful, and actionable evidence that is up-to-date, easily accessible, and machine interpretable.

Another major concern for the effective development and use of CDSS is the lack of positive acknowledgement and sufficient attention accorded to issues relating to human factors during product development. The concern has also been the partial neglect of socio-technical factors and their impact on the successful integration of CDSS into healthcare organisations and its successful adoption. The Socio-technical dimensions of designing, developing, and deploying CDSS play a significant role in the effectiveness of the system as the nature of human factors (ergonomics) has to do with the understanding of people and their interactions, as well as the relationships between these

interactions, and to improve those interactions in real life settings. Human performance therefore may influence the design and project specifications.

The mounting complexity of care delivery systems and evidence of resulting risk to patients have necessitated the need to incorporate human factors considerations into assessments of medical systems. The need for human factors assessments to elucidate interaction problems to help in gathering changing user requirements for the evolution of existing systems have been stressed. This need also implies that the involvement of end-users in all stages of design, development and deployment will be of necessity.

The need to develop the required knowledge base presentable in the format and language most appropriate for each intended type of user, and how the CDSS can generate flexible interfaces to the knowledge to fit with the different contexts of assessment have also become obvious in the effective development and use of CDSS [29]. The two most important issues in CDSS therefore may be knowledge representation and user interface which reflect changing requirements.

There is therefore the need to develop new methods for tracking and collecting data about user preferences which may be useful in understanding changing user requirements. This may require the development of more interactive and more engaging data collection methods to both attract more respondents and keep them motivated during the response process. The development of a tool that is more interesting to use than traditional data collection methods that would improve response rates and the quality of responses using a visual tool based on the concept of a mind-map to make the portrayal of complex inter-linkages easier for the respondents seem necessary.

Clinical Decision Support Systems (CDSSs) need to disseminate expertise in formats that suit different end users and with functionality tuned to the context of assessment [3]. This may require a methodology for eliciting, evolving, and delivering complex mental-health expertise using a psychological model of classification, a method for designing and implementing knowledge structures that facilitate the required flexibility and a fully-fledged knowledge engineering environment that can

manage both structure changes and subtle variations in knowledge parameters within an integrated system [3].

3.3 Clinical Decision Support System in Mental Health

CDSS plays a major role in helping those suffering from mental health issues to manage themselves with the use of computer systems; serving as an intermediary between the user and the mental health medical practitioner. CDSS is an example of complex applications designed for the complexities of mental healthcare delivery systems. The ability of CDSS to handle the complexities of mental healthcare delivery systems determines its success and usefulness. The evaluation of CDSS in medicine and mental health in particular may depend on how it is able to meet requirements in different dimensions. The different dimensions include the correctness, reliability, and validity of the CDSS knowledge base; the congruence of system-driven processes with clinical roles and work routines in actual practice; and the return-on-investment of system implementation.

The different views of CDSS in mental health show the different perspectives of evaluating CDSS. One view describes CDSS as an interactive decision support system (DSS) designed to assist physicians and other health professionals with decision making tasks, such as determining diagnosis of patient data [12]. This definition brings out the interactive nature of CDSS which is a critical success factor in its implementation. Clinical Decision Support Systems in mental health is said to be a system that links mental health observations with the knowledge of mental health acquired from the experts to influence health choices made by clinicians for improved mental health care [26]. This view shows the important role of observation, users' responses/behaviour, experts' knowledge and the input into the system, and how these may affect the outcomes.

Others view the CDSS as the act of providing clinicians and other users with pertinent knowledge and/or person-specific information intelligently presented at appropriate times, to enhance mental health and mental health care for users [46]. The clinicians and other users include mental health

professionals, patients (also called service users) and other mental health care stakeholders including carers, family friends and relatives. This view focuses on knowledge acquisition, representation and making relevant, appropriate and timely up-to-date information available as when needed. It also highlights the importance of effectively capturing both experts' and users' responses which are necessary for an effective mental health care.

These definitions and the views they represent, show the different perspective of mental health CDSS that need to be considered in making its implementation effective. The importance of CDSS therefore depends on its provision of decision support mechanism that enhances effective decision support based on current health knowledge and practices.

There have been some developments of mental health CDSS such as the Computerized Texas Medication Algorithm Project (CompTMAP) [195] and SADDESQ [135], all designed to provide support in the diagnosis, treatment, follow up and preventive mental health care. An overview of some CDSS developed for mental health care is given below.

The Computerized Texas Medication Algorithm Project implemented a decision support system used in the management of depression in real life called CompTMAP in 1999 [195]. This CDSS is for the early detection, treatment and management of depression in real world clinical settings in Texas. This project was brought about by a combined team of health care experts from Europe and United States to understand the challenge of implementing treatment guidelines for the management of depression and to identify strategies for improvement. The project's objective was to establish integration guidelines into computers systems which will be incorporated into clinical workflow in the health care sector [195]. Although CDSS have been used in medical health care with good results and benefits to the users, its use in the management and treatment of psychiatric illness has been limited. The implementation of CompTMAP demonstrates the usefulness of CDSS in mental health care.

Another CDSS for mental health is the system designed for the management of Attention Deficit Hyperactivity Disorder (ADHD). ADHD is a delicate brain disorder affecting older adults and children

[112]. An adult ADHD-patient is said to continuously have difficulties in organizing and getting things done which is currently underdiagnosed and undertreated in many European countries [112]. The ADHD CDSS was specifically designed to provide effective management and provide a new adult ADHD patient evaluation, diagnosis and treatment process. The complexity of the ADHD illness and the diagnosis process posed challenges to the effective use of the ADHD CDSS and hence an agile business process development approach was applied to develop a more effective CDSS which combines a workflow management tool with decision support system. The ADHD system enabled dialogue in the evaluation and diagnostic procedure which provided a platform for users to add some person specific information. The lack of regular update of the knowledge base of the system was a major challenge and the system was not comprehensive enough to contain all diagnosis tools for proper evaluation and treatment.

A CDSS for diagnosing schizophrenia called SADDESQ system was developed by a group of mental health experts from Brazilian University for Brazilian University students to diagnose psychotic disorders. The process of development was carried out using a combination of methodologies. Interview technique was used for knowledge acquisition to explore the experts' diagnostic decision-making process in the diagnosis of schizophrenia [135]. A graph methodology was used to identify the elements involved in the reasoning process. While a method to identify the psychiatric problems among patients using multi model decision support system, back propagation neural networks, radial basis function neural network and support vector machine models were used to design the DSS. The development process also considered 44 factors for feature extraction collected from 400 patients divided into four sets of equal size. Experimental results show that their CDSS achieved 98.75% accuracy in identifying psychiatric problems [135].

A major development of CDSS in mental health care is the Galatean Risk and Safety Technology, a clinical decision support system to aid mental-health clinicians assess and manage patients' risks of suicide, self-harm, harm to others, vulnerability, and self-neglect [3]. GRiST represents clinical

expertise using a psychological model of classification; mental-health risk knowledge is a hierarchical structure elicited initially from interviews with 46 experts [30]. This consensual model of risk knowledge has evolved over the years as more clinicians engage with the research and development.

The use of computers to support mental care has therefore been an ongoing concern for a long time since at least the 1950s [42]. The potential of computers to support information management within health organisations, and their potential to support health care itself as 'intelligent agents' are being appreciated [42]. CDSS and healthcare delivery have therefore been closely linked and worked together in different areas of medical practice. It is posited that the intrinsic complexity and diversity of care can be tackled with the flexibility, dynamics and reliability of CDSS [99].

3.4 Challenges of CDSS

CDSS like many other software and information systems projects have had challenging issues that have made their implementation not totally successful. Although CDSS has evolved over the years with new features, many physicians still choose not to use them in the field of clinical decision support. The challenging issues mostly are related to machine adaptability (ability of the system to evolve automatically reflecting new medical knowledge while discarding outdated knowledge), human interaction factors.

The ten "Grand Challenges" of clinical decision support [182] compiled by a group of medical school researchers highlighted ten main challenges faced by CDSS. The ten challenges grouped into three categories shows the problem areas to be examined, namely 1) need to improve the effectiveness of CDSS; 2) need to create new CDSS interventions; and 3) disseminating existing CDS knowledge and interventions [182]. This highlights the need for CDSS to act as successful intermediaries between the clinician and the patient, offering diagnostic and/or treatment suggestions that are clear and useful without being intrusive. This however may depend on the effectiveness of the human-computer interface of the system. The interface needs to be clear, intuitive and designed to allow clinical

workflow uninterrupted. The relatively poor human-computer interface of most CDSS has not enabled effective interaction with the users.

The challenges of creating new CDSS interventions focus on the ability of CDSS to provide the most accurate and relevant information to the clinician, and to prioritizing clinical decision support content that would enhance interventions for improving patient safety, chronic disease management, preventive health interventions [182]. This category of challenging issues also concerned with the ability of CDSS to "learn" from large databases, new research results to expand the total knowledge base for better intervention. This shows the need to evolve knowledge base automatically.

The impossibility of developing a consistently adequate database and functional set of rules/conditions with low accuracies in practical performance has also been described as a critical issue with the success of CDSS [68]. Shallow domain knowledge indicating a poor understanding of human physiology; a lack of robustness and flexibility; and inability for such systems to learn from their own experience have also been attributed to poor performance of CDSS [126].

The third group of challenges of disseminating existing CDSS knowledge and interventions focuses on monitoring users' behaviour and practices for changing requirements. This suggests the need to develop stronger methods for identifying and executing optimal CDSS practices. It is opined that a possible solution will be to establish a measurement system for identifying the strength and feasibility of decision support practices. This will enhance the production of new users' requirement necessary for system update/development.

This review shows that the successful implementation of CDSS will depend on its ability to provide a very rich content in terms of knowledge, references and data evidence. CDSS must also have the ability to powerfully and intelligently process huge amount of data with quick response times; and should be very sophisticated and intuitive to capture user's attention and not impede the user's action. The development of CDSS with these abilities requires an interactive CDSS with effective user interface design and a knowledge acquisition and representation mechanism that will capture changes to make

relevant, appropriate and timely up-to-date information available. The evolving nature of CDSS and the need for continual refining, reflecting changes and constant improvements need to be addressed.

Addressing these challenges for a successful development of CDSS bring to focus the importance of the interpersonal, cultural, and organizational aspects of the CDSS in practice. It also highlights the need to focus on the human dimension in understanding the user and in meeting his needs with a successful CDSS design by evolving knowledge base. It has been noted that the impracticality of many clinical decision tools may be due to the failure of developers to deal adequately with the logistical, mechanical, and psychological aspects of system use. Research shows that a better understanding of these factors that impact on the success of CDSS such as poor usability, incomplete decision making or integration of the system into the workflow of the user is required.

Evaluation therefore is focused on capturing the expertise for the system, the actual process of using a system and the functionalities of the system. The captured information would be analysed and used to generate new users' requirement or changes needed to improve features of the system prior to completion or update of the design of the system, or alternatively to assess the impact of fully implemented systems.

In conclusion, to provide a successful decision support mechanism the CDSS system has to overcome the challenges by providing a very rich content in terms of knowledge, references and data evidence; it must have the ability to powerfully and intelligently process huge amount of data with quick response times; and should be very sophisticated and intuitive to capture user's attention and not impede the user's actions.

These challenges reiterate the views of the different definitions of CDSS that highlight the different aspects of CDSS namely 1) the interactive nature of CDSS and users' interactions /user interface designs; 2) the important role of observation, monitoring of users' responses/behaviour and the input into the system; 3) knowledge acquisition, representation and making relevant, appropriate and timely up-to-date information available; and 4) the evolving nature of CDSS and the need for continual

refining, reflecting changes and constant improvements. The importance of these factors is examined in the next section.

3.5 Clinical Decision Making

A known hallmark of expert clinicians is the capability of sound clinical reasoning and clinical decision making [179] but 65% of adverse events that occur in hospitals are as a result of poor clinical decision-making [22, 119].

Clinical decision making has therefore been described as a contextual, continuous, and evolving process. It is a process that includes clinical reasoning as part of the decision-making process in which information is collected and evaluated and then an action is taken or decision is made [102, 41, 46, 155, 133]. The process may include antecedents such as considering information, gathering information, and weighing the risks and consequences [133].

Clinical decision-making is a cognitive process concerned with problem recognition through the identification of cues and clinical features, data gathering, integration, analysis, evaluation and choice to produce an informed decision [41]. It can also be described as a complex process that involves observation, information processing, critical thinking and clinical judgement to select the best course of action in promoting and maintaining a patient's health [188]. While Elstein and Schwarz [9] assert that clinical decision making involves a rational process of 'hypothetico-deductive reasoning' based on information processing.

Clinical decision making can be described as a diagnostic paradigm that is formed of four stages designed to assist the clinician to identify and interpret cues in the construction and evaluation of a hypothesis described as the primary diagnosis. These four stages are:

• Cue acquisition – primary data and sensory stimuli that steers the nurse towards a particular thought process through specific cues.

• Hypothesis generation – development of a provisional and differential diagnosis based on cues and baseline data.

• Interpretation of cues – re-exploration and interpretation of cues to support or dismiss hypothesis with further data collection to aid interpretation.

• Evaluation of hypothesis – the cues are then evaluated and applied to an overall hypothesis that directs the decision made and subsequent intervention/action taken

Clinical decision making is a unique process that involves the interplay between knowledge of pre-existing pathological conditions, explicit patient information, and experiential learning. Different decision-making tasks may also require different approaches according to the situation and task complexity [83].

3.6 Clinical Decision Making in Risk Formulation

The challenge remains to provide patients with non-biased, evidence based clinical recommendations that take into consideration objective assessment of risk. Formulation has been noted to have its roots in the "application of psychological science to clinical problems" [194] and is pivotal in the historical development of clinical psychology practice [107]. It provides a framework that enables inferences to be made about the factors causing and maintaining problems, and to inform interventions [117].

Risk formulation adopts a process of conceptualising the problems with the view of specifying necessary interventions by endeavouring to statistically model the decision rules that would enhance the accuracy of clinical judgements [192]. However, risk assessment has been described as an inexact science which questions the accuracy of the clinical judgement particularly when there appears to be little consistency or convention on how risks are classified and reported in practice [59].

Risk formulation essentially involves the integration of potentially complex and often ambiguous information from inherently complex patients through the risk assessment process. The importance of getting the relevant up-to-date information and the use of statistically based methods of combining,

scaling, or otherwise actuarially integrating suicide risk factors into some sort of formula for judging level of risk, is very crucial in the clinical decision-making process [173].

Maltsberger [131] notes that it is difficult to integrate the large mass of data collected during the assessment process, precisely and with empirical certainty which leaves the clinician to rely on clinical experience and inductive reasoning. Furthermore, Shea [178] argued that the clinical formulation of risk is based on a cognitive understanding of data gathered about risk, ideation, and protective factors and an intuitive process that takes into account such factors as the clinician's familiarity with the patient and the patient's character structure.

Maltsberger [131] also highlighted the use of proper classification and suggested roughly grouping personal factors (p), exterior factors (e), and mental state factors (ms) to allow for the use of some form of formulars or algorithm where risk (R) will be a rough function of the sum of these:

$R = f(p + e + ms)/f(c)$

with c = character which is the disposition to react.

However, Schiepek et al. [173], note that the use of some sort of formula for judging level of risk have been shown to have poor specificity [173], and therefore an alternative approach may be required. A new alternative approach is the use of a clinical decision support system which adopts unique models of clinical decision-making process and structured classification.

Achieving a better understanding of clinical decision making has been enabled by the representation of the process in different theories and models with the aim of understanding the process, elements involved and how changes can be evolved to enhance effectiveness in decision making.

3.7 Clinical Decision-Making Models

Decision making has been approached variously in the fashion of a pyramid with the base formed by the concept of intuitive judgment which seems to be a quick and easy approach. This intuitive

approach however is open to inconsistency and distortion, difficult to articulate, and difficult to apply consciously or unconsciously [175]. The next level in the pyramid is the heuristic procedural approach of decision making which applies rules that are generic or specific to a situation, articulated and applied consciously. Heuristics facilitates reasoning which often results in more effective decision making while intuition is a judgment based upon individual experience which focuses on recognizing the processes at an unconscious level for rapid, subliminal judgment of visual and verbal cues [154].

Another level of decision-making approach is the hypothesis generation approach which usually starts from a known starting point and working toward an unknown end point. This approach enables clinicians and decision makers to transform a seemingly unmanageable problem into a manageable one by generating a set of possible diagnoses and then testing their appropriateness in further data collection. Tools such as decision trees enable the isolation of a problem and the exploration of all possibilities [154]. There are many different decision-making theories that attempt to simplify clinical decision making with the aim of enhancing effective decisions. Hypothetico- deductive method, decision analysis theory, pattern matching and intuition models have been applied with distinctive concepts and terminology. The quality of the decision may be explained based on the different operational terms of the model of decision making. A decision tree based on an incorrect structure or wrong probabilities attached to choose points may lead to ineffective decisions. The correct hypotheses in a problem situation might not be generated if the correct initial patient cues are not formulated leading to faulty deduction of expected cues [154]. Using pattern matching may also result in cues being proposed that are connected to the wrong decision categories with the wrong weights.

The hypothetico-deductive model [148] suggests that the first decision-making activity in the decision process is data gathering aimed at providing the initial cues which leads to the induction of hypotheses that explains the input data. The initial cues might be data on the patient's age, weight, and various descriptors of feelings. These will lead to preliminary hypotheses of possible risks which will cause the deduction of further data by, for example, asking questions about previous history. The new data

provide evidence for or against the contrast hypotheses (differential diagnoses) and the cycle continues.

The model also expresses the language of classification where hypotheses become classes with their descriptive attributes or features as the evidence. The absence of data without data acquisition of the first activity implies there will be no outcome classes. The key point of the model is that the initial data provides cues which stimulate recall of their associated categories which define a class of some set of members. Clinical literature acknowledges the linking of the groups of cues with diagnostic categories as pattern recognition which is same as in connecting evidence with hypotheses. Both are classification activities where cues bring to mind potential outcomes, termed hypotheses, categories or classes. The patient descriptors referred to as the pattern vector are related / linked with relevant signs and symptoms described as the feature vector and then the output categories showing the possible decision or intervention classes for the patient.

The hypothetico-deductive model of clinical problem solving relates to the way the healthcare professional processes patient-relevant information [148]. This problem solving and analysis method is considered beneficial due to the linear approach and prescriptive manner in which clinicians address a given situation. The generation of hypothesis is considered rational and structured, and related to the directionality of interpretation [12]. The generation of a hypothesis through data acquisition and interpretation is defined as ‘forward reasoning’, an approach used by clinical experts in clinical decision making and diagnosis [21].

However, this mode of decision making is not totally reliable with doubts from a number of researchers about the ability of such a simplistic approach to assessment to facilitate safe, accurate diagnosis and subsequent treatment [12, 162]. The argument is that hypothetico deductive reasoning is dependent on the hypothesis generated which if inaccurate can lead to a misdiagnosis and an inaccurate result.

Another clinical decision-making model usually used in the clinical setting is the intuitive-Humanist model which focuses on intuition and the relationship between clinician's experience, the knowledge gained from it and how it enriches the clinical decision-making process as the clinician progresses along the professional trajectory [16]. The model does not use hypothesis testing as a marker of accurate or inaccurate propositions and reasoning but rely on reasoning based on hunches instead of scientific reasoning [186]. The use of this approach to clinical decision making is usually tied to the experience and knowledge of the clinician. The model is thus defined as 'the deliberate application of knowledge, or understanding that is gained immediately as a whole and that is independently distinct from the usual, linear and analytical reasoning process' [170].

According to Rew, [170] intuition has also been defined as 'a component of complex judgement, the act of deciding what to do in a perplexing, often ambiguous and uncertain situation. It is the act of synthesizing empirical, ethical, aesthetic and personal knowledge. Intuitive judgement is the decision to act on a sudden awareness of knowledge, that is related to previous experience, perceived as a whole and difficult to articulate' [170]. Intuitive decision-making is neither subjective judgment nor purely empiricism, but closely linked with the decision-makers' knowledge, experience, emotion, etc.

The different theoretical interpretations of decision-making process show the need for a general framework to facilitate the description of clinical decisions which is able to relate the data and their interpretations. Classification as a model for clinical decision making has been suggested. The unifying framework is based on psychological classification, constructed by considering judgements and decisions as a classification task and capable of describing all types of clinical decision. It involves organizing categories and methods of assigning objects to them. A good example of the use of the classification model is the Galetan Risk and Safety Technology (GRiST) decision support system based on the Galatean model of classification, which matches service users' information against 'perfect' membership of the risk category, which means maximum risk and not desirable risk.

Buckingham and Adams [31] suggest that the major clinical decision-making theories are so similar that they only differ in terminology and semantics. They argue that decision-making research would be much more efficient and communicable if the research community endorsed this approach rather than placing so much energy on distinguishing theories apart.

3.8 Chapter Conclusion

CDSS as a direct aid to the clinician is described as the smart use of computation and communication tools designed to support healthcare organizations and to meet the requirement of the complex health environment has improved healthcare. It is aimed at reducing the reliance on human experts by mimicking how a human handles problem situations in a particular domain. It therefor plays a vital a pivotal role in improving patient care.

Nevertheless, adaption of CDSSs in an actual healthcare workflow setup is challenging. The concerns for a mismatch between the functionality of most CDSSs and the expectations of the clinicians have raised the issue of misfit which impact on the usefulness of the CDSS. The importance of clinical decision making and the clinical decision-making process or model adopted in risk formulation is emphasised. The different clinical decision-making models examined show the different benefits and applicability in risk formulation process. The best practice guidelines of risk assessment and formulation shows the preference for a structured clinical approach based on the Hypothetico-deductive clinical decision-making model which requires the acquisition of appropriate cues for the generation of hypothesis. This highlights the need for an appropriate clinical decision-making tool for risk formulation to enhance the risk formulation process and positive intervention decisions. Overcoming these concerns require an evaluation of the clinical decision-making model of the CDSS and the users' mental model.

The next chapter examines the concepts of mental model and how it can be used to enhance the functionalities of the CDSS in mental risk assessment.

Chapter 4 Enhancing the Functionalities of Clinical Decision Support System using Mental Model

4.1 Chapter Introduction

Risk formulation in mental health is based on knowledge and cognitive process, and clinical decision-making processes which are represented by mental models. The developments and use of mental models in the development and enhancement of risk formulation is of paramount important in this research. This chapter will examine the concept and theories of mental model, the characteristics and utilisation of mental model in psychology, human computer interaction and clinical decision support system.

4.2 Mental Model: An Overview

Mental models are regarded as important cornerstones for building knowledge and defining some of the cognitive processes that support change and learning. Examining and extracting the model provides a good platform for understanding the biases, beliefs, experiences, and values of individuals incorporated in the model that are constantly interacting with patterns of perception, thought, and action. Extracting the mental model of the CDSS enables the examination of deeply ingrained assumptions, generalizations, or even pictures or images that influence the understanding of the system and how actions and decisions are taken.

The concept of mental model and the building of user' mental model has been widely applied in human computer interface to enhance better user interface design. Early research in mental models describes the concept operationally as a psychological representation of some domain or situation which facilitates understanding, reasoning, and prediction [105]. This definition has been extended in cognitive psychology and educational and organizational researchers by recognizing the role that past

experiences play in human development, as well as the ways that mental models guide and regulate all human perception of the physical and social world [132, 77].

Researches on mental models are however limited with focus on the wide varieties of the definition and characteristics of mental model such as the accuracy and completeness. Few studies have also been made on the impact of mental model on user's navigational behaviour and interaction with system for a better understanding of user's perception of the system [207]. Mental models of a dynamic system is defined as a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing, or projected) whose structure is analogous to the perceived structure of that system. Research on the use of mental model is aimed at having a better understanding of the cognitive process of the user in the decision-making process and in the effective use of clinical decision support systems [14, 69, 2].

The significance of mental models in the decision-making process is that they define the perception of the decision system and all of its elements. The effectiveness and suitability of any clinical decision-making system designed to reduce errors in a clinical process due to cognitive limitations of humans may depend on its ability to enable the end-user have a clear understanding of the right path to navigate and the tasks to cover. There may be a need to provide guidance in a consistent manner that is coherent with the user's mental model of the patient, processes, or the context of care and decision-making. This is illustrated in figures 1 and 2 below:

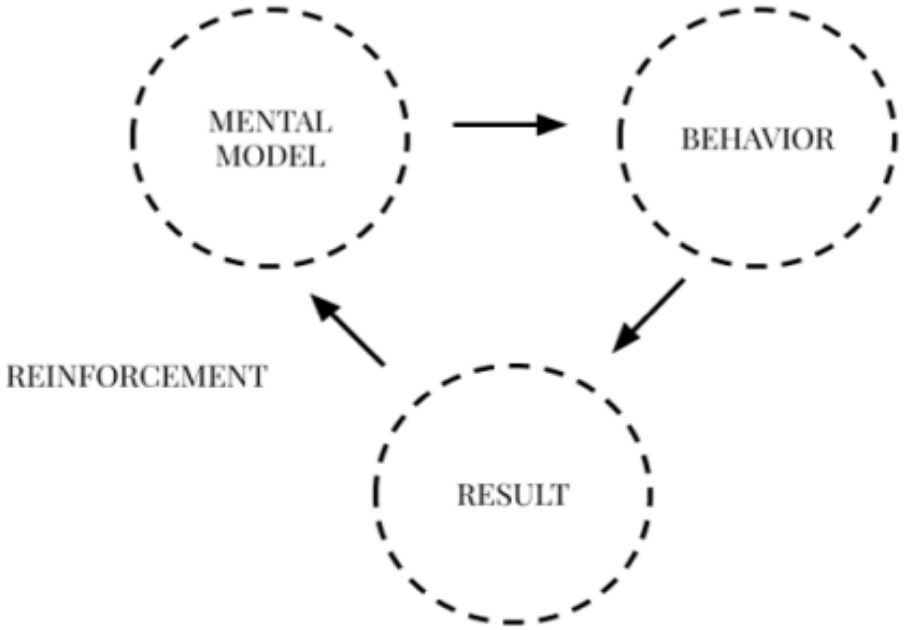


Figure 1: Mental Model Structure [47]

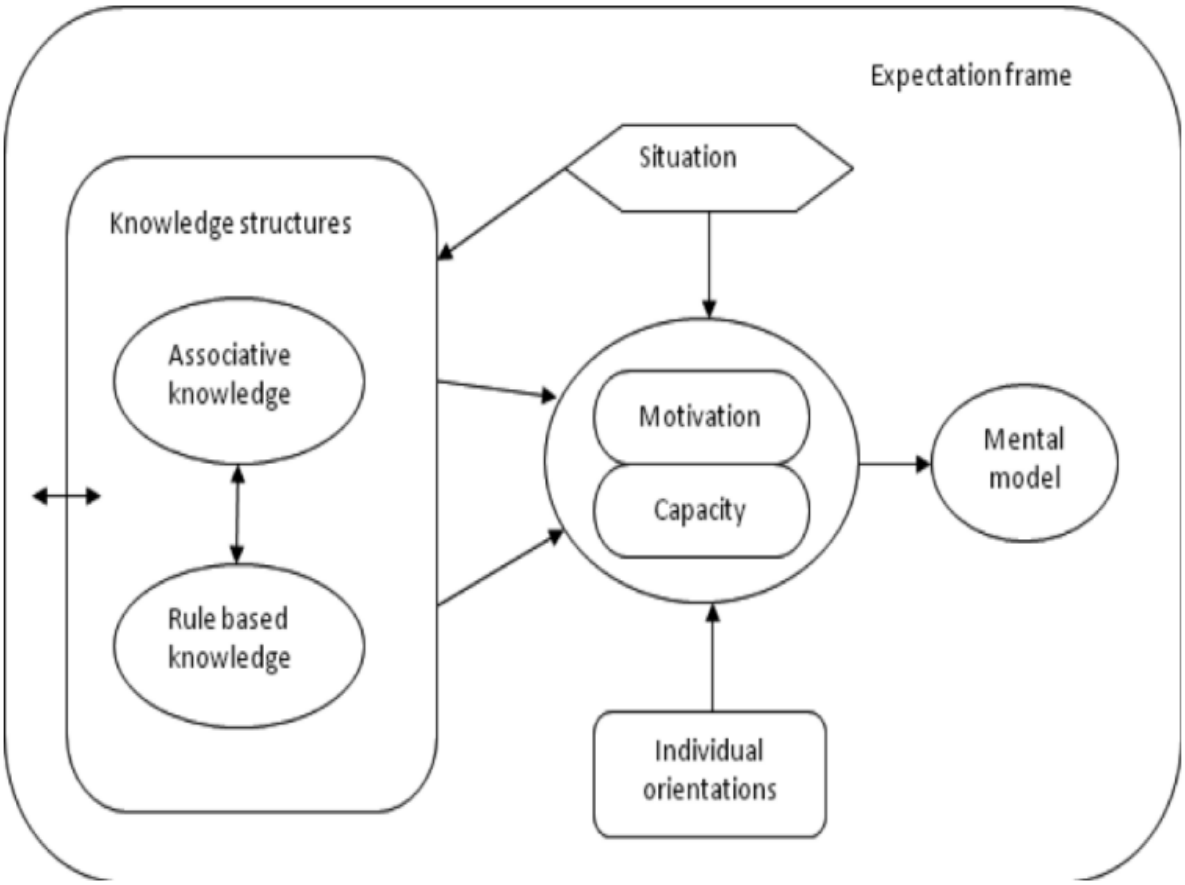


Figure 2: Knowledge Structures of Mental Modelling [127]

4.3 Characteristics of Mental Models in Human Computer Interaction

A mental model's content is only a partial representation of the environment and its scope is limited. It is worth noting that incompleteness is not necessarily a shortcoming of mental models. Keeping the model to a manageable size grant mental model's cognitive feasibility in people's information processing, because human beings' memories and processing capabilities are limited. Many studies provide empirical evidence for the incompleteness of mental models.

Another characteristic feature of a model is that it is often naïve and not scientific and therefore, may not be consistent with the normative conceptual model of the system. Users of a system often speculate about the system's underlying mechanisms as observed. Models based on these

speculations are assumed to be valid, even though the system's behaviours are not generated by the speculated mechanisms. Furthermore, users may also establish causal relationships based on co-occurrence of events, even though the co-occurrence might be random and for reasons that differ from the ones they believe [17].

Mental models are also noted to have the feature of involving misconceptions or errors [208]. Research shows the development of mental models of users of the internet and web search engines with misconceptions and which also failed to include the main issues of the system [159, 141].

A mental model also need to rhyme with the ability to respond to environmental changes in order to allow users predict the status and feedback of an interactive system and plan the methods for novel tasks [34]. This a key distinguishing feature of mental models and other static knowledge structures, such as schemata and scripts [67].

Mental models also do not have firm boundaries as users' experiences in one system may influence their opinion and perception of another system. Therefore, users' existing mental models of one domain may influence the construction of their mental models of another domain [148].

In summary, some of the characteristics of mental models are:

• They are incomplete and constantly evolving.

• They are usually not accurate representations of a phenomenon; they typically contain errors and contradictions.

• They are parsimonious and provide simplified explanations of complex phenomena.

• They often contain measures of uncertainty about their validity that allow them to used even if incorrect.

• They can be represented by sets of condition-action rules.

4.4 Mental Model Theories

The concept of mental model is based on the idea that the structure of a representation corresponds to the structure of what it represents. The perception of humans produces a vision of a mental model of what things are where in the scene in front of them. Their understanding of the world enhances the construction of a mental model which is a representation of the world based on the meaning of the description and on their knowledge.

Mental model therefore has the power to influence individuals' perception of the world, and the actions they subsequently choose to take based on those perceptions. This influence is based on the fact that the models are abstracted from everyday lived and vicarious experiences which form deeply held codes by which they decode and understand the world around them. However, the likely problem with these deeply held codes is that they are used untested which often lead to errors in reasoning, learning and problem solving thereby obstructing future growth and success.

Mental model theories suggest that people make reasoning errors because they construct partial – and inaccurate – mental models. They predict that where people are required to consider false information, they are more prone to making errors than when they are only required to consider true information. Findings consistent with these theories have been demonstrated across a number of studies, particularly the work of Johnson-Laird [105].

Johnson-Laird and colleagues [97] suggest that in order to solve reasoning problems, people construct mental models. However, as the complexity of the problem increases, people omit information from the models, neglecting to represent explicitly false information. While this keeps the problem within the limits of working memory, it inadvertently introduces errors into the reasoning process. The notion of a model is described as a representation of the content of a problem constructed in working memory for the purpose of applying problem solving skills to a particular content, namely the model of the logical possibilities implied by the premises of the logical problems.

Rouse and Morris [204] describe mental models as “the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states.” (p. 351). It is a representation of the external world and the different concepts they represent and therefore may help in predicting users’ interactions which illustrates the importance of constructing mental models.

In Chua Storey, and Chiang [204] study on how people interact with information systems, knowledge engineers were able to construct mental models of new knowledge through an iterative process of selective querying of acquired knowledge; the knowledge engineers then leverage their own knowledge with domain experts’ knowledge. Mental models were recognized as a dynamic construct in this study and were explored as a process involving constantly changing cognitive states and actions. However, this dynamic process was explored mainly at an abstract level with a focus on general cognitive activities, such as model building and testing. Few made attempts to connect the cognitive development to specific elements, features, or functions of the systems under review. The lack of connection between the abstract cognitive structures and concrete system functions might directly limit the potential of the research in informing system design.

In another study which sets out to investigate how users’ mental models of MedlinePlus, an information-rich web space, develop and change during a search session in relation to the system’s elements, the author focuses on examining elements of users’ mental models rather than mental models as a whole [210].

Proponents of propositional model theory depict decision makers as cognitively building on given parts of a construct to create a mental model. This mental model (or set of assumptions) is then used to deduce conclusions about the state of the world. Mental model theory thus is divided along the lines of deductive and inductive reasoning. Deductive reasoning involves deriving consequences from what is assumed. If the assumption is correct, then the consequence will be valid. Inductive reasoning is quite different. Inductive reasoning involves inferring a consequence based on multiple

instantiations of similar scenarios where those scenarios have led to that consequence. Induction is not guaranteed to be correct, no matter if all the previous scenarios are in fact truthful (e.g. one may conclude that all swans are white as they have only ever seen white swans, but this does not mean that black swans do not exist). In general, errors in reasoning occur two ways: 1) in deduction where the original assumptions are incorrect or (2) in induction where the consequence is in fact not generalizable.

Johnson-Laird's theories generally predict that errors are caused by the first error where the assumptions are wrong which lead to incorrect consequences in decision making. There is also the possibility that the consequence is not generalizable in decision making. This may occur when a decision maker incorrectly believes that one scenario is like another scenario leading to incorrectly assumed consequences. Logically, these types of errors would occur even if the mental model (of previous scenarios) is correct [105]. The relationship between inductive reasoning and mental models is further explored by Holland et al in their book Induction. They state that "despite their inherently transitory nature – indeed because of it – mental models are the major source of inductive change in long-term knowledge structures [as] model construction provides the opportunity for new ideas to arise by recombination and as a consequence of disconfirmation of model-based predictions."

Johnson-Laird and Byrne present a theory of conditional inference based upon the manipulation of mental models. It accounts for psychological data, principally focusing on the rate at which people draw the four basic inferences of modus ponens (MP), denial of the antecedent (DA), and affirmation of the consequent (AC) and modus tollens (MT). The mental model theory of conditional inference provides an interesting and potentially important contribution to our understanding of human reasoning [103]. However, the current formulation appears to be insufficiently specified with regard to the nature of the representations that subjects form and the precise mechanism by which inferences are drawn. This in turn leads to some uncertainty in the prediction of problem difficulty.

There are also a number of experimental findings in the literature on conditional reasoning which are either not considered or which are addressed in insufficient detail.

Reasoning with conditional statements is the largest area of study in the psychology of deductive inference. Research looking more into the role of inductive versus deductive reasoning and the role in CDM could prove interesting while also providing support for or against relations between propositional models and mental models [103].

4.5 Mental Models in CDSS

The construction of models which reflect the decision structure has been described as one major tool for dealing with decision making under uncertain conditions and to gain an understanding for better decisions because it allows decision experimentation with hypothetical consequences [139]. Models present reality which allows clinicians to understand and function in various situations.

CDSS is basically characterised by the underlying decision-making process or model such as problem-specific flowcharts encoded for computerized use, statistical models, mathematical techniques, decision trees, etc. A decision tree, together with literature-derived probabilities and defined outcome values, is used to model a given problem and help determine the best course of action [191].

Decision analysis requires the construction of a decision tree, which illustrates all plausible relationships, alternatives and outcomes involved with a given decision. Associated with each step in the decision tree is a corresponding probability and outcome value. Incorporating both probabilities and outcome values, the decision-analysis model expresses its conclusion in terms of an average expected result. By using such a tree, a decision maker can accurately weigh and compare outcomes associated with a given decision, thus leading to a more informed clinical decision [191].

Holland et. al [94] suggest that mental models are the basis for all reasoning processes: “models are best understood as assemblages of synchronic and diachronic rules organized into default hierarchies

and clustered into categories. The rules comprising the model, act in accord with the principle of limited parallelism, both competing and supporting one another." (p. 343).

4.6 Modelling a Clinical Decision Making

Ahituv [4] proposed a simple information flow model in which the state of an object is observed to collect data about it, the data are interpreted to obtain information, the information is used to make a decision, and the decision is used to act to change the state of the object. The figure below shows a first, simplified instantiation of this model for healthcare domains. The decision "domain" is the patient. The patient's temperature for example is measured (data), interpret the result as a fever (information), and decide whether treatment is needed (decision). A CDSS uses a formalized knowledge base to interpret the data.

The CDSS can offer either a conclusion about the state of the patient ("what is true," eg, a diagnosis) or an explicit recommendation ("what to do"). In much of the work on CDSSs, the advice is simply presented to the user with an implicit assumption that this is sufficient to prompt the recipient to act appropriately. However, it is noted from decades of psychology research that this assumption is naive. The fundamental function of a CDSS is to support the clinical decisions of the user. Consequently, interaction with the user is a fundamental part of the system's design. In early CDSSs, this led to adding features such as an explanation of the reasoning behind the advice given by the system [4]. The model is represented in the figure 3 below:

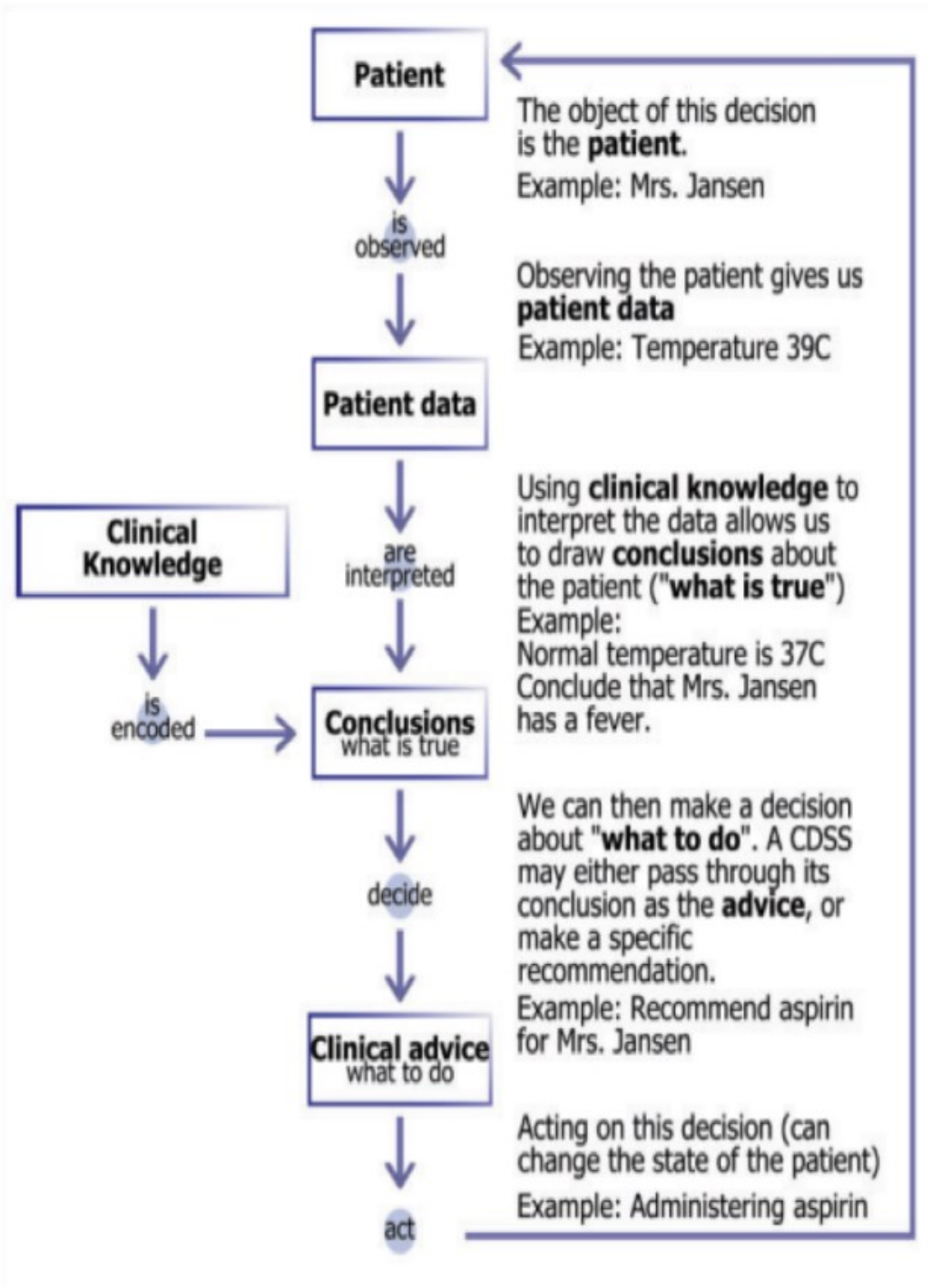


Figure 3: The Ahituv Flow Model of a CDSS in the Health Care Domain [4]

4.7 Mental Models and the User

A mental model is basically what the user believes about the system at hand based on previous experience which can be modified with time and new experiences or training. The model is what users know or think they know about the system and their future actions are thus based on how that model predicts the appropriate course. What users believe they know about the system therefore strongly impacts how they use it. This makes the understanding of what the user think they know about the system very important particularly to direct and guide their effective use of the system and to avoid a mismatch of models.

