E-Mental Health
Developing a general screening tool for Mental Disorders

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Abstract
Mental health care is critical and while governments are trying to increase awareness of the problem, the available resources is not sufficient to confront the growing problem. The thesis proposes a design theory, using Gregor and Jones’s (2007) ‘Anatomy of a Design Theory’ framework, for the current mental illness dilemma that all societies are facing. The proposed solution is one of using information systems, together with domain knowledge and conventional instruments from the field of psychology, to create a general screening tool. The design theory takes an ontological approach to defining the domain’s knowledge, using the MINI instrument along with expert knowledge to form the basis of the artifact. The artifact consists of four main entities: Background Information, Screening Questions, Pre-Requisite Questions and Other Questions. The thesis discusses the theoretical rationale for the screening tool and then presents an instantiation of the artifact. This tool would be able to screen any person (with the exception of the mentally handicapped) to ascertain if they have a mental disorder as defined in the DSM-IV.

Key words: mental disorders, DSM-IV, MINI, Protégé, open source, screening tool, ontology.
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Abbreviations

Co-morbidity – presence of one or more disorders

DSM – IV - American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders

ESB – Expert System Builder

ICD-10 - International Statistical Classification of Diseases and Related Health Problems 10th Revision

MINI600 – Mini International Neuropsychiatric Interview

MINI KID - Mini International Neuropsychiatric Interview for Children and Adolescents

Ontology - as an explicit formal specifications of the terms in the domain and relations among them (Gruber 1993)

OWL – Web Ontology Language

RDF – Resource Description Framework

XML - Extensible Markup Language
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1. Introduction

While man has dominated many of the natural marvels in his environment there still remain a mystery in the unconquered world of the human mind. Herein lay the root of a great proportion of challenges any individual is likely to face during their lifetime.

The proximate cause of mental disorders cannot be easily isolated and a positive diagnosis for a specific illness is sometimes dependant on the interpretation of the examining clinician. Nevertheless, the effects of mental disorders have been a part of man’s history.

In the 1600s the shamans in North America believed the cause of mental illness was supernatural. The Salem witch trials in 1692 acquainted the mysterious behavior of children to demonic devices. Then in 1724 Mather (1663-1728) proposed an alternative to the superstition beliefs, a physiological explanation. 70 years later, in 1812 Rush (1745-1813) ‘Medical Inquires and Observations upon Disease of the Mind’ was published increasing awareness of this illness. Sigmund Freud ideas on psychoanalysis gained interests in the early 1900s. From the 1920s and throughout the following decades there has been an ever increasing awareness of the illness and methods of diagnosis and treatment. The unfortunate incident that resulted in the death of the Swedish Foreign Affairs minister Anna Lindh in 2003 was an alleged consequence of the act of a mentally disturbed man. A BBC report during the trial reminded readers of ‘Sweden’s failing psychiatric care system’ (BBC news, 19.01.2004).

Mental illness is a problem which continues to plague every society and no one is immune; it can manifest silently within you, a family member, neighbor, leaders in government, religious advisors, no one is exempted from this potentially detrimental phenomenon. However, much has been learnt about mental illness and how it is best treated. As the use of technology increases each year, it is inevitable for a technological platform such as the internet, to be used as a key instrument in the campaign to combat the increasing direct and indirect effects of mental illness in our generation.
1.1 Background

The World Health Organization (WHO) is part of the United Nations and the coordinating body responsible for world health issues. The WHO also oversees the publication of the International Statistical Classification of Diseases and Related Health Problems, commonly called the ICD-10. The history of this document can be traced back to 1893; it categorizes epidemiology and is used by all WHO member states as the benchmark for defining causes of death and health problems. WHO provides statistics on the status of mental health for each member country. Alarmingly the study on ‘Global Burden of Disease’ showed:

Mental disorders such as depression are among the 20 leading causes of disability worldwide. Depression affects around 120 million people worldwide and this number is projected to increase. Fewer than 25% of those affected have access to adequate treatment and health care, (WHO Fact file, 2008).