A very important issue in systems' use is the common gap between designers' and users' mental model. The users' mental model may be different and more deficient which makes it more likely for users to make mistakes and find it difficult to use the system. A mismatch often occurs when users form erroneous mental model which affects the proper use of the system. This situation may be corrected by making the system conform to user's mental model or by improving users' mental model to more accurately reflect the system. Making the system conform to user's mental model will require updating the system's functionalities and processes to fill the gap and meet the need of the user. Improving users' mental model can be achieved by training the user or clear user documentation. Mental models are regarded as a key concept in the development of instructions, documentation, tutorials, demos, and other forms of user assistance.

Mental model theory suggests that individuals' mental models encompass procedural knowledge of how the individual is to use a system to solve problems [77]. A mental model is therefore internal to each user's brain, and different users might construct different mental models of the same system. This implies that there is a need to distinguish between the mental models of a system and knowledge about how to work with it.

The failure of systems developers to deal adequately with the logistical, mechanical, and psychological aspects of system use may have contributed to the impracticability of most systems such as CDSS. The

result is usually poor usability and failure of integrating the practical clinical workflow into the system. This makes the development of user's mental model a necessity in building an effective clinical decision-making system as user's mental model which represents user's cognitive process provides an evaluative view of the system from the user's perspective. The mental model captures the cognitive thinking and behaviour of the user during the use of a system.

These features of user mental model make it useful in providing an understanding of the features and functions of the system considered as critical and most useful by users. Zhang [207] suggests that user's perceptions of a system are usually in four components namely system, content, information organization, and interface which may be exploited to make the system more effective and useful. These components will help in identifying important user-based system criteria to be considered in the evaluation and update of the system's functionalities.

4.8 Construction of Mental Models

The construction of models which reflect the decision structure has been described as one major tool for dealing with decision making under uncertain conditions and to gain an understanding for better decisions because it allows decision experimentation with hypothetical consequences [139]. Models present reality which allows clinicians to understand and function in various situations.

There are different methods of eliciting user's mental model with no standard technique. Most of the techniques involve generalisations based on the assumption that users' mental models are formed on comparisons to similar systems [187]. However, a user's mental model and its details are created consequent upon the user's interaction with the system no matter how brief. Users normally form a mental representation of the system during actual interaction with the system which makes the transaction log representing usage data very important and necessary for the construction of the user's model. The transaction log could therefore provide much information relating to the mental model. Moreover, the system aspects of the model which form the basis of the users' evaluative view

are formed on the aspects and features that facilitate the accomplishment of a task through interaction with the system.

One of the main methods used for eliciting user's mental models has been interviews where user participants are asked to answer a set of questions concerning a system [187, 205]. Another method that is widely used to elicit mental models is the identification of the type and/or strength of relationships between a set of concepts or the drawing of a concept map of a set of concepts.

There are various specific tools to assess, extract, and alter the mental models of systems. The tools for examining mental models include cognitive mapping, mind mapping, relationship mapping, dynamic system generation, knowledge task analysis, drawing, concept listing, observation, repertory grid technique and the use of mental model deductive reasoning theory and each has a slightly different approach to uncovering individual and group assumptions and biases about the world.

Task analysis is the interpretation of users' common tasks and goals. It involves a listing of user tasks for the functionality layer. It is speculative but it is an easier way to deduct the user's mental model. Its accuracy may however be low due to lack of user interaction with the system. Method of extracting, representing, and analysing mental models is the Carley and Palmquist [36] computer-driven method which views mental models as networks of concepts and the relationships between them. The method is based on four components of a system/model namely (a) concepts, (b) relationships, (c) statements, and (d) maps. The method focuses on capturing the set of concepts used in the system, identify the relationships between the concepts, statements are formulated involving two concepts and the relationship between them and a map is drawn showing the network formed from statements.

4.9 Methods of Eliciting Mental Models

The methods of eliciting mental model may depend on various factors and situations and for different purposes. Elicitation basically refers to the process of inquiry to encourage a person to externalize a

mental model. Externalising a mental model could be a vocal expression of the mental model conveyed during an interview situation, or by graphical drawings and images.

Literature has also shown that mental models have been elicited in different forms for the purpose of understanding the basis for people's actions [14]; to integrate different perspectives to improve the overall understanding of a given system [211]; to explore similarities and differences in stakeholders' understanding to improve communication [2]; and to support decision-making and negotiation processes in contentious situations [62].

A variety of mental model elicitation procedures have been used in different disciplines to suit different research contexts and purposes, including, for example, the study of system dynamics [58] human–computer interaction [43] and risk communication. A review of elicitation procedures used reveals that they differ in terms of two key dimensions: (1) a situated and non-situated dimension and (2) an oral and visual-based dimensions. These dimensions provide a starting point to begin exploring how different interview procedures might affect the mental models people express in an elicitation exercise. The difference between situated and non-situated procedures concerns the location in which the elicitation interview is conducted, which may affect the mental representations people form and use.

Situated procedures involve eliciting a person's mental model in a location corresponding to the phenomena to be elicited [2]. A "non-situated" procedure involves eliciting a person's mental model in a location removed from the phenomena of interest. The majority of mental model elicitation procedures are conducted as a non-situated interview.

In terms of the oral- and visual-based dimension, Carley and Palmquist [36] advocate the use of oral-based procedures. They state that the symbolic or verbal structure extracted from a text, such as an interview transcript, can be considered a sample of the full symbolic representation of the individual's cognitive structure. They believe that language provides a "window through which to view the individuals mind [36]. A common oral-based mental model elicitation technique is the oral interview

[140]. It is argued that linguistic structure alone cannot be taken as representative of an individual's cognitive structure but should incorporate an imagistic approach to mental model elicitation [111].

This argument of combining oral- and visual-based procedures is based on the theory that cognition is not only language based and that verbal and imagistic thought are carried out by two distinct, though partly connected, systems. It is noted that semantic organization in memory may differ from the organization of objects or concepts in memory. Therefore, creating a visual representation of one's understanding can help the interviewee explore his or her own mental model through the process of "mapping" it [111].

4.9.1 Verbal Elicitation Methods

Verbal elicitation methods are based on communication which is regarded as part of the thinking process. These methods therefore explore the cognitive thought process to help identify the linkages and relationships of concepts individuals create when communicating. Mental models are therefore extracted through verbal communication using interviews or case studies. Although these methods are easy and straightforward to use, the main criticism is that there can be misunderstanding between users' intent and the interviewer's interpretations [169]. This can however be addressed using a combination of two or more techniques, such as using both open and question–answer approaches which can help decrease incidences of interviewer distortion to the participant's mental model [118]. Perceived interviewer's distortion can also be avoided where feedback is sought from the user of the interpretation. Feedback received will clear all issues and confirm the mental model elicited by both parties. Feedback could be received and used to clarify all issues in two ways.

Feedback can be received during the interview session as the interviewer asks follow-up questions to confirm perceived thoughts concerning the answer that was previously given. Answers to follow-up questions serve as feedback to clarify and confirm the thoughts and views of the user and thus can help to ratify the constructed model under investigation. The second way of receiving feedback is to

provide the report and findings of the research or the constructed model to the user for a review. The feedback of the review provides clarification on all issues raised and implicit approval of the findings or the constructed model.

Other factors that may be affecting the successful use of interview technique can be categorised as external (situational, environment, etc) or internal factors (personal knowledge, memory issues or lack of comprehension, availability, time frame) [104].

4.9.2 The Case Study Method

The case study approach to eliciting mental model explores the use of self-contained stories read by participants which is then analysed through open discussions. This discussion can be with either a principal investigator or other study participants. The analysis stage is when the participant begins to understand the content of the elicited mental model.

The approach was implemented by Feeney and Handley [69]; the authors investigated the participants' initial mental model representations for action and inaction, believing that people may sometimes construct multiple mental models of a phenomenon. Research participants were presented with one of three case studies. Participants were instructed to read the presented case study, and no time limits were given. Once the case was read, the participants answered a series of rating questions. Analysis of the responses is what leads to the elicitation of mental models.

The approach is descriptive and interacting; participants are indulged with expressing themselves and as such leading to the disadvantage of not having enough time to fully express themselves. On the other hand, writing the case if one is not available for use can be time consuming. Ensuring the case studies are constructed in a way that explicitly simulates reality for the domain or situation it is meant for and constructively targeting the mental model to be elicited van be challenging. Some domains such as medicine do evolve over time and tends to be difficult to keep up with the updated case as the change can be unpredictable [110, 92, 166]. Similar to its use in medical settings, the multi-staged

nature of the method can enable mental health professionals as they may have numerous ways to capture risk formulation, judgement and management of a service user.

Azzarello and Wood [11] argued that the value of this method for elicitation is that the numerous collection points enable multiple views of a person's mental model, allowing for a more detailed collection. However, one potential issue with this method is that as the individual receives new information, different mental models may be activated. This may lead one to question if the original mental model of interest is actually being elicited and such may lead to complex mental models or unending models elicited.

4.9.3 The Graphical Elicitation Method

Graphical elicitation refers to the use of any manner of graphic or pictorial representation of an individual's mental model. This category can be broken down into those methods that are author generated and those that are computer generated. In the most general sense, graphical elicitation methods are defined as graphic or pictorial notation, made for the purpose of representing a domain of knowledge, using patterns of interconnected concepts and arcs [75, 210]. The inter-connecting arcs indicate the conceptual links between the concepts as perceived by the user in their map. The argument in favour of this method is based on cognitive psychology theory and research which posits that the organization of an individual's knowledge can affect the efficiency and effectiveness of subsequent recall and problem solving [174]. In addition, Fraser [74] argued the use of verbal forms of elicitation may be inferior to graphical methods because the former is intrinsically linear in focus and are unable to capture the complexity of the relationships between the expressed concepts and ideas. The methods in this category used by researchers include knowledge mapping, concept mapping, cognitive mapping, semantic map ping, semantic network mapping, cognitive structure mapping, knowledge structure mapping, and conceptual knowledge mapping [74, 75].

Concept Mapping (CM) is an example of graphical elicitation method that makes use of diagrammatic representation of knowledge structures and perceptions in the form of interconnect concepts and

arcs [75, 74]. There has been a remarkable growth in the use of CMs throughout the world over the past decade. The most prevalent applications of concept mapping are facilitating meaningful learning and capturing and archiving expert knowledge in a form that would be easy to use by others. Furthermore, CMs have been known to be an effective tool to organize and navigate through large volumes of information.

The automatic or semi-automatic creation of CMs from documents is called concept map mining (CMM) [199]. In a semi-automatic process, the system finds and suggests elements of a map, and a person manually has to finish the map using the provided information. In the automatic construction process, the user's assistance is not required, and the process creates the map automatically from available resources.

In a semi-automatic process, the system finds and suggests elements of a map, and a person manually has to finish the map using the provided information. In the automatic construction process, the user's assistance is not required, and the process creates the map automatically from available resources.

From the Concept Mapping Modelling (CMM) point of view, a document can be formalized as a set

$D = \{Cd, Rd\}$

where

$Cd = \{cd0, cd1, ..., cdn-1\}$ is a set of all concepts, and

$Rd = \{rd0, rd1, ..., rdn-1\}$ is a set of all relationships that can be extracted from the document.

Three general phases of the CMM process are depicted in the figure below:

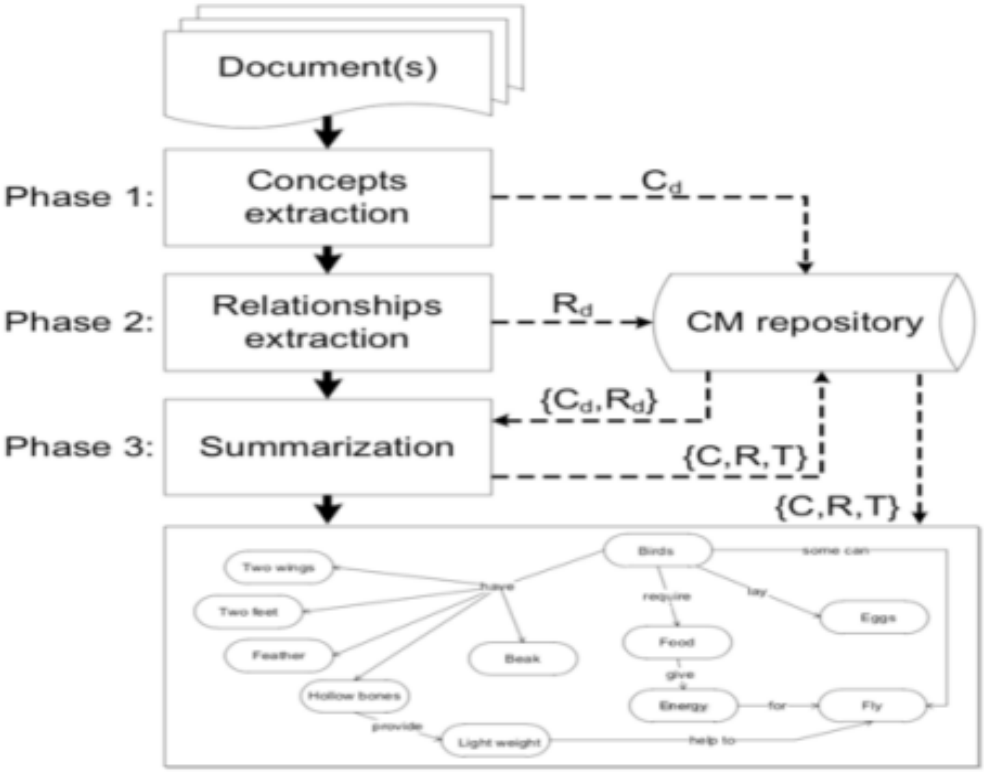


Figure 4: The General CMM Process [199]

4.9.4 Hybrid Elicitation Method

This method of elicitation involves the use of combination methods; usually the verbal and graphical techniques. A hybrid approach to mental model elicitation has the potential to offer techniques that more closely resemble what clinicians actually use in an organizational context.

The use of pictures to illustrate the mental model of users has also been helpful in eliciting participants' mental model. The pictures are developed, and the participants can then describe the pictures in form of symbols. This method is a combination of graphical and verbal elicitation methods called Photo ethnography. Arcidiacono and Procentese [8] utilized photo ethnography for their study of Neapolitans' sense of community in their historic town. Fifteen residents of Naples were purposefully sampled and asked to take pictures of phenomena that represented their mental model

of community which were meaningful to them with regard to their personal history and to the life of the district.

The method may facilitate the elicitation of both explicit and tacit knowledge that makes up the mental model. An individual may take a picture of an instructed phenomenon because something about the subject in the photo reached some tacit level of his or her understanding of the phenomenon. It is then the probes during the interview that enable the tacit element to be unearthed and expressed.

Alternatively, though, this approach can be overwhelming in the sense that many unrelated pictures may be collected and may cause participants not to understand what is expected of them and may not be able to make a sense out of the images or pictures gotten [142].

Pask and Scott [161] implemented the teach back method for eliciting mental models where participants are expected to teach imaginary colleague, user or other participant their perspective or understanding of a system and especially how to solve a problem. The question format for this type of method includes “What”, “How”. The responded to the questions can be in the form of written documentations, diagrams, sketched or any other graphical representation that is chosen or suits the scenario.

The method tends to pose benefit as participants carefully understand the steps needed to teach the imaginary colleague. The orderly progression in turn can help to elicit deep mental models [161]. A limitation of this method is that it may not encourage participants to express themselves in the entirely of how they want to due to time and schedule constraint [197]. Another major disadvantage of this method is that only knowledgeable users are expected to give the description. Mental models elicited are only restricted to the knowledgeable participants about the particular system [161].

Overall, for hybrid approaches to be successful, more studies must be undertaken regarding its conceptual framework, designs, procedures, and the rationale for use. A combination of two or more elicitation methods may be the best way to overcome the shortcomings of each method [118].

4.10 Eliciting Users' Mental Model of GRiST Using Logged Users Interactions

The process of eliciting users' mental model of GRiST will be carried out based on the standard processes as outlined in previous researches described in the last section. The process in this study will use logged users' interactions with GRiST in place of interview transcripts and diagrams/images.

The use of the transaction log of users' interactions will present a valid and rich set of data from mental health professionals that is void of any shortcomings associated with the data collected using the interview eliciting method.

Concept analysis would be carried out to identify the number of concepts expressed in the interactions, identify the number of functional linkages, i.e., causal relationships, expressed, and to determine the density of the mental model or the ratio of functional links to concepts.

The use of concept mapping will help generate a comprehensive conceptual hierarchy used by experts in risk assessments and help to identify data directly corresponding to tangible patient cues as expressed by users' interactions. The proposed method; conceptualising users interactions contributes to existing literature in two ways. Firstly, it helps in formalizing cognitive processes for mental model elicitation through building the foundation of system's users' interactions. These processes by the professionals are logged in the server end. This approach tends to overcome the verbal mental model elicitation method by ensuring users are in their "comfort zone"; there is no rush as well as time management is never going to be a problem. It also proposes therefore a sequential

cognitive process through several steps that pay particular attention to how to translate the knowledge of individuals into formal maps and how to make the emergent properties appear.

The proposed method is structured into four phases:

• The data mining stage is cleaning and understanding the user interactions data set.

• Based on the data retrieved from the server end, the concept mapping is implemented to extract users' mental models. The result are them compared to get definite map.

• Statistical method is used to evaluate the mental models by analysing assessments; extracting frequent patterns.

• The output of the modelling and analysis are compared with GRiST ontology to identify gaps between users' mental model about GRiST and the system's model. The result of the comparison gives the foundation of the research output.

4.11 Conclusion

Mental models are regarded as important cornerstones for building knowledge-based systems and defining the cognitive processes of the system that also support change and learning. It provides a good platform for understanding the biases, beliefs, experiences, and values of individuals incorporated in a system. It enables the examination of deeply ingrained assumptions, generalizations, or even pictures or images that influence the understanding of the system and how actions and decisions are taken.

The mental model of a CDSS can therefore be captured as a product to be disassembled, and reconfigured, added to, subtracted from and returned with value added [57]. This can be achieved because mental models are able to communicate system design parameters to help designers produce more usable and enjoyable computer systems and to facilitate user training. Mental models thus help

people learn a new system and further use the system in a more productive way as it enables the end-user have a clear understanding of the right path to navigate and the tasks to cover.

Mental models do not only help users learn to use a new system, but also help users who have had experience with a system understand the system at a more abstract level and use the system in a more efficient manner. Mental models can also inform the design of new system mechanisms or functions.

Using mental model to design new system mechanisms or functionalities however depend on the construction of and understanding of users' mental model to understand the users' perspective. The process of creating and maintaining an up-to-date user model by a system is known as user modelling which allows a system to be adaptive to users' current status in knowledge or preferences so as to create a friendlier computing environment for the user. The user's mental model of a system is a rich and elaborate structure, reflecting the user's understanding of what the system contains how it works, and why it works that way. It can be conceived as knowledge about the system sufficient to permit the user to mentally try out actions before choosing one to execute.

The significance of mental models in the decision-making process is that they define the perception of the decision system and all of its elements. Risk formulation in mental health is based on knowledge and cognitive process, and clinical decision-making processes which are represented by mental models. The developments and use of mental models in the development and enhancement of risk formulation is of paramount importance in this research. The next chapter discusses the Galatean Risk and Safety Technology.

Chapter 5 The Galatean Risk and Safety Technology

5.1 Introduction

Previous chapters in this research have established the need for an examination of the clinical decision-making tool adopted for risk formulation. This is with the view of determining how the clinical decision model of the adopted CDSS meets the requirements of the standard best practice guideline on risk assessment/formulation. It will also identify how the CDSS supports and facilitates decision making in risk formulation and how it meets the workflow requirements of the clinicians. The clinical decision-making tool that will be used as a case study for the research is the Galatean Risk and Safety Technology [79], a web based clinical decision support system.

This chapter will present an examination of GRiST to review its conceptual model, its theoretical base and the clinical decision-making processing to provide a platform for an understanding of the structure of the functionalities of GRiST and an understanding of how GRiST supports the risk formulation process and guides the user the process. The Galatean Classification model adopted by GRiST will be examined with a review of its underlying theories and how it supports clinical decision making. The chapter will also examine the ontology of GRiST to review the nodes, attributes, data types, and the XML knowledge tree and these supports risk formulation. The chapter will review the kind of interactions undertaken with GRiST and the static and dynamic relationships between GRiST's functionalities with a high-level description of how the system is organized and operates.

The review of GRiST will help in understanding the conceptual processes of the system; how data are collected as well as the understanding of the question tree. The question tree will enhance the motivation behind clinicians answering questions for pattern extraction

5.2 Overview and Rationale for GRiST

Galatean Risk Screening Technology available at (http://www.eGRiST.org) [79], is one of three recommended multiple risk tools by the department of Health, UK as an attempt to comply with best practice [51]. GRiST is a web-based decision support system for risk assessment that links mental health expertise to a database of patient cues for mathematical analysis, thus integrating structured clinical judgement with empirical evidence. The design is aimed at ensuring that its structure and content accurately reflected how mental health experts conceptualize risk assessment [25, 26, 27, 28, 30]. The concerns thus include the understanding and identification of what information clinicians collect in order to carry out risk assessment; how and where this required information is recorded; how the collected information is used to formulate risk management plans; and how the dynamic nature of risk is captured, recorded and acted upon.

GRiST entails collecting relevant static and dynamic risk information from clinicians; this information is collected and recorded in the system's database. These processes are evaluated in this chapter to understand how the underlying ontology of the system works. These components of GRiST are essential to its relevance in clinical practices and its effectiveness in enhancing quality risk formulation. Achieving this aim and design of GRiST require a capture of clinical practices and an encapsulation of risk expertise on suicide, self-harm, harm to others, self-neglect, and vulnerability, making it universally accessible to people without training, accessible across all practitioner disciplines and across clinical services. GRiST also represents human knowledge and knowledge reasoning processes based on a classification model that makes it easy to elicit expertise, and easier to understand and validate. Knowledge representation in GRiST may be described as an intuitive format such as it is generally done by clinicians.

Different data gathering interface with more dynamic features to allow for the exploration of risks and risk factors in any order, and a more controlled entrance to risk exploration that is less overwhelming

and clear navigation with the use of different colour scheme. This also aid interactive understanding of risk exploration especially with animated features.

The focus of GRiST is thus to provide a platform where information on risk factors could possibly be collected in the easiest, fastest, and simplest manner to be organised and integrated to provide an information profile to support rather than replace clinicians' risk judgements [28, 31].

5.3 Process of Collecting Information in GRiST

GRiST design is to make it a systematic, structured and holistic tool for gathering risk related information both the static and dynamic information. Dynamic risk factors are those relating to the current status of the patient and can easily change, such as emotions, social circumstances and plans. They contrast with the more static and historic factors, such as dates of first risk episodes or traumatic life events [27]. The information collection system of GRiST is thus designed to aid quick and easy collection of information with a system organized in layers, starting with a short series of screening questions that, if answered affirmatively, point to areas requiring further, more detailed investigation. This provides a platform where only the needed questions are asked and answered.

It is designed with lots of filter questions with the aim of making navigation quicker. A yes answer to a question determines the next set of the filter questions. The Rapid Screening questions are the first set of filters, with subsidiary screening questions comprising the second layer of GRiST [27, 28].

The screening questions begin with those for specific risks (e.g., suicide or self-harm) followed by questions for gathering generic risk information that may be relevant to more than one risk, e.g., about patients' social context, physical health, personality, current behaviours. The integration of these generic questions is where GRiST provides a more holistic profile than tools focussing predominantly on risk specific behaviours. The generic questions include protective factors such as supportive relationships, belief systems, motivation, etc. and show how changing circumstances can impact on risk, which means GRiST can play a part in monitoring recovery as well as at initial assessment. The

specific risks questions and the generic risk questions are based on the 5Ps model framework which guides the process of collecting relevant information on the risk behaviour of the individual [29, 30]. The specific risk questions focus on the first P which is the Problem (that is, risk of what?). These first set of questions ae very important and key to the success of the process. The key task on beginning the formulation process is organizing the most relevant information available about the problem to be prevented. Getting a good understanding of the problem based on the answers given to the first set of screening questions determines the quality of the risk formulation and intervention programme. Furthermore, clarity about the range of answers to the problem factors will be a guide as to how comprehensive risk management will be. Answers to these first set of questions provides the risks that are to form the main focus of the risk assessment and formulation [27].

Following on the successful identification of the specific problem risk factor (the first P), generic questions to collect information on predisposing (or vulnerability) factors, precipitating factors (or triggers to harm), perpetuating (or maintenance) factors, and protective factors will be displayed in structured and interactive format. Predisposing factors' questions which describe the most relevant historical factors that make the individual vulnerable to the identified risk factor will be displayed next. The set of questions to identify historical factors such as previous suicide attempts and bullying at school are branded as gold padlocks questions in GRiST [28.29].

The next set of questions were designed to describe and collect precipitating factors or triggers that would provide an understanding of those short-term variables or acute difficulties or problems that trigger a change in the identified risk. Questions asked on the precipitating factors focuses on issues such as suicidal ideation, recent detrimental change to relationships, and cases of high anxiety. Questions relating to the perpetuating (or maintenance) factors include substance misuse, impulsive behaviour, a show of no regret over suicide attempts, and chronic pain. Perpetuating factors are the subset of predisposing factors that need to be worked around in a risk management plan. These

factors show the characteristics of the individual or his or her situation that will not change in the short- or even medium-term, or change easily [3].

The last set of questions were designed to identify protective factors which describes the strengths or attributes the individual usually draws on to help them to manage risk factors, which can sometimes fail them. This set of protective questions is also described as silver padlocks. The use of the 5Ps framework in GRiST is to help organise risk information and provide a structure for integrating and formulating intervention plan.

The descriptions of the different sets as gold and silver padlocks indicate their potential impact on escalating the identified risk. The gold padlock factors have a high potential of risk escalation. Furthermore, the framework allows relevant risk factors to be considered in terms of their role as predisposing factors meaning that subsequent considerations, about precipitating (trigger), perpetuating (maintenance) and protective factors, emerge from this empirical base [88].

The hierarchical structure of GRiST provides top-down access to the patient data or cues by a series of 'filter questions' that determine whether or not a particular branch of the tree, and thus its associated leaf node cues, are relevant for that patient [28]. For example, there is a high-level filter question asking whether the patient has made any past suicide attempts. If not, this part of the tree is immediately closed off with no further exploration. If, however clinicians say yes, then further questions open up. Clinicians carry out the assessment in this top-down fashion and at the end they are asked to provide their overall risk judgement for the patient in the form of a score ranging from 0 (no risk) to 10 (maximum risk).

GRiST requires clinicians to provide patient risk evaluations for all the risks covered. It also has space for recording additional, qualitative, information about the risks as well as to devise an appropriate action plan. The use of this structured tool thus provided a good opportunity to study how and what risk information was collected, updated and used to formulate risk management plans. Furthermore, the dynamic design of the GRiST interface allows users to enter information dynamically with freedom

to choose which information to enter first and to go backward or forward as the case maybe. There is therefore the possibility of missing out on some information deliberately or by omission.

The argument for the design of the information collection process of GRiST which requires clinicians to complete the rapid screening questions is that it provides the opportunity to consider all areas which mental health experts consider relevant for assessing risk without necessarily having to collect all the detailed data [28]. The flexible interfaces enabled by web-based technologies also allows the clinicians to flag up areas requiring further investigation along the selected and required care pathway in order to allow the collection of the right level of detail that is appropriate to the particular point in the care pathway [29]. It is pertinent to note that the key to clinical risk judgements is an individual patient's qualitative and idiosyncratic cues [93].

Therefore, risk assessments could be improved by the systematic incorporation of the full range of cues considered by clinicians. There is however no agreement on what the full range of cues should be and how they should be combined [192].

5.3.1 The GRiST Hierarchical Task Analysis

GRiST is based on the principle that modern risk assessment should be structured, evidence based and as consistent as possible across settings and across service providers. It is organised in easy to navigate layers:

- Personal Details
- Rapid Screening Questions
- Additional Questions Specific to Particular Risks
- Risk Judgements
- Additional Questions Relevant to More Than One Risk.

The layers are designed for easy navigation and to collect the required information ranging from emergency situations, when the rapid screening questions may be all that is required, to more stable situations when there is time to conduct a more thorough risk assessment. The GRiST system guides the user through the process of navigating the form, to ensure that only the relevant information is collected for a particular service user. (Where the answer to a filter question is 'no' or 'don't know (DK), further questions about an area will not appear) [25, 3, 30].

A decision is made based on the completion of a series of steps/procedures or sets of activities. The series of activities/procedures are put together as the hierarchical task analysis which can serve as the clinical knowledge model for the domain application. GRiST allows expert users to browse the website after logging in to carry out assessment or other tasks with existing or new patients. The expert is able to preview the service user's report and view judgement report, risk formulation report and also the safety plan. Each activity or task has a hierarchy of structured sub-activities which are followed systematically to arrive at a decision point. Each task or sub-task represents some form of knowledge and also represents a source of data collection [26, 27, 28]. The hierarchical task analysis for GRiST is presented in mind map as illustrated in figure 5.

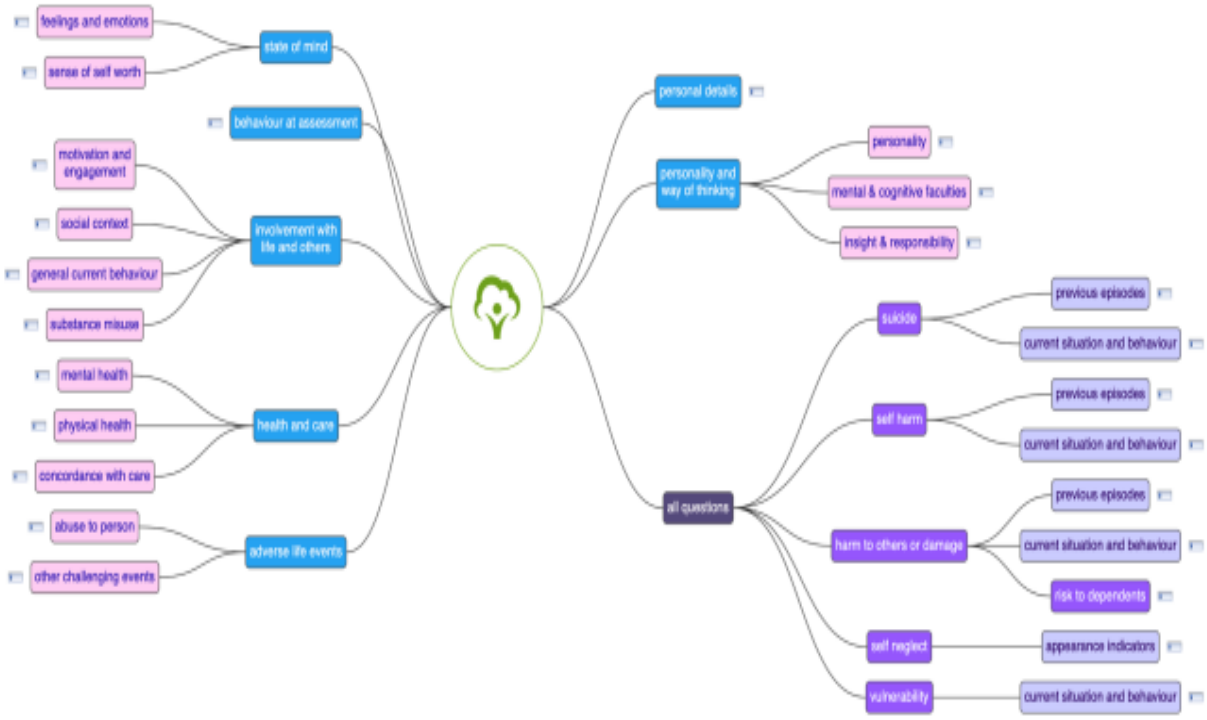


Figure 5: Mind Map of Hierarchical Nodes in GRiST [79]

5.4 GRiST Ontology Data Structures

The risk information underpinning GRiST is represented by a number of related hierarchies or trees. They each have a particular role, either in the knowledge engineering process when the expertise was elicited or during risk assessments using the GRiST DSS [28]. Part of the rationale for GRiST ontology is to formalise the relationships between these trees and facilitate consistency checking. The trees are described below.

5.4.1 The Structure Tree (ST)

ST defines the structuring of risk knowledge by experts, including the low-level risk data or cues that are collected during assessments and their associated questions. It also contains information about how the GRiST DSS will generate membership grades that represent the degree to which a person is a member of the various risk categories. This information is contained by a list of paired values and MGs

(the value-mgs) that defines the specific MG generated by a patient cue when it matches the associated leaf node. The objects of the Galatean model of classification show uncertainty in terms of fuzzy sets or set memberships. The idea behind the ST is to provide a single definition of each concept's structure (e.g., depression) and mark all the different places where the concept might be located throughout the risk tree without having to repeat the structure information (similarly to the idea of normalised databases). XML attributes are used to specify information about how knowledge is distributed in the tree, such as the "generic" attribute that allows the tree to specify the location of a repeating concept and points to the path where the full structure information is defined [27].

5.4.2 The Relative Influence Tree (RIT)

RIT holds information on the relative influences (RIs) of a node, which are essentially weightings for how much influence child nodes have on their parent MG relative to the sibling nodes. RIs range between 0 and 1 and are contained in the RIT rather than the ST because some generic (repeating) nodes have different RIs in different locations. Hence their structure has to be repeated in full in these locations so that the variant RIs can be specified [27].

5.4.3 The Client Assessment Tree (CAT)

CAT is the one that represents the complete classification information about a client. It thus requires all nodes to be fully expanded wherever they occur and is used to drive the graphical interface for the Data Gathering Tool (DGT) that collects information during risk evaluations [27].

5.4.4 The Question Tree (QT)

QT is generated from the structure tree and has all the information needed to display questions, obtain the associated client answers, and generate the membership grades for the answers. It is used

by the DGT as an efficient means of accessing the information it requires without having to navigate the much larger ST.

5.4.5 The Answer Tree (AT)

AT holds the information about a client that is collected during an assessment and is dynamically created as the assessment progresses.

This brief discussion of the various GRiST trees shows how their roles support both the knowledge engineering and risk-assessment processes: that is, the development and maintenance of the GRiST expertise as well as how the knowledge is used within the online DSS. Clearly there needs to be consistency of information across the trees, which is one of the rationales for developing ontology. All the trees are related to each other and any updating of information must be propagated throughout them to maintain their integrity. The ST has information that can create the RIT structure and the RIT has additional information about the RIs [29, 30].

The CAT is the fully expanded tree and the QT and AT are used to support the DSS assessment process. For example, there is a high-level filter question asking whether the patient has made any past suicide attempts. If not, this part of the tree is immediately closed off with no further exploration. If, however clinicians say yes, then further questions open up. Clinicians carry out the assessment in this top-down fashion and at the end they are asked to provide their overall risk judgement for the patient in the form of a score ranging from 0 (no risk) to 10 (maximum risk) [25, 3]. In this way, the hierarchic tree structure drives clinical data collection and provides a systematic approach to how clinicians answer GRiST questions.

The process of collecting service users' information is therefore considered an important stage of the risk assessment and formulation process. The next stage which is equally important is the organisation and use of the collected information based on some rules of classification / categorisation to determine potential risk levels. The next section examines the use of the Galatean model of

classification, which matches service users' information against 'perfect' membership of the risk category to identify maximum risk and not desirable risk.

5.5 Classification in Clinical Decision Making

Risk assessment like all other clinical decision-making activity can best be regarded as a classification activity. It requires assigning a person based on features and similarities to a relevant category such as suicide or self-harm with a degree of certainty. Classification represents uncertainty in terms of set membership and facilitates elicitation of accurate measures of uncertainty. If one considers the outcome categories as sets and the objects being classified as potential members, the likelihood that an object is in any one set is given by the degree of membership. This amount is called the membership grade (MG) [29] which, like probabilities, may vary from 1, representing certainty that an object is in a set, to 0, representing certainty that it is not a member.

GRiST uses this classification approach and represents the integrated risk-assessment knowledge of different clinicians within a single classification model. The "Galatean" model which is argued to encapsulate people's classification behaviour and facilitate elicitation of accurate measures of uncertainty is used in GRiST. It is a psychological classification, constructed by considering judgements and decisions as a classification task. It involves organizing categories and methods of assigning objects to them [31, 25, 26, 27, 28, 3, 29, 30].

The galatea's generic form is a hierarchical tree structure that identifies the patient data for collection during assessments as well as how experts organise the data when making risk assessments. Galateas also contain the values that determine the degree of membership of a patient in the overall risk class (e.g., suicide and harm to others). Because membership grades are associated with all parts of the galatean hierarchy, risk can be decomposed into its constituent elements at any level.

5.6 GRiST Galatean Classification Model

GRiST uses the Galatean classification model based on the prototype theory where abstract member represent a class. The model uses a hypothetical 'perfect' member for its prototypical representation instead of using the mean as the central tendency to define the proto type. The Galatean model is named after the mythical Pygmalion's perfect woman and thus ensures that its perfect member which is termed the galatea is the one whose constituent cues' values yield the highest possible probability of membership.

The galatean model represents uncertainty in terms of set membership. If the outcome categories are to be considered as sets and the items being classified as potential members, the likelihood that an item is in any one set is given by the degree of membership. This amount is called the membership grade [209] which, like probabilities, may vary from 1, representing certainty that an object will be in a set, to 0, representing certainty that it will not be a member [27, 28].

Prior to any classification, the MG will already have been set up with a category Galatea (e.g., suicide) instantiated with component galatean cues (e.g., number of past suicide attempts, history of depression etc). When a patient is presented to the MG for classification, each patient attribute (patient cue) is matched with the corresponding galatean cue. The galatean cue maintains a profile of cue values and corresponding membership grades.

The formal underpinning of the model is to classify the real-world ideas or concepts into their appropriate categories which provides support for different decision support systems for making correct decisions. Most of the time, people recognise, differentiate and predict the things, concepts and ideas on the basis of their categorisation and classification, which lies at the heart of decision support system. The Galatean model of classification provides a unifying framework within which to conceptualise decision making processes as classification behaviour. The Galatean model of classification is necessary for facilitating the classification and decision making of different concepts.

The Galatean model offers a novel theory and its classification theory is a process through which the concepts are classified in their related categories. Classification divides the set of entities in hierarchical form. An abstract root node is a core component of domain knowledge hierarchal structure as that root node has some individual concepts. The individual concepts break down into some essential concepts through a successive top-down iteration process. The leaf or datum nodes are the final concept of the hierarchy.

The use of the Galatean model of classification in GRiST decision support system therefore allows the matching of service users' information against 'perfect' membership of the risk category to identify maximum risk and not desirable risk. It enables easy organizing of categories and methods of assigning objects to them. It also enables data to be captured directly from human experts to create its knowledge domains. Its classification process which enables the classification of things or objects into their natural categories identifies with the generic form of decision making and thus facilitates the making of decisions and predictions. Based on the classification process, the model can easily help to provide advice on which class to choose. The classification theory of the model provides a process through which the identified concepts and the sets of entities are divided in hierarchical form. An abstract root node is a core component of domain knowledge hierarchal structure as that root node has some individual concepts. The individual concepts break down into some essential concepts through a successive top-down iteration process. The leaf or datum nodes are the final concept of the hierarchy.

Each decision class is represented by a single classification model and it is represented by an XML structure termed the Classification Assessment Tree (CAT). CAT alone is sufficient to manage complete knowledge of the knowledge domains having one category or class for making decision for exactly one population. The user's provided data trigger the classification process and the first uncertain variable (i.e., membership grade) of the model is initialised in the leaf nodes of the CAT knowledge hierarchy.

A category is automatically predicted that has a high degree of membership grade. When the model is expanded to many risks many of the concepts are duplicated across all of them [27, 29].

The GRiST ontology is expressed in the web ontology language OWL which provides the ability to declare classes within a hierarchy; declare properties that either have a set of data values or a union of OWL classes as the range; declare individuals of the classes, together with the values of their properties; and use metadata and annotation properties to give information about the ontology. The Galatean model of classification allows users to classify the real-world ideas or concepts into their appropriate categories. The effectiveness of a decision support system lies in the ability of the system to allow users recognise, differentiate and predict the things, concepts and ideas on the basis of their categorisation and classification.

The GRiST and the CDM model using this Galatean model of classification provide this essential platform. The different nodes or components of the data variables modelled in the GRiST structure and the relationships between them are represented by a hierarchical tree structure and uncertainty is processed using fuzzy-set membership grades (MGs). In the GRiST knowledge structure (GKS), there are two main types of nodes (variables), namely concept nodes and datum nodes. Datum nodes are leaf nodes in the tree and thus do not have children. They represent measurable input data such as a person's insight into behaviour. Concept nodes are made up of two or more component nodes, which could be datum nodes or other concept nodes. The individual concepts break down into some essential concepts through a successive top-down iteration process.

5.7 The GRiST Ontology and Risk Formulation

GRiST ontology is a structured tree (ST) available in XML file format. On the top label, we have the mental health risk node. This is then divided into five main areas of mental- health risk. These are suicide, self-harm, harm to others, self-neglect, and vulnerability. A schematic representation of the ST is presented in the following figure:

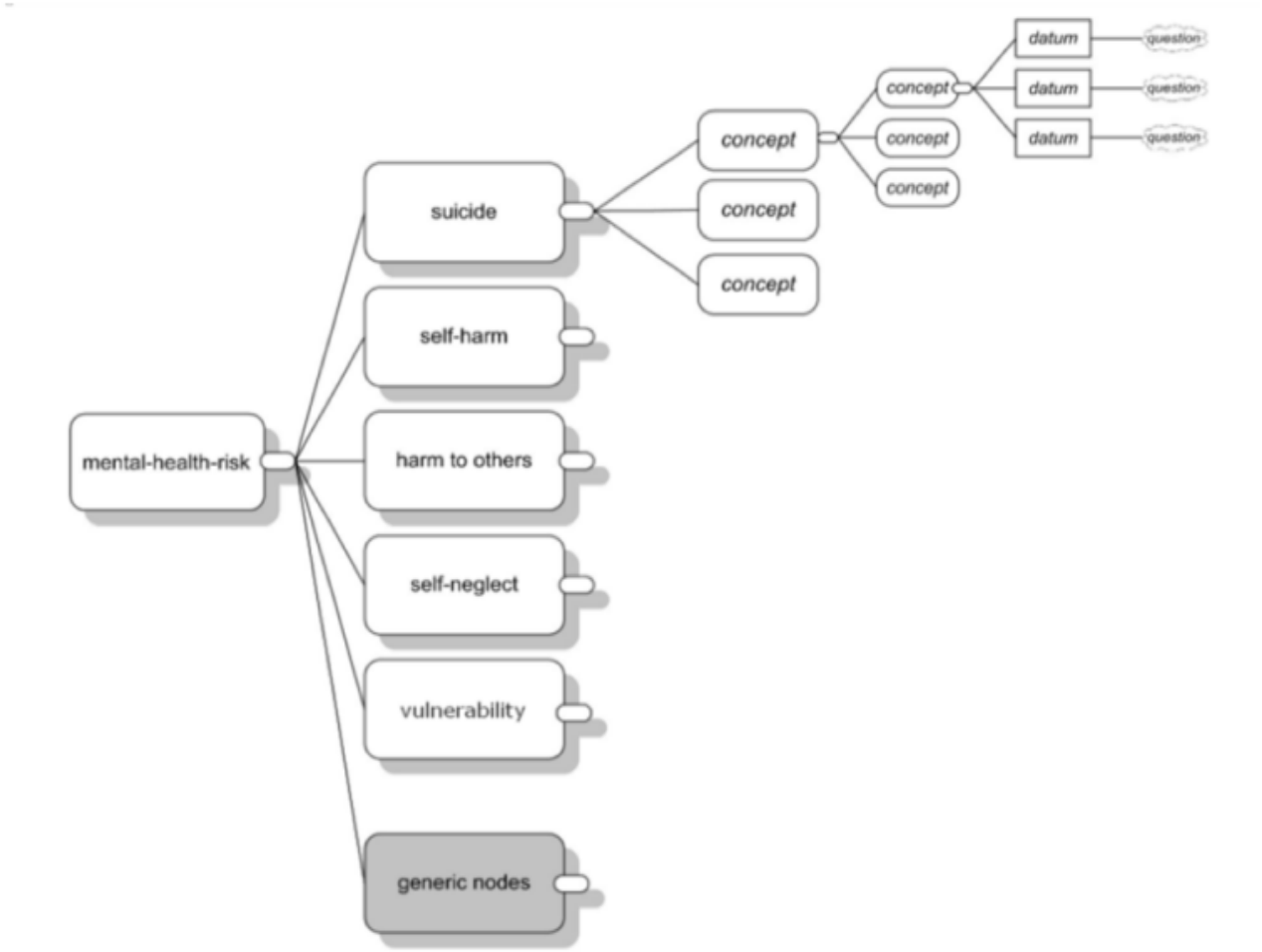


Figure 6: Schematic Representation of the GRiST Structure Tree Below the root node, there are five top-level root risks (coloured white) and one pseudo-risk (coloured grey) to store repeating nodes. Rectangular nodes are datums, with attached clouds indicating question attributes [5].

Each top-level node is subdivided into its constituent's child nodes. The last nodes in the tree are the individual datum or leaf nodes. Each datum node represents a piece of information that can be collected by clinicians. There is a question attached to the leaf node via an additional question attribute.

The risk section of GRiST is categorized into suicide, self-harm, harm to others, self-neglect and vulnerability. The experts tend to concentrate more on this section of risk assessment for the risk judgement to formulate risks.

Risk formulation in GRiST is carried out by organising the overall picture of a person's risks into a format that makes it easier to see how they need to be addressed. In essence, it sits between the risk assessment and the management plan by distinguishing symptoms from causes and identifying the timescale of addressing issues: some must be immediately tackled to reduce the risks now and others are longer term, for reducing risks on a more permanent basis [27, 28, 29]. The overall process of risk assessment is illustrated below:

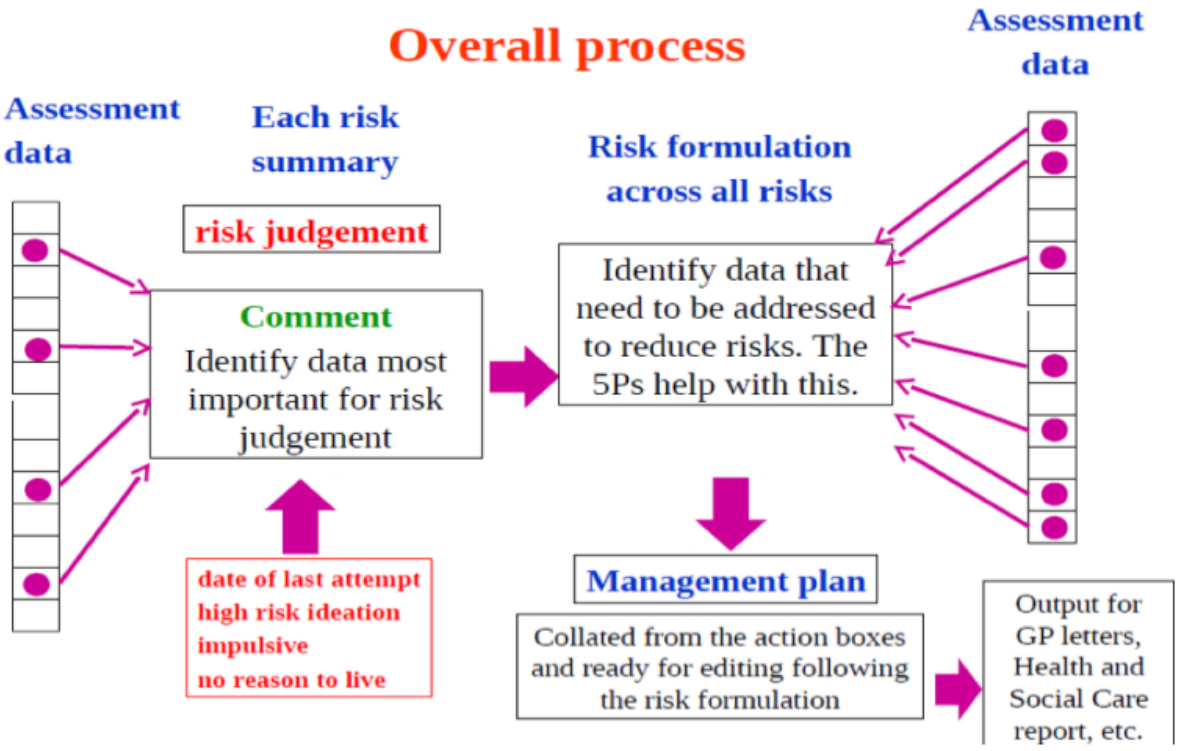


Figure 7: Risk Assessment Processes in GRiST [30]

Information is collated across all the structure present in the GRiST ontology which exposes the probability of potential risk formulation outcomes explaining the elements of the risk factor that may

be managed from those that cannot. The risk judgement link in GRiST does the risk formulation. The purpose of the risk formulation is to connect the symptoms of risks, their causes, and the timescales of managing them. The risk formulation should make it easier to ensure the management plan tackles the most urgent immediate problems as well as the longer-term reasons for those problems.

5.8 Evaluation of Risk Formulation

There is a general consensus in mental health professions that formulation is a core competence and a critical aspect of daily practice [31]. However, there is no common agreement on how the process of formulation which is usually covert or implicit, should be carried out. Literature however agrees on the common features of formulation in mental health which include inferential, action oriented, theory driven, individualised, narrative, diachronic, testable, and ampliative features [73, 28].

These features describe the character of the formulation process and provide a basis for evaluation. The inferential feature of the formulation process implies that risk formulation process goes beyond mere description, statement of facts, or classification to make predictions but provide an explanation or justification for those predictions. It is argued that formulation in mental health is best conceptualized as a form of abductive inference [73]. This characterization highlights two important aspects of abduction: First, the best explanation is only one of many possible explanations of a given set of observations; and, second, it may be superior to others, yet may not be completely, ultimately, or fundamentally correct.

The action-oriented feature of risk formulation process highlights the characterisation of risk formulation to assist the mental health professional to develop an overall understanding of a patient's problems, prioritize treatment issues and problems, plan general treatment strategies and select specific interventions, anticipate the patient's responses to strategies and interventions, evaluate treatment progress, and enhance the therapeutic relationship. The theory-driven feature of risk

formulation suggests that the determination of which facts are noteworthy or identifying which explanations are legitimate requires some a priori guidance based on a theory [73].

Formulation is therefore guided by or embedded in a particular theory of problem cause or solution. Each different theoretical approach predetermines which target behaviours, variables, and treatments are legitimate, as well what constitutes a valid explanation. The individualised feature of risk formulation also suggests that the process is not only driven by theory but also by each person's detailed life history data. A formulation that is not individualized is merely a restatement of the nature and solution of the problems experienced by the average patient [60].

Formulation process is also evaluated by examining its simplicity which considers the degree to which a formulation is free from unnecessary details, propositions, and assumptions. In a survey where clinical risk tools were assessed [155, 60], the opinion of most clinicians centred on the length of the risk assessment tool/process and the time taken to complete it. Other challenges with risk assessment tools include the difficulty in finding relevant information; Information may not always be accessible if updated incorrectly; Difficulty in inputting information and tracking back, leading to details being lost; The use of tools may prevent staff from using experience and clinical judgement and provide false reassurance; tables and tick boxes are not always read by clinicians.

The general conclusion is that risk assessment tools are only as effective as the individual carrying them out and can create a false sense of safety.

5.9 Evaluation of GRiST Assessment and Data Collection Interface

GRiST has been accepted and recommended by the department of Health, UK as a multiple risk tool to provide a platform where information on risk factors could possibly be collected in the easiest, fastest, and simplest manner, based on best practices [28, 31, 51]. GRiST therefore provides a safe, whole health and social care system approach to risk assessment and its management. Achieving this aim thus depends on the effectiveness of the platform in how it collects and organise relevant

information. This brings to question the efficiency of the design of the data gathering interface of GRiST and its ability to provide dynamic features that would allow the exploration of risks and risk factors in orderly manner [28, 31].

The data collection interface is therefore structured to reflect how mental health experts conceptualize risk assessment [25, 26, 27, 28, 30]. GRiST thus provides a holistic approach to patients' situation as it enables the collection of both risk-specific information and also generic information about patients' life contexts. This is made to inform risk formulation and management decisions, as well as clinical risk judgments.

The process of collecting relevant information in Grist therefore need to comply with evidence-based practice and be systematic, structured and holistic. It is thus designed to aid quick and easy collection of information with a system organized in layers, starting with a short series of screening questions that, if answered affirmatively, point to areas requiring further, more detailed investigation.

Thus, the answers to screening questions need to be accurate as it can determine the success of the risk assessment process. However, research shows evidence for the reliability of clinical judgements recorded in GRiST. Mathematical analysis of the GRiST database shows that GRiST can predict the suicide risk judgement a clinician would make for the given assessment within plus or minus one on an 11-point scale with an accuracy of 85%. This further shows that the reliability of the prediction of the suicide risk judgement depends on the assessment information given [79].

Furthermore, the correlation between judgements and predictions is testimony to the reliability of clinicians' judgements which implies that GRiST collects the right data for supporting clinician's risk judgements. GRiST therefore helps clinicians identify the right data to collect, record them accurately, and provide the associated judgements thus providing an effective support for structured clinical judgement [79].

GRiST identifies the data required for determining the reliability of current intention and can ensure that assessments collect this minimum data set. Statistical records of the use of GRiST shows that 32,580 patients did not have the minimum data set and 1,289 suicide attempts were missed in them. It also shows that only 1,849 people of the 3,138 who made a new suicide attempt had enough data in their assessment to evaluate their current intention. GRiST data analysis showed that 1,231 (67%) of them had an unreliable current intention [79]. GRiST would have flagged up two thirds of these as requiring a bit more attention due to the unreliability of their negative current intention [79].

This shows that the key to successful clinical risk judgements is an accurate identification and description of the individual patient's qualitative and idiosyncratic cues presented by the clinicians [93]. Therefore, risk assessments could be improved by the systematic incorporation of the full range of cues considered by clinicians [192]. The dynamic interface design of GRiST allows clinicians to enter information dynamically with freedom to choose which information to enter first and to go backward or forward depending on the clinician's preferred best practice. This however increases the possibility of missing out on some information deliberately or by omission.

The argument for the design is that it provides the opportunity to consider all areas which mental health experts consider relevant for assessing risk without necessarily having to collect all the detailed data [28].

GRiST provides assessments covering the complete care pathway, from screening to full assessments, focused repeat assessments, and specialist versions for forensic services and learning disabilities. GRiST has been adopted by a number of secondary and community mental-health Trusts, and charities with over 160,000 patients and about 380,000 completed assessments as at 2018. The database contains over 1.5 million individual risk judgements which forms the knowledge base of GRiST. This knowledge base is regularly updated to inform evidence-based practice. GRiST is therefore an ongoing research project that is continually being updated and improved [79].

This research on GRiST's assessment and collection of essential information is therefore necessary to assist in the ongoing research update on GRiST.

5.10 Chapter Conclusion

The chapter concludes that key to clinical risk judgements is an individual patient's qualitative and idiosyncratic cues [93] that should be collected in a systematic and structured method. The chapter highlights the importance of a structured and systematic approach to mental health risk assessment which helps integrate information across the patient care pathway. GRiST provides a vehicle with the potential to improve risk assessment practice across the care pathway, by helping clinicians and patients collect and share appropriate information more easily and at a level commensurate with the particular point in the care pathway. The design is aimed at ensuring that its structure and content accurately reflected how mental health experts conceptualize risk assessment, enable the collection of what clinicians consider necessary in order to carry out risk assessment. The web-based technologies underpinning GRiST facilitate flexible interfaces to ensure the right level of detail appropriate to the particular point in the care pathway is collected using the galatean model of classification and the hierarchical tree structure.

Chapter 6 Research Design

6.1 Introduction

GRiST is a web-based decision support system for risk assessment that links mental health expertise to a database of patient cues for mathematical analysis, thus integrating structured clinical judgement with empirical evidence [30]. The Galatean Classification model adopted by GRiST has been examined with a review of its underlying theories and how it supports clinical decision making.

This chapter discusses the overall research design and framework. It illustrates the strategies and techniques adopted in the research to implement the extraction of mental models, analysing them to understand the gap between the clinical decision making of the users' model and the conceptual system model.

The chapter includes the methods and tools adopted in the ultimate success of the proposed framework development. The data for the research is discussed; the means of collecting the data, how the data collected is to be represented and implemented alongside with the general research strategy used in this research.

6.2 Presentation of Research Design

The source of data is collected from risk assessments done by the clinicians while interacting with the Galatean Risk and Safety Technology (GRiST) [30]. Data is stored in the system's database with the processes involved in performing the assessments such as questions answered, not answered are stored. For the purpose of this research, no personal data is analysed. Hence, no personal data is included in the assessments.

The data set in the .csv file format collected only contained 71,023 assessments done in the years 2010, 2011, 2012, 2013 and 2014. This was the set of data available and I was given access to by my supervisor due to some ethical and access issues.

University of Aston being one of the two universities undertaking research and development activities on GRiST, has the privilege of having a large database of over one million patient risk profiles and associated clinical risk judgments which can be accessed for analysis and the improvement of risk prediction and prevention. The university has the NHS Research Ethics Committee approval as a research institute.

The initial design plan was to observe and interview clinicians as they use GRiST for risk assessment with patients in their clinics/hospitals. I applied for ethics approval in the university through my supervisor who did not sign the application and did not approve it, but promised to provide required dataset which I received after many months. The excuse for refusal was that patients may not like been observed and it may not be ethical. I also suggested having interview sessions with some clinicians on their views on GRiST for effective risk assessment and challenges noted. Once again, I was discouraged to take this approach as the ethics approval was denied by my supervisor. The last suggestion of using some medical students and other mental health professionals to use Grist with dummy data and to provide feedback was also rejected.

This left me with the only option of using the dataset provided by my supervisor for the analysis. Although current data were not available, the data set covered a range of five years records of assessments carried out by clinicians which can provide useful trend for analysis. The data is analysed to get a deeper understanding clinicians' thought processes and perspectives on how they make use of the system as well as clinical decision making. The clinical decision-making tool that will be used as a case study for the research is the Galatean Risk and Safety Technology (GRiST), a web based Clinical Decision Support System (CDSS) [30].

6.3 Research Methodology

The overall research methodology covers four distinct stages:

• The data mining stage is cleaning and understanding the user interactions data set.

• Extracting users' mental models using the concept mapping and data analytical tool

• Statistical method is used to evaluate the mental models by analysing assessments; extracting frequent patterns.

• The output of the modelling and analysis are compared with GRiST ontology to identify gaps between users' mental model about GRiST and the system's model. The result of the comparison gives the foundation of the research output in the form if then statements illustrated as decision trees.

The research methodology is summarized in the figure 10 below where I1, I2....In are set of inputs; P1, P2..., Pn are set of patterns extracted from the data transformation stage; R1, R2...Rn are set of Rules elicited from the mental models derived from the set of patterns; the rules are represented as decision trees using the ID3 Algorithm.

The data mining stage involves preparing and cleaning the data ready for analysis. Data preparation involves understanding the data collected. The nodes and different data attributes are identified with the conceptual processes of the use of GRiST.

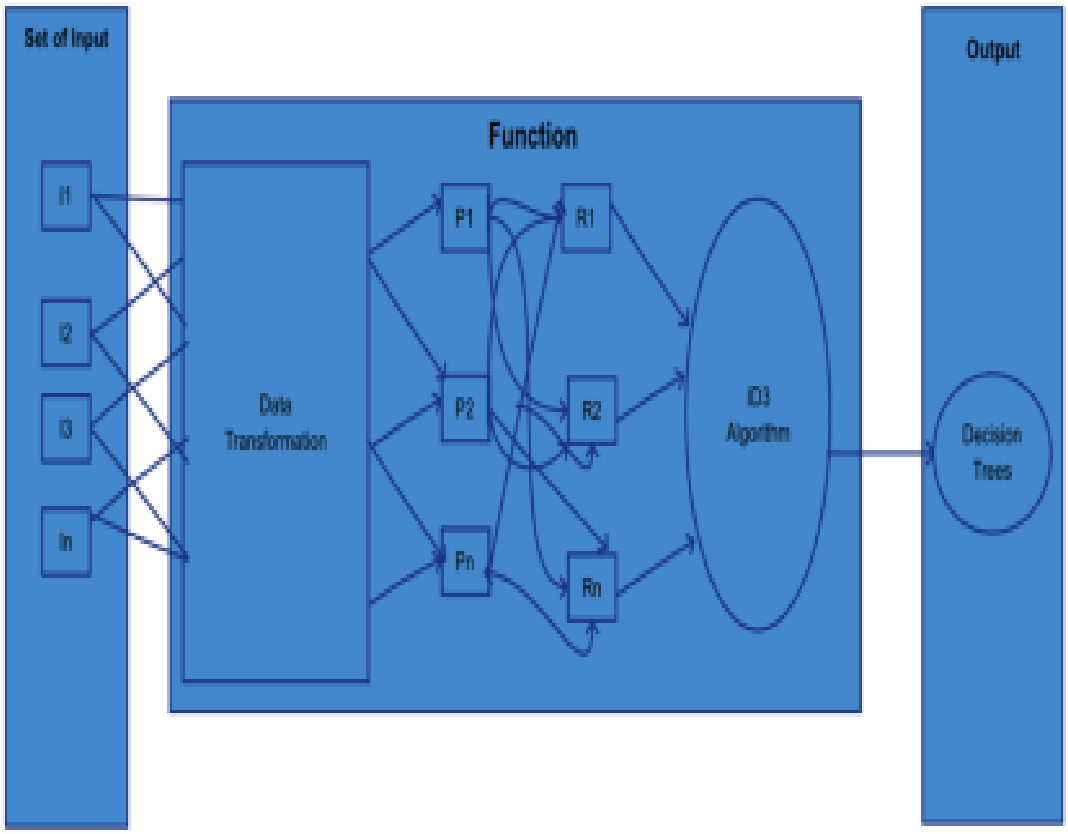


Figure 8: Synopsis of the Research Methodology Illustrating Input, Function and Output

Data cleaning involves ensuring the data is in the right format with the choice of software to be used for the data analysis. Personal data were removed from the data to ensure the confidentiality of the analysis. This was to ensure that the data used was effectively anonymised that it does not relate to any identified or identifiable individual.

The data set was also used for the academic purpose it was collected for and was not shared with any third party. Concept analysis would be carried out to identify the number of concepts expressed in the interactions, identify the number of functional linkages, i.e., causal relationships, expressed, and to determine the density of the mental model or the ratio of functional links to concepts.

The research design is illustrated in figure 9 as follows:

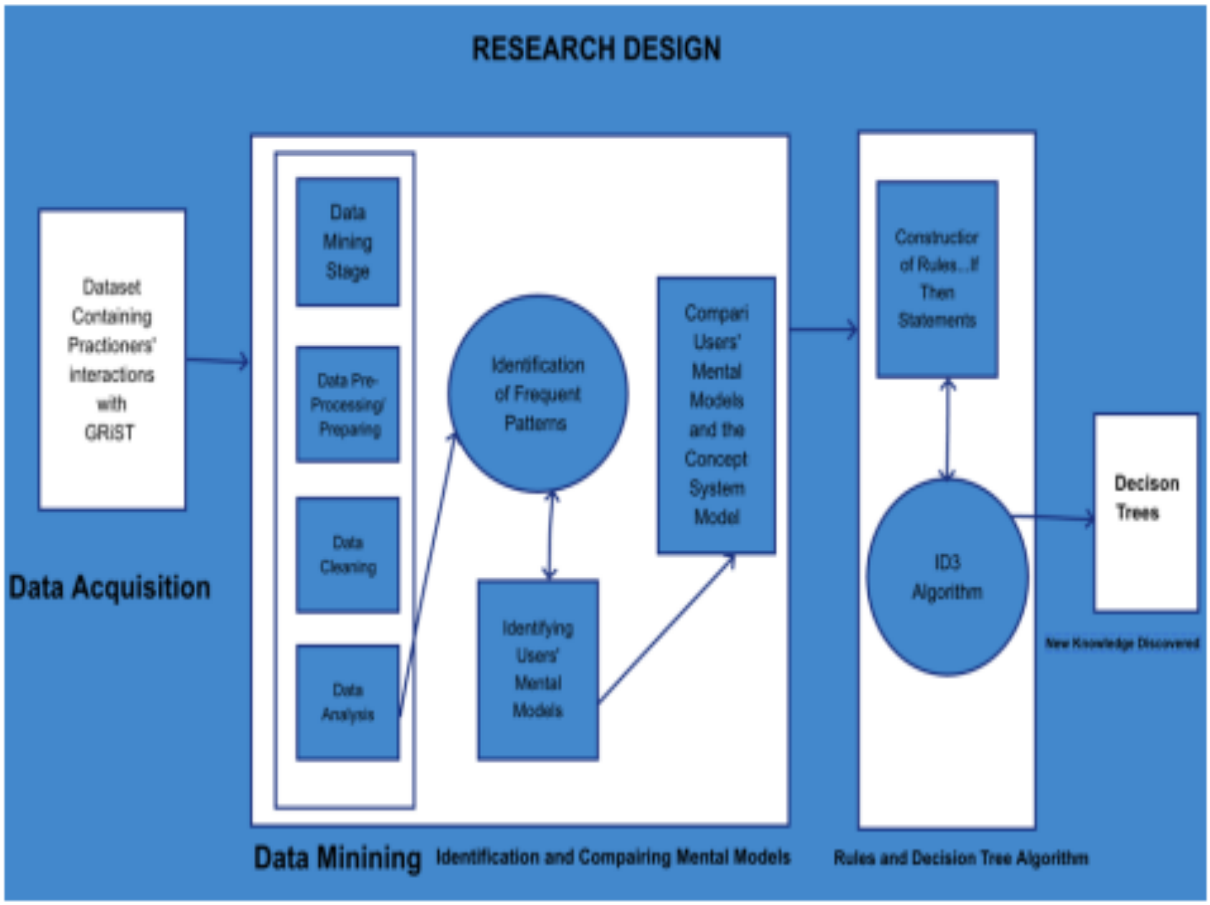


Figure 9: The Overall Research Design

6.3.1 Choice of Data Analytical Tool

Knowledge discovery from data set involves examining and creating knowledge, understanding the processed to be used to elicit or recover the potential knowledge. A crucial part of the knowledge discovery process is a thorough identification of interactions patterns from the metadata.

This involve identifying the relationship of the attributes and entities in relation to the specific data. This can be enormous to implement or manage especially when the data is voluminous; this is beyond manual as it will be time draining and inefficient; hence, the need to make use of capable tools to analyse the data.

Data analysis involve data visualization of information extracted from the dataset. In fact, visualization and data analysis works hand in hand [6]. Due to the nature of the data gotten, it is essential to be able to view analytics for to enhance the decision-making process. Complex ideas are easily understood and aids in the identification of new patterns.

There are different ways in which variable and attributes of a data set can be viewed in a particular methodological layout. These include the use of tables, charts such as bar chart, line charts, pie charts, regression charts etc. These are used regardless of any mathematical analysis and hence can be recognised as data mining techniques [6].

The choice of data analytics tool for this research is based on three factors. Firstly, is the ability of the software to project analytical visualisation of the data in a user-friendly interface. Secondly, how easy the tool can be used in analysing data to extract patterns and construct mental model and thirdly, how fast the software can analyse the type of data.

Out of the big data analytical tools that can easily analyse data, visualise data and give useful information was a comparison by Rajeswari, C. et al [168] featuring R [198]and Tableau [193]. The performance of the tools using two different multivariate datasets was investigated using .CSV and .XLSX for both R and Tableau respectively. The analysis showed that Tableau is better for data analytics and decision making compared to R. Tableau is faster in analysis big data, user friendly interfaces by providing attractive visual representation of data; such as charts and tables. It provides different platforms for analysis through its different versions (Tableau Server, Tableau Desktop, Tableau Online and Tableau Reader). The graphical abilities of R, are good with a complete programmable design. However, notable disadvantage of R is the level of difficulty of the R Programming Language and time consuming to learn if not an expert already. Initial data processing is needed in Tableau by preparing and cleaning the data [168].

Tableau is chosen for this research as Tableau has an excellent user interface. Its integration feature is also very attractive as it can be integrated with other advanced big data analytical

technology/platforms such as Hadoop. It is fast in both usage and computational abilities. Tableau allows connection to data in the cloud (that is, big data, SQL, spreadsheet, or Google Analytics), build calculations from existing data, create reference lines and forecasts, make trend analyses, regressions, and correlations, with respective statistical summaries. The pattern of the analysis is illustrated using statistical method by cumulating the sum of assessments illustrating the pattern.

The patterns are ensured to align with the standard and filter questions in GRiST. The highest value of the patterns is highlighted which are then used in the construction of the mental models in each section of the suicide specific questions illustrating the suicide risk assessments. The result and interpretation of the data analysis is used for the construction of the clinicians' mental models.

The differences between the users' mental models and the conceptual model are extracted and serve as the foundation of the proposed framework which serves as the contribution to knowledge serving as recommendations to enhancing clinical decision making and the overall usage of GRiST

6.4 Framework Presentation

The aim of the analysis is the extraction of mental models; to understand the pattern of practitioner's interaction with the system. The mental models are compared with how it is expected to use the system (conceptual model of the system). The gap between the models is interpreted and serve as the foundation for the research framework necessary for the enhancement of the clinical decision making [123, 172]. The interpretation forms a new knowledge discovered in the research and the representation and implemented using rule-based system. The rule base (also called the knowledge base) is the set of rules which represents the knowledge about the domain. The general form of a rule is:

If cond1 and cond2 and cond3 ... then action1, action2, ...

Such rules are interpreted to mean that if the antecedents of the rule together evaluate to true (i.e., if the Boolean combination of the conditions is true), the actions in the consequents (i.e., action1,

action2, etc.) can be executed. The Rule based methodology is chosen because it is easy to understand, and the syntax is easy to learn and use. These basic advantages of the rule-based methodology make it easier for rules to be well represented and that the overlapping of rules is minimized to the barest minimum. The fact that the rules are represented in the very direct fashion makes it easy to use and the future implementation of the research framework are easily done. Also, in situations that the rules are to be checked, it is easy to trace and debug [123].

6.5 Construction of Rule Based Systems

The construction of the rules is implemented using the data-based approach method. One of the reasons is the method of data collection used; the research makes use of dataset derived from clinicians' interaction with the system due to the fact that expert knowledge may be incomplete or inaccurate due to the biased nature of other knowledge gathering techniques. Data engineers may misinterpret the users' requirements or misjudge the competency of users [123]. System build on biased knowledge may be difficult to correct or amend when encountered error or system failure. With the data approach, some unknown knowledge can be discovered from the data. This data may also be used to support the pattern extracted while modelling the data [123]. More importantly, since the data is collected when experts are making use of the system in carrying out assessments, any analytical modelling technique used could be revised automatically as the update of database in real time. Therefore, data-based approach may be more suitable than knowledge-based approach for construction of the rules for this research. The rules extracted is detailed in Appendix A section the research.

Below is the sample of the rules generated:

```
no value = don't know
Value= 1,2,3,4,5,,,10
if (suic = 'yes') {
        cat ("suic-attempt options = yes and no")
}
#don't know option should be disabled for suicide specific leaf question

if (suic-past-att = 'yes') {
        cat ("no option to input suicide attempt date")
}
if (suic-freq = "yes") {
        cat ("suicide attempts change frequency options")
}

#no option including don't know has if suic freq has been answered, an
#answer is expected.
if suic-past-att = no {
        (suic-id-freq = no value)
}
```

Figure 10: Sample of Rules Created

6.5.1 Rule Based System Representation

The rules are then represented in decision trees. Decision tree is one of the most popular methods for inductive inference. If then statements can be represented in decision trees and vice versa. The decision tree is useful in clarifying instances by sorting them down the tree from the root to the leaf node. The leaf node provides the classification of the instance [191, 177]. A decision tree can be built using many algorithms. Among them Iterative Dichotomiser (ID3) tree is most used method which is discussed in the next section.

6.5.2 Decision Tree Algorithm

ID3 constructs decision tree by employing a top-down, greedy search through the given sets of training data to test each attribute at every node starting with the root node. Then the property values are

generated corresponding to each branch. Each branch has generated new node. For the best attributes of the selection criteria, ID3 using entropy-based definition of information gain to select the test attribute within the node. Entropy characterizes the purity of any sample set [191].

The decision trees are represented using mind mapping technology. Mind mapping, which is also called “clustering ideas”, is a way of collecting ideas around a particular topic and defining connections [32]. A mind map software is a tool that helps in the development of mind maps. Mind maps and decision trees are related as they are both hierarchical in nature representing ideas and their relationships using starting from the root node. The Decision tree is illustrated using mind map. The software chosen is the Free Plane software [76].

The resulted decision trees are detailed in Appendix B section the research. Below in figure 13 is a sample of a decision tree of the GRiST suicide question nodes in Freeplane:

The research data has been explained and understood. The choice of the computer aided tool and knowledge representation methods are also justified. The different stages of the data analysis are also illustrated. The detailed methodology implementation is described in the data analysis, results and conclusion presented in the next chapter.

Chapter 7 - Data Presentation

7.1 Introduction

This chapter presents the data collected in form of users' interactions with GRiST for risk assessment over a period of use. The chapter also presents the analysis of the data in terms of the various types of assessments, concepts investigated, questions answered or omitted, pattern of answers given for each of the questions, clinicians' general pattern of interactions and users' behaviour. The analysis highlights the process of collection of data and process of risk assessment as modelled by GRiST, and the preferred pattern or process convenient for the user and the clinical workflow. The highlights of the analysis will help in the elicitation of users' mental model based on their interactions with GRiST as they carry out the risk assessment process.

7.2 Data Summary

The data to be evaluated gives an overview of what clinicians collect in completing assessments, investigating the consistency and completeness of the assessments based on the data collected. GRiST has been designed with lots of filter questions, to make navigation of the document quicker. If the answer "no" to a filter question, the next set of filter question is presented without having t answer more detailed questions relating to the question. The technology guides clinicians through the process of navigating the form, to ensure that only the relevant information is collected for a particular service user. (Where the answer to a filter question is 'no' or 'don't know (DK), further questions about an area will not appear).

Although GRiST does not directly collect intervention and outcome information following an assessment, it does contain relevant data for those patients who have more than one assessment. An important piece of information recorded for all patients who have a history of suicide attempts is the date of the most recent attempt. If this has changed between assessments then it means the person

has carried out a new suicide attempt. The data provide the membership grades (MG)/raw values associated with the given columns. The leaf node data are the ones that are used to evaluate the risks, but filter nodes are contained in the columns because the answer to these determine whether the underlying leaf node data are missing or are undefined. They are undefined if the filter question answer is NO because the data only apply if the answer is YES. If filter questions are answered as YES. The values of the answers for the filter question are represented as 0,1,2„,10; low to high degree respectively. A case of no input; missing data or don't know answer is represented as \N

7.3 Data Columns Representing Assessment Nodes in GRiST

The relationship between the assessment modes is represented in mind map, illustrating the different nodes to carry out the risk assessment and carry out the clinical decision making. This research focuses on the suicide node of the decision making of GRiST which accounts for the majority of mental health cases, the suicide section is also the most commonly used section for assessment; the suicide section of GRiST focusses on the precious episodes of suicide and current situation and behaviour. The suicidal assessment investigates a number of factors; such as the state of mind, personality and way of thinking, heath and care, involvement with life and others, adverse life events, person's behavioural presentation during assessments. These factors help in the decision-making process of the assessment of the service user of being suicidal. The figure below illustrates the different core questions in GRiST Suicide specific questions (Left Hand Side) under the branches section:

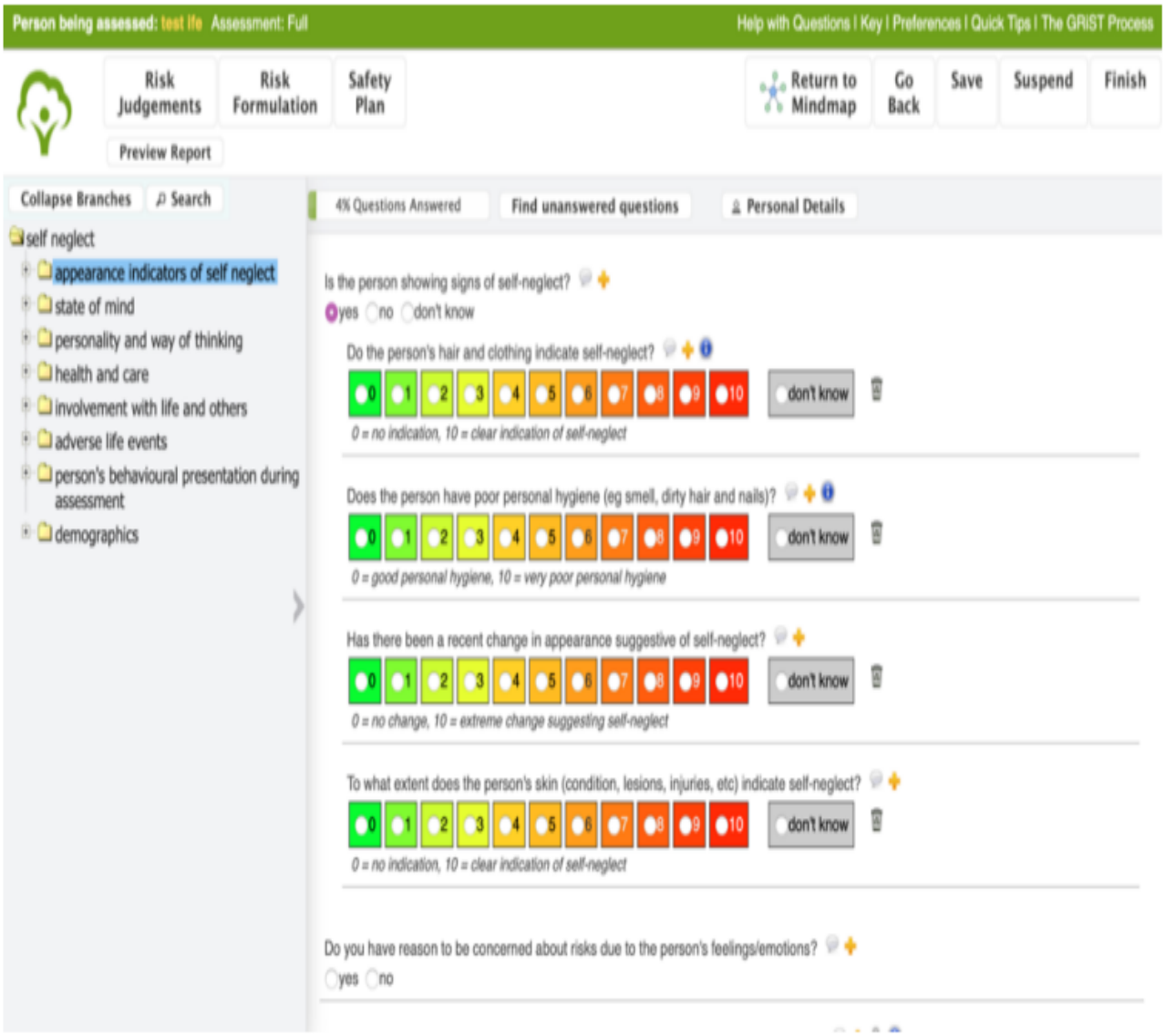


Figure 12: GRiST Question Interface [79]

A total of 171 concepts are extracted from the data; due to ethics and data protection; two concepts are not used in the analysis; the patient ids and the assessment ids were removed. Each concept corresponds to the questions asked in GRiST. For example, “GEN-ETHNICITY” represents the Ethnicity question in GRiST; “GEN-GENDER” represents gender question in GRiST. Concepts extracted that violate the ethics of academic research were excluded from the analyses; the PAT-ID and the ASSESSMENT-ID were removed from the data prior to analysis. The data was loaded to Tableau; a data mining tool to extract the concepts in the data; which appear at the left-hand side of the software.