Even more disturbing were WHO’s reports on premature deaths from physiological diseases which occurred as a result of some form of mental illness, for example, poor diet or increase in tobacco use that leads to increase in heart attacks, strokes and cancers. Worldwide data on another mental disorder – suicide, showed that European countries accounted for nine of the ten highest rates of global suicides (WHO Europe, 2009). WHO’s 52 European member states signed a mental health plan to address twelve critical areas in dealing with mental illness in 2005. The provisions aimed at taking a holistic approach to the growing mental health problems (WHO Mental Health Action Plan and Declaration for Europe, 2005). However even with the best intent the question arises as to how these twelve actions will be achieved with the current resources such as the limited number of clinicians and facilities available.

‘No Health without Mental Health’ is the slogan of the organization called Mental Health Europe (MHE). The MHE serves a liaison function for mental health promotion with the European Commission (EU) and also has relations with the World Health Organization. The EU also has declarations that recognizes how problematic mental illness can be and proposals to address it, as can be seen for example in the European Pact for Mental Health and Well-being (launched in Brussels 2008), SUPPORT project (lead by the Scottish Development center 2003-2008), and the Green Paper – improving the mental health of the population: towards a strategy on mental health for the European union (published by the Health and Consumer Directorate-General, 2005).

Two of the problems highlighted by the EU that need urgent attention are: ‘Mental ill health affects every fourth citizen and can lead to suicide, a cause of too many deaths; and Mental ill health causes significant losses and burdens to the economic, social, educational as well as criminal and justice
systems’ (Green Paper, 2005). Once again the question arises of how these problems can be managed with the existing resources.

‘From vision to action – a policy for mental health’ summarizes the plan of the Swedish government to address the problem, with a proposed 900 million investment for psychiatric care in 2009. Sweden’s preventative approach to mental problems is demonstrated in the State run Systembolaget, the success of this approach is debatable but such discussion is not within the scope of the thesis. Some facts on mental illnesses in Sweden includes: the suicide rate have steadily been reduced, yet it remains higher than the EU average. Older women are especially prone to depression, stress related problems have significantly increased across the working population leading to more sick leave, there is an increase in tobacco and alcohol use by children and adolescents which often leads to bullying in school. (Europa Mental Health Briefing Sheet, 2008).

Parallel to the increase in mental illness across borders is the heightened awareness of how technology can be used to tackle global, environmental and medical problems. Examples can be seen in using alternative forms of energy like wind, geothermal, water, nuclear and solar, to combat the effects of global warming (Schultz and Hotinski, 2004), as well as creating genetically modified food and organisms that are more resistant to environmental hazards, both natural and manmade. Some genetically modified organisms can provide ‘sustainable agriculture, forestry, aquaculture, bioremediation, and environmental management, both in developed and developing countries’ (Snow et al, 2005). Technological uses in the field of medicine have led to major breakthroughs in gaining understanding of the workings of both the human body and mind. Now diseases and disorders that used to severely impair a person, family or society, can be treated and even cured. The eradication of the infectious disease small pox (Henderson, 2009), spinal cord surgery returning the ability to walk, removal of cancerous tumors that prolong a patient’s life, using caesarian sections on high risks mothers leading to more live births are just a few examples of how technology has improved health care.

Using computer technology in the realm of psychology and psychiatry can be traced back to the 1960s (Rialle & Ohayon, 1991). In the paper ‘Computers as clinicians’ Keinmuntz described a program he wrote that could automatically interpret some mental disorders. This was a forerunner of numerous attempts to use information systems in a clinical domain to address psychiatric problems.

Spitzer and Endicott asked the question ‘Can the Computer Assist Clinicians in Psychiatric Diagnosis?’ in 1968 and this was answered with DIAGNO (Schmid et al, 1982), a diagnostic program which invited the user to select either yes/no to questions from the psychiatric questionnaire used during that time. This system later developed into different versions, one of the versions called DiaSika was used in Germany and France (Schmid et al, 1982).

Presently there are several well known and notable attempts to develop advance applications which can be used by both clinicians and non clinicians for screening of mental health disorders. One of the most popular is called MoodGYM, which screens for depression and anxiety, and was developed by the Centre
for Mental Health Research at the Australian National University, others include E-couch and ULifeline which serve similar functions.

There are common features in all the current applications, that is they usually focus on either one or two of the ‘common’ mental disorder categories, usually Depression and Anxiety, and are targeted for specific sectors of the population, for example adolescents, veterans, elderly, students within a specific age range, cancer survivors, persons with specific medical diagnosis, prisoners and so on. However, mental disorder does not discriminate, so it is possible that at some point in a person’s life they are at risk to succumb to an ailment. Additionally, an accurate diagnosis of anxiety or depression is seldom an isolated event, but often either the cause of or lead to another form of mental disorder. This is referred to as co-morbidity. An example of phenomenon this is drug addiction which can lead to depression, schizophrenia, anxiety, and mania (Volkow, 2008).

Consequently, when the scale, societal effects and cost of mental illness is realized, one would recognize the urgency to find a way to deal with this silent, but potentially catastrophic problem. While the intent of governments is clear from their policies, the fact remains that there is no great drive to increase the number of mental health clinicians who are needed to address the problem. Much remains to be done to deal with the stigma associated with the disorders and being institutionalized for treatment. Therefore being able to identify and treat mental illness at its early stages, can lessen the impact on the individual and demands on existing institutions. Mental illness accounts for a large proportion of health care costs and should arguably be included as part of primary health care. In this thesis I propose that technology can be used to confront the growing problem of global mental illness. To be more precise, a screening tool will be presented that can be incorporated in primary health care. This is in line with the suggestions in the joint report done by the World Health Organization and the World Organization of Family Doctors (WHO-Wonca,2008).

1.2 Problem

There are many interesting questions which can be asked to pursue research into the realm of technology in the mental health domain. However, this thesis focuses on one research question:

How is it possible to use a collaborative approach of information systems capabilities together with popular psychology and psychiatry instruments, to create a general mental disorder screening tool?

The accepted standard for defining mental disorders are found in two documents, the WHO’s International Statistical Classification of Diseases and Related Health Problems (ICD) and the American Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders (DSM). The current versions of these documents are the ICD-10 and DSM-IV. They are mainly used by clinicians and the research community respectively.
1.3 Purpose

In this thesis I propose an information system design theory, using an ontology approach, to create a screening tool for mental disorders. The tool should be able to assess the mental state, as defined in the DSM-IV, of a cross section of a population. It should be noted that the tool is not intended to be used by mentally handicapped persons. The system design put forward an ontological concept to modeling the knowledge base. Ontology, within the context of this thesis, is ‘an explicit specification of a conceptualization’ (Gruber, 1992), that is, concepts or entities and the relationships between them. The purpose of the ontology is to model some form of domain knowledge to facilitate the use and sharing of the domain’s knowledge. Gregor and Jones (2007) design theory framework is used to present the details of the screening tool.

1.4 Structure

The structure of the thesis is as follows: Chapter 1 consists of several subsections which firstly introduces the topic of mental health and give background details of the extent of the problem on a global scale, within the EU and in Sweden. The research question is stated under the subheading of ‘Problem’, delimitations, intended audience and the detailed methodology concludes the first chapter. Chapter 2 further expands the background discussion in relation to past and current research as well as general discussion on mental health and disorders. Chapter 3 gives the system requirements for the proposed prototype and evaluation method to determine success. Chapters 4 discuss the design and implementation of the design theory. Chapter 5 presents the prototype of the artifact. Chapter 6 presents the evaluation of the prototype as compared to the specifications in Chapter 3. Chapter 7 includes the conclusions of the thesis work, a summary of the results, and a discussion of the findings and recommendations for future work.

1.5 Delimitations

The validity of the ICD-10, DSM-IV and MINI instruments referred to in the thesis is not discussed in detail since for the purpose of this research they are amongst the accepted standards for categorizing and diagnosing mental illnesses.

The prototype of the screening tool is presented to validate the design theory, as such; there will not be any clinical testing of this prototype. The testing will primarily be the instantiation of the prototype proposed, reviewed by the trained psychologists who also served as domain experts.
1.6 Audience

The design theory proposed aims to add new knowledge to the existing information systems and mental health knowledge bases used by researchers or mental health interest groups.