The concept listed were stored in the database relating to the data source. The list of 169 analysis ready extracted concepts are illustrated below:

S/N	Concepts	Meaning
1	SUIC-DISCOVERY	Suicide Discovery
2	SUIC-LETHALITY	Suicide Lethality
3	SUIC-SER-SUCCD	Suicide Attempt Success
4	SUIC-REGRET	Suicide Regret
5	SUIC-LETH-INSGHT	Insight to Suicide Lethality
6	SUIC-CURR-INT	Current Intentions to Complete Suicide
7	SUIC-PLANS	Suicide Plans
8	SUIC-PLAN-REAL	Suicide Plans Making Real
9	SUIC-STEPS-TAKN	Steps taken for commit Suicide
10	SUIC-PROSP-LETH	Potential Lethality of Suicide Method
11	SUIC-INT-INFORM	Informed Others about Suicide Intentions
12	SUIC-EOL-PREP	Suicide End of Life Preparations
13	SUIC-S-H-BEHV	Suicidal Suitation and Behaviour
14	SUIC-REL-BELIEF	Belief impact on Suicide Risk
15	SUIC-INT-P-TRIG	Potential Triggers of Suicide Intentions
16	SUIC-POT-TRIG	Potential Triggers of Suicide
17	SUIC-P-TRIG-MTCH	Potential Triggers Match to commit Suicide
18	SUIC-FAM-HIST	Suicide Family History
19	SUIC-IDEATION	Suicide Ideation
20	SUIC-ID-CONTROL	Suicide Ideation Control
21	SUIC-ID-HI-RISK	Suicide High Risk
22	SUIC-ID-FREQ	Frequency of Committing Suicide
23	SUIC-ID-STRNGTH	Strength, Intensity of Suicidal Ideation
24	SN-APPEARNCE	Appearance Indicators of Suicide
25	SN-HAIR-CLOTHES	Hair and Clothing Indicative of Self Neglect
26	SN-HYGIENE	Personal Hygiene
27	SN-RECNT-APP-CHNGE	Recent Change in Appearance of Self Neglect
28	SN-SKIN	Recent Change in Appearance of Self Neglect
29	GEN-FEEL-EMOT	Emotional Feelings
30	GEN-MOOD-SWINGS	Mood Swings
31	GEN-NEGATIVE-SELF	Feeling Negative about Self
32	GEN-PLANS-FUTURE	Future Plans
33	GEN-LIFE-NOT-LIVNG	Feeling Life not worth Living
34	GEN-ANGRY-EMOTNS	Feeling Angry
35	GEN-ANX-EMOTNS	Anxious Emotions
36	GEN-HELPLESS	Helplessness
37	GEN-SAD	Feeling Sad
38	GEN-DISTRESS	Distress
39	GEN-JEALOUS	Feeling Jealous
40	GEN-SELF-WORTH-P	Self Worth

Table 1: List of Data Concept (a)

S/N	Concepts	Meaning
41	GRANDIOSITY	Grandiosity
42	WORTHLESSNESS	Worthlessness
43	GEN-PERSONALITY	Personality
44	GEN-ASSERTIVE	Assertiveness
45	GEN-EMPATHY-ABIL	Ability to Emphasize
46	GEN-DEPENDENCE	Dependence
47	GEN-CONTROLLING	Controlling/Organisation Approach
48	GEN-COPING-ABIL	Ability to Cope with Major Life Stress
49	GEN-HOSTILE	Hostility
50	GEN-IMPULSE	Impulsiveness
51	GEN-RELIABLE	Reliability
52	GEN-PERS-DIS	Personality Disorder
53	MENT-FAC	Mental Faculty
54	GEN-IMPAIRD-COG	Impaired Cognitive Function
55	GEN-COG-THINK-MEM	Changes in Thinking and Memory Processes
56	GEN-CONCENTR	Concentration
57	GEN-LEARN-DISAB	Learning Disability
58	INSIGHT-RESP	Insight and Responsibility
59	GEN-INSGHT-BEHVR	Insight Behavour
60	GEN-RESP-IMPCT-OTH	Responsibility for Impact of Behaviour on Others
61	GEN-ND-HLP-DIFF	Need for Help with Difficulties
62	MENTAL-HEALTH	Mental Health
63	CLIN-DEPRESSION	Clinical Depression
64	GEN-DEP-STAGE	Depression Stage
65	GEN-MNTL-CUR-SYMPT	Mental Current Symptoms
66	GEN-MANIA	Mania Voices/Behaviour
67	GEN-VOICE-HAL	Voice Halluciniations
68	GEN-VOICE-DANG-S	Acting on the Voices to Harm Self
69	GEN-VOICE-DANG-O	Acting on the Voices to Harm Others
70	GEN-PROB-ACT-VOICE	Probability on Acting on Voice
71	GEN-PARANOID-DEL	Paranoid Dellusions
72	GEN-PARAN-DEL-SPEC	Paranoid Dellusion Specifications
73	GEN-PARAN-DEL-PERS	Paranoid Dellusion on Particular Person
74	GEN-PROB-ACT-PAR-DEL	Probability of Acting on Paranoid Dellusions
75	GEN-PHYS-HLTH-PRB	Heath Problem
76	GEN-CHRONIC-DISEASE	Chronic Disease
77	GEN-PHYS-HLTH-DEG-DIAG	Degree of Physical Health Diagnosis
78	GEN-PHYS-HLTH-PAIN	Physical Health Pain
79	GEN-PHYS-HLTH-DISA	Physical Health Dextrerty
80	GEN-COM-IMP	Communication Impairement

Table 2: List of Data Concept (b)

S/N	Concepts	Meaning
81	GEN-PHYS-HLTH-DET	Deteriorating Physical Health
82	GEN-MEDS-THERPY	Medication and Therapy
83	GEN-MEDS-CONCORD	Medication Concordance
84	GEN-SERV-PERC-SUPP	Perception of Support Service
85	GEN-MED-PERC-BENFT	Perception of Medication Support
86	MOTIVE-ENG	General Motivation in Life
87	GEN-PHYS-WITHD	Physical Withdrawal
88	GEN-MENTAL-WITHD	Mental Withdrawal
89	GEN-MOTIVATION	Motivation
90	GEN-LISTLESS	Feeling Listless
91	GEN-SOC-CONTXT	Social Context
92	GEN-RELATNSHPS	Relationships
93	GEN-NET-RELAT	External Network of Relationship
94	GEN-RELAT-SUPP	Supportive Relationship
95	GEN-RELAT-DETR	Detrimental Relationship
96	GEN-RELAT-DETR-CHG	Detrimental Changes to Relationship
97	GEN-LIVING-ARR	Living arrangement
98	GEN-MOVE-FREQ	Frequency of moving accommodation
99	GEN-ACCOM-LOSS	Loss of Accommodation
100	GEN-HOME-TYPE	Accommodation/Home Type
101	GEN-ISOL-ACCOM	Isolated Accommodation
102	GEN-NEIGBRHD-RSKY	Risky Neighbourhood
103	GEN-ACCOM-HM-CARE	Accommodation/Home Care
104	GEN-ACCOM-HABITBL	Accommodation fitness to live
105	GEN-FINANCE-EMPL	Finances and Employability
106	GEN-PERC-DEBT-ANX	Perception of Debt Anxiety
107	GEN-POVERTY	Poverty
108	GEN-JOB-CHG-FRQ	Frequency of Job Changes
109	GEN-REC-BAD-JOB-CH	Recent Bad Job Changes
110	GEN-CURRNT-BHVR	Current Behaviour
111	GEN-RSK-BEHAVR	Risky Behaviour
112	GEN-UNINT-RISK-BEHAVR	Unintented Risky Behaviour
113	GEN-SLEEP-DIST	Sleep Disturbance
114	GEN-UNUSL-REC-BHVR	Unusual Recent Behaviour
115	GEN-CHALL-BHVR	Challenging Behaviour
116	GEN-DAY-STRUCT	Day Structure
117	GEN-DAY-ACTVTY-LEV	Level of Day Activities
118	GEN-DIET-EATING	Eating Diet
119	GEN-DIET-WEIGT-EXT	Extreme Weight Change
120	GEN-DIET-WEIGT-CHG	Weight Change

Table 3: List of Data Concept (c)

S/N	Concepts	Meaning
121	GEN-DIET-DRINK	Drinking Diet
122	GEN-SUBS-MISUSE	Substance misuse
123	GEN-ALC-MISUSE	Alcohol Misuse
124	GEN-DRUG-MISUSE	Drug Misuse
125	ADV-LIFE-EVENT	Adverse Life Event
126	GEN-LIFE-ABUSE	General Abuse
127	GEN-LIFE-SEX-ABUSE	Sexual Abuse
128	GEN-SEX-ABSE-LAST	Last Sexual Abuse Experience
129	GEN-SEX-ABSE-AS-CH	Experience of Sexual Abuse as a Child
130	GEN-PHYS-ABSE	Physical Abuse
131	GEN-PHYS-ABSE-LAST	Last Physical Abuse Experience
132	GEN-PHY-ABSE-AS-CH	Physical Abuse Experience as a Child
133	GEN-EMOT-ABSE	Emotional Abuse
134	GEN-EMOT-ABSE-LAST	Last Emotional Abuse Experience
135	GEN-EMO-ABSE-AS-CH	Emotional Abuse Experience as a Child
136	GEN-FINANCIAL-ABUSE	Financial Abuse
137	GEN-FORENSIC-PROC	Forensic Proceedings
138	GEN-FORENSIC-PROC-CURR	Current Forensic Proceedings
139	GEN-ENV-GREW-UP	Environment Service User Grew Up
140	GEN-EATING-DIS	Eating Disorder
141	GEN-EDUC-EXPR	Educational Experience
142	GEN-PRESENTATION	Presentation/Serious Injury
143	GEN-ENGAGEMENT	Engagement
144	GEN-RAPPORT	Rapport
145	GEN-RESPONSVE	Responsiveness
146	GEN-GUT-ASSMNT	Gut Feeling Assessment
147	GEN-RISK-VERBAL	Verbal Risk
148	GEN-RISK-AGGRSV	Risk of being Aggressive
149	GEN-RISK-UPBEAT	Risk of being Upbeat
150	GEN-COHERENCE	Coherence
151	GEN-BODY-FACE	Body and Face Injuries
152	GEN-DISTRSS-B-LANG	Distress in Body Language
153	GEN-LOW-MOOD	Low Mood
154	GEN-THREAT-MOVE	Threat Movement
155	GEN-DETACHED	Feeling Detached
156	GEN-AVOID-EYE-CONTACT	Avoiding Eye Contact
157	GEN-EYE-MOVEMENT	Eye Movement
158	GEN-CONGRUENCE	Congruence
159	GEN-AGE	Date of Birth
160	GEN-GENDER	Gender

Table 4: List of Data Concept (d)

S/N	Concepts	Meaning
161	GEN-MARITAL-STATUS	Marital Status
162	PARTNER-SHARE-ACC	Patner Shairing Accommodation
163	GEN-ACCOM-SHARE	Accommodation Share
164	GEN-ACCOM-DEPNDNTS	Accommodation Share with Dependents
165	GEN-ACCOM-NUM-DEP	Number of Dependents
166	GEN-DEP-YGNST-AGE	Youngest Dependent Age
167	GEN-ACCM-SHARE-ND	Numbber of Non-Dependents Shairing Accommodation
168	GEN-ETHNICITY	Ethnicity
169	MAPPA	Menmber of Multi-Agency Public Protection Arrangements

Table 5: List of Data Concept (e)

The data was loaded to Tableau; a data mining tool to extract the concepts in the data; which appear at the left-hand side of the software. The concept listed were stored in the database relating to the data source. Data analysis was carried out using Tableau software which provided a detailed analysis of the data concepts and the pattern of answers given by different user. These identified patterns were used to construct the users' model in chapter 8.

The figure of Tableau with the listed concepts is as follows:

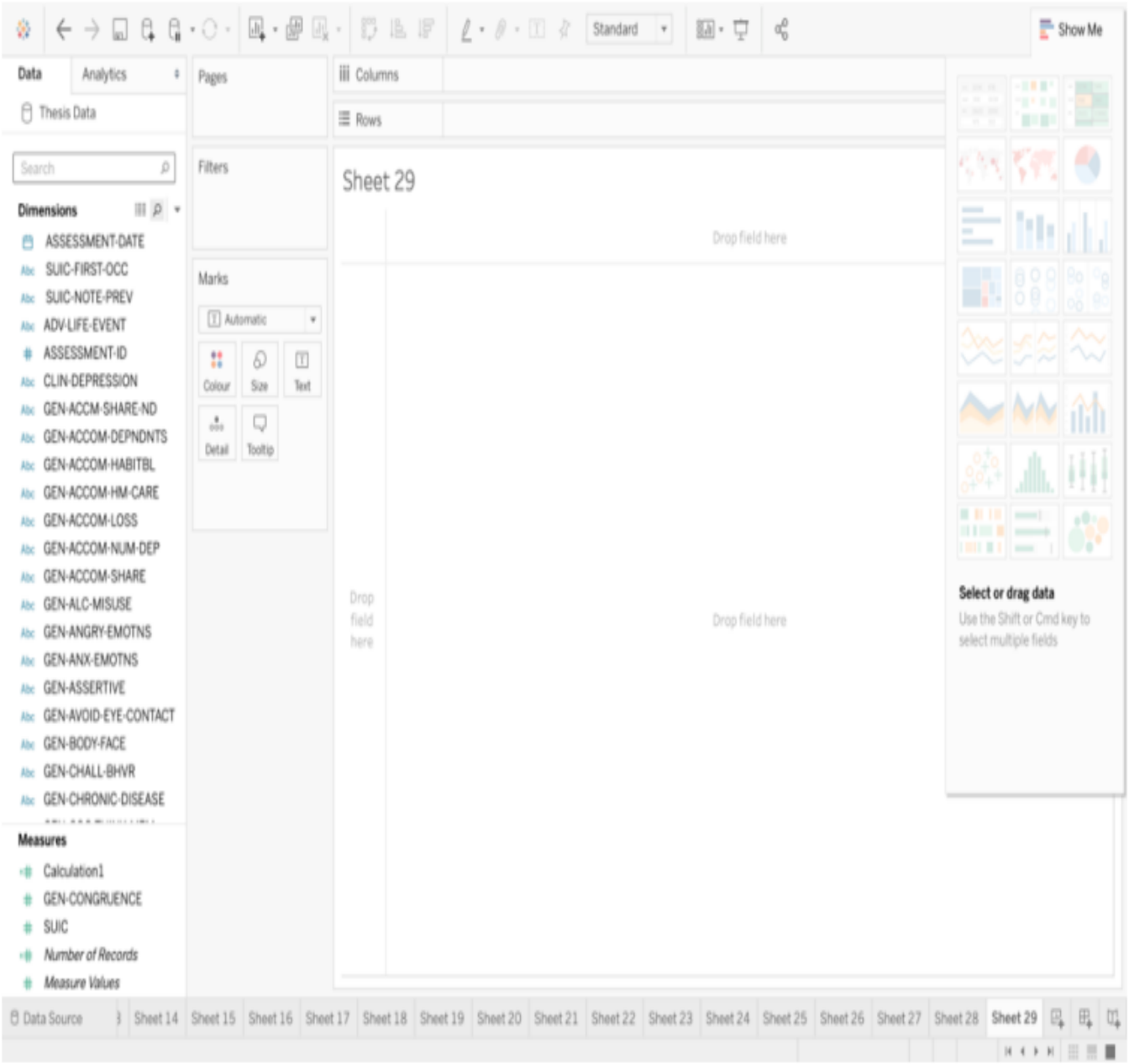


Figure 13: Tableau interface listing the data concepts [193]

7.4 Assessments' Demographic data

A total number of 71,023 assessments are analysed in the research. The assessment spanned over the span of 5 years from 2010 to 2014. Total number of assessments in the years increased steadily over the period of time the assessments were made. The distribution of number of assessments is illustrated in the figure below:

ASSESSMENT-DATE				
2010	2011	2012	2013	2014
3,845	9,955	13,674	21,057	22,492

Figure 14: Overview of Total Assessments

The data has been collated from May 2010 till December 2014. The distribution of total assessments over the period of data collection is illustrated in the figure below:

	ASSESSMENT-DATE				
Month of ASSESSMENT-DATE	2010	2011	2012	2013	2014
January		623	980	1,861	1,966
February		664	966	1,530	1,740
March		805	963	1,649	1,931
April		788	900	1,704	1,952
May	138	788	1,025	1,884	1,988
June	213	781	948	1,732	1,937
July	425	837	1,044	1,830	1,983
August	738	875	1,018	1,756	1,663
September	530	919	1,111	1,659	1,946
October	610	949	1,535	1,898	2,186
November	654	963	1,736	1,796	1,930
December	537	963	1,448	1,758	1,270

Figure 15: Distribution of Total Assessments

The steady increase of the number of assessments over the period of years is illustrated in the line char below: The assessments were carried out on service users of different ethnicity. A total of 16 ethnic groups were extracted from the data with a no value in ethnicity of 530 assessments. The ethnicity groups are illustrated in the figure below:

Figure 16: Progression Chart of Number of Assessments Collected

GEN-ETHNICITY	
\N	530
BANGLADESHI	24
BLACK-AFRICAN	111
BLACK-CARIBBEAN	18
CHINESE	74
INDIAN	69
OTHER-ASIAN	151
OTHER-BLACK	34
OTHER-ETHNIC	336
OTHER-MIXED	337
OTHER-WHITE	944
PAKISTANI	53
WHITE-ASIAN	81
WHITE-BLACK-AFRICAN	52
WHITE-BLACK-CARIBBEAN	83
WHITE-BRITISH	67,705
WHITE-IRISH	421

Figure 17: Ethnicity Groups in Assessments

The highest number of ethnicities represented in the assessments is the White British representing 67,705 out of 71,023 total assessments which is 95% of the assessments.

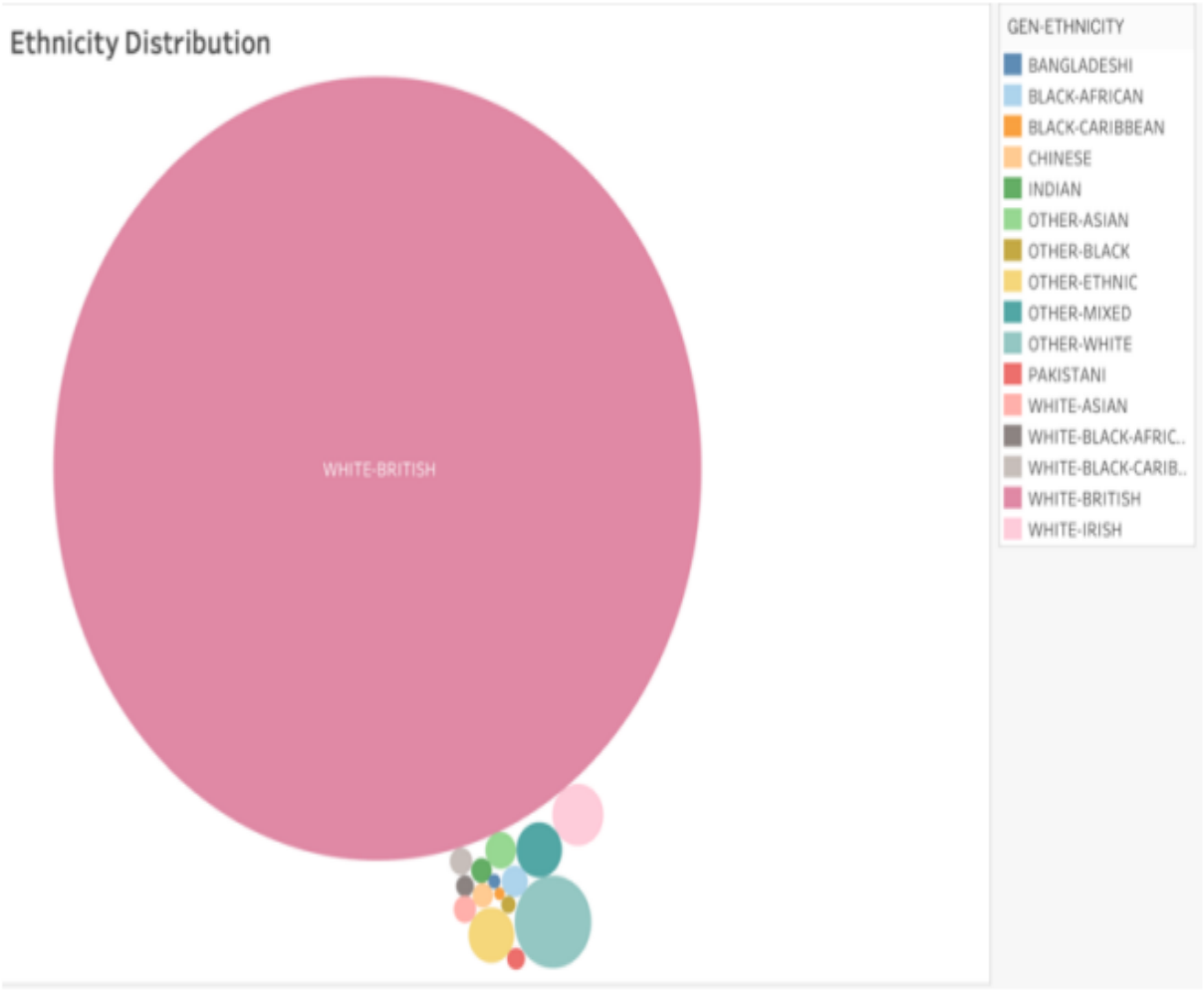


Figure 18: Ethnicity Groups Chart

Chapter 8 - Eliciting Users' Mental Model of GRIST (Data Analysis / Interpretation)

8.1 introduction

This chapter elicits users' mental model from the analysed data of users' interactions to identify patterns of interactions, preferred path to risk assessment and current clinical workflow. It also highlights differences between the established mental model of GRiST and the preferred options of users indicating users' mental model and behaviour. The process of risk assessment which is based on the hierarchical structure trees of concepts and questions will be examined to identify users' path based on questions answered or ignored.

The construction of mental model is constructed in a particular context. Mental models of users when communicating with a system is a good foundation for a good implication for system updates, system design and user modelling. Construction of mental models is affected by users' existing knowledge structures, workplace practices, training conditions and the system image. The research has two main goals. The first is to investigate the construction of mental models of users using data collected during clinicians' interactions with the system. The second goal is to investigate the differences between the users' mental models and the system's conceptual model in the development of framework useful to enhance the risk judgement and formulation processes.

8.2 Service User Gender Distribution in Assessments

The data on specific suicide condition of the patient focuses on two main conditions namely past and current suicide attempt, and current suicidal situation and behaviour. It also encapsulates questions relating to assessor or practitioner's view of the service user relating to concerns on risk of suicide, state of mind, personality and way of thinking, heath and care, involvement with life and others, adverse life events, person's behavioural presentation during assessment, living arrangement etc.

Each concept in the hierarchical structural trees will be examined individually to identify users' path based on questions answered or ignored.

8.3 Risk of Suicide

These questions initiate concerns with service user's risk of suicide and to understand if the service user made current or previous suicide attempt. To understand the interaction with the users' interactions inputs for the questions are analysed. Different pattern of how these questions were answered during assessments were gotten; the highest number of patterns are extracted. The data analysis extracted are illustrated as follows:

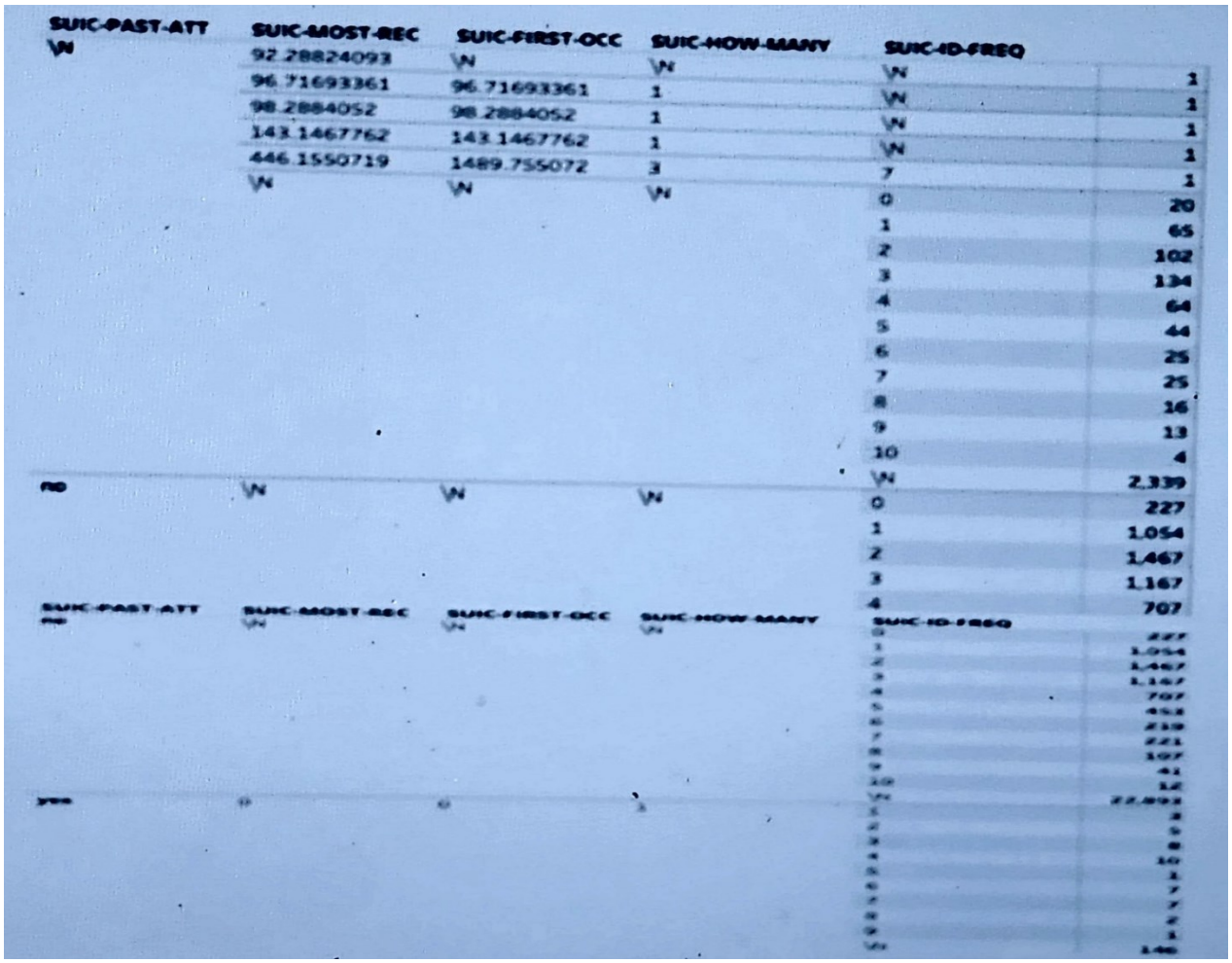


Figure 20: Risk of Suicide Analysis

The filter question to request for the past suicide attempt and most recent attempt is if there is a reason to be concerned about the patient's risk of suicide with a yes answer. Most entries however show no answer to past suicide attempt and no most recent attempt even though there is a concern for the patient's risk of suicide.

2,851 out of 71,023 assessments did not fill the Past Suicide and Suicide Most Recent questions. In 28,568 assessments, professionals answered no to Suicide Past and no input for the Suicide Most Recent.

8.3.1 User's Path/Mental Model – Risk of Suicide

From this analysis, the interaction gave rise to the following mental models:

a. Pattern of no input (I don't know) in the past intentions, with the most recent suicide inputted, no input for the first suicide occurrence, no input in the how many suicides and the number of frequencies.

b. Pattern of input in no nodes relating to suicide questions and a value is inputted in the number of suicide frequency

c. Pattern of no input in the suicidal questions

d. Past suicide intentions answered as NO; with inputs in the suicide frequency questions

e. NO answered to past suicide intentions, no input to the most recent, first suicide occurrence, how many suicides and the suicide frequency questions.

f. YES, answered in the suicide past intentions, input in the rest of the questions.

g. NO answered to past suicide intentions, no input to the most recent, first suicide occurrence, how many suicide and the suicide frequency questions.

The entries show contradictions either through deliberate omission or lack of understanding of what is expected of the clinician. The percentage of assessments with such entries shows a common pattern

among the clinicians who may have a different mental model of the process projected by the set of questionings of GRiST. The common pattern of entries shows no input in past suicide attempt, most recent, how-many attempts and frequencies question nodes. This kind of entries may imply incomplete data with negative consequences for the risk assessment and judgement and may need to be controlled and avoided by the system

8.4 Suicide Notes

Here the question relating to the any written suicide note for any previous or current suicide attempts. In the analysis, a significant amount of the assessments answered (don't know) to the questions. 42,508 assessments have no input which is about 60% of the assessments. The answer to this question should be related to answers given for past or current suicide attempts.

The analysis of the suicide notes is as follows:

SUIC-NOTE..	
\N	42,508
NO	23,913
YES	4,602

Figure 21: Overview of Answers to Suicide Notes Question

If past or current attempt is yes suicide-note should not be blank, the common pattern shows 60% of the assessments left the node blank. This is an anomaly of incomplete data with probable negative consequences on risk judgement and management plan.

8.5 Seriousness of Suicide Methods

These questions investigate the lethality of the suicide methods used and how the service user tries to hide any suicide attempted not making sure the suicide attempt was not stopped. The answer

should be related to the answers given to past suicide attempt and current suicide attempt. Past or current suicide attempt should have suicide method lethality and suicide discovery answer. Common pattern shows blank or no to both lethality and suicide discovery, while some shows high lethality but no value in the suicide discovery as represented in the figures 24a and 24b:

SUIC-LETHALITY	SUIC-DISCOVERY	
0	0	251
	1	205
	2	228
	3	132
	4	92
	5	100
	6	64
	7	59
	8	40
	9	17
	10	36
	\N	221
1	0	125
	1	542
	2	439
	3	413
	4	254
	5	244
	6	91
	7	109
	8	91
	9	65

Figure 22: Suicide Lethality Analysis (a)

SUIC-LETHALITY	SUIC-DISCOVERY	
10	2	10
	3	5
	4	25
	5	13
	6	40
	7	84
	8	133
	9	166
	10	438
	\N	32
\N	0	39
	1	151
	2	289
	3	372
	4	354
	5	608
	6	369
	7	554
	8	549
	9	241
	10	315
	\N	36,392

Figure 23: Suicide Lethality Analysis (b)

8.5.1 User's Path/Mental Model – Seriousness of Suicide Methods

The mental model extracted as follows:

a. The pattern of users inputting in the suicide lethality and suicide discovery.

b. The pattern of users inputting in the suicide lethality and no input in the suicide discovery.

c. The pattern of users inputting in the suicide lethality (high level) and suicide discovery (low level).

d. The pattern of users not inputting in the suicide lethality question and value in the suicide discovery question.

e. The pattern of users not inputting in the suicide lethality question and suicide discovery question.

8.6 Person's Current Perspective on Suicide Attempts

The questions are to understand the insight to the lethality of previous suicide attempts. Based on the answers given, the next question about regret to complete a suicide comes up. As interconnected these nodes are; it is expected from the conceptual model that there should not be a no value input in any of them. Also, if the answer to attempt to succeeded with suicide is no; it is expected that the suicide regret answer to be no.

		SUIC-LETHALITY											
SUIC-SER-SUCCD	SUIC-REGRET	0	1	2	3	4	5	6	7	8	9	10	\N
0	0	718	496	590	457	278	340	182	225	171	89	81	837
	1	32	120	96	96	42	45	34	21	25	5	1	63
	2	28	41	76	47	35	51	15	15	17	4	5	27
	3	20	28	23	68	15	21	7	26	2	3	1	11
	4	18	64	16	17	10	12	10	10			2	8
	5	21	9	10	12	12	10	3	7	8	2	6	9
	6	1	2	10	6	1	5	4	1	2			1
	7	3	11	8	9	2	4		2			2	11
	8	1	2	1		1	2	3	4				1
	9			3	2	1	5		1	1			
	10	1	1					1	1			1	
	\N	43	37	30	31	13	12	9	13	12	2	3	240
1	0	56	132	105	129	87	122	37	73	85	12	33	136
	1	61	587	527	418	312	253	163	151	147	60	43	467
	2	7	100	160	110	91	106	55	42	36	23	11	83
	3	13	41	50	73	57	50	17	23	9	3	2	17
	4	4	45	19	30	19	7	9	10	4	1		3
	5	3	18	21	22	9	34	15	4	5			20
	6	2	2	13	4	7	3		8	2	2		8
	7		5	10	3	7	7	2	3				2
	8		2			1	3			3			4
	9		5		1		3		1	2	5		
	\N	6	59	41	31	29	27	3	7	7	3	2	219

Figure 24: Lethality of Previous Suicide Attmepts(a)

8.6.1 User's Path/Mental Model – Person's Current Perspective on Suicide Attempts

Mental models extracted is as follows:

a. Patterns of no values in the Suicide Lethality, Suicide Success and Suicide Regret questions

b. Patterns of no value in the Suicide Lethality, Suicide Success and a value in the suicide regret nodes

c. Patterns of value inputted in the Suicide Lethality, Suicide Success and no values in the suicide regret questions

		SUIC-LETHALITY											
SUIC-SER-SUCCD	SUIC-REGRET	0	1	2	3	4	5	6	7	8	9	10	\N
9	9				1		4				12		5
	10				3					5	1		3
	\N		1		2	4	4	4	4	5	13	5	13
10	0	3	6	3	2	1	8	6	16	20	7	40	12
	1	1	1						4	10	7	8	3
	2			7	2	1	2					9	5
	3	6		1				7	3	2	3	1	3
	4		1						1	1	4	1	2
	5	2			2	3	2			7	1	9	3
	6			2						3	1	1	2
	7				1		1		1		3		
	8		2				1		3	1	6		
	9					4	1	1			1		
	10	1	1		2				1	2	2	23	13
	\N	1		1		1	4		7	20		2	7
\N	0	30	23	10	28	12	20	16	23	16	8	13	223
	1	4	28	24	20	12	13	9	23	25	5	15	178
	2		6	46	24	18	25	9	29	38	7	2	123
	3	3	9	12	30	16	22	19	7	8	4	3	71
	4	2			5	8	3	2	4	1	2	8	29
	5	3	7	1	14	3	9	10	3	12	2	2	21
	6	1	7	5	2	3	2	2	5				10
	7		5	2			17		1	2	3		27
	8	1	1	1	1	1	1			6	1		9
	9								1		6	2	4
	10											1	4
	\N	87	151	327	267	202	230	107	196	132	58	54	34,466

Figure 25: Lethality of Previous Suicide Attmepts(b)

d. Patterns of values in the Suicide Lethality, Suicide Success and suicide regret questions

e. Patterns of value in the suicide lethality, suicide regret and no value of the success of suicide

The three nodes registered input of values and no values. Users responded to the Suicide success, suicide lethality and well as if service users do have suicide regrets and suicide success. There are however large number of assessments of 34,466 recorded no input values in both nodes. According to the assessment, there are service users that do not have suicide regrets as well as no high-risk suicide frequency. The pattern of answers may imply incomplete data due to omission by users or ignorance of systems' expectations.

8.7 Potential Triggers for Perspective Suicide

The node represents questions highlighting potential triggers for prospective suicide questions. In this section of questions in GRiST, questions relating to the potential triggers, triggers match with those that have caused suicide attempts as well as family history of suicide are investigated. These nodes from the conceptual model perspective expects clinicians to answer a yes, no to further investigate the service users' exposure to feelings or circumstances that may trigger a suicide attempt (answers from 0 to 10) and the match of these feelings with known triggers for previous attempts. Answers may range from 0 to 10 or a don't know. However, if leaf question is answered as a yes; it is expected that the three nodes are answered.

		SUIC-P-TRIG-MTCH		
SUIC-INT-P-..	SUIC-FAM-..	\N	NO	YES
\N	\N	4,571	661	360
	no	33,060	2,944	1,080
	yes	7,501	650	244

Figure 26: Potential Triggers for Perspective Suicide

8.7.1 User's Path/Mental Model – Potential Triggers for Perspective Suicide

From the analysis, the following are the mental models extracted:

a. No values in the suicide potential triggers, suicide potential family match and the suicide family history questions

b. Potential Triggers answered as no value, suicide family history answered no and the trigger match as no value

c. Potential Triggers answered as no value, suicide family history answered yes and the trigger match as no value

d. Potential Triggers answered as no value, suicide family history answered yes and the trigger match as no

e. Potential Triggers answered as no value, suicide family history answered yes and the trigger match as yes.

f. Potential Triggers answered as no value, suicide family history with no value and the trigger match as no

g. Potential Triggers answered as no value, suicide family history with no value and the trigger match as yes

Common pattern shows no values in the suicide potential triggers, suicide potential family match and the suicide family history questions which highlights inconsistencies and incomplete set of data.

8.8 Suicide Ideation

The node represents the suicide ideation questions. In this section of GRiST, the ability of the service user to control suicidal ideation indicating high risk, content of suicidal ideation indicating risk, the strength, intensity, intrusiveness and persistence of suicidal ideation and the frequency of suicidal ideation. On answering yes to question about service user having suicidal thoughts or fantasies it is expected to input a value or don't know to the filter questions. There exist mental models of the

	SUIC-IDEATION											
SUIC-ID-CO..	0	1	2	3	4	5	6	7	8	9	10	\N
0	630	304	153	85	27	14	4	8	1	1		34
1	225	1,545	563	179	42	31	8	4	1		1	76
2	149	490	1,910	581	178	86	16	15	13	2		123
3	51	197	631	1,277	356	154	39	32	11		1	129
4	20	75	285	484	589	223	77	36	14	1		142
5	14	45	128	255	264	535	124	97	37	8	3	131
6	10	8	39	83	122	153	215	80	40	4	3	63
7	7	12	33	47	83	146	144	267	64	15	2	90
8	5	8	17	22	27	66	84	114	211	27	5	76
9	2	5	1		6	15	21	33	42	83	7	25
10	4			2	1	2	5	9	12	18	31	20
\N	32	94	183	181	117	121	51	53	31	7		53,453

Figure 27: Suicide Ideation Analysis

user; from the analysis made.

8.8.1 User's Path/Mental Model – Suicide Ideation

The following are the mental models extracted:

a. Value inputted in the suicide ideation and the ability to control suicidal ideation.

b. No values inserted in suicide ideation and ability to control suicidal ideation

c. Value inputted in the suicide ideation and no value the ability to control suicidal ideation

d. No value inputted in the suicide ideation and value the ability to control suicidal ideation.

From the analysis made, a significant amount of assessment (53,453) has no value in the suicide ideation and ability for the user to control suicidal ideation. There are 20 assessments of service users whose inability to control suicide ideation is high (given as 10) with no value in the suicide ideation.

This may imply that clinicians do not consider these questions as necessary or they are ignorant of the need for those answers. It also indicates missing data with consequential impact on risk judgement and management.

8.9 Appearance Indicators of Suicide

This section investigates appearance indicators of self-neglect. Questions relating to hair and clothing indicative of self-neglect, personal hygiene, recent change in appearance of self-neglect, skin and self-harming injuries are asked. Conceptual model of the system expects users to input at least a value; answer at least one question in this section of the question nodes.

8.9.1 User's Path/Mental Model - Appearance Indicators of Suicide

The following are the mental models extracted from the analysis:

a. Pattern of no value inputted in hair and cloth neglect, hygiene, appearance and skin injury question

b. Pattern of no value in hair and cloth neglect, hygiene, appearance and a 'yes' answered in skin injury question

c. Pattern of no value in hair and cloth neglect, hygiene, appearance and a 'no' answered in skin injury question.

SN-HAIR-CLOTH..	SN-HYGIENE	SN-APPEARNCE	SN-SKIN	
\N	\N	2		
			no	5
			yes	12
		3	\N	2
			no	12
			yes	11
		4	\N	1
			no	2
			yes	6
		5	\N	1
			no	3
			yes	8
		6	no	2
			yes	8
		7	\N	1
			no	2
			yes	2
		8	no	1
			yes	1
		9	\N	1
		\N	\N	4,431
			no	29,138
			yes	25,946

Figure 28: Appearance Indicators of Suicide Analysis

d. Pattern of high value answer for concerns with appearance and no value in hair and clothes neglect, hygiene and skin injury

e. Pattern of no/Low risk attached to hair and clothing indications of risk (Value as 0), no value in Hygiene; with a combination of yes, no or no input in Skin.

8.10 State of Mind

The state of mind layer of questions covers questions regarding the feelings/emotions and hopelessness of patients. Data is entered if there is a concern for patient's feelings/emotions. This helps in understanding service user's feelings and emotions relating to mood swings, negative feelings as well as the degree of hopelessness in risk assessment.

In these nodes; values are expected in all the questions if there is a concern for persons' feelings/emotions. The analysis uncovered many assessments with no values which highlights missing data.

8.10.1 User's Path/Mental Model – State of Mind

The mental model extracted from these nodes are summarised as follows:

a. Pattern of all values in both mood swings and feeling negative about self-questions

b. Pattern of no values in both mood swings and feeling anxious questions

c. Pattern of no value in the mood swings and value in feeling negative about self-questions

d. Pattern of values in the mood swings and no value in the feeling negative about self-questions.

However, there are 38,722 assessments that does not have any value which is more than half of the total assessments. This may indicate that clinicians do not see the relevance of these questions or that the questions are lengthy and time consuming.

	GEN-NEGATIVE-SELF											
GEN-MOOD-SWINGS	0	1	2	3	4	5	6	7	8	9	10	\N
0	1,469	225	136	113	64	50	30	22	22	7	11	152
1	607	668	276	156	63	56	31	28	18	6	2	91
2	814	725	633	305	147	94	46	57	24	4	2	157
3	848	791	840	590	278	143	63	60	25	10		185
4	865	749	912	761	391	230	95	86	41	24	4	190
5	833	688	850	750	484	467	146	132	76	22	5	231
6	453	341	492	502	394	345	207	160	80	37	11	188
7	391	317	476	456	385	404	242	310	173	52	16	218
8	255	170	261	247	194	268	183	216	255	121	38	156
9	59	51	73	73	60	112	71	97	137	83	30	47
10	19	6	15	16	22	30	12	18	24	31	49	16
\N	487	349	349	219	116	149	87	64	71	40	29	38,722

Figure 29: State of Mind Analysis

Other State of Mind Questions

The mental model extracted from these nodes are summarised as follows:

a. Pattern of all values in both life not worth living and plans for the future questions

b. Pattern of no values in both life not worth living and plans for the future questions

c. Pattern of no value in the life not worth living and values in plans for the future questions

d. Pattern of values in the life not worth living and no values plans for the future questions

8.11 Person's Perspective of Self Worth

The questions are asked regarding risks associated with the person's sense of self-worth; investigating if the service user regard him or herself as worthless and the level of grandiosity. Answer is expected in the two questions covering self-worth if there is concern for the person's self-worth has been answered affirmatively.

	GRANDIOSITY											
WORTHLES..	0	1	2	3	4	5	6	7	8	9	10	\W
\W		3	3	15	13	12	10	14	18	3	3	553
no	196	224	623	1,178	1,342	1,359	1,005	958	633	256	100	38,388
yes	149	159	436	881	1,166	1,274	949	955	734	320	72	17,019

Figure 30: Perspective on Self Worth Analysis

8.11.1 User's Path/Mental Model - Person's Perspective of Self Worth

Mental Model extracted are as follows:

a. Pattern of value in the worthlessness and grandiosity questions.

b. Pattern of no value in the worthlessness and grandiosity questions

c. Pattern of no value in the worthlessness and a value in grandiosity questions

8.12 Personality and Way of Thinking

This set of questions is aimed at collecting data on personality issues that may have an impact on risk, problems with mental faculties/cognitive capacities and insight and responsibilities. Clinicians are expected to answer all the questions relating to the degree of impulsiveness, assertiveness, dependence, ability to emphasise up to the personality disorder if there is a concern about personality factors and their impact on risks. The analysis shows users input, no value and a mixture of no and yes.

GEN-RELIABLE	GEN-CONTROLLING	GEN-COPING-ABIL	GEN-HOSTILE	GEN-PERS-DIS	
\N	\N	10	\N	yes	3
		\N	0	no	2
				yes	1
			1	no	4
				yes	1
			2	\N	1
				no	2
			3	no	1
				yes	1
			4	no	7
				yes	1
			5	no	4
			6	\N	3
				no	5
			7	no	6
			8	\N	1
				no	9
				yes	1
			9	no	4
				yes	3
			10	no	1
			\N	\N	482
				no	38,903
				yes	4,964

Figure 31: Personality and Way of Thinking Analysis (a)

GEN-RELIABLE	GEN-CONTROLLING	GEN-COPING-ABIL	GEN-HOSTILE	GEN-PERS-DIS	
NO	0	0	0	no	3
				yes	2
			2	no	1
			6	no	1
			\N	no	1
		1	5	no	1
		2	0	no	1
			5	no	2
		6	7	no	1
		8	7	no	1
	1	0	0	no	6
			1	no	6
			2	no	2
			4	no	2
		1	0	no	1
			1	no	1
			2	no	2
			\N	no	3
		3	\N	no	1
		\N	7	no	1
			\N	no	2

Figure 32: Personality and Way of Thinking Analysis (b)

GEN-RELIABLE	GEN-CONTROLLING	GEN-COPING-ABIL	GEN-HOSTILE	GEN-PERS-DIS	
YES					
	1	0	2	no	1
			3	no	1
	2	0	0	no	1
			3	no	3
				yes	1
		1	3	no	1
		2	3	no	4
			6	no	4
		3	1	no	1
	3	0	0	no	1
			1	no	1
			2	no	2
			3	no	1
			7	no	1
			\N	no	1
		1	3	no	1
			4	no	1
		2	5	no	1
		3	2	no	3
			4	no	1
			5	no	1
		4	3	no	1
		5	7	no	1

Figure 33: Personality and Way of Thinking Analysis (c)

8.12.1 User's Path/Mental Model - Personality and Way of Thinking

Mental Model extracted are as follows:

a. Patterns of no value in the questions relating to personality issues.

b. Patterns of no value in most of the personality issues related questions and a yes answer in the general personality questions.

In the analysis done, there are about 4,964 assessments answering yes to general personality questions and 38,903 assessments have no personality issues according to the data set.

8.13 Problems with Mental Faculties/Cognitive Capacity

This node of the assessment investigates if there are any impaired cognitive functions. The current level of impaired thinking processes and memory is asked and to investigate the level of the impaired function. The ability for the person to concentrate is looked into and to understand if the person has learning disabilities. In the conceptual model, when the cognitive function is answered yes; it is expected that the current level of impaired thinking is answered. The data analysed illustrates the number of records for input in the mental faculties. The filter questions relating to the mental faculty were answered with no values, values and also yes or no. From the input, a larger amount of the assessments has no value inputted and this is illustrated below:

8.13.1 User's Path/Mental Model - Problems with Mental Faculties/Cognitive Capacity

When analysed with other filter questions; such as general cognitive impairment, cognitive thinking and memory impairment, ability to concentrate and learning disabilities the following mental models are derived;

a. Pattern of no input in answering mental health question; include a value in the general impairment, concentration (values of 0 to 10) and a no value for learning disability questions

b. Pattern of no input in answering mental health question; include a value in the general impairment, concentration (values of 0 to 10) and a yes answer for learning disability questions

c. Pattern of no input in answering mental health question; include a value in the general impairment, concentration (values of 0 to 10) and a no answer for learning disability questions.

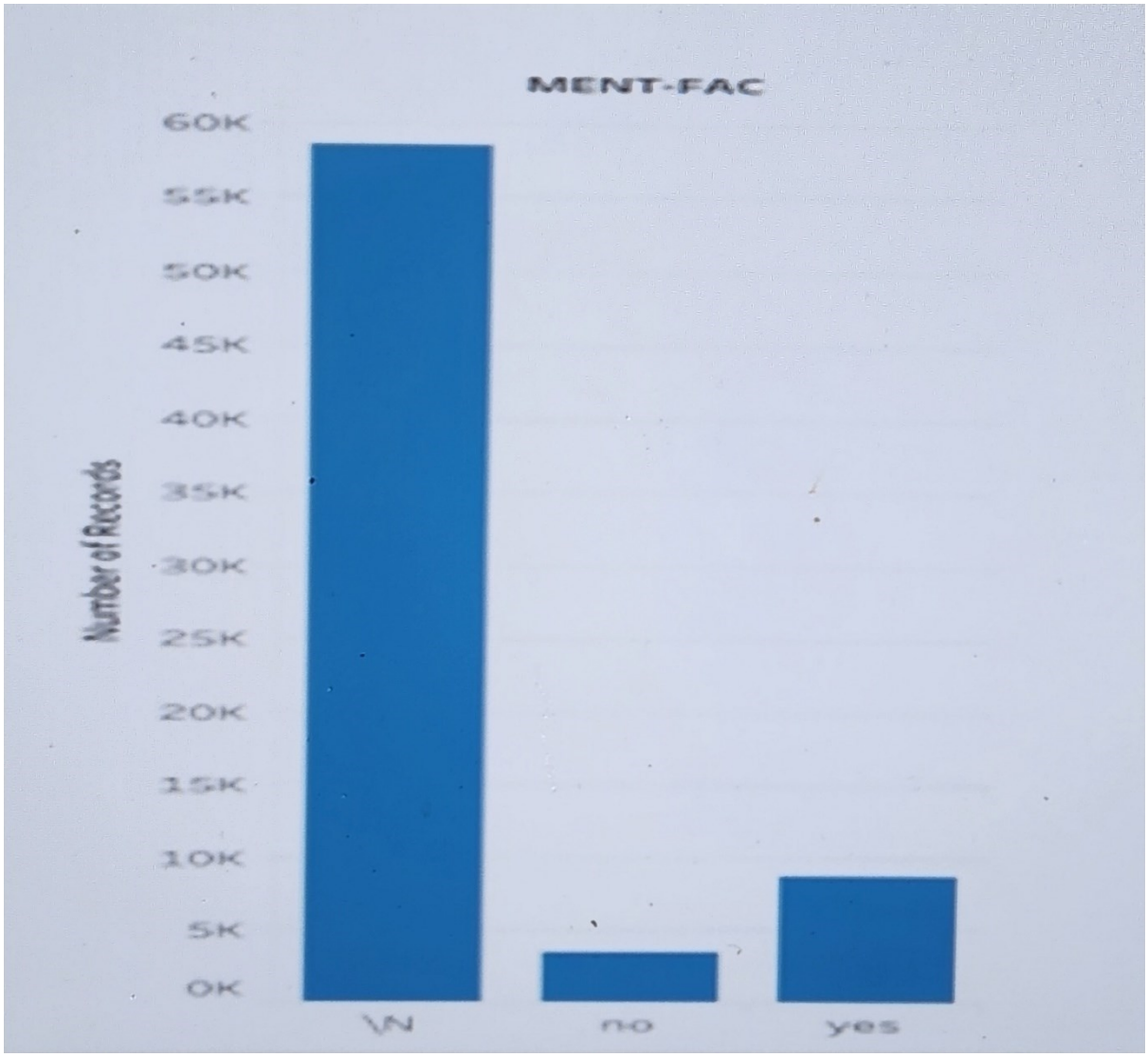


Figure 34: Mental Faculty Bar Chart Analysis

8.14 Insight and Responsibility

The node investigated service user's lack of insight and sense of responsibilities If answered yes, the degree at which the service user fails to understand the potential consequences for taking risk is questioned; which is expected to be answered. The degree at which the person lacks any sense of responsibility for the outcomes of risk-taking behaviours and lacking insight about needing help with mental issues is asked. The three filter questions are expected to be answered illustrating the insight and degree of the service user's responsibilities. At least one of the filter questions must be answered.

GEN-INSGH..	GEN-ND-HL..	GEN-RESP-IMPCT-OTH	
2	yes	\N	8
3	\N	\N	1
	no	\N	3
	yes	\N	46
4	\N	\N	1
	no	\N	9
	yes	\N	23
5	\N	\N	5
	no	\N	18
	yes	\N	35
6	\N	\N	7
	no	\N	16
	yes	\N	33
7	\N	\N	9
	no	\N	19
	yes	\N	42
8	\N	\N	10
	no	\N	15
	yes	\N	65
9	\N	\N	3
	no	\N	3
	yes	\N	28
10	\N	\N	4
	no	\N	6
	yes	\N	3
\N	\N	\N	2,887
	no	\N	12,982
	yes	\N	34,808

Figure 35: Insight and Responsibility Analysis

8.14.1 User's Path/Mental Model - Insight and Responsibility

The mental models extracted include:

a. Pattern of values inserted answering all the questions

b. Pattern of answers to general insight into behaviour and consequences, no value in the responsibility to others and no value in the responsibility of impact of behaviour on others.

c. Pattern of no values for all the nodes relating to insight and responsibility questions.

8.15 Health and Care Questions: Clinical Depression

The set of questions on health and care considers the condition of patients and history of mental health problems; physical health problems; and concordance with health services/medication/therapies. The questions investigated if the person have any history of depression, mania, hallucinations or delusions and diagnosis of clinical depression; the level of the clinical depression status. If the clinical depression is answered as yes; it is expected that the level of current depression must be answered.

GEN-DEP-S..	CLIN-DEPRESSION	
\N	\N	25,281
	FIRST-DIAGNOSIS	1,589
	RECOVERY-REPEAT-EPIS..	7,187
	RECOVERY-SINGLE-EPISO..	1,070
	RELAPSE	8,290
no	\N	3,063
	FIRST-DIAGNOSIS	243
	RECOVERY-REPEAT-EPIS..	3,837
	RECOVERY-SINGLE-EPISO..	358
	RELAPSE	2,021
yes	\N	6,875
	FIRST-DIAGNOSIS	378
	RECOVERY-REPEAT-EPIS..	4,697
	RECOVERY-SINGLE-EPISO..	285
	RELAPSE	5,849

Figure 36: Heath and Care Analysis

8.15.1 User's Path/Mental Model - Health and Care Questions: Clinical Depression

The following mental models are extracted:

a. Pattern of users answering all questions relating to the clinical diagnosis of depression

b. Pattern of users not inputting any value in all clinical depression questions

c. Pattern of users answering yes to the clinical depression and no value inputted in the level of clinical depression

d. Pattern of users answering yes to the clinical depression and no value inputted in the level of clinical depression

e. Pattern of users answering no to the clinical depression and no value inputted in the level of clinical depression

From the analysis made, a significant amount of the assessments does not a value included in both question nodes (25,281); there have been no value for the general depression question and the values for the level of clinical depression. The no answer for the general depression question have a value and has a clinical depression value. The general depression questions answered yes and about 6,875 assessments had no input attached to them.

8.16 Current Symptoms of mental Illness Questions: Voice Hallucinations

This section of the system is to investigate if the person hears voices that are not present in reality; if the answer is yes; a set of questions are presented to know if the person acts on the voices and how much the voices urge the person to harm or endanger himself or herself and other as well as the degree of the person displaying hypomanic behaviour. The conceptual model expects the user to answer at least one of the filter questions when the leaf/standard is answered as a yes.

8.16.1 User's Path/Mental Model - Current Symptoms of mental Illness Questions: Voice Hallucinations

The extracted mental models are summarized as follows:

a. Pattern of answers to all the nodes

b. Pattern of answers to at least one of the nodes

c. Pattern of no value inputted into the nodes

8.17 Paranoid Delusions

This investigate the person suffer from delusions, how likely the person will act on any delusions; how the perceived bad behaviour of particular known people can increase risk factors or prosecuted by known people as well as if the service user is displaying manic or hypomanic behaviour. When the answer to if the service user is suffering from delusion is yes; it is expected that at least one of the filter questions is answered. When the answer is answered as no or don't know; it is expected that none of the filter question is to be answered.

GEN-PARANOID-DEL	GEN-PROB-ACT-PAR-DEL	
0	\N	4
	no	944
	yes	340
1	\N	1
	no	495
	yes	180
2	\N	2
	no	484
	yes	202
3	\N	2
	no	477
	yes	175
4	\N	3
	no	397
	yes	162
5	\N	3
	no	404
	yes	171
6	\N	2
	no	293
	yes	116
7	no	300
	yes	134
8	\N	1
	no	262
	yes	116
9	\N	1
	no	108

Figure 37: Paranoid Delusion Analysis (a)

GEN-PARANOID-DEL	GEN-PROB-ACT-PAR-DEL	
2	\N	2
	no	484
	yes	202
3	\N	2
	no	477
	yes	175
4	\N	3
	no	397
	yes	162
5	\N	3
	no	404
	yes	171
6	\N	2
	no	293
	yes	116
7	no	300
	yes	134
8	\N	1
	no	262
	yes	116
9	\N	1
	no	108
	yes	59
10	no	77
	yes	37
\N	\N	649
	no	49,848
	yes	14,574

Figure 38: Paranoid Delusion Analysis (b)

8.17.1 User's Path/Mental Model – Paranoid Delusions

From the analysis made, the following mental models are extracted:

a. Pattern of value inputted in the different nodes

b. Pattern of no input in the answer to paranoid delusion question and a yes answer to probability of acting on the delusion.

c. Pattern of no input in the answer to paranoid delusion question and a no answer to probability of acting on the delusion

d. Pattern of value in the paranoid delusion and no answer in the probability of acting on paranoid delusions

e. Pattern of value in the paranoid delusion and yes answer in the probability of acting on paranoid delusions

8.18 Physical Health Problems

The questions illustrate the risks associated with risks due to physical health problems and the type of chronic health conditions. Also, to understand the first date life threating illness was first diagnosed. This is further investigated by finding out if the service user suffers from chronic or periodic pain, problems that affect mobility, trouble communicating as a result of physical health problems such as hearing impairment.

GEN-PHYS-..	GEN-PHYS-..	GEN-CHRONIC-..	GEN-COM-IMP	
\N	4	\N	0	159
			1	79
			2	88
			3	111
			4	138
			5	84
			6	52
			7	53
			8	25
			9	8
			10	7
			\N	555

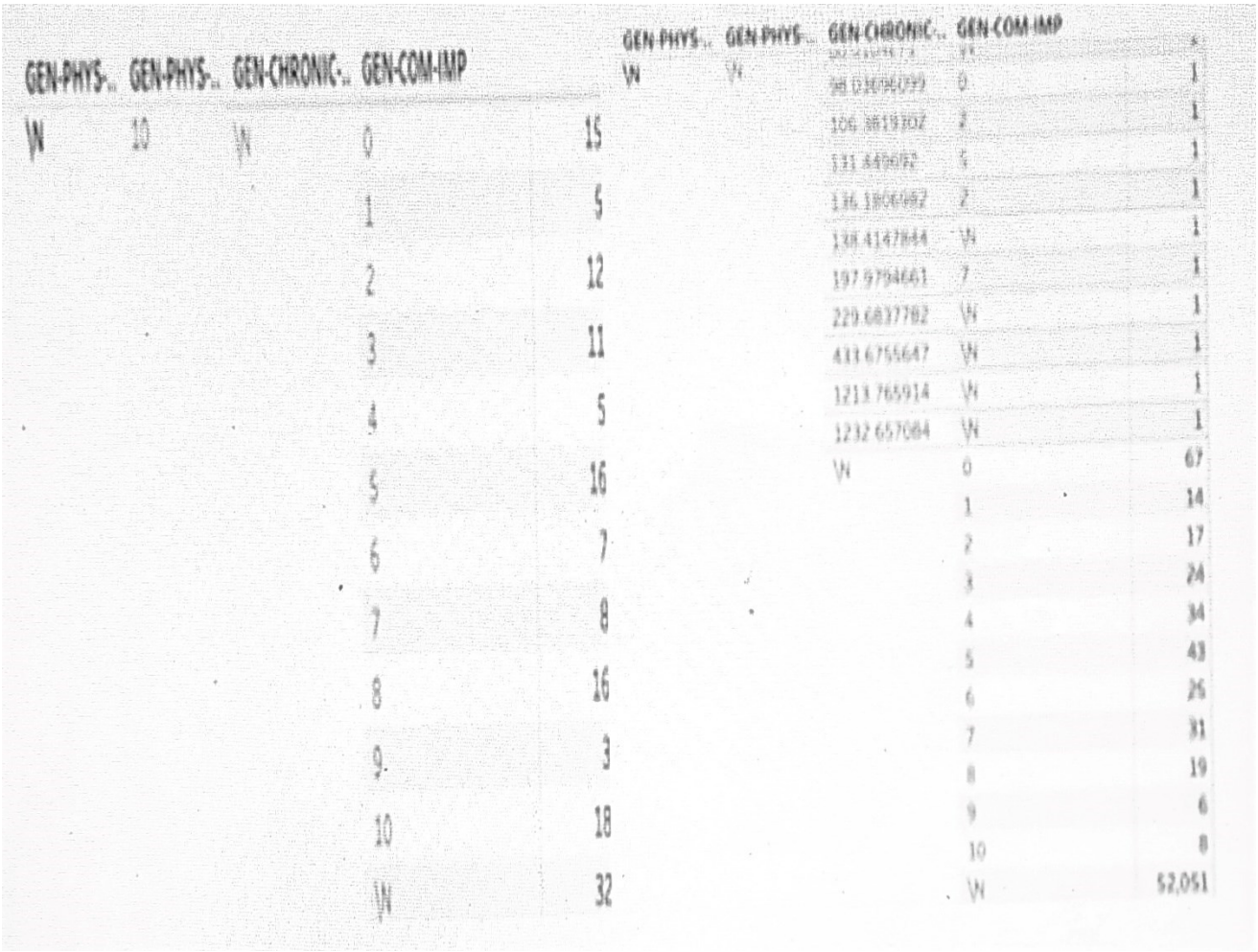
GEN-PHYS-..	GEN-PHYS-..	GEN-CHRONIC-..	GEN-COM-IMP	
\N	7	\N	0	105
			1	50
			2	51
			3	50
			4	89
			5	106
			6	84
			7	94
			8	51
			9	17
			10	6
			\N	363

Figure 39: Physical Health Problems Analysis (a)

GEN-PHYS-..	GEN-PHYS-..	GEN-CHRONIC-..	GEN-COM-IMP	
\N	8	\N	0	65
			1	26
			2	37
			3	32
			4	46
			5	78
			6	51
			7	43
			8	80
			9	28
			10	9
			\N	237

GEN-PHYS-..	GEN-PHYS-..	GEN-CHRONIC-..	GEN-COM-IMP	
\N	9	\N	0	25
			1	16
			2	14
			3	20
			4	12
			5	18
			6	21
			7	20
			8	31
			9	19
			10	14
			\N	95

Figure 40: Physical Health Problems Analysis (b)



GEN-PHYS..	GEN-PHYS..	GEN-CHRONIC..	GEN-COM-IMP	
W	10	W	0	15
			1	5
			2	12
			3	11
			4	5
			5	16
			6	7
			7	8
			8	16
			9	3
			10	18
			W	32

GEN-PHYS..	GEN-PHYS..	GEN-CHRONIC..	GEN-COM-IMP	
W	W	[illegible]	[illegible]	[illegible]
		98 0305039	0	1
		106.3819302	2	1
		131.4406952	5	1
		136.1906492	2	1
		138.4147844	W	1
		197.9794661	7	1
		229.6837782	W	1
		433.6755647	W	1
		1213.765914	W	1
		1232.657084	W	1
		W	0	67
			1	14
			2	17
			3	24
			4	34
			5	43
			6	26
			7	31
			8	19
			9	6
			10	8
			W	52,051

Figure 41: Physical Health Problem Analysis (c)

8.18.1 User's Path/Mental Model - Physical Health Problems

The mental model derived from the analysis is summarized as below:

a. Pattern of users inputting no value for physical health problem, value in the physical health pain, value in the chronic condition and value in the hearing impairment condition

b. Pattern of users inputting no value in all the nodes relating to the health problems questions

c. Pattern of no value in the physical health problem, value in the general physical health pain, no value in the choice of chronic condition and value in the hearing impairment

d. Pattern of no value in the nodes except physical health pain.

8.19 Concordance with Health Services

This question investigates concerns about person's concordance with health treatments; especially with failing to concord with medication or therapies, the service ser thoughts about health or social care services that are not supportive as well as the thought of medication or therapy not working. From the conceptual model perspective, when a yes is answered for the leaf question, at least one of the filter questions should be answered; if the answer is no, it is expected that none of the filter questions should be answered.

GEN-MEDS-CONCORD	GEN-SERV-PERC-SUPP	GEN-MEDS-THERPY	
0	0	0	120
		1	20
		2	49
		3	44
		4	45
		5	55
		6	30
		7	31
		8	19
		9	12
		10	13
		\N	28

Figure 42: Concordance with Health Services Analysis (a)

GEN-MEDS-CONCORD	GEN-SERV-PERC-SUPP	GEN-MEDS-THERPY	
0	\N	0	36
		1	4
		2	10
		3	8
		4	10
		5	17
		6	4
		7	17
		8	12
		9	5
		10	3
		\N	116

Figure 43: Concordance with Health Services Analysis (b)

GEN-MEDS-CONCORD	GEN-SERV-PERC-SUPP	GEN-MEDS-THERPY	
\N	10	2	3
		3	1
		4	1
		5	3
		6	1
		7	1
		8	5
		9	1
		10	26
		\N	5
	\N	0	70
		1	23
		2	45
		3	58
		4	57
		5	98
		6	57
		7	92
		8	83
		9	43
		10	54
		\N	61,709

Figure 44: Concordance with Health Services Analysis (c)

8.19.1 User's Path/Mental Model - Concordance with Health Services

From the analysis made; the following are the summary of the mental models extracted:

a. Pattern of no values in the medication concordance, service perception, medication and therapy questions

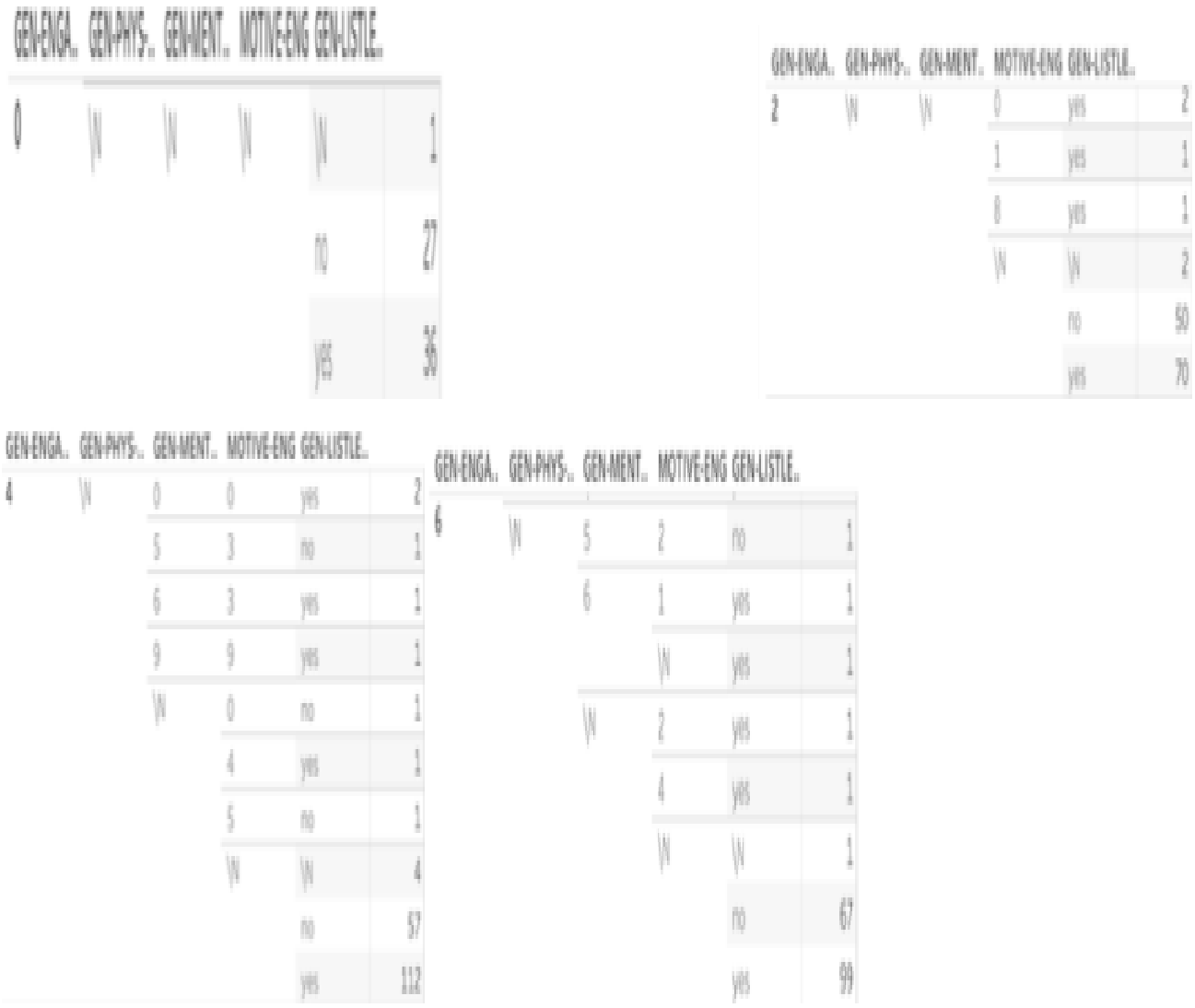
b. Pattern of value in the answer to medical concordance and no value in the service perception and attitude to medications and therapy.

c. Pattern of no values in the medication concordance and service perception and value in the medication therapy questions.

d. Pattern of no value in the medication concordance, value in the service perception and value in the medication and therapy.

8.20 Motivation and Engagement with World

This question investigates reason to be concerned about the person's motivation and engagement with the world. Filter questions investigate if the service user is physically, mentally isolated from the world; also, to know if the person lacks motivation in general or appear listless; lacking enthusiasm and drives. In the conceptual model, the answer can be a yes or no to the leaf question. If yes; the filter questions are expected to be answered. If the answer to the leaf question is no; it is expected that the filter questions are not answered.



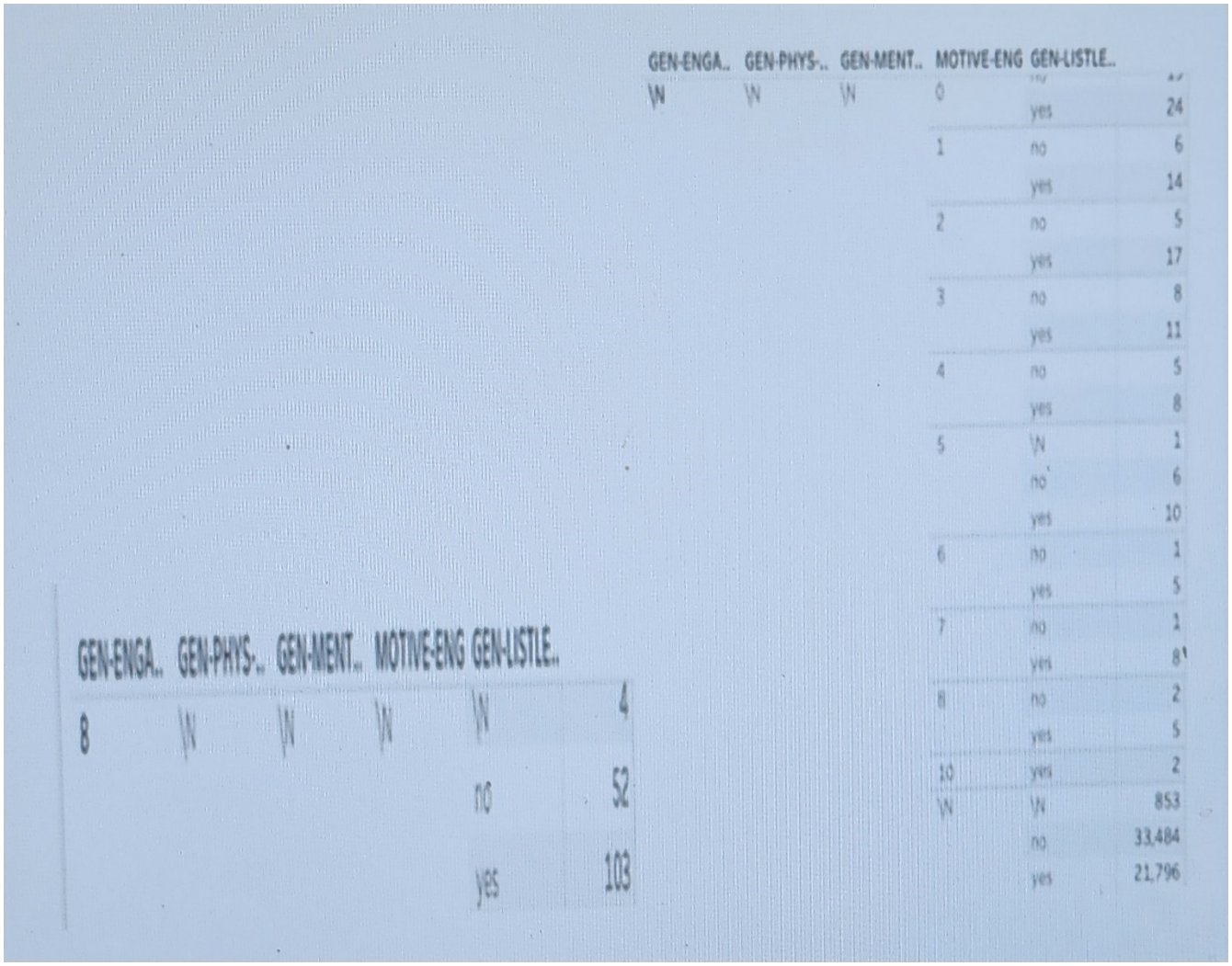
GEN-ENGA..	GEN-PHYS..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
0	|V	|V	|V	|V	1
				no	27
				yes	36

GEN-ENGA..	GEN-PHYS..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
2	|V	|V	0	yes	2
			1	yes	1
			8	yes	1
			|V	|V	2
				no	50
				yes	70

GEN-ENGA..	GEN-PHYS..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
4	|V	0	0	yes	2
		5	3	no	1
		6	3	yes	1
		9	9	yes	1
		|V	0	no	1
			4	yes	1
			5	no	1
			|V	|V	4
				no	57
				yes	112

GEN-ENGA..	GEN-PHYS..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
6	|V	5	2	no	1
		6	1	yes	1
			|V	yes	1
		|V	2	yes	1
			4	yes	1
			|V	|V	1
				no	67
				yes	99

Figure 45: Motivation and Engagement with World Analysis (a)



GEN-ENGA..	GEN-PHYS-..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
\N	\N	\N	0		
				yes	24
			1	no	6
				yes	14
			2	no	5
				yes	17
			3	no	8
				yes	11
			4	no	5
				yes	8
			5	\N	1
				no	6
				yes	10
			6	no	1
				yes	5
			7	no	1
				yes	8
			8	no	2
				yes	5
			10	yes	2
			\N	\N	853
				no	33,484
				yes	21,796

GEN-ENGA..	GEN-PHYS-..	GEN-MENT..	MOTIVE-ENG	GEN-LISTLE..	
8	\N	\N	\N	\N	4
				no	52
				yes	103

Figure 46: Motivation and Engagement with World Analysis (b)

8.21 Social Context

This question helps in investigating reasons to be concerned about risks due to the person's social context (relationships, living arrangements, finances, employment and any related detrimental changes). In relationship specific questions, filter questions are based on understanding if the service user lack a good network relationship outside the home, lacking supportive relationship; experience of the service user having detrimental relationships; change of relationship due to divorce, new role etc.

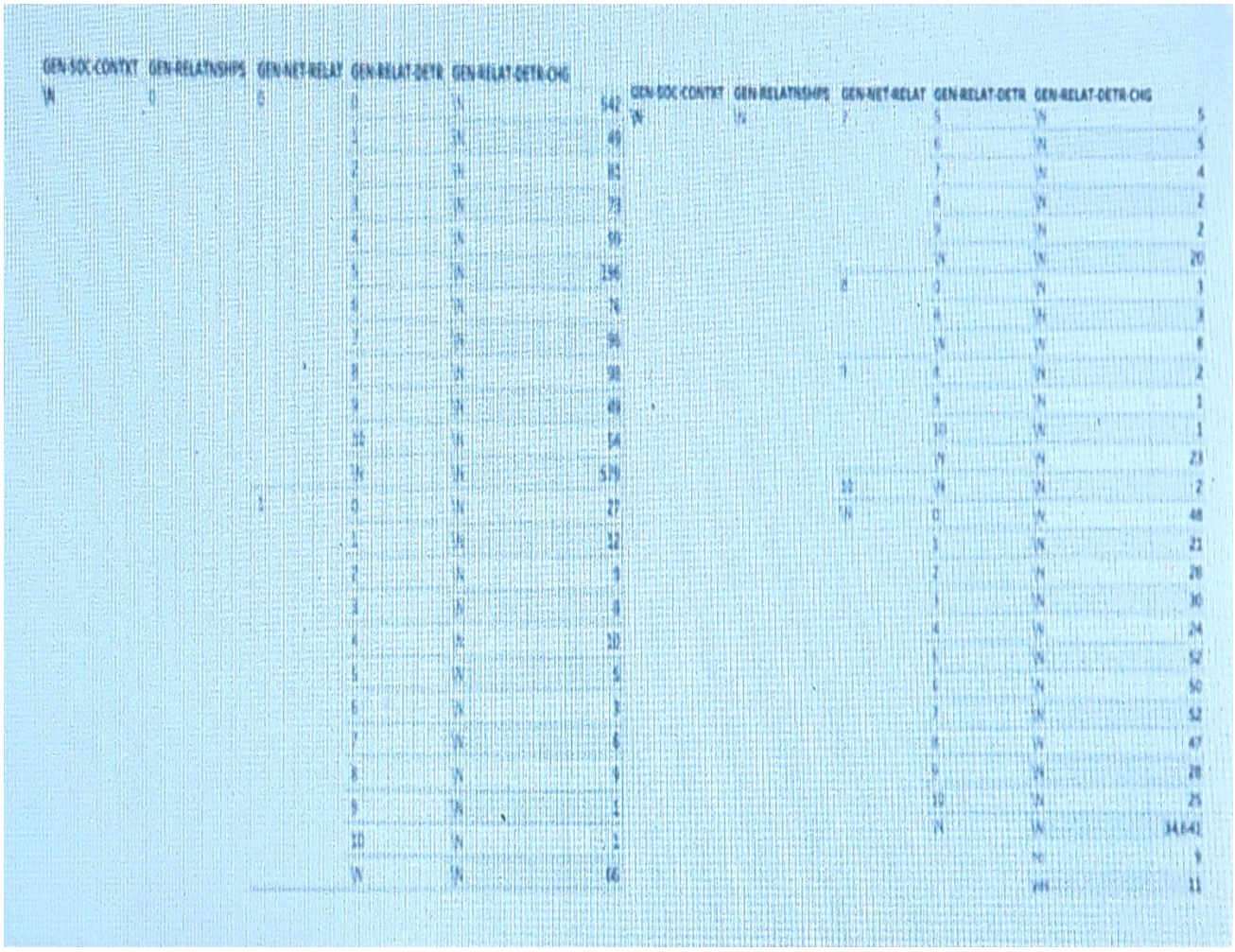


Figure 47: Social Context: Relationship Analysis

8.21.1 User's Path/Mental Model – Social Context

From the analysis, the following mental model are summarized as follows:

a. Pattern of values in all the nodes relating to social context and relationships

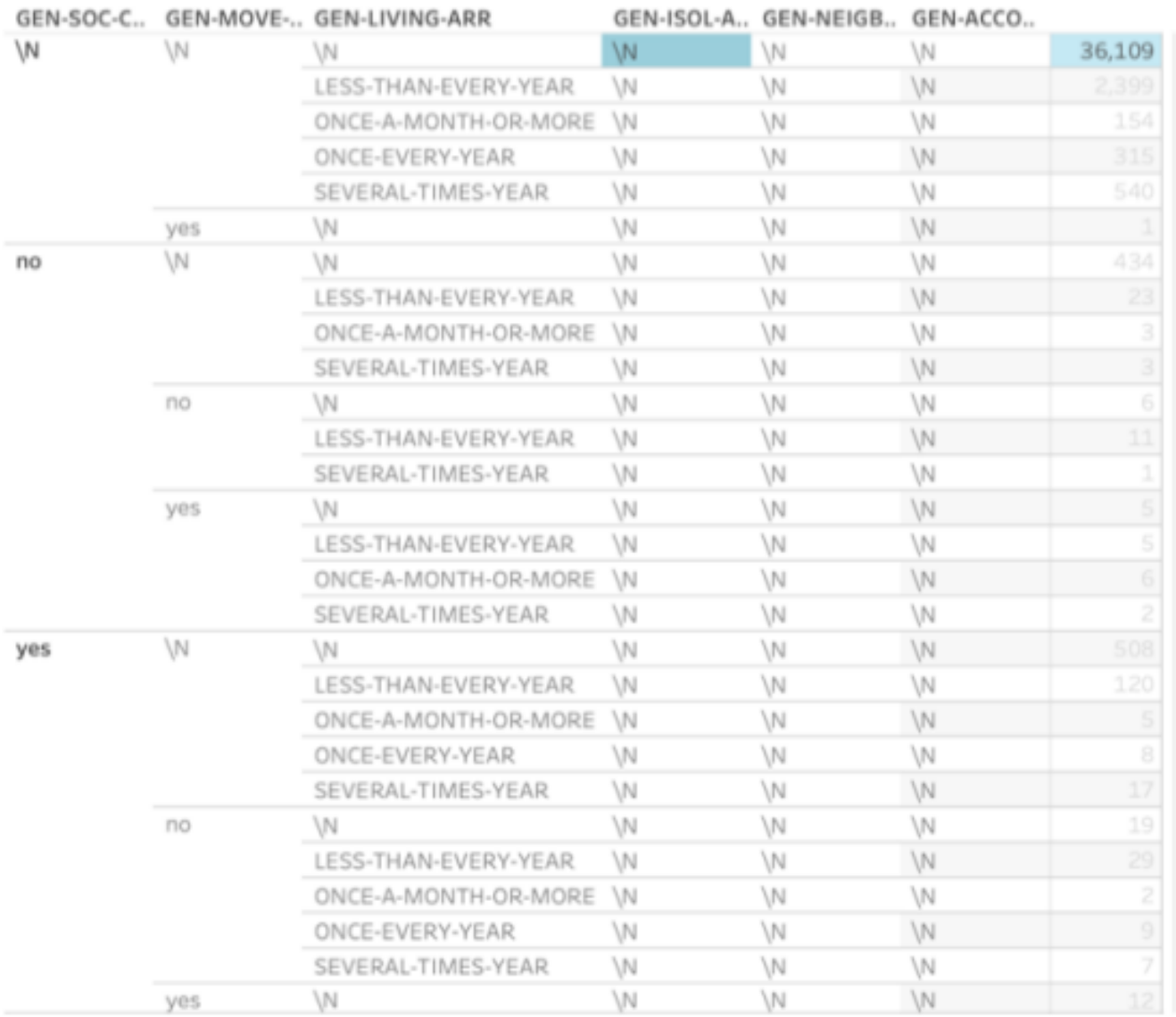
b. Pattern of no values in all nodes relating to social context and relationships

c. Pattern of no values in some of the nodes and values in the other nodes.

For example, no values in the social context, relationships and values in the deteriorating relationships and no changes in relationships; models like these needs to be looked into.

8.22 Living Arrangements:

These questions are related to the risks due to service user's living arrangements. Looking at knowing the frequency in which accommodation changes; if it has been taken away or in the process of being taken away; the type of supported living the person have, how isolated, neighbourhood or care environment impact and traces of the place showing lack of care and to know if the accommodation is unfit to live. When the question is answered as a yes; it is expected that the filter questions are answered.



GEN-SOC-C..	GEN-MOVE-..	GEN-LIVING-ARR	GEN-ISOL-A..	GEN-NEIGB..	GEN-ACCO..	
\N	\N	\N	\N	\N	\N	36,109
		LESS-THAN-EVERY-YEAR	\N	\N	\N	2,399
		ONCE-A-MONTH-OR-MORE	\N	\N	\N	154
		ONCE-EVERY-YEAR	\N	\N	\N	315
		SEVERAL-TIMES-YEAR	\N	\N	\N	540
	yes	\N	\N	\N	\N	1
no	\N	\N	\N	\N	\N	434
		LESS-THAN-EVERY-YEAR	\N	\N	\N	23
		ONCE-A-MONTH-OR-MORE	\N	\N	\N	3
		SEVERAL-TIMES-YEAR	\N	\N	\N	3
	no	\N	\N	\N	\N	6
		LESS-THAN-EVERY-YEAR	\N	\N	\N	11
		SEVERAL-TIMES-YEAR	\N	\N	\N	1
	yes	\N	\N	\N	\N	5
		LESS-THAN-EVERY-YEAR	\N	\N	\N	5
		ONCE-A-MONTH-OR-MORE	\N	\N	\N	6
		SEVERAL-TIMES-YEAR	\N	\N	\N	2
yes	\N	\N	\N	\N	\N	508
		LESS-THAN-EVERY-YEAR	\N	\N	\N	120
		ONCE-A-MONTH-OR-MORE	\N	\N	\N	5
		ONCE-EVERY-YEAR	\N	\N	\N	8
		SEVERAL-TIMES-YEAR	\N	\N	\N	17
	no	\N	\N	\N	\N	19
		LESS-THAN-EVERY-YEAR	\N	\N	\N	29
		ONCE-A-MONTH-OR-MORE	\N	\N	\N	2
		ONCE-EVERY-YEAR	\N	\N	\N	9
		SEVERAL-TIMES-YEAR	\N	\N	\N	7
	yes	\N	\N	\N	\N	12

Figure 48: Social Context: Living Arrangements

8.22.1 User's Path/Mental Model – Living Arrangement

The mental models derived are as follows:

a. Pattern of no values in all the nodes relating to the living arrangement questions

b. Pattern of most of the nodes having no value and one of the nodes having a value

c. Pattern of users inputting no value in all the nodes and inputting a value on question asking how isolated the accommodation is.

d. Pattern of users answering yes for social context node and no value related to living arrangement filter questions

e. Pattern of no values inserted except the living arrangement change

f. Pattern of users having no concern about risks related to the general social context and inputting values in other living arrangement filter nodes.

8.23 Financial and Employment Concerns

This question is investigating the concerns about the risks due to the service user's employment and or finances status.

GEN-POVER..	GEN-REC-BAD-JOB-CH	GEN-JOB-CHG-FRQ	
\N	\N	0	31
		1	6
		2	2
		3	2
		4	5
		5	2
		6	1
		7	1
		8	3
		9	1
		\N	4,087

GEN-POVER..	GEN-REC-BAD-JOB-CH	GEN-JOB-CHG-FRQ	
\N	yes	0	569
		1	74
		2	39
		3	14
		4	40
		5	53
		6	36
		7	32
		8	47
		9	15
		10	7
		\N	10,593

GEN-POVER..	GEN-REC-BAD-JOB-CH	GEN-JOB-CHG-FRQ	
\N	no	0	720
		1	97
		2	45
		3	38
		4	52
		5	63
		6	40
		7	52
		8	36
		9	16
		10	15
		\N	30,787

Figure 49: Social Context: Financial and Employment Concerns Analysis

8.23.1 User's Path/Mental Model - Financial and Employment Concerns

Mental models derived are as follows:

a. Pattern of users inputting no value in the poverty filter question and the recent bad job change with values in the frequency of job change.

b. Pattern of users inputting no value in the poverty filter question, recent bad job changes and in the frequency of job change.

c. Pattern of users inputting no value in the poverty filter question; yes, in the recent bad job change with values in the frequency of job change.

d. Pattern of users inputting no value in the poverty filter question; yes, in the recent bad job change with no values in the frequency of job change.

e. Pattern of users inputting no value in the poverty filter question; no in the recent bad job change with values in the frequency of job change.

f. Pattern of users inputting no value in the poverty filter question; no in the recent bad job change with no values in the frequency of job change.

8.24 General Current Behaviour

The questions are investigating the person's general current behaviour e.g., risk-taking, sleep patterns, daily activities, challenging behaviour and diet. The concept model allows answers to the filter questions only when yes is answered.

GEN-RSK-B..	GEN-UNINT..	GEN-SLEEP-..	GEN-UNUSL..	GEN-CHALL..	GEN-DAY-STRU..	
0	0	0	0	0	\N	14
					NORMAL	57
					OVERACTIVE	5
					UNDERACTIVE	10
				1	NORMAL	1
					UNDERACTIVE	1
				2	NORMAL	7
					OVERACTIVE	1
					UNDERACTIVE	5
				3	\N	3
					INACTIVE	2
					NORMAL	2
					UNDERACTIVE	10
				4	\N	2
					INACTIVE	1
					NORMAL	4
					UNDERACTIVE	9
				5	\N	2
					NORMAL	4
					UNDERACTIVE	10
				6	NORMAL	2
					UNDERACTIVE	11
				7	INACTIVE	1
					UNDERACTIVE	8
				8	\N	1
					INACTIVE	1
					NORMAL	2
					UNDERACTIVE	5

GEN-RSK-B..	GEN-UNINT..	GEN-SLEEP-..	GEN-UNUSL..	GEN-CHALL..	GEN-DAY-STRU..	
\N	\N	\N	\N	3	OVERACTIVE	1
					UNDERACTIVE	1
				4	\N	5
					NORMAL	1
					OVERACTIVE	1
					UNDERACTIVE	2
				5	\N	3
					UNDERACTIVE	8
				6	\N	7
					OVERACTIVE	1
					UNDERACTIVE	1
				7	\N	4
					INACTIVE	1
					UNDERACTIVE	4
				8	\N	5
					INACTIVE	2
					NORMAL	1
					OVERACTIVE	1
					UNDERACTIVE	5
				9	\N	1
					INACTIVE	3
					UNDERACTIVE	1
				10	INACTIVE	1
				\N	\N	50,505
					INACTIVE	1
					NORMAL	40
					OVERACTIVE	7
					UNDERACTIVE	21

Figure 50: General Current Behaviour Analysis

8.24.1 User's Path/Mental Model – General Current Behaviour

Mental models derived are as follows:

a. Pattern of value inputted in concerns with risk aggression, unintended behaviour, unusual behaviour, challenges in relating and the day structure.

b. Pattern of value inputted in concerns with risk aggression, unintended behaviour, unusual behaviour, challenges in relating and no value in the day structure.

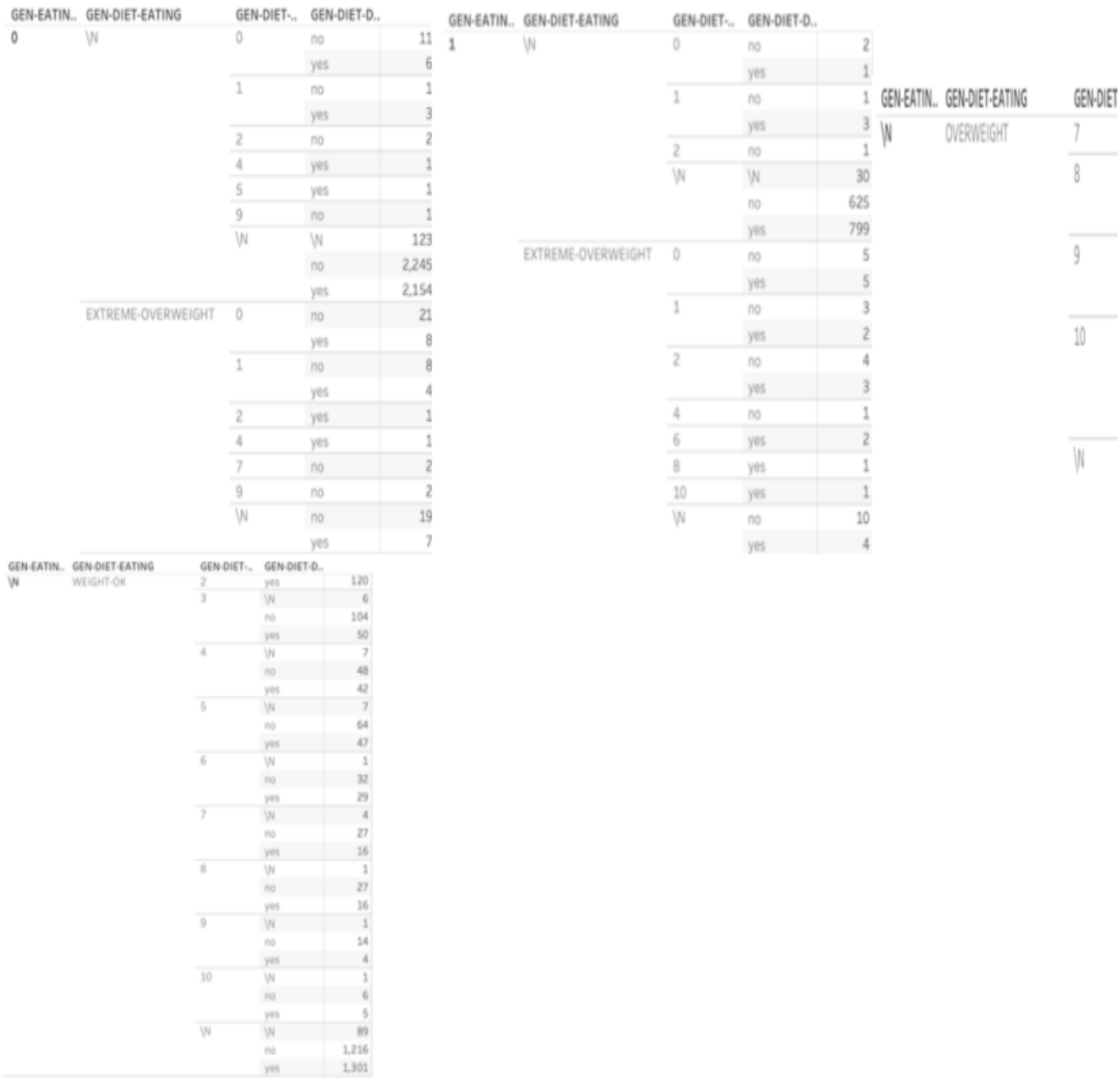
c. Pattern of no value inputted in all the nodes

d. Pattern of no values in the nodes except value in the challenge node

e. Pattern of no values in the nodes except the day structure.

8.25 Appropriateness of Diet

The questions investigate how healthy the service user diet is as regards to eating, drinking, weight gain or loss in recent months. Answers to these questions can be with a value or no value.



GEN-EATIN..	GEN-DIET-EATING	GEN-DIET-..	GEN-DIET-D..	
0	\N	0	no	11
			yes	6
		1	no	1
			yes	3
		2	no	2
		4	yes	1
		5	yes	1
		9	no	1
		\N	\N	123
			no	2,245
			yes	2,154
	EXTREME-OVERWEIGHT	0	no	21
			yes	8
		1	no	8
			yes	4
		2	yes	1
		4	yes	1
		7	no	2
		9	no	2
		\N	no	19
			yes	7

GEN-EATIN..	GEN-DIET-EATING	GEN-DIET-..	GEN-DIET-D..	
1	\N	0	no	2
			yes	1
		1	no	1
			yes	3
		2	no	1
		\N	\N	30
			no	625
			yes	799
	EXTREME-OVERWEIGHT	0	no	5
			yes	5
		1	no	3
			yes	2
		2	no	4
			yes	3
		4	no	1
		6	yes	2
		8	yes	1
		10	yes	1
		\N	no	10
			yes	4

GEN-EATIN..	GEN-DIET-EATING	GEN-DIET
\N	OVERWEIGHT	7
		8
		9
		10
		\N

GEN-EATIN..	GEN-DIET-EATING	GEN-DIET-..	GEN-DIET-D..	
\N	WEIGHT-OK	2	yes	120
		3	\N	6
			no	104
			yes	50
		4	\N	7
			no	48
			yes	42
		5	\N	7
			no	64
			yes	47
		6	\N	1
			no	32
			yes	29
		7	\N	4
			no	27
			yes	16
		8	\N	1
			no	27
			yes	16
		9	\N	1
			no	14
			yes	4
		10	\N	1
			no	6
			yes	5
		\N	\N	89
			no	1,216
			yes	1,301

Figure 51: Appropriateness of Diet Analysis

8.25.1 User's Path/Mental Model - Appropriateness of Diet

Mental models derived are as follows:

a. Pattern of values in eating disorder and dieting, change in diet and no in diet due to drinking.

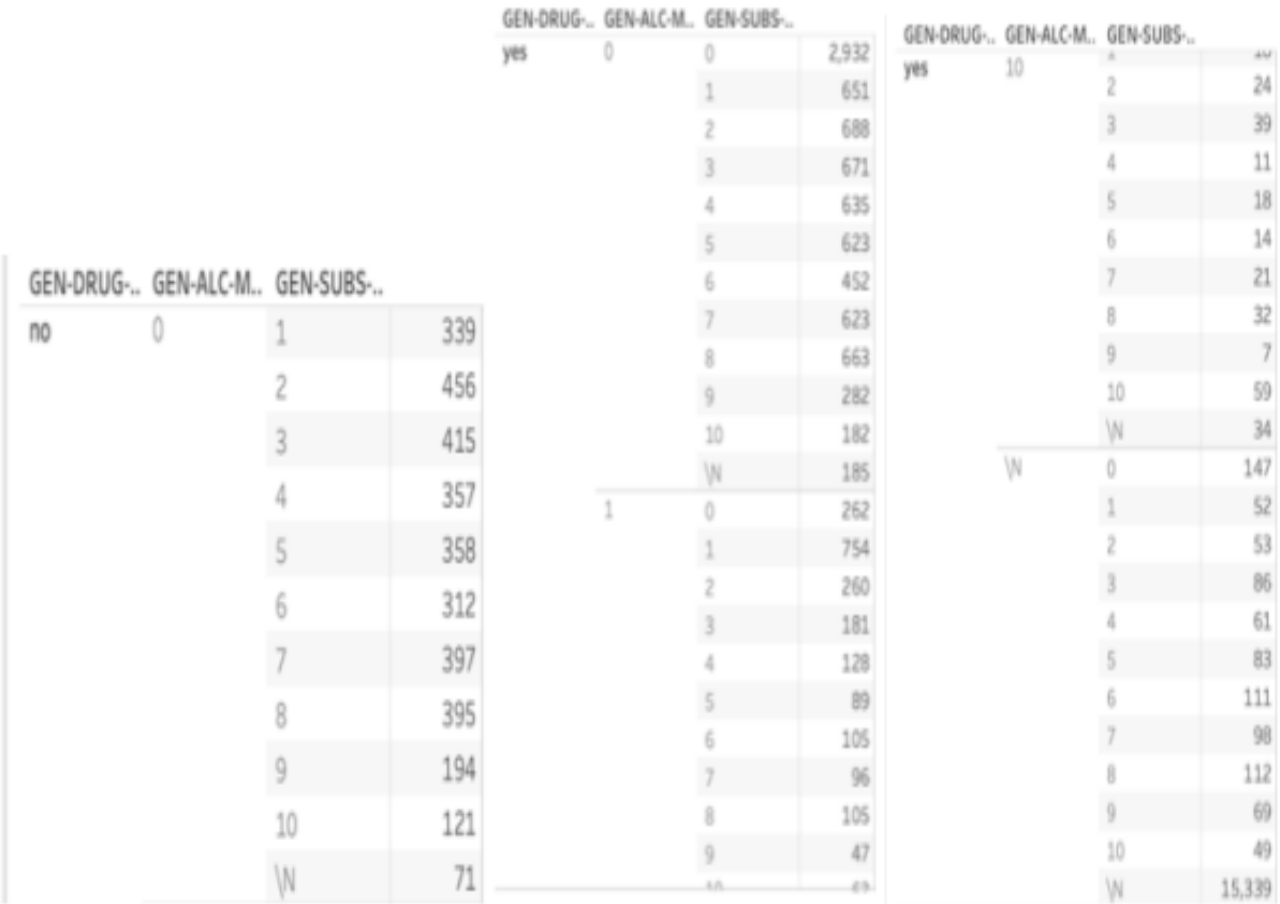
b. Pattern of answers to general eating disorder and no value in other nodes.

c. Pattern of values in the eating disorder question and no value in the rest of the questions.

d. Pattern of values in the eating disorder question and no value in the rest of the questions.

8.26 Substance Misuse

The degree at which effect of alcohol and drugs misuse. When the leaf question is answered yes, one of the filter questions has to be answered.



GEN-DRUG-..	GEN-ALC-M..	GEN-SUBS-..	
no	0	1	339
		2	456
		3	415
		4	357
		5	358
		6	312
		7	397
		8	395
		9	194
		10	121
		\N	71

GEN-DRUG-..	GEN-ALC-M..	GEN-SUBS-..	
yes	0	0	2,932
		1	651
		2	688
		3	671
		4	635
		5	623
		6	452
		7	623
		8	663
		9	282
		10	182
		\N	185
	1	0	262
		1	754
		2	260
		3	181
		4	128
		5	89
		6	105
		7	96
		8	105
		9	47

GEN-DRUG-..	GEN-ALC-M..	GEN-SUBS-..	
yes	10	2	24
		3	39
		4	11
		5	18
		6	14
		7	21
		8	32
		9	7
		10	59
		\N	34
	\N	0	147
		1	52
		2	53
		3	86
		4	61
		5	83
		6	111
		7	98
		8	112
		9	69
		10	49
		\N	15,339

Figure 52: Substance Misuse Analysis

8.26.1 User's Path/Mental Model – Substance Misuse

Mental models derived are as follows:

a. Pattern of values in drug misuse, alcohol and substance misuse questions

b. Pattern of values in drug misuse, alcohol and no value in substance misuse questions

c. Pattern of values in drug misuse, no value in the alcohol misuse and substance misuse questions

d. Pattern of no values in drug misuse, alcohol and substance misuse questions

e. Pattern of values in drug misuse, alcohol and no value in substance misuse

8.27 Adverse Life Events

The question in this section investigates if the person has any adverse life events e.g. suffered abuse, criminal justice proceedings, serious injury, detrimental upbringing/education, eating disorders that contribute to his/her being suicidal.

GEN-PHYS-ABSE	GEN-PHY-A..	GEN-PHYS-..	GEN-LIFE-SEX-..	GEN-SEX-A..	GEN-EMOT-AB..	GEN-EMOT-..	GEN-FINAN..	
0	\N	\N	\N	\N	\N	\N	\N	1
	yes	YES	\N	\N	\N	\N	NO	1
				NO	0	\N	NO	1
				YES	\N	YES	yes	1
0.27926078	yes	NO	\N	YES	0.27926078	YES	no	1
0.31211499	\N	\N	0.483230664	YES	\N	\N	NO	1
			\N	\N	\N	\N	NO	1
0.59137577	\N	\N	\N	\N	\N	\N	NO	1
				YES	\N	\N	NO	1
	no	NO	\N	\N	\N	\N	NO	1
0.032854209	\N	\N	\N	\N	\N	\N	NO	1
							YES	1
				YES	\N	\N	\N	1
		NO	\N	\N	\N	\N	no	2
							NO	2
							yes	1
				NO	\N	\N	NO	1
		YES	\N	\N	\N	\N	\N	1
							NO	1
				YES	\N	\N	NO	1
	no	\N	\N	YES	\N	\N	NO	1
		NO	0.457221081	NO	\N	\N	YES	1
			\N	\N	\N	\N	\N	1
							no	1
				YES	\N	\N	NO	1
							YES	1
		YES	\N	\N	\N	\N	NO	1
							yes	1

GEN-PHYS-ABSE	GEN-PHY-A..	GEN-PHYS-..
\N	no	\N

Figure 53: Adverse Life Events Analysis

8.27.1 User's Path/Mental Model – Adverse Life Events

Mental models derived are as follows:

a. Pattern of values in at least one of the questions relating to physical, sex and emotional abuse experience

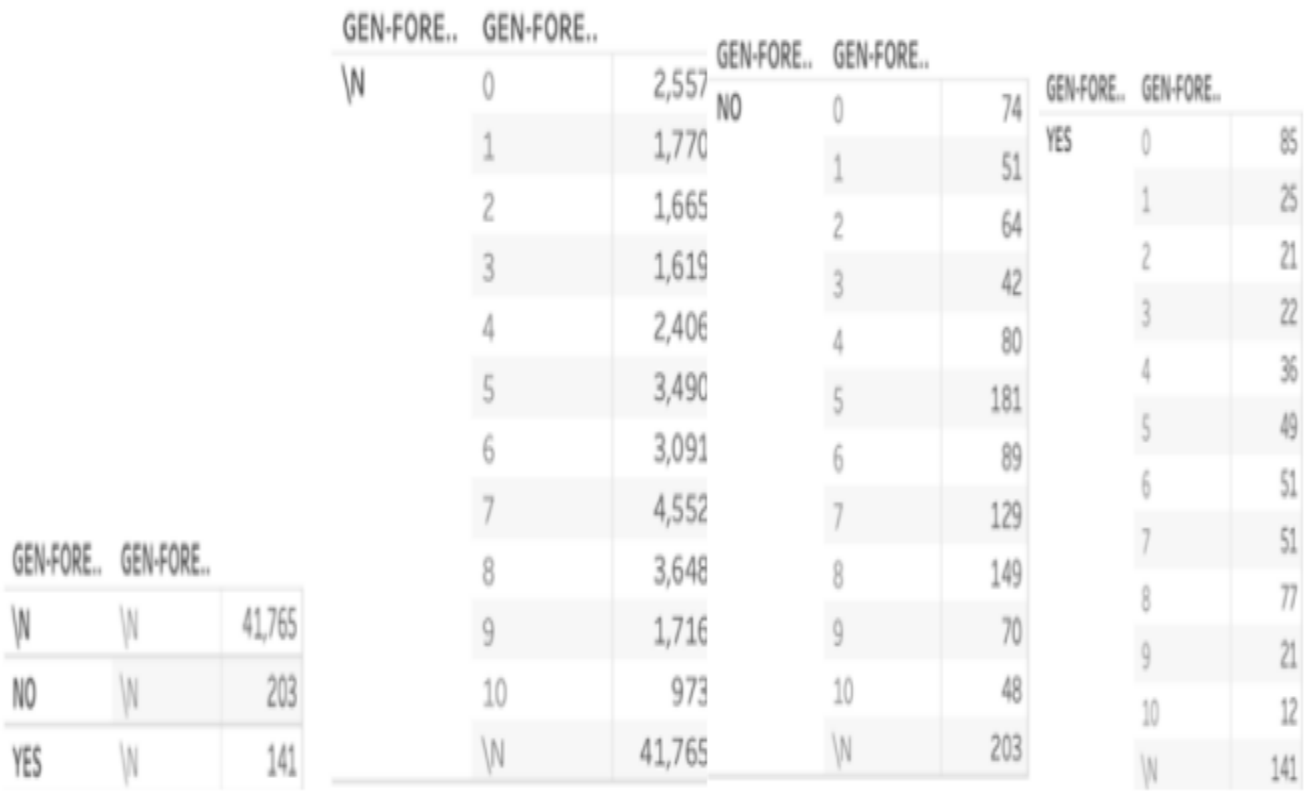
b. Pattern of values answering yes to a node and inputting no value to the rest of the physical, sex and emotional abuse experience questions

c. Pattern of no values in all nodes relating to physical, sex and emotional abuse experience

d. Pattern of inputting no value in the general physical abuse and inputting a value in in abuse as a child experience

8.28 Other Challenging Experiences

Forensic/ Criminal Proceedings Questions In this node, the questions relating to criminal proceeding questions



GEN-FORE..	GEN-FORE..	
\N	\N	41,765
NO	\N	203
YES	\N	141

GEN-FORE..	GEN-FORE..	
\N	0	2,557
	1	1,770
	2	1,665
	3	1,619
	4	2,406
	5	3,490
	6	3,091
	7	4,552
	8	3,648
	9	1,716
	10	973
	\N	41,765

GEN-FORE..	GEN-FORE..	
NO	0	74
	1	51
	2	64
	3	42
	4	80
	5	181
	6	89
	7	129
	8	149
	9	70
	10	48
	\N	203

GEN-FORE..	GEN-FORE..	
YES	0	85
	1	25
	2	21
	3	22
	4	36
	5	49
	6	51
	7	51
	8	77
	9	21
	10	12
	\N	141

Figure 54: Other Challenging Experiences Analysis

8.28.1 User's Path/Mental Model – Other Challenging Experiences

Mental Models include:

a. Pattern of no values in the forensic and criminal proceedings questions

b. Pattern of 'no' answer in the forensic question and no value in the criminal proceedings

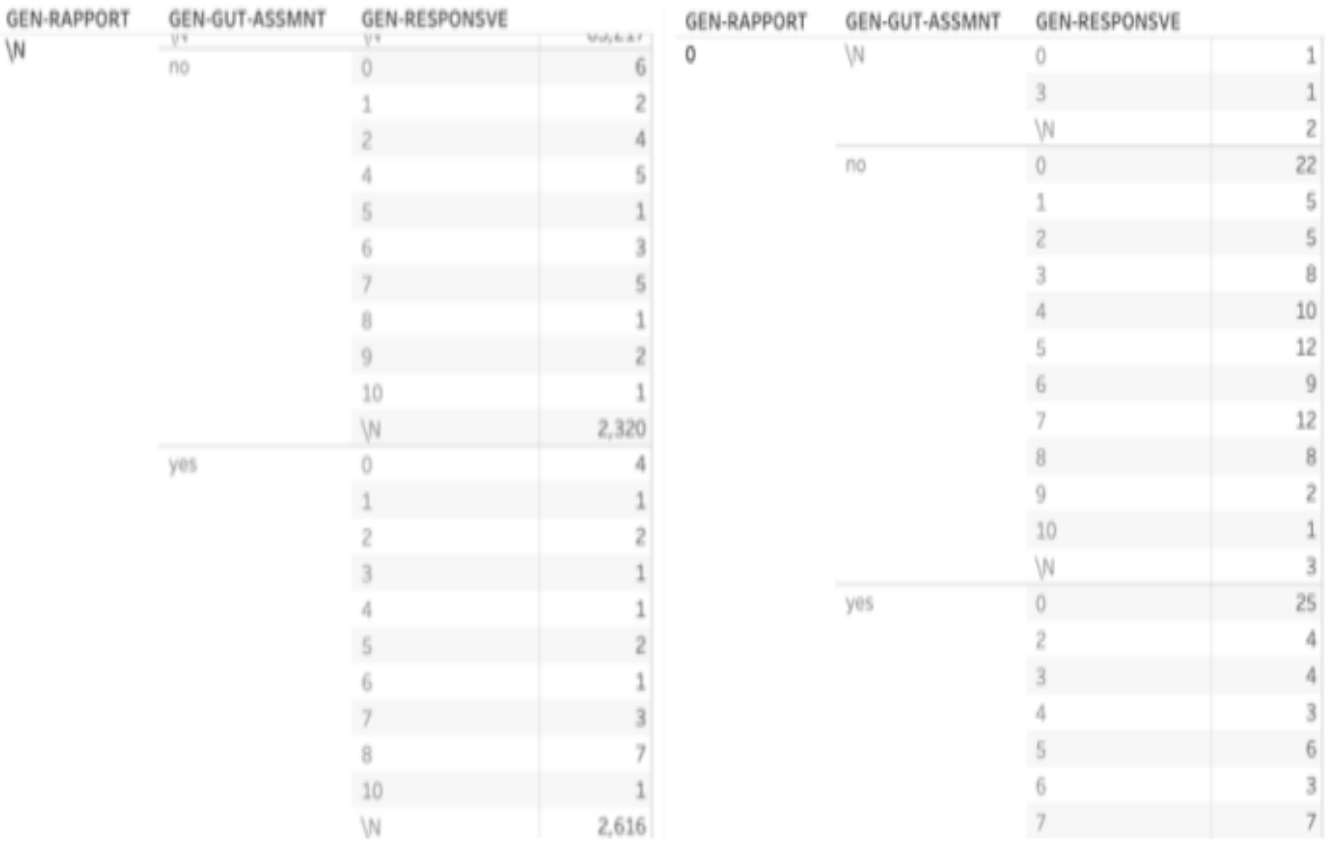
c. Pattern of 'no' answer in the forensic question and value in the criminal proceedings question

d. Pattern of 'yes' answer in the forensic question and no value in the criminal proceedings

e. Pattern of 'yes' answer in the forensic question and value in the criminal proceedings

8.29 Person's Behaviour Presentation during Assessment

These questions investigate how difficult it to rapport with the service user and the un-willingness is to communicate as well as the assessor's uneasiness about the service user.



GEN-RAPPORT	GEN-GUT-ASSMNT	GEN-RESPONSVE	
\N	no	0	6
		1	2
		2	4
		4	5
		5	1
		6	3
		7	5
		8	1
		9	2
		10	1
		\N	2,320
	yes	0	4
		1	1
		2	2
		3	1
		4	1
		5	2
		6	1
		7	3
		8	7
		10	1
		\N	2,616

GEN-RAPPORT	GEN-GUT-ASSMNT	GEN-RESPONSVE	
0	\N	0	1
		3	1
		\N	2
	no	0	22
		1	5
		2	5
		3	8
		4	10
		5	12
		6	9
		7	12
		8	8
		9	2
		10	1
		\N	3
	yes	0	25
		2	4
		3	4
		4	3
		5	6
		6	3
		7	7

Figure 55: Person's Behaviour Presentation during Assessment Analysis

8.29.1 User's Path/Mental Model – Person's Behaviour Presentation during Assessment

Mental models derived are as follows:

a. Pattern of no values in all nodes; the general rapport, gut assessment, responsiveness questions.

b. Pattern of values in all the general rapport, gut assessment, responsiveness questions.

c. Pattern of no value in the general rapport question, no in the gut assessment but a value in the general responsive question.

d. Pattern of value in the general rapport question, no in the gut assessment but a value in the general responsive question.

e. Pattern of value in the general rapport question, yes in the gut assessment and a value in the general responsive question.

8.30 Verbal Indicator of Risk

The questions are asked to understand assessor's concerns about the service user's verbal indicators of risk. If the answer is yes; it is expected that the degree of aggression, level of depression and the degree to which the person is generally making sense is assessed.

GEN-COHERENCE	GEN-RISK-V..	GEN-RISK-A..	GEN-RISK-UPBEAT	
yes	0	0	0	13
			3	3
			4	3
			5	2
			6	1
			7	3
			8	1
			9	1
			\N	1
		1	0	5
			1	1
			3	1
			4	1
		2	0	12
			1	1
			2	1
			3	1
			4	2
			5	2
			6	1
			\N	1
		3	0	20
			1	2
			3	2
			5	4
			6	2
			8	1

GEN-COHERENCE	GEN-RISK-V..	GEN-RISK-A..	GEN-RISK-UPBEAT	
yes	10	8	9	1
			\N	2
		10	10	1
		\N	8	1
			9	1
	\N	0	0	1
			2	1
		2	0	1
			8	1
		3	10	1
		4	1	1
		5	0	1
			1	1
			3	1
		6	0	1
			8	1
			\N	1
		7	0	1
			1	3
			4	1
		8	0	1
			1	1
			4	1
		9	\N	1
		10	10	1
		\N	5	1
			9	1
			\N	1,159

Figure 56: Verbal Indicator of Risk Analysis

8.30.1 User's Path/Mental Model – Verbal Indicator of Risk

The mental model derived from this include:

a. Pattern of no value in all nodes relating to the verbal indicator of risks questions.

b. Pattern of 'Yes' answered in general coherence and no value inputted in all other nodes relating to the verbal indicator of risks questions.

c. Pattern of values in the coherence question(yes) and no value in the risk and a value in the risk aggressive questions.

d. Pattern of 'Yes' answer in the coherence questions and no value in the other nodes relating to the verbal indicator of risks questions.

8.31 Body Language and Expression

Questions relating to concerns about the service user's body language and expression.

GEN-DISTRSS-B-LANG	GEN-LOW-MOOD	GEN-THREAT-MOVE	GEN-DETACHED	GEN-EYE-M...	GEN-AVOID-EYE-CONTACT	
0	0	4	0	8	APPROPRIATE	1
			3	0	APPROPRIATE	1
			4	7	DARTING	1
		5	0	10	FIXED-STARING	2
			1	5	APPROPRIATE	1
					DARTING	1
			5	6	FIXED-STARING	1
				8	FIXED-STARING	1
		6	0	2	APPROPRIATE	1
				3	APPROPRIATE	1
				8	FIXED-STARING	1
				10	APPROPRIATE	1
			3	8	APPROPRIATE	1
		7	0	0	APPROPRIATE	1
			2	8	APPROPRIATE	2
			3	4	DARTING	1
			7	8	\N	1
			8	0	APPROPRIATE	1
			9	6	DARTING	1
		8	0	2	APPROPRIATE	1
				10	FIXED-STARING	1
		9	9	0	DARTING	1
			\N	0	UNRESPONSIVE-GLAZED	1
		\N	0	0	APPROPRIATE	1
					FIXED-STARING	1
				4	APPROPRIATE	1
			8	\N	UNRESPONSIVE-GLAZED	1
			\N	2	\N	2
GEN-DISTRSS-B-LANG	GEN-LOW-MOOD	GEN-THREAT-MOVE	GEN-DETACHED	GEN-EYE-M...	GEN-AVOID-EYE-CONTACT	
\N	7	4	6	10	FIXED-STARING	1
		5	3	5	APPROPRIATE	1
		7	0	\N	FIXED-STARING	1
			6	7	\N	1
		\N	\N	0	\N	1
				6	\N	1
	8	6	\N	\N	\N	1
	9	1	2	0	APPROPRIATE	1
	10	9	5	7	\N	1
	\N	3	1	\N	\N	1
		5	0	\N	UNRESPONSIVE-GLAZED	1
			3	4	APPROPRIATE	1
		7	6	\N	DARTING	1
		8	0	\N	\N	1
		\N	\N	0	\N	897
					FIXED-STARING	1
					UNRESPONSIVE-GLAZED	1
				1	\N	550
				2	\N	551
				3	\N	496
				4	\N	432
				5	\N	423
				6	\N	234
				7	\N	206
				8	\N	171
				9	\N	36
				10	\N	12
				\N	\N	63,748

Figure 57: Body Language and Expression Analysis

8.31.1 User's Path/Mental Model – Body Language

Mental Model extracted:

a. Pattern of inputting values in all the associated nodes relating to body language and expression questions

b. Pattern of no values in all the associated nodes relating to body language and expression questions

c. Pattern of no values in the threat movement, feeling detached, and avoiding eye contact and values in other nodes

d. Pattern of value in no other questions apart from the eye movement question

e. Pattern of value in eye movement and no value in avoiding eye contact

8.32 Sharing Accommodation Statistics

To ascertain if the service user is living with someone aside his/her partner.

GEN-MARITAL-STATUS	PARTNER-SHARE-ACC	
\N	\N	2,740
	no	1,552
	yes	1,440
no	\N	1,789
	no	553
	yes	105
yes	\N	24
	no	371
	yes	1,179

Figure 58: Sharing Accommodation Statistics

8.32.1 User's Path/Mental Model – Sharing Accommodation

Mental Models extracted include:

a. Pattern of no values for the marital status and sharing accommodation with partner

b. Pattern of no values for the marital status and a no answered to sharing accommodation with partner question

c. Pattern of no values for the marital status and a yes answered to sharing accommodation with partner question

d. Pattern of 'Yes' answered for the marital status and a no value answered to sharing accommodation with partner question

e. Pattern of 'Yes' answered for the marital status and a yes answered to sharing accommodation with partner question

f. Pattern of 'Yes' answered for the marital status and a no value inputted to sharing accommodation with partner question.

8.33 Dependents

To understand the number of dependents living with service user if applicable

GEN-MARITAL-STATUS	PARTNER-SHARE-ACC	GEN-ACCOM-SHARE	GEN-ACCOM-DEPNDNTS	GEN-ACCOM-NUM-DEP	
yes	\N	yes	yes	3	1
				5	1
	no	\N	\N	\N	8
		no	\N	\N	152
		yes	\N	\N	4
			no	\N	143
			yes	0	5
				1	31
				2	13
				3	9
				4	4
				7	1
				\N	1
	yes	\N	\N	\N	15
			yes	2	1
		no	\N	\N	411
		yes	\N	\N	3
			no	\N	246
			yes	0	7
				1	192
				2	201
				3	58
				4	31
				5	6
				6	2
				8	1
				9	1
				\N	4

GEN-MARITAL-STATUS	PARTNER-SHARE-ACC	GEN-ACCOM-SHARE	GEN-ACCOM-DEPNDNTS	GEN-ACCOM-NUM-DEP	
no	\N	\N	\N	\N	25
		no	\N	\N	1,124
		yes	\N	\N	11
			no	\N	457
			yes	0	10
				1	97
				2	44
				3	10
				4	5
				\N	6
	no	\N	\N	\N	2
		no	\N	\N	79
			no	\N	5
		yes	no	\N	367
			yes	0	3
				1	67
				2	17
				3	9
				4	4
	yes	\N	\N	\N	1
		no	\N	\N	32
		yes	\N	\N	1
			no	\N	42
			yes	0	1
				1	15
				2	6
				3	4
				4	3

GEN-MARITAL-STATUS	PARTNER-SHARE-ACC	GEN-ACCOM-SHARE	GEN-ACCOM-DEPNDNTS	GEN-ACCOM-NUM-DEP	
\N	\N	\N	\N	\N	518
			yes	1	1
		no	\N	\N	1,953
		yes	\N	\N	59
			no	\N	131
			yes	0	1
				1	48
				2	19
				3	5
				4	2
				6	1
				9	1
				\N	1
	no	\N	\N	\N	3
			no	\N	41
			yes	0	2
				1	5
				2	4
				3	5
				\N	1
		no	\N	\N	43
		yes	\N	\N	20
			no	\N	1,111
			yes	0	31
				1	169
				2	69
				3	23
				4	12

Figure 59: Dependents Analysis

8.33.1 User's Path/Mental Model – Dependents

Mental models extracted are as follows:

a. Pattern of no values for the living with dependents and number of dependants

b. Pattern of value answered as yes for the living with dependents questions and no value for the number of dependant question

c. Pattern of values inputted for the two questions

d. Pattern of no answered in the accommodation dependent question and no value for the rest of the questions

e. Pattern of no values for all the nodes relating to dependent questions.

Chapter 9 - Discussion – Comparing GRIST's Mental Model and Users' Mental Model of GRIST

9.1 introduction

This chapter highlights the gaps between the conceptual model of GRiST and the elicited users' mental model. It focuses on the process of data collection driven by the dynamic interface of GRiST through the question tree (QT), and how the users respond. It highlights the challenges of users and the implication to effective risk assessment and the preferred pathway of the users. This will highlight options for aligning the GRiST model with the identified users' mental model and set the base for the provision of possible solutions in the enhancement of GRiST model.

9.2 Overview of Issues / Challenges

The presentation of the data and its analysis highlights issues in the data collection process of GRiST and how the model used in the system helps to direct data collection based on some initial data entered or answers given to questions. The highlights show strong dependencies between data variables and the type of relationships that determine the data needed to be collected.

It also highlighted the presence and absence of some data that may be instrumental to the risk formulation and judgement. Patterns of data collection, the perception of risk assessment by clinicians/users, data perceived as important that are considered relevant for risk assessment and inconsistencies in the entries of data were all highlighted in the data presentation.

These highlights provide the basis to examine the data collection process in risk assessment; patterns and approaches of data collection; data inconsistencies and incomplete data; clinical workflow; and the role played by the dynamic data collection interface of GRiST and the hierarchical task structure in providing a structured and objective approach to using GRiST.

9.3 GRiST's Acceptability

The findings show that GRiST is increasing in popularity and acceptance with increasing number of assessments. The number of users and assessments almost doubled from 13,674 in 2012 to 21,057 in 2013 but increased in 2014. Due to the steady increase of the assessment; this could imply that GRiST is supporting clinicians in meeting their risk assessment needs. It may also imply that users are finding it easier to use GRiST may be due to its structured systematic approach or its ability to accommodate clinicians' workflow and practices.

The ability of GRiST to meet users' requirements and needs has been emphasised in software development research as a critical success factor of a system. The simplicity and ease of use of the system and the alignment of its operations with the users' workflow are among the usability features of a system which may not have been demonstrated effectively by GRiST. These characteristic features are important in the development and use of any CDSS.

9.4 Unanswered Questions

The data analysis shows many blank nodes or unanswered questions which means required data were omitted or not given/answered deliberately by the user. The blank nodes are required data to a filter branch with a yes answer. This could imply that the user does not find the questions in the branch relevant or the answer options does not meet the answers the user has in mind or the question(s) is confusing to the user.

GRiST with the filter questions identifies the data required for determining the reliability of current intention and can ensure that assessments collect this minimum data set. Therefore, there is a minimum data set required to produce meaning clinical judgements. This implies that every node in the tree requires answers which help to define and direct the required data to be captured by the user. However, statistical records of the use of GRiST shows that 32,580 patients did not have the

minimum data set and 1,289 suicide attempts were missed in them. The findings thus show that the unanswered questions and nodes ignored may lead to some missing data set which the user has failed to capture. The findings show that this can been attributed to the perspective of the user based on current workflow due to the common pattern among various users.

This highlights the importance of using GRiST' functionality in ensuring that important risk information with consequential impact on the risk judgement and plan is captured and communicated across the care pathway. GRiST's model is aimed at guiding clinicians towards the most appropriate data for an individual patient's circumstances and assessment context, but the situation where the clinician fails to enter the appropriate data at the required point puts the effectiveness of the model in doubt.

GRiST model is expected to reflect clinician's practice and mimic the way clinician's carry out risk assessment. The common pattern of omitting certain questions among the various users show that users may be adopting a different model than that of GRiST model.

This finding may raise doubt on the efficiency and effectiveness of the dynamic data collection interface in responding to the emerging patient profile in synchrony with the way human experts gather evidence. This may also imply some differences in the users' mental model with that of GRiST. It may also infer on the ability of the hierarchical structure of GRiST to drive effective and complete clinical data collection. It indicates an anomaly in the pattern of data collection which provides an insight into how users collect data and what data are required or collected.

The findings therefore highlight issues on usability based on the dynamic data collection interface used, issues on the structured and systematic approach used which relates to the GRiST model, and issues on relevance of some leaf nodes or required data and identifying the most important data to collect at every stage.

9.5 Data Inconsistencies

The data analysis shows some inconsistencies in the data entered which could mean lack of understanding of the questions or that users do not pay attention to the questions and what is required due to time pressure. It could also mean that users are prone to entering any data that is convenient for them or they pick any option without considering the implications.

This situation highlights three critical issues in the development and effective use of GRiST. First, it highlights the integrity of the algorithm and model used in GRiST for the systematic collection of data. The system may be lacking in the ability to check and control data entry which allows only valid and consistent answers to be entered.

The dynamic data collection interface may have provided a good support to the hierarchical structure of risk assessment for structured collection of data but its ability to ensure accurate collection of valid answers may be in doubt. There may be a need for the system to flag such data entries and prompt directions on what is expected of the user in such circumstances.

User's thought processes are very important in the data collection process. Concepts and the related data understanding is essential in the collection of risk information. This highlights the need for regular training to bring users up-to-date with the system functionalities and how to use the system effectively. Furthermore, it confirms the complexity of clinical risk assessment and a system that is not well understood which affects the effective use of the system [57].

It highlights the issue of lack of clarity on how to assess individual cases for mental health risk which is becoming a major concern for clinicians and mental health professionals [120]. It also confirms the challenges mental health professionals face in effectively collecting information on risks on the individual [120]. It also shows the importance of the interpersonal, cultural, and organizational aspects of the clinical decision tool in practice and the need to focus on the human dimension in understanding

the user and in meeting his needs with a successful design. A better understanding of these factors is required to enhance the risk assessment tool.

Thirdly, the findings show that the process of risk assessment may be long with too many questions to answer. In order to improve consistency, the process could be made shorter, clearer and easier to complete.

9.6 Dynamic data collection interface of GRiST

The findings show the importance of effective data collection process that will ensure the collection of relevant, related and consistent and complete set of data. The findings show that there is a risk of missing out on some important risk information due to some factors such as time pressure, clinician's assessment skills and the process of data collection.

This highlights the importance of using GRiST functionality in ensuring that important risk information is captured and communicated across the care pathway. GRiST model is aimed at guiding clinicians towards the most appropriate data for an individual patient's circumstances and assessment context, but the situation where the clinician fails to enter the appropriate data at the required point puts the effectiveness of the model in doubt.

The dynamic data collection interface of GRiST allows clinicians to enter required data at any point as they interact with the system. The clinician has the freedom and option to select any specific layer of information to answer related questions. The clinician also has the option to pick and choose the leaf nodes/questions to answer in any format. The implication is that some leaf nodes may be ignored or deliberately avoided due to the preference of the clinician. These preferences and decision to avoid some leaf node may be based on the skills, experiences and intuition; the mental model of the clinician that defines a way of data collection; options to choose and the irrelevance of the questions/data [98, 114].

This highlights the importance of clinician's skill, experiences and intuition which have been described as essential elements of risk assessment [12]. Clinicians' skills may have to be given a big consideration in risk assessment especially when a tool such as GRiST is in use. The reliance of the clinician on clinical experience and inductive reasoning further corroborates the argument that clinical formulation of risk is based on a cognitive understanding of data gathered about risk, ideation, and protective factors [178].

The design of the dynamic data collection interface of GRiST is based on extensive research on how experts think and is modelled on how experts carry out risk assessment. However, this research show that there are various approaches of data collection in risk assessment which may not have been accommodated in the model of GRiST. This confirms the contention and little agreement over what information should be collected and what cues should be recorded and how they might be considered in combination.

The freedom of the clinician to pick and choose data entry points may have allowed the clinician to depend on skills and experience. However, this freedom of choice has opened up issues of missing data, incomplete data and data inconsistencies which may have serious implications for risk judgement and management plan. There is need to ensure the incorporation of crucial transient, dynamic, qualitative, and idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement [85, 184, 129, 93, 128].

A standardised minimum data set that needs to be collected has been suggested based on the recommended guideline by NHS National Programme for Information Technology (NPfIT) [10]. The preference of the clinician may also be based on the clinician's mental model which determines the user's preferred way and therefore is used by the clinician to guide the interaction with GRiST.

The preferred pattern of the user identified in the analysis captures the cognitive thinking and behaviour of the user during the use of a system [25]. It identifies the aspects and features of the system that can facilitate the accomplishment of a functional task during interaction with the system

[28, 29]. It also identifies users' expectations of the system and the same time gives an evaluative view of the system for further enhancements [30].

This highlights the importance of identifying and understanding the users' mental model. Users' mental model shows how users perceive a system, how it works and the processes involved. The implication of the findings where the user prefers to carry out tasks differently from the expectations of the model of the system is that many tasks will not be carried out or completed. An identification and understanding of the perception of the user and how the user carries out tasks becomes imperative in the use of the system for risk assessment.

The findings identify common patterns used by clinicians in risk assessment which describes the users' mental model. The third implication of the preferences of the clinicians in avoiding some data may be due to the irrelevance of data/questions. GRiST is based on the outcome of an extensive research which identified data required and regarded as essential for risk assessment. However, changes in medical policies, procedures and guidelines, and medical innovations and scientific discoveries may introduce new data requirement making existing data requirements redundant and irrelevant.

This confirms one main challenge in risk assessment which is the collection of relevant individualised information of the patient to produce a comprehensive assessment report that will facilitate effective risk formulation and consequent clinical decisions. It shows that an understanding of how clinicians collect required relevant information and the process followed may be vital to the enhancement of the risk assessment and formulation process.

The avoidance and omission of some data sets may highlight data redundancy in GRiST which may have a major negative impact on risk assessment, judgement and management. The findings identify the pattern of the types of data that were omitted. This may require further research to identify new data set to replace or add to the required data set of GRiST.

Finally, the dynamic data collection interface provides a structure and a systematic approach of data collection but lacks the ability to control and guide data entries in a way of ensuring that all required data in a layer of questions are entered correctly and completely at every point. There may be the need to monitor entries at each layer of questions and a prompt given by the system to guide the completion of the data set if the user is leaving the page when it has not been completed.

9.7 Clinical Workflow

GRiST's hierarchical task analysis based on a form of classification provides a structure that enhances the arrangement of tasks in groups. This structured hierarchical arrangement of tasks therefore determines the workflow which is supposed to mimic how experts reason and carry out risk assessment. However, the findings show common patterns and approaches different from the workflow projected/portrayed by GRiST. The common pattern portrays how the clinicians perceive how things should be done.

This different perception may have affected the data collection process, the set of data collected, and the risk judgement and management. Embedding clinical workflow in a system such as GRiST has been described as vital to the successful use of the system in the accomplishment of set tasks. Most CDSSs have been rejected on the basis of the CDSS not aligned with the practical clinical workflow.

The common pattern highlighted in the analysis showed the preferred workflow of users by their selection of only portions of the data to complete and tasks to perform. This has resulted into incomplete task and incomplete data which may have negative implications on the outcome of the process.

This confirms that the importance and usefulness of a clinical decision tool lies in its ability to effectively mimic expert knowledge of the human expertise and the clinical workflow in practice which has been a major challenge. Its impact in facilitating risk assessment [2, 3] and enhancing quality

health care is also dependent on effective understanding and accommodation of the clinician's cognitive workflow which is formalised in the clinician's mental model of the system. This will make it easy for its acceptance and effective utilisation by the clinicians [26, 30].

9.8 Chapter Conclusion

The analysis of the set of data representing users' interaction with GRiST and data entered in a risk assessment process highlights a set of important issues and raises a set of questions. The important issues highlighted relate to the role of GRiST in solving or meeting the challenges of risk assessment and formulation with a focus on its functionalities as enabled by its dynamic data collection interface and its hierarchical task analysis structure.

The findings show missing, incomplete and inconsistent set of data and incomplete task which highlight the impact and importance of clinical skills, experience, intuition, mental model, and the need for clinical workflow alignment. The findings also raise questions on how GRiST has effectively accommodated clinical workflow and aligned its model with users' mental model, and the ability of GRiST to monitor and control users' entries with some promptings to guide the completion of tasks.

The identification of some common patterns in the data collection process of risk assessment indicates the existence of different clinical workflow and different users' mental model from that of the GRiST model. The identification of some commonly omitted data also indicates some irrelevant or redundant set of data which needs further investigation.

The next chapter gives recommendations to findings by presenting the framework, further studies and thesis conclusion. The framework is developed using the if then statement in providing solutions to the clinical decision making based on the results of the analysis.

Chapter 10 Proposed Framework

10.1 introduction

The findings show the need to enhance the risk assessment process of GRIST by addressing the shortcomings identified in the study based on the elicited users' mental model. The proposed framework is based on the elicited users' mental model in the data analysis chapter which is aimed at aligning the users' mental model with the GRIST model. It is also aimed at redesigning the dynamic data collection interface to provide a structured and systematic guide to data collection but with a good measure of control to ensure the collection of all relevant and required data.

10.2 Overview of Framework

Framework is represented using the if -then statements illustrating the flow of the system and users' interaction with the system. If- then- statements represents the conditionalities and the rule base of a CDSS and also form the knowledge base of the system. The use of the if-then-statements highlights the proposed structure of the process of risk assessment in GRiST. A Decision Tree is further used to highlight the mind-map and decision points of the new proposed structure.

The proposed model is aimed at resolving the issues identified in the data analysis. For example, the proposed model will not allow some options to be displayed as these options will be disabled. An example is that the "don't know" option should be disabled for suicide specific leaf question from the If-then statement. Another example is that no option including don't know should be accepted if suic freq has been answered, an answer is expected. Again, suic-id freq should be disabled when the past intention is no.

An example of the If-Then statement encapsulated in R language is given below to provide an explanation of the structure and control in the data collection interface to guide the collection of required data.

no value = don’t know

value= 1,2,3,4,5„,10

if (suic = ‘yes’) {

cat (“suic-attempt options = yes and no”)

} #don’t know option should be disabled for suicide specific leaf question

if (suic-past-att = ‘yes’) {

cat (“no option to input suicide attempt date”)

}

if (suic-freq = “yes”) {

cat (“suicide attempts change frequency options”)

}

#no option including don’t know has if suic freq has been answered, an #answer is expected.

if suic-past-att = no { (suic-id-freq = no value)

} #suic-id freq should be disabled when the past intention is no

if suic-past-att = yes {

(suic-id-freq = value) and (suic-most-rec = value) and (suic-first-occ = ‘value’) and (suic-how many = value) and (suic-id-freq = value)

#none of the filter questions should be allowed to input don’t know when the suic-past is answered as a yes. #suic-id freq should not include don’t know option when the past intention is yes.

10.3 Discussion and explanation of the proposed framework

The proposed framework is based on the elicited users' mental model which highlights users' behaviour and interactions with GRiST, and identified users' pattern indicating clinical workflow or expertise. The framework is aimed at enhancing the risk assessment processes by addressing the issues raised due to the gap between the GRiST model and the elicited users' model. The framework also builds on the users' pattern as new knowledge discovery / generation which should be aligned with GRiST model. The new knowledge is represented using rule-based system (IF then statements) to form the new knowledge base (Rule Base) of the system which determines the risk assessment processes.

The framework therefore is focusing on the effective modelling of human expertise, effective update / modification of the knowledge base to reflect current clinical practice, effective modification of the Client Assessment Tree (CAT) which drives the graphical interface for data collection, effective collection of complete data, and the usability of the user interface.

GRiST as a knowledge base CDSS has three component parts namely the data management layer (knowledge base/expertise/IF-Then Rules; Patient data and clinical data); inference engine, and; interface layer (user interface for data collection and reports). The framework is focused on the data management layer and the interface layer.

10.4 Concepts of the framework

GRiST is based on how humans in general organise their knowledge and reason with it. Therefore, it models human expertise within a generic model of psychological classification which determines the processes of risk assessment. It is pertinent to note therefore that its models of human expertise should be appropriate for the different users and also be current or reflect current practices / expertise. The proposed framework helps in solving this issue identified in the analysis and also helps

in modifying the process of risk assessment to reflect current practices identified in the elicited users' mental model and meeting the users' need.

GRiST psychological model of expertise creates the knowledge base of the system represented by the hierarchical structuring of classifications which should help in disseminating clinical expertise in formats that suit different end users and with functionality tuned to the context of assessment. The elicited users' model from the research shows the users' pattern of assessment and the new clinical expertise which should form the new knowledge base of GRiST. The proposed framework showcasing the IF-THEN statement rules represents a new knowledge base capturing new users' pattern and expertise.

The psychological underpinnings of GRiST also require knowledge engineering techniques that would elicit clinical expertise which would also ensure that the knowledge and reasoning processes in risk assessment are easy to validate by mental-health clinicians and are also made agreeable to machine processing. The proposed IF-THEN statement rules are validated by clinicians based on their behaviour and identified pattern of risk assessment, and are amenable to machine processing.

The galatea's generic form is a hierarchical tree structure that identifies the patient data for collection during assessments as well as how experts organise the data when making risk assessments. GRiST therefore uses various trees and tree structure to support both the knowledge engineering and risk-assessment processes. The tree system is thus designed to help in the development and maintenance of the GRiST expertise as well as how the knowledge is used within the system. The Client Assessment Tree (CAT) represents the complete classification information about a client. It thus requires all nodes to be fully expanded wherever they occur and is used to drive the graphical interface for the Data Gathering Tool (DGT) that collects information during risk assessment. The DGT uses the Question Tree (QT) as an efficient means of accessing the information it requires. The QT has all the information needed to display questions, to obtain the associated client answers, and generate the membership

grades for the answers. Thereafter, the Answer Tree (AT) holds the information about a client that is collected during an assessment and is dynamically created as the assessment progresses.

Therefore, the CAT is the fully expanded tree and the QT and AT are used to support the risk assessment process. The proposed framework redesigned the QT by adjusting the questions, removing redundant and non-relevant questions and providing clear options to enhance the collection of relevant and complete response/answer from users for the AT to hold. The proposed framework therefore redesigns the Client Assessment Tree (CAT) which drives the graphical interface for the Data Gathering Tool (DGT). The dynamic data collection interface is thus adjusted to provide a structured and systematic guide to data collection but with a good measure of control to ensure the collection of all relevant and required data.

10.5 Identified Problems addressed by the framework

The framework is formulated to address four major problem categories identified in the risk assessment processes (data collection) of GRiST. The problems categories include patterns and approaches of data collection; data inconsistencies and incomplete data; non-alignment of clinical workflow; and the usability of the dynamic data collection interface of GRiST. The framework in addressing the identified problems is focused on knowledge generation and validation, and knowledge management and dissemination elements of GRiST as a knowledge management tool.

10.5.1 Patterns and approaches of data collection – Knowledge Generation

GRiST like any other CDSS is primarily a knowledge management tool to provide clinical support based on multiple items of patient data. A CDSS therefore relies on high quality data to work. Assuring the correct collection of data and their quality is vital before starting to program the clinical rules themselves. A part of the requirements should therefore be a thorough description and testing of items to be used in the clinical rules. The clinician would input the information and wait for the CDSS to output the "right" choice, and the clinician would simply act on that output. This implies the

importance of collecting the right input data. Additional traits of a CDSS that improve efficacy include allowing a minimal amount of user-entered data. The issue of many unanswered questions shows either too many questions or many irrelevant questions.

The framework helps to redesign GRiST's functionality to ensure that important risk information with consequential impact on the risk judgement and plan is captured and communicated across the care pathway. The new framework of GRiST's model would guide clinicians towards the most appropriate data for an individual patient's circumstances and assessment context. Clinicians would be able to enter the appropriate data at the required point.

The hierarchical structure of GRiST that defines data structures and types of data to be collected is re-designed by the framework and properly aligned with users' model. to be able to drive effective and complete clinical data collection, based on how users collect data and what data are required or collected.

10.5.2 Controlling data inconsistencies and incomplete data – Knowledge Validation

Data validation is an important aspect of a CDSS and a key contributing factor of its success. The new framework of GRiST's model is designed to check and control data entry and allow only valid and consistent answers to be entered. The ability to ensure accurate collection of valid answers is important and the need for the system to flag such invalid data and incomplete entries and to prompt directions on what is expected of the user in such circumstances should be incorporated in the data collection process/design.

Furthermore, data generation and validation should be based on users' thought process / mental model of data requirements in order to improve consistency and make the process shorter, clearer and easier to complete.

10.5.3 Enabling input of clinical expertise / workflow – Knowledge Management / Clinical Data

The clinician's skill, experience and inductive reasoning in risk assessment play a major role in the data collection process of risk assessment and the building of the clinical data / knowledge base of the system [28; 30]. Embedding clinical workflow in GRiST therefore is vital to the successful use of the system in the accomplishment of set tasks.

GRiST's hierarchical task analysis provides the structured hierarchical arrangement of tasks and determines the workflow of the data collection / risk assessment. The new framework provides a structure that is aligned with how clinicians carry out risk assessment as highlighted by the users' model.

The clinicians' clinical experience and inductive reasoning in risk assessment is accommodated as an enhancement to the process, update of clinical data of the knowledge base and the system.

10.5.4 Functional dynamic data collection interface of GRiST

The quality of a decision support system very much depends on its user interface. The user interface influences how users interact with the CDSS as it provides users a picture-oriented (visual) way to interact with the system and balances the technicality (functionality of the system) and mentality (user's state of mind). The new framework enhances the functionality of the system and aligns it with the user's state of mind. The new framework modifies the hierarchical structure of GRiST model that drives the data collection interface to simplify interactions, remove ambiguity that often led to confusion and unanswered questions, and create satisfaction of use. The IF-THEN statement/rule provides the pathway of data collection and a guide to the redesigning of the dynamic data collection interface. The decision tree in the appendix gives a pictorial view of the framework and the pathway of data collection.

10.6 Evidence Base of New Proposed Framework

The evidence of the effectiveness of CDSS and its challenges have been highlighted in several empirical studies and systematic reviews by medical researchers [28, 29, 31,46]. While the evidence of the effectiveness and success of CDSS is mixed, there is a consensus on the common challenges which needs to be addressed. The common issues are, the integration with clinical workflow; user friendly functional interface; and reliable data collection process as experienced with GRiST from the analysis which the new framework has addressed [71, 79, 29].

Different studies have confirmed that one main feature associated with successful CDSS is the integration of the system into the clinical workflow [30;79; 69]. GRiST was designed to avoid the two fundamental reasons why CDSS are not successfully adopted namely, the failure to integrate with the way organisations and their individual employees work; and the inability to communicate information effectively [29, 31]. GRiST has therefore been designed to circumvent both problems with its flexible requirements and data sharing protocols built into the design process. This validates the new framework which reflects the flexibility of acknowledging new clinical practises and effective data sharing protocols. A 2014 systematic review in line with other reviews confirms that the failure of most CDSS is due to the large gap between the postulated and empirically demonstrated benefits of the system [71,51,31]. The new framework aligns the two models and leaves no gap for the success of GRiST.

On the issue of the effectiveness of the data collection process, empirical evidence from surveys of the opinions of clinicians shows that one of the problems identified by clinicians is the length of the risk assessment / data collection process and the time taken to complete it. Other related problems in the data collection process include the difficulty in entering information and finding relevant information. It was also observed that the data collection process may prevent clinicians from using experience and clinical judgement and provide false reassurance [155, 60]. Studies have shown that users find it inconveniencing when required to enter redundant data and to enter copious amounts of

data. Furthermore, the inconvenience of being required to enter large amounts of data causes users to feel unhappy with the system. These empirical findings support the need for the new framework which provides a structure for easy, simplified and controlled data collection.

On the requirement for a user-friendly functional user interface, empirical studies affirm that a user interface need to be logical and intuitive to reduce errors and increase speed [28, 29, 31]. It should also balance the technicality, that is the functionality of the system, and mentality of the user which can enhance flawless communication and interaction between the user and the decision support system. A report on the usability inspection of GRiST suggests that users use satisficing strategies in selecting the first option that seem good enough.

The study examined the usability of GRiST using a hierarchical task analysis, a cognitive walkthrough and applying heuristics and made some recommendat5ions to improve the user interface. Some of the recommendations include the modification of the implementation model to incorporate user's mental model; avoiding too many information; implement static and dynamic hinting; Avoid giving too many instructions, in fact make instructions unnecessary; skip some processes; omit some pages, etc. The findings support the recommendations of the new framework which provides a clear, structured task analysis process.

Furthermore, the analysis was based on users' data of interactions with GRiST over a period of use which gives empirical evidence of the challenges in the process of risk assessment and data collection. The framework also has to be implemented in GRiST to have a modified hierarchical structure and process of risk assessment that would allow for an empirical validation of the new model.

Chapter 11 Recommendations and Conclusion

11.1 Introduction

The research is aimed at enhancing risk assessment and formulation with an objective focus on examining the processes and approaches of risk assessment and formulation, the challenges and requirements for the enhancement of the process. The research is also objectively focused on the evaluation of the clinical decision-making model of the risk formulation tool represented by GRIST in this research with a view of identifying ways to facilitate the enhancement of risk formulation.

Accomplishing this aim also required the evaluation of the users' perspective of risk formulation by eliciting users' mental model for a better understanding of users' behaviour and preferred method of data collection and risk assessment. This chapter brings together all the highlights of the research to establish and provide answers to the research questions. The chapter discusses the findings of the research in relation to the set research objectives and how the research aim has been fulfilled.

11.2 Research Findings

11.2.1 Critical Examination of Risk Assessment and Formulation Approaches and Tools

The study findings show that formal risk assessment involves complex processes which require a structured approach to facilitate simple and easy risk assessment. The chosen approach determines the capability of the process and tool in incorporating crucial transient, dynamic, qualitative, and idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement. The main concerns in risk assessment include successful collection of relevant complete risk information, the effective recording and integration, and the accommodation of the clinical workflow practice of the clinician.

The importance of effective data collection process that will ensure the collection of relevant, related and consistent and complete set of data was highlighted by the research findings. This places the

burden on GRIST's functionalities in general and the dynamic data collection interface of GRIST in particular to ensure that important risk information is captured and communicated across the care pathway.

The GRIST interface which is based on Galatean classification model allows clinicians to enter required data at any point as they interact with the system. The GRIST' model is aimed at guiding clinicians towards the most appropriate data for an individual patient's circumstances and assessment context, but the findings show some missing data, blank answers, and data inconsistencies which queries the effectiveness of the model.

The underlying reasons for these anomalies in the data collection process could be attributed to time pressure, too many questions to answer, non-relevant questions/data, and difference in clinical workflow in practice and the workflow projected by GRIST; and differences users' mental model and GRIST model.

The main implication of this finding is that the differences in clinical workflow of the system and the clinical workflow in practice need to be synchronised. The cognitive workflow adopted by the user will have to be accommodated in the system. Furthermore, GRIST CDM model will also have to be aligned with the users' mental model. The GRIST CDM model was represented with the drawing of a mind map that showed the kind of interactions undertaken with GRiST, it showed the structure of the functionalities of GRIST and an understanding of how GRIST as a decision support system supports decision making by guiding people through a series of stages.

11.2.2 A critical evaluation of users' interactions with GRIST by eliciting users' mental model

The findings identified patterns, behaviours and preferred options or paths of data collection by the user which represent users' cognitive process and their expectations of the system. The patterns

identified highlight the aspects and features of the system that can facilitate the accomplishment of a functional task during interaction with the system.

The findings show that user' preferred options or path when different from the guidelines of GRIST result in incompletion of some tasks or incomplete data. Some questions were deliberately ignored or unanswered which showed the non-relevance of the questions or data in the process of data collection and risk assessment.

The identified common patterns also show the workflow the user is practicing in risk assessment which is different from the workflow projected/portrayed by GRIST. Situations where a path of questions is ignored with only few questions answered show the choice of the clinician not to follow the path.

The elicited users' mental model identified such common preferred path of the user which highlights the need to embed the current clinical workflow in the GRIST in order to avoid missing and incomplete data. The extent to which GRIST is able to effectively mimic expert knowledge of the human expertise and accommodate the clinical workflow in practice is therefore of paramount importance to the effective use of GRIST.

The elicited users' mental model highlighted issues that need to be addressed to facilitate the enhancement of risk assessment using GRIST. The issues are lack of understanding; role play of clinician's skill, experience and intuition; non-relevance of some questions and or data points; and differences in approaches / workflow practices.

The users' mental model showed some elements of lack of understanding in some of the questions and paths of assessment. Contradictory answers given to some of the questions showed confusion or lack of understanding. This may require the provision of help form the system to guide users in explaining what is expected to continue the task or expected answers at some points of interaction.

The users' mental model also showed the important role the clinician's skill, experience and intuition play in the data collection process of risk assessment. The reliance of the clinician on clinical

experience and inductive reasoning in risk assessment need to be accommodated as an enhancement to the process and the system.

The users' mental model also indicated non-relevance of some questions and or data points which the users ignored. The non-relevance of the questions may be due to changes in policies and medical procedures and innovations which the system needs to identify and accommodate. The elicited users' mental model also indicated that there are various approaches of data collection in risk assessment which may not have been accommodated in the model of GRIST.

The elicited users' mental model therefore shows some differences with the GRIST model which need to be amended and aligned to the users' mental model. This will facilitate the enhancement of GRIST to be fit for purpose.

11.2.3 A critical evaluation of the clinical decision-making model of the Risk Formulation Tool and Process

GRiST's model design is to make it a systematic, structured and holistic tool for gathering risk related information both the static and dynamic information. The model is thus a platform here information on risk factors could possibly be collected in the easiest, fastest, and simplest manner to be organised and integrated to provide an information profile to support rather than replace clinicians' risk judgements.

The information collection system of GRIST based on hierarchical task analysis classification provides a structure to aid quick and easy collection of information with a system organized in layers, starting with a short series of screening questions that, if answered affirmatively, point to areas requiring further, more detailed investigation. This structured hierarchical arrangement of tasks using the structured approach of risk assessment is in line with the standard best practice guideline on risk assessment/formulation. The structure determines the workflow which is supposed to mimic how experts reason and carry out risk assessment.

The findings show that the model provides a structure and a systematic approach of data collection but lacks the ability to control and guide data entries in a way of ensuring that all required data in a layer of questions are entered correctly and completely at every point. Although the dynamic data collection interface provides a structure and a systematic approach of data collection it however lacks the ability to control and guide data entries in a way of ensuring that all required data in a layer of questions are entered correctly and completely at every point.

The clinician's option to pick and choose the leaf nodes/questions to answer in any format resulted in the avoidance of some data and incomplete data. The findings show that some questions were ignored or deliberately avoided due to the preference of the clinician. This freedom of choice based on the GRIST model has opened up issues of missing data, incomplete data and data inconsistencies which may have serious implications for risk judgement and management plan. The chosen actions of users also show differences between the users' mental model and the GRIST model and also show the important role played by clinicians' skills, experience and intuition and clinical workflow in practice.

11.3 Research Questions Answered

The section brings together the research activities and findings to show how the research questions have been answered. The main research question is:

Can clinicians' mental models be extracted from system interactions with the aim of improving clinical decision process for mental health risk assessment and management?

Providing answers to this main research question requires answers to the following three sub questions:

1. Can mental models provide an understanding of users' behaviour?

2. Can mental models be elicited from clinicians' use of Decision Support System?

3. Can the Decision Support encapsulate beneficial mental models?

11.3.1 Can mental models provide an understanding of users' behaviour?

The research explored the use of mental models in understanding the cognitive reasoning, behaviour and perception of users of a system. This understanding of the users' perspective of the system provides an evaluative view of the user which can be used to improve the system functionalities by accommodating the views of the users.

The elicited users' mental model showed common pattern of data collected at different layers of the hierarchical task structure of GRIST. It also showed data that were commonly omitted and questions that were ignored when answers are expected. Missing data, incomplete tasks/data and data inconsistencies were common issues identified.

The elicited users' mental model with the incomplete data and missing data or ignored questions showed the different approach of risk assessment the user has taken. This new identified approach of the user is beneficial to the user and indicates the users' preferred approach and workflow different from the suggested approach of GRIST model.

The underlying reasons behind the chosen approach of the user could be based on the decision to use the prevailing clinical practise / workflow which is not the same provided by the GRiST model. Other reasons could also be lack of understanding of the system and its expectations, confusion arising from the set of questions, nonrelevance of the required data or task, time pressure with too many questions, the overriding factor of the clinician's skills, experience and intuition. These identified factors are taken into consideration in the new proposed framework to enhance the functionalities of GRiST.

11.3.2 Can mental models be elicited from clinicians' use of Decision Support System?

The research also explored how the users' mental model can be extracted effectively from users' interactions with the system. The different possible approaches of eliciting mental models were examined and a method suitable to meet the objectives of this research was chosen. A data set of users' interactions with GRIST containing data collected using the dynamic data collection interface of GRIST was obtained and used for the extraction of the users' mental model.

The data set was prepared and cleaned for the data analysis and extraction of users' mental model. Data analysis and visualisation software was used to identify the common themes, patterns and approaches. The result of the analysis enabled the extraction of users' mental model.

11.3.3 Can the Decision Support encapsulate beneficial mental models?

The elicited users' mental model therefore shows some differences with the GRIST model which need to be amended and aligned to the users' mental model. This will facilitate the enhancement of GRIST to be fit for purpose as it encapsulates the beneficial mental model of the user.

Based on the identified common pattern in the users' mental model, a framework is proposed to integrate the users' approach in the GRIST model that will be beneficial to the users. The framework is in an IF-THEN statement that would be used to modify the algorithm of GRIST and change the dynamic data collection interface to ensure the collection of complete and relevant data in risk assessment and formulation.

11.3.4 Can clinicians' mental models be extracted from system interactions with the aim of improving clinical decision process for mental health risk assessment and management?

The research findings therefore have shown that users' mental models which can be described as the evaluative view of users concerning the system in use can be extracted from their interactions with

the system. It also shows that the extracted users' mental model provides useful information on the users' behaviour and how they prefer to use the system to meet their needs. The understanding of this preferred approach of the user can help in modifying the system to accommodate users' preferences.

11.4 Research Contributions

The research has made contributions to knowledge in two distinct academic domain namely mental models and clinical decision-making process and support systems.

In the academic domain of mental model, the research findings have specifically demonstrated the importance of users' mental model, and how to elicit users' mental model in enhancing the effective development of CDSS and enhancing its functionalities. The research has therefore contributed to academic knowledge in the area of eliciting user mental model using data log of users' interactions with a system, and in the area of using the users' mental model for knowledge generation and validation in CDSS modification and enhancements.

The research has also broadened the knowledge of using users' mental model in capturing current clinical practices and workflow in a clinical environment which is applicable in all other domain where CDSS may be used. The framework also builds on the users' pattern as new knowledge discovery / generation which should be aligned with GRiST model. The new knowledge is represented using rule-based system (IF then statements) to form the new knowledge base (Rule Base) of the system which determines the risk assessment processes. The elicited users' model from the research shows the users' pattern of assessment and the new clinical expertise which should form the new knowledge base of GRiST. The research has also contributed to knowledge in the area of effective modelling of human expertise which is an important prerequisite of developing a functional CDSS.

In the academic domain of clinical decision-making process and support systems, the research has contributed to the enhancement of the data management layer (knowledge base/expertise/IF-Then

Rules; Patient data and clinical data), and the interface layer (user interface for data collection and reports).

The research demonstrates how clinical expertise can be identified and captured to update the knowledge base and modify the hierarchical structure of the risk assessment process (clinical decision-making process) which drives the dynamic interface of the system for data collection. The framework redesigns the hierarchical structure of GRiST which defines data structures and types of data to be collected, in order to modify the risk assessment process and enhance the effective collection of clinical data. The framework helps to redesign GRiST's functionality to ensure that important risk information with consequential impact on the risk judgement and plan is captured and communicated across the care pathway.

11.5 Further Research on the Framework

The simplicity and ease of use of the system and the alignment of its operations with the users' workflow are among the usability features of a system which may not have been demonstrated effectively by GRiST. These characteristic features are important in the development and use of any CDSS.

The framework provides a guide for systems (GRIST) developers to facilitate the modification of the GRIST ontology, model and the dynamic data interface. It contains issues relating to missing data and data inconsistencies to ensure that expected answers and data are entered appropriately. These issues can be put in the context of system's usability. A usability study of GRiST is therefore suggested to identify the usefulness, level of satisfaction and the ease of use of the dynamic data interface of GRiST in meeting up the objectives and needs of the users. The usability study would help identity the best way of designing the graphical user interface of GRiST to accommodate the different needs of the various users in different applications.

GRIST ontology and its base classification model play important roles in the success of GRiST application. It is intended to reflect evidence-based practice and mimic clinicians' mindset and perspectives on risk assessment and formulation. It also determines the design of the dynamic user data interface, and thus affect the data collection process. A further study on the GRIST ontology to understand its usefulness in relation to current mental health risk assessment and formulation practices is therefore suggested.

The framework can be applied in other clinical decision support systems and other web-based application. Further research on how to automatically capture clinical expertise as experts use the system is required for the automatic validation and update of the knowledge base of GRiST and other CDSS. The update of the knowledge base of GRiST is an important concept especially as GRiST is an ongoing project. A further study on how the knowledge base can be effectively updated based on accurate assessment information and clinical judgement is therefore suggested.

Further research is also needed in the area of providing effective guide and direction in the form of pop-ups, and how to capture experts' opinions as they carry out the process of risk assessment for effective data collection. A system's usefulness and ease of use if contingent on the useful help tips provided and the effective data entry validation process embedded in the system.

11.6 Research Conclusion

The complexities of mental health diagnoses and the challenges of risk assessment and formulation highlight the need for a good understanding of the risk assessment process and how it can accommodate the complexities of mental health risk assessment. Mental health risk assessment and formulation is part of a comprehensive review of the mental health of an individual requiring the consideration of a combination of psychological, social and other factors to assess risk level and identify the care needs of the patient. It involves steps determined by the clinical decision-making process adopted in the chosen risk formulation tools based on accepted clinical workflow.

The increasing errors in risk assessment has raised concerns on the clinical decision-making process and the risk assessment approach applied in making appropriate clinical decisions for intervention. This suggests the need to examine the clinical decision-making model of the decision support system used for the risk formulation.

Enhancing risk formulation may therefore require an examination of the clinical decision making (CDM) model of the risk formulation tool used and the users' perceived mental model of the tool based on actual clinical workflow.

This research therefore examines the challenges and issues in risk assessment and formulation, examination of clinical decision-making model of the risk formulation tool; and evaluation of users' perspective of risk formulation. The problem domain will thus be focused on enhancing risk formulation through having a good evaluation and understanding of the clinical decision-making model of the risk formulation process/tool and a good evaluation and understanding of the users' perspective of risk formulation.

The research concludes that formal risk assessment involves complex processes which require a structured clinical decision-making approach to facilitate simple and easy risk assessment. The chosen approach determines the capability of the process and tool in incorporating crucial transient, dynamic, qualitative, and idiosyncratic cues to enable the formation of cue patterns and aid effective clinical judgement.

The use of the risk assessment tool to accomplish required task also depend on the users' preferred approach which is encapsulated in the users' mental model of the system. The users' mental model guides the user in the interactions with the system. However, the essence and effectiveness of a clinical decision tool lies in its ability to effectively mimic human expertise and the clinical workflow in practice which has been a major challenge. Differences between the users' mental model and the system's model are attributed to the non-accomplishment of tasks and incomplete data identified in

the data analysis. A framework that is aimed at aligning the users' mental model with GRIST model is thus proposed.

References

[1] What Factors Determine the Success of Clinical Decision Support Systems? 2003.

[2] N. Abel, H. Ross, and P. Walker. Mental models in rangeland research, communication and management. Rangeland Journal, 20:77–91, 1998.

[3] A. Adams and C.D. Buckingham. GRiST Training Manual. www.egrist.org, 2012.

[4] N. Ahituv. A meta-model of information flow - a tool to support information system theory. Communication ACM, 30:781–791, 1987.

[5] Abu Ahmed. Knowledge engineering for mental-health risk assessment and decision support. Phd thesis, Aston University, Birmingham, UK, February 2011.

[6] Samuel Soma Ajibade and Anthonia Adediran. An overview of big data visualization techniques in data mining. International Journal of Computer Science and Information Technology Research, 4(3):105–113, 2016.

[7] B. L. Allen. Information Tasks: Toward a User-centred Approach to Information Systems. Academic Press, San Diego, 1996.

[8] C. Arcidiacono and F. Procentese. Distinctiveness and sense of community in the historical centre of Naples: A piece of participatory action research. Journal of Community Psychology, 33:631–638, 2005.

[9] S. Elsteing Authur and Alan Schwarz. Evidence base of clinical diagnosis. clinical problem solving and diagnostic decision making: selective review of the cognitive literature. Education and Debate, 324(729-732), 2002.

[10] Oliver Campion Awwad, Alexander Hayton, Leila Smith, and Mark Vuaran. The National Programme for IT in the NHS: A Case History. Technical report, University of Cambridge, 2014.

[11] J. Azzarello and D. E. Wood. Assessing dynamic mental models: Unfolding case studies. Nurse Educator, 31:10–14, 2006.

[12] M. Banning. A review of clinical decision making: models and current research. Journal of Clinical Nursing, 17(2), 2007

[13] P. Bayman and R. E. Mayer. Using conceptual models to teach BASIC computer programming. Journal of Educational Psychology, 80(3):291–298, 1988.

[14] J. Baynes, J. Herbohn, and I. Russell. The influence of farmers' mental models on anagroforestry extension program in the Philippines. Small-Scale Forestry, 10:377–387,2011.

[15] J.S. Beck. Cognitive Therapy: basics and beyond. The Guilford Press, 1995.

[16] P. Benner. From novice to expert: Excellence and power in clinical nursing practice. Addison-Wesley, Menlo Park, CA, 1984.

[17] Denis Besnard, David Greathead, and Gordon D. Baxter. When mental models go wrong: Co-occurrences in dynamic, critical systems, 2004.

[18] P. J. Bieling and W. Kuyken. Is cognitive case formulation science or science fiction. Clinical Psychology: Science and Practice, 10(1):52–69, 2003.

[19] I.M. Blackburn and K. Davidson. Cognitive Therapy for Depression and Anxiety. Blackwell Science, Oxford, 1995.

[20] R. Borum. Improving the clinical practice of violence risk assessment. American Psychologist, 51(9):945–956, 1996.

[21] M. Botti and R. Reeve. Role of knowledge and ability in student nurses' clinical decision-making. Nursing & Health Sciences, 5(1):39–51, 2003.

[22] T. A. Brennan, L. L. Leape, N. M. Laird, L. Hebert, A. R. Localio, A. G. Lawthers, and H. Hiatt. Incidence of adverse events and negligence in hospitalized patients. Technical report, Harvard Medical Practice Study, Quality & Safety in Health Care, 2004.

[23] P. Brusilovsky and E. Millan. The Adaptive Web: Methods and Strategies of Web Personalization, Lecture Notes in Computer Science, chapter User models for adaptive hypermedia and adaptive educational systems, pages 3–53. Springer, 2007.

[24] Bruce G Buchanan and Edward H. Shortliffe. Rule-based Expert System – The MYCIN Experiments of the Stanford Heuristic Programming Project. Addison-Wesley, 1984.

[25] C. D. Buckingham. Psychological cue use and implications for a clinical decision support system. Medical Informatics and the Internet in Medicine, 27(4):237–251, 2002.

[26] C. D. Buckingham, G. Kearns, S. Brockie, A. E. Adams, and I. T. Nabney. Developing a computer decision support system for mental health risk screening and assessment. In J Bryant, editor, Current perspectives in healthcare computing, pages 189–194. Swindon BCS HIC, 2004.

[27] C. D. Buckingham, A. Ahmed, and A. E. Adams. Using XML and XSLT for flexible elicitation of mental-health risk knowledge. Medical Informatics and the Internet in Medicine, 32(1):65–81, 2007.

[28] C. D. Buckingham, A. E. Adams, and C. Mace. Cues and knowledge structures used by mental-health professionals when making risk assessments. Journal of Mental Health, 2008.

[29] C. D. Buckingham, A. Ahmed, and A. E. Adams, editors. Designing multiple user perspectives and functionality for clinical decision support systems, 2013. Proceedings of the 2013 Federated Conference on Computer Science and Information Systems.

[30] C.D. Buckingham. GRiST Handbook. egrist, 2015.

[31] C.D. Buckingham and A. Adams. Classifying clinical decision making: interpreting nursing intuition, heuristics, and medical diagnosis. Journal of Advanced Nursing, 32:990–998, 2000.

[32] T. Buzan. The mind map book. BBC Consumer Publishing: London, 2003.

[33] R.M.J Byne and P.N. Johnson. Spatial reasoning. Journal Memory Language, pages 564–575, 1989.

[34] S. K. Card, T.P. Moran, and A. Newell. The Psychology of Human Computer Interaction. Erlbaum, Hillsdale, NJ, 1983.

[35] Care Services Improvement Partnership. 10 high impact changes for mental health services. Technical report, Department of Health, London, 2006.

[36] K. Carley and M. Palmquist. Extracting, representing, and analyzing mental models. Social Forces, 70:601–636, 1992.

[37] John M. Caroll and Judith Reitman Olson. Mental Models in Human-Computer. National Academies Press, Washington D.C., 1987.

[38] L.P. Cascante, M. Plaisent, B. Prosper, and Maguiraga. The impact of expert decision support systems on the performance of new employees. Information Resources Management Journal, 15(4), Oct-Dec 2002.

[39] P. Chadwick, M. Birchwood, and P. Trower. Cognitive Therapy for Delusions, Voices and Paranoia. Wiley, Chichester, 1997.

[40] Chan, Melissa, Bhatti, Henna, Meader, and Nicholas. Predicting suicide following self-harm: A systematic review of risk factors and risk scales. The British journal of psychiatry: the journal of mental science, pages 277–283, 2016.

[41] G. Clack. Decision making in nursing practice: A case review. Paediatric Nursing, 21(5): 24–27, 2009.

[42] Enrico Coiera. Guide to Medical Informatics, the Internet and Telemedicine. Chapman and Hall, Ltd, 2-6 Boundary Row, London SE1 8HN, United Kingdom, 1997.

[43] D. J. Cooke and C. Michie. The generalizability of the risk matrix 2000: On model shrinkage and the misinterpretation of the area under the curve. Technical Report 1, 2014.

[44] S. Corrie and D.A. Lane. Constructing stories telling tales: A guide to formulation in applied psychology. Karnac, London, 2010.

[45] M. J. Crawley. The R book. John Wiley and Sons, West Sussex, UK, 2007.

[46] P. Croskerry. Achieving quality in clinical decision making: Cognitive strategies and detection of bias. Academic Emergency Medicine. Official Journal of the Society for Academic Emergency Medicine, 9(11):1184–1204, 2002.

[47] Anne-Laure Le Cunff. Mental models. https://nesslabs.com/mental-models, 2019.

[48] Kieras E. David and Susan Bovair. The role of a mental model in learning to operate a device. Cognitive Science, 8(3):255–273, July-September 1984.

[49] K. Davidson. Case formulation in cognitive behaviour therapy: The treatment of challenging and complex cases, chapter Cognitive formulation in personality disorder, page 216–237. Routledge, London, 2006.

[50] Cecilia Vallejos de Schatz and Fabio Kurt Schneider. Intelligent and Expert Systems in Medicine - A Review. Jornadas de Ingeniería Clínica Mar del Plata, 7:1–9, 2011.

[51] Department of Health. Best Practice in Managing Risk: Principles and evidence for best practice in the assessment and management of risk to self and others in mental health services. Technical report, Department of Health, London, 2007.

[52] A. Dimitroff. Mental models theory and search outcome in a bibliographic retrieval system. Library and Information Science Research, 14:141–156, 1992.

[53] K. Douglas, D. Cox, and C. Webster. Violence risk assessment: science and practice. Legal and Criminological Psychology, 4:194–184, 1999.

[54] Kevin S. Douglas, Stephen D. Hart, and Christopher D. Webster. Historical-Clinical-Risk Management-20, Version 3 (HCR-20V3): Development and Overview. International Journal of Forensic Mental Health, 13:93–108, 2014.

[55] D. Dowding and C. Thompson. Measuring the quality of judgement and decision making in nursing. Journal of Advanced Nursing, 44:49–57, 2003.

[56] J. K. Doyle and D. N. Ford. Mental models concepts for system dynamics research. System Dynamics Review, 14(1):3–29, 1998.

[57] M. Doyle and M. Dolan. Violence risk assessment: Combining actuarial and clinical information to structure clinical judgements for the formulation and management of risk. Journal of Psychiatric and Mental Health Nursing, 9:649–657, 2002.

[58] M. Doyle and M. Dolan. Evaluating the validity of anger regulation problems, interpersonal style, and disturbed mental state for predicting inpatient violence. Behavioural Sciences and the Law, 24:783–798, 2006.

[59] M. Doyle and M. Dolan. Understanding and managing risk, chapter 10. Cullompton: Willan, 2008.

[60] M. Doyle and D. Duffy. Assessing and managing risk to self and others. In National Forensic Nurses Research and Development Group. Quay Books, 2006.

[61] M. Doyle, M. Dolan, J. Shaw, and S. Carter. The development of a practical risk assessment framework for multidisciplinary use in mental health services. Technical report, Research Report for the National Forensic Programme, 2008.

[62] A. Dray, P. Perez, N. Jones, C. Le Page, P. DAquino, I. White, and T. Auatabu. The Atoll Game experience: from knowledge engineering to a computer-assisted role playing game. Journal of Artificial Societies and Social Simulation, 9(6), 2006.

[63] G. Drennan and D. Alred. Secure recovery: approaches to recovery in forensic mental health settings. Routledge, London, UK, 2012.

[64] R. Dudley and W. Kuyken. Cognitive Behaviour Therapy: a principle-driven approach, chapter Case Formulation in Cognitive Behavioural Therapy: A principle driven approach, pages 18–44. Routledge, London, 2014.

[65] E. Eckert and B. Alexandra. Continuity and Change: Themes of Mental Model Development Among Small-Scale Farmers. Journal of Extension, 44(1):1–11, 2006.

[66] Tracy D. Eells. Psychotheraphy case formulation: History and current status, chapter History and Current Status of Psychotheraphy Case Formulation, pages 5–25. The Guilford Press, London and New York, 2007.

[67] K. Ehrilich and E Soloway. Human Factors in Computing Systems, chapter An empirical investigation of the tacit plan knowledge in programming. Ablex, Norwood, 1984.

[68] R.L. Engle J. Attempts to use computers as diagnostic aids in medical decision making: A thirty-year experience. Perspectives in Biology and Medicine, 35(2):207–219, 1991.

[69] A. Feeney and S. J. Handley. Comparisons, mental models, and the action effect in judgments of regret. Memory and Cognition, 34:1422–1430, 2006.

[70] Edward A. Feigenbaum and Bruce G. Buchanan. DENDRAL and Meta-DENDRAL roots of knowledge systems and expert system applications. Artificial Intelligence, 59:233–240, 1993.

[71] G. Fischer. User modeling in human-computer interaction. User Modeling and UserAdapted Interaction, 11(1-2):65–86, 2001.

[72] Mental Health Foundation. Fundamental facts about mental health. Technical report, Mental Health Foundation, London, 2016.

[73] Mental Health Foundation. The state of the UK's mental health. Mental Health Foundation, 2017.

[74] K. M. Fraser. Theory based use of concept mapping in organization development: Creating shared understanding as a basis for the cooperative design of work changes and changes in working relationships. PhD thesis, Cornell University, Ithaca, NY, 1993.

[75] L. Freeman and L Jessup. The power and benefits of concept mapping: Measuring use, usefulness, ease of use, and satisfaction. International Journal of Science Education, 26: 151–169, 2004.

[76] Freeplane. Freeplane Tutorials Extensions. Freeplane, 2018. Available online at: http://www.freeplane.org/wiki/index.php/FreeplaneTutorial Extensions.

[77] D. Gentner and A. L. Stevens. Mental Models. Hillsdale, N.J.: Erlbaum, 1983.

[78] Don M Gottfredson and Stephen D. Gottfredson. Stakes and risks in the prediction of violent criminal behavior. Violence and Victims, 3(4):247–262, 1988.

[79] GRiST. egrist. egrist.org, 2020.

[80] W. Grove and P. Meehl. Comparative efficiency of informal (subjective, impressionistic) and formal (mechanical, algorithmic) prediction procedures: the clinical-statistical controversy. Psychology Public Policy and Law, 2:293–323, 1996.

[81] J. Gunn. Let's get serious about dangerousness. Criminal Behaviour and Mental Health, pages 51–64, 1996.

[82] Brian D. Haig. On the permissiveness of the abductive theory of method. Journal of Clinical Psychology, 64(9):1–9, 2008.

[83] K. Hammond. How convergence of research paradigms can improve research on diagnostic judgement. Medical Decision Making, 16:281–287, 1996.

[84] K. Hanisch, A. F. Kramer, C. Huhn, and R. Schumacher, editors. Novice-expert differences in the cognitive representation of system features: Mental models and verbalizable knowledge, 1988.

[85] R. K. Hanson. Twenty years of progress in violence risk assessment. Journal of Inter-personal Violence, 20(2):212–217, 2005.

[86] S. D. Hart. The role of psychopathy in assessing risk for violence: conceptual and methodological issues. Legal and Criminological Psychology, 3:121–137, 1998.

[87] S. D. Hart, P. R. Kropp, D. R. Laws, J. Klaver, C. Logan, and K. A. Watt. The Risk for Sexual Violence Protocol (RSVP): Structured professional guidelines for assessing risk of sexual violence. Technical report, Mental Health, Law, and Policy Institute, Simon Fraser University, Burnaby, BC, 2003.

[88] Stephen Hart and Caroline Logan. Formulation of violence risk using evidence-based assessments: The structured professional judgement approach. Forensic Case Formulation, 10:83– 106, 2011.

[89] C. J. Hawley, B. Littlechild, T. Sivakumaran, H. Sender, T. M. Gale, and K. J. Wilson. Structure and content of risk assessment proformas in mental healthcare. Journal of Mental Health, 15: 437–448, 2006.

[90] S.N. Haynes and W.H. OBrien. Functional analysis in behaviour therapy. Clinical Psychology Review, 10:649–668, 1990.

[91] E. Hewlett and K. Horner. Mental health analysis profiles. Health Working Papers, 81, 2015.

[92] D. O. Himes and P. K. Ravert. Situated peer coaching and unfolding cases in the fundamental skills laboratory. International Journal of Nursing Education Scholarship, 9:265–272, 2012.

[93] N. Holdsworth and G. Dodgson. Could a new Mental Health Act distort clinical judgement? a Bayesian justification of naturalistic reasoning about risk. Journal of Mental Health, 12(5): 451–462, 2003.

[94] J.H. Holland, K.J. Holyoak, R.E. Nisbett, and P.R. Thagard. Processes of Inference, Learning and Discovery. MIT Press, 1986.

[95] F. Holloway and J. Carson. Intensive case management for the severely mentally ill. British Journal of Psychiatry, (172):19–22, 1998.

[96] L. R. Huessmann. The role of social information processing and cognitive schema in the acquisition and maintenance of habitual aggressive behaviour, chapter Human aggression: Theories, research and implications for social policy. Academic Press, London, 1998.

[97] Bowen Hui, Grant Partridge, and Craig Boutilier, editors. A probabilistic mental model for estimating disruption, 2009. IUI '09: Proceedings of the 14th international conference on Intelligent user interfaces.

[98] Aleem Ilyas, H. Schemitsch, Emil, Hanson, and Beate. What is a clinical decision analysis study? Indian journal of orthopaedics, 42:137–139, 2008.

[99] D. Isern and A. Moreno. A Systematic Literature Review of Agents Applied in Healthcare. Journal of Medical Systems, 40(2), 2016.

[100] D.G. Jacobs and M.L. Brewer. APA Practice Guideline provides recommendations for assessing and treating patients with suicidal behaviour. Psychiatric Annuals, 34(5):373–380, 2004.

[101] D.G. Jacobs and M.L. Brewer. Application of the APA practice guidelines on suicide to clinical practice. CNS Spectrums, 11:447–454, 2006.

[102] E. Jefford, K. Fahy, and D. Sundin. A review of the literature: Midwifery decision-making and birth. Women and Birth: Journal of the Australian College of Midwives, 2010.

[103] Judith Johnson. Case Formulation in Cognitive Behaviour Therapy: The Treatment of Challenging and Complex Cases. Routledge: London and New York, 2nd edition, 2015.

[104] S. D. Johnson. Invited reaction: Measuring mental models-thoughts on a research agenda. Human Resource Development Quarterly, 6:257–262, 1995.

[105] Johnson-Laird, P. N. Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Cambridge, MA: Harvard University Press, 1983.

[106] Johnson-Laird, P. N. How We Reason. Oxford: Oxford University Press, 2006.

[107] L. Johnstone and R. Dallos. Formulation in psychology and psychotherapy. Routledge, Hove, 2006.

[108] N. A. Jones, H. Ross, T. Lynam, P. Perez, and A. Leitch. Mental models: an interdisciplinary synthesis of theory and methods. Ecology and Society, 16(1):46, 2011.

[109] N. A. Jones, H. Ross, T. Lynam, and P. Perez. Eliciting mental models: A comparison of interview procedures in the context of natural resource management. Ecology and Society, 19(1), 2014.

[110] R. Karani, R. M. Leipzig, E. H. Callahan, and D. C. Thomas. An unfolding case with a linked objective structured clinical examination (OSCE): A curriculum in inpatient geriatric medicine. Journal of the American Geriatrics Society, 54:1191–1198, 2004.

[111] A. R. Kearney and S. Kaplan. Toward a methodology for the measurement of knowledge structures of ordinary people: The Concept Content Cognitive Map (3CM). Environment and Behavior, 29(5):579–617, 1997.

[112] Juha Kemppinen, Jukka Korpela, Kalle Elfvengren, Timo Salmisaari, Jussi Polkko, and Markku Tuominen. A clinical decision support system for adult adhd diagnostics process. In 46th Hawaii International Conference on System Sciences, pages 2616–2625, 2013.

[113] H. Kemshall. Reviewing Risk: A Review of Research on the Assessment and Management of Risk and Dangerousness: Implications for Policy and Practice in the Probation Service. Technical report, Home Office, London, 1996.

[114] K. Kerrigan. Decision making in today's complex environment. Nursing Administration Quarterly, 15(4):1–5, 1991.

[115] H. Kraemer, A. Kazdin, D. Offord, R. Kesler, P. Jensen, and D. Kupfer. Coming to terms with the terms of risk. General Psychiatry, 54:337–343, 1997.

[116] J. Krik. Cognitive Behaviour Therapy for Psychiatric Problems: A Practical Guide, chapter Cognitive-behavioural assessment. Oxford Medical Publications, Oxford, 1989.

[117] W. Kuyken, C. D. Fothergill, M. Musa, and P. Chadwick. The reliability and quality of cognitive case formulation. Behaviour Research and Therapy, 43:1187–1201, 2005.

[118] J. Langan-Fox, S. Code, and K. Langfield-Smith. Team mental models: Techniques, methods, and analytic approaches. Human Factors, 43:242–271, 2000.

[119] L. L. Leape. Institute of medicine medical error figures are not exaggerated. Journal of the American Medical Association, 284:95–97, 2000.

[120] Lewis and Doyle. Risk Formulation: What are We Doing and Why? International Journal of Forensic Mental Health, 8(4):286–292, 2009.

[121] C.W. Lidz, E.P. Mulvey, and W. Gardener. The accuracy of the predictions of violence to others. Journal of the American Medical Association, 269:1007–1011, 1993.

[122] M. M. Linehan. Cognitive-behavioral treatment of borderline personality disorder. Academic Press, 1993.

[123] Han Liu, Alexander Gegov, and Fredeic T. Stahl. Categorization and construction of rule based systems. In Communications in Computer and Information Science, 2014.

[124] C. Logan, R. Nathan, and A. Brown. Self-harm and Violence: Towards best practice in managing risk, chapter Formulation in clinical risk assessment and management, page 187–204. Chichester, UK: Wiley-Blackwell., 2011.

[125] Caroline Logan. The HCR-20 Version 3: A case study in risk formulation. International Journal of Forensic Mental Health, 13(2):172–180, 2014.

[126] George F. Luger. Artificial intelligence Structures and Strategies for Complex Problem Solving. Addison-Wesley, 5th edition edition, 2005.

[127] Tim Lynam, Raphaël Mathevet, Michel Etinne, Samantha Stone-Jovicich, Anne M. Leitch, Nathaline Jones, Helen Ross, Derick Du Toit, Sharon Pollard, Harry Biggs, and Pascal Perez. Waypoints on a Journey of Discovery: Mental Models in Human-Environment Interactions. Ecology and Society, 17(3), 2012.

[128] A. Maden. Practical application of structured risk assessment. The British Journal of Psychiatry, page 22, 2001.

[129] A. Maden. Standardised risk assessment: why all the fuss? . Technical report, Psychiatric Bulletin, 2003.

[130] A. Maden, F. Scott, R. Burnett, G. Lewis, and P. Skapinakis. Oendinginpsychiatricpatientsaf terdischargefrommediumsecureunits : prospectivenationalcohortstudy.British Medical Journal, 2004.

[131] J.T. Maltsberger. The psychodynamic formulation: An aid in assessing suicide risk. 1992.

[132] E. Mathieu, T.S. Heffner, G. Goodwin, E. Salas, and J. Cannon Bowers. The influence of shared mental models on team process and performance. The Journal of Applied Psychology, 85(2): 273—283, 2000. [

133] P. Matteson and J. W. Hawkins. Concept analysis of decision making. Nursing Forum, 25(2): 4–10, 1990.

[134] S. McManus, P. Bebbington, R. Jenkins, and T. Brugha. Mental health and wellbeing in England: Adult Psychiatric Morbidity Survey 2014. Technical report, NHS, Leeds:NHS Digital, 2016.

[135] Alexander L. Miller, M. Lynn Crismon, A. John Rush, John Chiles, T. Michael Kashner, Marcia Toprac, Thomas Carmody, Melanie Biggs, Kathy ShoreSWilson, Judith Chiles, Brad Witte, Christine BoWThomas, Dawn I. Velligan, Madhukar Trivedi, Trisha Suppes, and Steven Short. The Texas

Medication Algorithm Project: Clinical Results for Schizophrenia. Schizophrenia Bulletin, 30(3):627–647, 2004.

[136] J. Monahan. Mental disorder and violent behaviour: perceptions and evidence. American Psychologist, 47:511–521, 1992.

[137] J. Monahan and H. J. Steadman. Violent storms and violent people: How meteorology can inform risk communication in mental health law. American Psychologist, 51:931–938, 1996.

[138] B. Moore. Risk assessment: A practitioner's guide to predicting harmful behaviour. Whiting and Birch, London, 1996.

[139] J. D. W. Morecroft. System dynamics: Portraying bounded rationality. Omega: The International Journal of Management Science, 11(2):131–142, 1983.

[140] M. G. Morgan, B. Fischhoff, A. Bostrom, and C.J. Atman. Risk communication: a mental models approach. Cambridge University Press, New York, USA, 2002.

[141] Jack Muramatsu and Wanda Pratt. Transparent Queries: investigation users' mental models of search engines. ACM Computing Surveys, September 9-12 2001.

[142] K. Nakamura. A case against giving informants cameras and coming back weeks later. Anthropology News, 49(2):20, 2008.

[143] Staggers Nancy and A. F. Norcio. Mental models: Concepts for human computer interaction research. International Journal of Man Machine Studies, 38(4):587–605, 1993.

[144] National Confidential Inquiry into Suicide and Safety in Mental Health. Annual report. Technical report, University of Manchester, England, Northern Ireland, Scotland, Wales, October 2018.

[145] J. Newson. The Challenges of Mental Health Diagnosis. 2018.

[146] Jacob Nielsen. Enhancing the explanatory power of usability heuristics. Human Factors in Computing Systems, 1994.

[147] D.A Norman. The Psychology of Everyday Things. Basic Books, New York, NY, 1988.

[148] Geoffrey Norman. Research in clinical reasoning: past history and current trends. Medical Education, 39:418–427, 2005.

[149] R. W. Novaco. Violence and mental disorder: Developments in risk assessment, chapter Anger as a risk factor for violence among the mentally disordered. University of Chicago Press, Chicago, 1994.

[150] Division of Clinical Psychology. Good practice guidelines on the use of psychological formulation. Technical report, British Psychological Society, Leicester, 2011.

[151] Institute of Medicine. Clinical practice guidelines we can trust [Committee on Standards for Developing Trustworthy Clinical Practice Guidelines]. National Academies Press, Washington, DC, 2011. Retrieved from: www.iom.edu/Reports/2011/Clinical-Practice-Guidelines-We-CanTrust.aspx.

[152] Royal College of Psychiatrists. Assessment and clinical management of risk of harm to other people. Technical report, Royal College of Psychiatrists, 1996.

[153] BMA Board of Science. Recognising the importance of physical health in mental health and intellectual disability. BMA Science and Education department and the Board of Science, May 2014.

[154] M. Offredy. The application of decision-making concepts by nurse practitioners in general practice. Journal of Advanced Nursing, 28(5):988–1000, 1998.

[155] L. Orme and C. Maggs. Decision-making in clinical practice: How do expert nurses, midwives and health visitors make decisions? Nurse Education Today, 13(4):270–276, 1993.

[156] M. O'Rourke, S. Hammond, and M. Bucknall. Multiagency Risk Management: Safeguarding Public Safety and Individual Care, 2001.

[157] D. Orrell. The future of everything: The science of prediction. Thunder's Mouth Press, New York, 2007.

[158] Victor C Osamor, Ambrose A Azeta, and Oluseyi O Ajulo. Tuberculosis–Diagnostic Expert System: An architecture for translating patients' information from the web for use in tuberculosis diagnosis. Health Informatics Journal, 20(4):275–287, 2013.

[159] Marina Papastergiou. Students' Mental Models of the Internet and Their Practical Exploitation in Informatics Education. Education and Information Technologies, 10(4):341–360, 2005.

[160] Healthcare Quality Improvement Partnership. The assessment of clinical risk in mental health services. Technical report, National Confidential Inquiry into Suicide and Safety in Mental Health (NCISH), University of Manchester, Manchester, 2018.

[161] G. Pask and B. C. E. Scott. Learning strategies and individual competence. International Journal of Man Machine Studies, 4:217–253, 1972.

[162] Vimla L. Patel and Guy J. Groen. Knowledge based solution strategies in medical reasoning. Cognitive Science, 10:91–116, 1996.

[163] M. Persons, J. andTompkins. Handbook of psychotherapy case formulation, chapter Cognitive behavioural formulation. Guilford Press, 1997.

[164] Sturmey Peter. Restrictive Behaviour Practices. Journal of Applied Research in Intellectual Disabilities, 22(2), 2009.

[165] Donald E. Polkinghorne. Narrative configuration in qualitative analysis. International Journal of Qualitative Studies in Education, 8(1):5–23, 1995. doi: 10.1080/0951839950080103. URL ?iiTb,ff/QBXQ`;fRyXRy3yfyN8R3jNN8yy3yRyj.

[166] L. J. Porter-Wenzlaffs. Unfolding multicourse case study: Developing students' administrative competencies. Nurse Educator, 38:241–245, 2013.

[167] National Risk Management Programme. Best practice in managing risk. Technical report, Department of Health, 2007.

[168] C. Rajeswari, Dyuti Basu, and Namita Maurya. IOP Conf. Series: Materials Science and Engineering. In Comparative Study of Big data Analytics Tools: R and Tableau, pages 1–9. IOP Publishing, 2017.

[169] R. E. Redding and J. R. Cannon. In proceedings of the human factors society 36th annual meeting. In Expertise in air traffic control (ATC): What is it, and how can we train for it? pages 1326–1330, Santa Monica, CA:, 1992. Human Factors and Ergonomics Society.

[170] Lynn Rew. Acknowledging intuition in clinical decision making. Journal of Holistic Nursing, 18 (2):94–108, 2000.

[171] Hannah Ritchie and Max Roser. Mental health. Our World in Data, 2019. https://ourworldindata.org/mental-health.

[172] M Sasikumar, S. Ramani, S. Muthu Raman, KSR. Anjaneyulu, and R. Chandrasekar. A Practical Introduction to Rule Based Expert Systems. Narosa Publishing House, New Delhi, 2007.

[173] G. Schiepek, C. Fartacek, J. Sturm, K. Kralovec, R. Fartacek, and M. Ploderl. Nonlinear dynamics: Theoretical perspectives and application to suicidology. Suicide and Life-Threatening Behavior, 41:661–675, 2011.

[174] H. J. Schmidt. Alternative approaches to concept mapping and implications for medical education: Commentary on reliability, validity and future research directions. Advances in Health Sciences Education, 9(251-256), 2004.

[175] P.J.H. Schoemaker and J.E. Russo. Decision Theory and Decision Analysis: Trends and Challenges, chapter A Pyramid of Decision Approaches. Springer, Dordrecht, 1994.

[176] P. M. Senge, A. Kleiner, C. Roberts, R. Ross, G. Roth, and B. Smith. The dance of change: The challenges of sustaining momentum in learning organizations. New York, NY: Doubleday, 2000.

[177] Xinyu Shao, Guojun Zhang, Peigen Li, and Yubao Chen. Application of id3 in knowledge acquisition for tolerance design. Journal of Materials Processing Technology, 117:66–67, 2001.

[178] S.C. Shea. The American Psychiatric Publishing textbook of suicide assessment and management, chapter The interpersonal art of suicide assessment: Interviewing techniques for uncovering suicidal intent, ideation, and actions, pages 29—56. Washington, DC: American Psychiatric Publishing, 2012.

[179] B. Simmons, D. Lanuza, M. Fonteyn, F. Hicks, and K. Holm. Clinical reasoning in experienced nurses. Western Journal of Nursing Research, 25:701–719, 2003.

[180] N. Singleton, R. Bumpstead, A. Lee, and H. Meltzer. Psychiatric morbidity among adults living in private households. International Review of Psychiatry, 15(1):65–73, 2003.

[181] N. Singleton, A. Lee, and H. Meltzer. Psychiatric morbidity among adults living in private households, 2000. Technical report, Office for National Statistics, London, 2003.

[182] D. F. Sitting, A. Wright, J. A. Osheroff, B. Middleton, J. M. Teich, J. S. Ash, E. Campbell, and D. W. Bates. Grand challenges in clinical decision support. Journal of Biomedical Informatics, 41:387–392., 2008.

[183] Sivlerman and Berman. Suicide Risk Assessment and Risk Formulation Part I: A Focus on Suicide Ideation in Assessing Suicide Risk, Suicide and Life. Threatening Behaviour, 44(4), 2014.

[184] K. Skegg. Self Harm, volume 366. Lancet, 2005.

[185] D. Slone. The influence of mental models and goals on search patterns during web interaction. Journal of the Association of Information Science and Technology, 53(13), 2002.

[186] S.A. Smoyak. Clinical practice: intuitive or based on research? Psychosoc Nursing Mental Health Services, 20(4):9–13, 1982.

[187] N. Staggers and A.F. Norcio. Mental models: Concepts for human computer interaction research. International Journal of Man-Machine Studies, 38(4):587–605, 1993.

[188] M. Standing. Clinical judgement and decision-making in nursing – nine modes of practice in a revised cognitive continuum. Journal of Advanced Nursing, 62(1):124–134, 2008.

[189] Sarah Steeg, Leah Quinlivan, Rebecca Nowland, Robert Carroll, Deborah Casey, Caroline Clements, Jayne Cooper, Linda Davies, Duleeka Knipe, Jennifer Ness, Rory C O'Connor, Keith Hawton, David Gunnell, and Nav Kapur. Accuracy of risk scales for predicting repeat self-harm and suicide: a multicentre, population-level cohort study using routine clinical data. BMC Psychiatry, pages 2–11, 2018.

[190] P. Sturmey. Practical resources for the mental health professional. Functional analysis in clinical treatment. Elsevier Academic Press, 2007.

[191] L. Surya Prasanthi and R. Kiran Kumar. ID3 and Its Applications in Generation of Decision Trees across Various Domains- Survey. International Journal of Computer Science and Information Technologies, 6(6):5353–5357, 2015.

[192] J.A. Swets, R.M. Dawes, and J. Monahan. Psychological science can improve diagnostic decisions. Psychological Science in the Public Interest, 1:1–26, 2000.

[193] Tableau. Tableau Blueprint. Tableau, 2019.

[194] N. Tarrier and R. Calam. New developments in cognitive-behavioural case formulation. Epidemiological, systemic and social context: an integrative approach. Cognitive and Behavioural Psychotherapy, pages 311–328, 2002.

[195] M.H. Trivedi, J.K. Kern, B.D. Grannemann, K.Z. Altshuler, and P. Sunderajan. A computerized clinical decision support system as a means of implementing depression guidelines. Psychiatric Services, 55(8):879–885, 2004.

[196] Uygar Özesmi and Stacy L. Özesmi. Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological Modelling, 176:43–64, 2004.

[197] G. Van der Veer and M. Puerta Melguizo. The human-computer interaction handbook: Fundamentals, evolving technologies, and emerging applications, chapter Mental models, pages 52–80. Hillsdale, MI: Lawrence Erlbaum, 2003.

[198] W.N. Venables, D. M. Smith, R. Gentleman, and R. Ihaka. An Introduction to R. R Core Team, December 2019.

[199] J. J. Villalon and R. A. Calvo. Proceedings of the International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT). In Concept map mining: A definition and a framework for its evaluation, page 357–360, Los Alamitos, CA, USA, 2008. IEEE Computer Society.

[200] P. Weerasekera. Multiperspective case formulation: A step towards treatment integration. Krieger Publishing Company, Malabar, FL, US, 1996.

[201] H. Whiteford. Fighting Mental Health: A Personal Review. Austrialian and New Zealand Journal of Psychiatry, 37(3):387, 2003.

[202] WHO. The Global Burden of Disease: 2004 Update. Technical report, World Health Organization, Geneva, 2008.

[203] Peder Wikstro, Lars Edenius, Bjorn Elfving, Ljusk Ola Eriksson, Tomas Lamas, Johan Sonesson, Karin Ohman, Jorgen Wallerman, Carina Waller, and Fredrik Klinteback. The Heureka Forestry Decision Support System: An Overview. Mathematical and Computational Forestry and Natural Resource Sciences, 3(2):87–94, 2011.

[204] B.R. William and M. Nancy. On looking into the black box: prospects and limits in the search for mental models. Technical report, Centre for man-machine systems research, 1985.

[205] J.R. Wilson and A. Rutherford. Mental models—Theory and application in human factors. Human Factors, 31(6):617–634, 1989.

[206] A. Worthington, P. Rooney, and R. Hannan. The Triangle of Care - Carers Included: A Best Practice Guide in Acute Mental Health Care. Technical report, Carers Trust, London, 2013.

[207] Zhang Yan. The influence of mental models on undergraduate students' searching behavior on the Web. Information Processing and Management, 44(8):1330–1345, 2007.

[208] R. M. Young. Mental Models, chapter Surrogates and mappings: Two kinds of conceptual models for interactive devices, pages 32–52. Erlbaum, Hillsdale, NJ, 1983.

[209] L.A Zadeh. Fuzzy sets. Information and Control, 9:338–353, 1965.

[210] X. Zhang and M. Chignell. Assessment of the effects of user characteristics on mental models of information retrieval systems. Journal of the American Society for Information Science and Technology, 52:445–459, 2001.

[211] U. Özesmi and S. L. Özesmi. Ecological models based on people's knowledge: a multi-step fuzzy cognition mapping approach. Ecological Modelling, 176:43–64, 2004.

Appendices

Appendix A: Proposed Framework Prototype using Rules

The framework is illustrated in the form of If....Then Statement as illustrated in this section

```
PLEASE NOTE THE FIRST TWO COLUMNS FOR THESE DATA ARE THE CLIENT ID
AND THE ASSESSMENT ID ARE REMOVED
------------------------------------------------------------------------
------


        columns for paient answers that are for processing
        --------------------------------------------------
<suic
 assessment-date suic-past-att suic-most-rec suic-patt-att suic-first-occ
suic-escalate suic-how-many suic-note-prev suic-discovery suic-lethality su
ic-ser-succd
 suic-regret suic-leth-insght suic-curr-int suic-plans suic-plan-real suic-
steps-takn suic-prosp-leth suic-int-inform suic-eol-prep suic-s-h-behv suic
-rel-belief
 suic-int-p-trig suic-pot-trig suic-p-trig-mtch suic-fam-hist suic-ideation
suic-id-control suic-id-hi-risk suic-id-freq suic-id-strngth gen-sh-cuts sn
-appearnce
 sn-hair-clothes sn-hygiene sn-recnt-app-chnge sn-skin gen-feel-emot gen-mo
od-swings gen-negative-self gen-plans-future gen-life-not-livng gen-angry-e
motns
 gen-anx-emotns gen-helpless gen-sad gen-distress gen-jealous gen-self-wort
h-p grandiosity worthlessness gen-personality gen-assertive gen-empathy-abi
l gen-dependence
 gen-controlling gen-coping-abil gen-hostile gen-impulse gen-reliable gen-p
ers-dis ment-fac gen-impaird-cog gen-cog-think-mem gen-concentr gen-learn-d
isab insight-resp
 gen-insght-behvr gen-resp-impct-oth gen-nd-hlp-diff mental-health clin-dep
ression gen-dep-stage gen-mntl-cur-sympt gen-mania gen-voice-hal gen-voice-
dang-s
 gen-voice-dang-o gen-prob-act-voice gen-paranoid-del gen-paran-del-spec ge
n-paran-del-pers gen-prob-act-par-del gen-phys-hlth-prb gen-chronic-disease
 gen-phys-hlth-deg-diag gen-phys-hlth-pain gen-phys-hlth-disa gen-com-imp g
en-phys-hlth-det gen-meds-therpy gen-meds-concord gen-serv-perc-supp gen-me
d-perc-benft
 motive-eng gen-phys-withd gen-mental-withd gen-motivation gen-listless gen
-soc-contxt gen-relatnshps gen-net-relat gen-relat-supp gen-relat-detr gen-
relat-detr-chg
 gen-living-arr gen-move-freq gen-accom-loss gen-home-type gen-isol-accom g
en-neigbrhd-rsky gen-accom-hm-care gen-accom-habitbl gen-finance-empl gen-p
erc-debt-anx
 gen-poverty gen-job-chg-frq gen-rec-bad-job-ch gen-currnt-bhvr gen-rsk-beh
avr gen-unint-risk-behavr gen-sleep-dist gen-unusl-rec-bhvr gen-chall-bhvr
gen-day-struct
```

```
 gen-day-actvty-lev gen-diet-eating gen-diet-weigt-ext gen-diet-weigt-chg g
en-diet-drink gen-subs-misuse gen-alc-misuse gen-drug-misuse adv-life-event
gen-life-abuse
 gen-life-sex-abuse gen-sex-abse-last gen-sex-abse-as-ch gen-phys-abse gen-
phys-abse-last gen-phy-abse-as-ch gen-emot-abse gen-emot-abse-last gen-emo-
abse-as-ch
 gen-financial-abuse gen-forensic-proc gen-forensic-proc-curr gen-env-grew-
up gen-eating-dis gen-educ-expr gen-presentation gen-engagement gen-rapport
gen-responsve
 gen-gut-assmnt gen-risk-verbal gen-risk-aggrsv gen-risk-upbeat gen-coheren
ce gen-body-face gen-distrss-b-lang gen-low-mood gen-threat-move gen-detach
ed
 gen-avoid-eye-contact gen-eye-movement gen-congruence gen-age gen-gender g
en-marital-status partner-share-acc gen-accom-share gen-accom-depndnts gen-
accom-num-dep
 gen-dep-ygnst-age gen-accm-share-nd gen-ethnicity mappa
>
--------------------------------------------------------------------------
no value = don't know
Value= 1,2,3,4,5,,,10
if (suic = 'yes') {
        cat ("suic-attempt options = yes and no")
}
#don't know option should be disabled for suicide specific leaf question

if (suic-past-att = 'yes') {
        cat ("no option to input suicide attempt date")
}
if (suic-freq = "yes") {
        cat ("suicide attempts change frequency options")
}

#no option including don't know has if suic freq has been answered, an
#answer is expected.
if suic-past-att = no {
        (suic-id-freq = no value)
}
#suic-id freq should be disabled when the past intention is no
if suic-past-att = yes {
        (suic-id-freq = value) and (suic-most-rec = value)
        and (suic-first-occ = 'value') and (suic-how many = value) and (sui
      c-id-freq = value)
#none of the filter questions should be allowed to input don't know when
#the suic-past is answered as a yes.
#suic-id freq should not include don't know option when the past intention
is yes
```

```
if (suic-lethality= value) {
 (suic-attempt = value suic-ser-succeed = value and suic-regret = value and
suic-dang-att = value)
 Else {{
        cat (“kindly answer all lethality questions before you can proceed”)
}
#don’t know option should not be allowed

if (suic-int-pot =’yes’)
{
        (suic-pot-trig = value) and (suic-pot-match = value)
}
if (suic-pot-trig = no value) and (suic-pot-match = no value) {
cat (“please enter potential trigger values before proceeding”)
{
 if (suic-int-pot =’no’) {
        cat (“No option to answer filter questions, to continue the answer
should be a yes”)
}

if (suic-ideation = ‘yes’) {
        (suic-control-thought = value and suic-thoughts= value and suic-int
-thought = value)
}

if (suic-control-thought = <high values> and suic-thoughts= <low value> and
suic-int-thought =<low value>) {
        cat (“Kindly recheck assessment; high value in suic control thought
should equate to mild value for suic-int-thought and suic-thoughts”)
}

if (suic-control-thought = <low values> and suic-thoughts= <high value> or
suic-int-thought =<high value>) {
        cat (“Kindly recheck assessment; high value in suic control thought
should equate to mild value for suic-int-thought and suic-thoughts”)
}

if suic-ideation = ‘yes’ {
        (suic-control-thought =value; suic-thoughts= <value> and suic-int-t
hought =<value> and suic-thought = <value>)
else {
        cat (“enter a value to continue”)
}
```

```
if (self-neglect = 'yes')
        {
        (gen-hair-cloth = value and gen-hygiene = value and appearance-chg-
neglect = value and skin = value)
         (gen-hair-cloth = <high value> and gen-hygiene = <high value> and
appearance-chg-neglect =<high value> and skin = <high value>)
        else { {
        cat ("Check the assessment as high value in any of the filter quest
ions should correspond to high value in other filter questions correspondin
g to self-neglect. Kindly correct before you can proceed")
}

if gen-emotions= 'yes' {
        (mood-swing = value and gen-neg-self = value)
        (mood-swing = value> and gen-neg-self = no value)
        cat ("Kindly input the value before proceeding or summarize why not
inputting data")

        if (mood-swing = <high value> and gen-negative-self = <low value>)
        cat ("Comment on this before continuing")
        if (mood-swing = <low value> and gen-negative-self = <high value>)
        cat ("Comment on this before continuing")
        if (mood-swing = no value and gen-negative-self = <low value> or ge
      n-negative-self = <low value>)
        cat ("Comment on this before continuing")
        if (mood-swing = no value and gen-negative-self = no value)
        cat ("Comment on this before continuing; you are not allowed to inp
ut don't know for all data relating to feelings and emotions")
}


if (gen-life-worth-living= value) {
        (gen-plans-future = value)
        else {
        cat ("value must be inserted")
}

if (gen-life-worth-living = no value and gen-plans-future self = no value)
{
        cat ("Comment on this before continuing; you are not allowed to
 input don't know for all data relating to feelings and emotions")
        else {
        if (gen-life-worth-living = no value and gen-plans-future self = va
lue)
        cat ("Kindly revisit to check the assessment")
```

```
}
if (gen-angry-emtns and gen-anx-emotions and gen-helplessness and gen-sad a
nd gen-distress = no value) {
        cat (“Kindly revisit the assessment or comment on why there is no v
alue in the emotions related question”)
}

if (self-worth = ‘yes’) {
        (worthlessness = value and grandiosity = value)
        if worthlessness = no value and grandiosity = < no value>
        cat (“Kindly revisit the assessment and comment on reasons”)
}

if (gen-pers-issues =’yes’) {
        (gen-impulsiveness = no value and gen-assertiveness = no value and
gen-empathy = no value and gen-cop-ability = no value and gen-hostility =no
value> and gen-person-dis = no value {
        cat (“Kindly revisit the assessment”)
}

if (men-fac = ‘yes’) {

        (gen-cog-imp = value and gen-thk-process = value and gen-concentrat
      ion = value and learn-disability = value)
        else {
        cat (“Kindly revisit or comment on why there is no value”)
        if (gen-insight-behaviour = value)
        (gen-resp-impact-oth = no value and gen-nd-help-diff =no value)
        cat(“Kindly revisit the assessment”)
        if (gen-insight-behaviour = no value)
        (gen-resp-impact-oth = value and gen-nd-help-diff = no value)
        Cat (“Kindly revisit the assessment”)
}
if (gen-insight-behaviour = no value) {
        (gen-resp-impact-oth = no value and gen-nd-help-diff = value)
        cat (“Kindly revisit the assessment”)

}

if (gen-depression = ‘yes’ and clin-depression = ‘no’) {
        cat (“Clinical Depression answer needs to be checked”)

        if gen-depression = ‘no value’ and clin-depression = ‘value’
        cat (‘Kindly recheck as you have answered depression as no value’)
```

```
        if (gen-depression = 'yes' and clin-depression = 'no value')
        cat ('Kindly recheck as you have answered clinical depression as no
      value')
}

if (gen-paranoid-del = value and gen-prob-act-par-del = no value) {
        cat ("Kindly recheck the assessment")
        if (gen-paranoid-del = no value and gen-prob-act-par-del = 'yes')
        cat ("Kindly recheck the assessment")
}

if (gen-phy-hlth = 'yes') {
        (gen-phys-hlth-deg-diag = 'yes')
        if (gen-phy-hlth = yes)
        (gen-phy-pain = value and gen-chronic-health = no value and gen-com
-imp = no value)
        cat ("Not allowed; kindly revisit the assessment")
        if (gen-phy-hlth = 'yes')
        (gen-phy-pain = no value and gen-chronic-health = value and gen-com
      -imp = no value)
        cat ("Kindly check again if chronic health has a value; then physic
      al pain should also have a value")
}

if (gen-meds-concord = no value and gen-serv-perc-supp= no value and gen-me
ds-therapy = no value) {
        cat("kindly recheck assessment")
        if (gen-meds-concord = no value and gen-serv-perc-supp= no value
         and gen-meds-therapy = value)
        cat ("kindly recheck assessment")
}

if (gen-engagement = 'yes' and gen-phys-wthd = no value and gen-ment-wthd =
no value and motive-eng = no value and gen-listless = no value) {
        cat ("check the assessment")
        if (gen-engagement = 'yes' and gen-phys-wthd = value and gen-ment-w
      thd = no value and motive-eng = no value and gen-listless = no value
        cat("check the assessment")
}

 if (gen-soc-contxt = no value and gen-relationships = no value and gen-net
-relat = no value and gen-net-relat-detr = no value and gen-relat-detr-chg=
no value) {
        cat ("kindly recheck")
```

```
        if (gen-soc-contxt = no value and gen-movement= no value and gen-is
      ol-accomm = no value and gen-neighb=no value and gen-accomm = no valu
      e)
        cat (“kindly recheck”)
        if (gen-soc-contxt = no value and gen-movement= no value and gen-li
ving-arr = no value and gen-isol-accomm = no value and gen-neighb=no value
and gen-accomm = no value)
        cat (“kindly recheck”)
        if (gen-soc-contxt = no value and gen-movement=  value and gen-livi
ng-arr = value and gen-isol-accomm = value and gen-neighb=value and gen-acc
omm = no value)
        cat (“kindly recheck”)
}

if (gen-poverty = no value and gen-rec-bad-job-ch = no value and gen-job-ch
g-frq = no value) {
        cat (“kindly recheck”)
        if (gen-poverty = no value and gen-rec-bad-job-ch = yes and gen-job
-chg-frq = no value)
        cat (“kindly recheck; if there is a recent bad job change then ther
      e should be an entry”)
        if (gen-poverty = no value and gen-rec-bad-job-ch = no value and ge
      n-job-chg-frq = value)
        cat (“kindly recheck; there should be a value in the recent bad job
      change experience”)
}

if (gen-poverty = no value and gen-rec-bad-job-ch = no value and gen-job-ch
g-frq = no value)
        cat(“kindly recheck”)
        if (gen-poverty = no value and gen-rec-bad-job-ch = no value and ge
n-job-chg-frq = no value)
        cat (“kindly recheck”)
}

if (gen-risk-behavr = no value and gen-unint-behavr = no value and gen-slee
p-dis = no value and gen-challenge = value and gen-day-stru = no value)
        cat (“kindly recheck the assessment on the general current behaviou
      r”)
        if (gen-risk-behavr = no value and gen-unint-behavr = no value and
      gen-sleep-dis = no alue and gen-challenge = no value and gen-day-stru
      = no value)
        cat (“kindly recheck the assessment on the general current
        behaviour”)
}
```

```
if (gen-eating= no value and gen-diet-eating= no value and gen-diet-drinkin
g= no value) {
        cat (“Kindly recheck the assessment”)
        if gen-eating= no value and gen-diet-eating= value and gen-diet-dri
       nking= value
        cat (“Kindly recheck the assessment; general diet must include a
        value”)
        if (gen-eating= no value and gen-diet-eating= “overweight” and gen-
diet-drinking= no value)
        cat (“Kindly recheck the assessment; if the service user is
        overweight, there must be a value for the eating disorder question)
        if (gen-eating= no value and gen-diet-eating= “extreme-overweight”
        and gen-diet-drinking= no value)
        cat (“Kindly recheck the assessment; if the service user is extreme
       -overweight, there must be a value for the eating disorder question”)
       if (gen-eating= no value and gen-diet-eating= “extreme-overweight” an
       d gen-diet-drinking= value)
        cat (“Kindly recheck the assessment; there should be a value for
        the eating disorder question”)
}

if (gen-drug-misuse = no value and gen-alc-misuse = no value and gen-subs-m
isuse = no value) {
        cat (“Kindly recheck assessment”)
}

if (gen-engagement = ‘yes’){
 (gen-rapport = value and gen-responsivess = value and gen-gut-assmnt = val
ue}
        if (gen-rapport = no value and gen-responsivess = no value and gen-
       gut-assmnt = no value)
        cat (“Kindly check the assessment all questions must have a value”)
        if (gen-rapport = no value and gen-responsivess = value and gen-gut
       -assmnt = value)
        cat (“Kindly check the assessment all questions must have a value”)
}

if (gen-risk-verbal = ‘yes’)
        (gen-coherence = value and gen-risk-verbal= value and gen-coherent=
       value and gen-upbeat = value)
        if (gen-coherence = no value and gen-risk-verbal= no value and gen-
coherent= no value and gen-upbeat = no value)
        cat (“Kindly recheck the assessment”)
}
```

```
if (gen-distress-b-lang= no value and gen-low-mood= no value and gen-thret-
move= no value and gen-eye-movment = no value and gen-avoid-eye-contact = n
o value)
        cat("Kindly recheck the assessment")
}

if (gen-drug-misuse = 'yes' and gen-alc-misuse = value and gen-subs-misuse
= no value)
        cat("Kindly recheck if drug misuse is yes, the substance misuse sho
uld have a value")
```

Appendix B: Decision Tree

Appendix C: List of Publications

Agboola, Ifeoluwa. International Journal of Computer Science and Software Engineering; Dubai Vol. 7, Iss. 9, (Sep 2018): 218-228.

I. Agboola," Development of Mental Model in Understanding Users' Thought Processes for the Evaluation and Functional Enhancement of Clinical Decision Support Systems," 2018 IEEE International Conference on Data Mining Workshops (ICDMW), Singapore, Singapore, 2018, pp. 1493-1494. doi: 10.1109/ICDMW.2018.00214