The intention is for the tool to eventually be available free online so that anyone can use it. However, it is specifically designed to be used by the following:

- individuals for self screening
- parents who are concerned about a child’s behavior
- social workers or teachers who might be concerned about a child’s behavior
- non clinicians and non technical health care workers who can use the screening tool as a first step in evaluating individuals with possible mental problems and thereafter scheduling appointments for those that need help
1.7 Methodology

The goal of the thesis is not to create another decision support system, but to provide a framework for designing and implementing a screening tool; built on existing domain knowledge but straightforward enough to be used by an average citizen. In order to present the proposal for the screening tool in a rational way, the framework provided by Gregor and Jones will be used to discuss the different aspects of the design. This framework comprises of eight components (6 mandatory and 2 optional), for any information system design theory (Gregor and Jones, 2007). The following is a summary of the components with a short description, taken directly from Gregor and Jones’ article:

| Purpose and scope (the causa finalis) | What the system is for,” the set of meta-requirements or goals that specifies the type of artifact to which the theory applies and in conjunction also defines the scope, or boundaries, of the theory”. |
| Constructs (the causa materialis) | Representations of the entities of interest in the theory |
| Principle of form and function (the causa formalis) | The abstract “blueprint” or architecture that describes an IS artifact, either product or method/intervention |
| Artifact mutability | The changes in state of the artifact anticipated in the theory, that is, what degree of artifact change is encompassed by the theory. |
| Testable propositions | Truth statements about the design theory. |
| Justificatory knowledge | The underlying knowledge or theory from the natural or social or design sciences that gives a basis and explanation for the design (kernel theories) |
| Principles of implementation (the causa efficien) | A description of processes for implementing the theory (either product or method) in specific contexts. |
| Expository instantiation | A physical implementation of the artifact that can assist in representing the theory both as an expository device and for purposes of testing |

Table 1.1: Gregor and Jones (2007) The Anatomy of a Design Theory

These components are used to steer the discussions in chapters 4 and 5, but are re-examined in the epilogue.

1.7.1 Preparatory work

The objective for the system to be used internationally meant that the knowledge base must be built on well-established, recognized and accepted tools within the domain. In the case of mental health, the widely accepted authorities, as previously mentioned, are the DSM and the ICD-10. More recently there is the International Health Regulations (IHR), which is a legal binding instrument that 194 WHO member countries ascribe too. The goal of this instrument is to guide countries in prevention and response to
acute public health risks that can potentially have global implications. The DSM gives the classification of mental disorders used by professionals and researchers in the field. The ICD-10, which is inclusive of all known disease by the World Health Organization, is commonly used by clinicians, medical personnel, insurance companies and other health stakeholders in every day practice.

There are various instruments used in the screening and diagnosing of mental disorders. The Structural Clinical Interview for DSM disorders (SCID) and the Mini International Neuropsychiatric Interview (MINI) are two of the best known interviews which work in accordance with the categorization and definitions of the DSM. Originally the plan for the thesis was to use the SCID. However, due to several reasons including copyright limitations, problems to source the instrument in English and the complexity of questions, the MINI was chosen instead. The MINI instrument forms the base knowledge of the screening instrument for the system. An advantage of using the MINI was the simplicity in the layout of the questions, without compromising the complexities in the psychology domain. Previous research has shown that the MINI is generally viewed positively by patients, that it can be completed in approximately 16 minutes and is able to diagnose co-morbid conditions (Pinninti et al, 2003).

The choice of software was either to use a proprietary product called MATCH™, which was used in a previous course, or to seek an open source option. MATCH™ is used in the banking and insurance industry and uses decision tables for reasoning. There were unreasonable obligations to use the proprietary product and consequently an open source product called Protégé was instead used for producing the ontologies and a simple expert system shell called Expert System Builder was utilized to develop the instantiation of the artifact.

While there are ongoing debates as to the pros and cons of using open source versus proprietary software, for the purposes of the screening tool the appropriate choice was open source. Some reasons for open source include: greater accessibility for users since there are no licenses fees, there is flexibility when designing the knowledge base, inference engine and GUI and there is a global drive by governments to encourage open source development. The EU resolution in 2001 asked member states to promote the use of open source in projects (Evans et al, 2003). The Swedish government plan for ‘the world’s simplest Administration’ is also an advocate for open source (e-practice Sweden, 2009).

Protégé is a free, open-source platform with a suite of tools to construct domain models and knowledge-based applications with ontologies. It was developed by Stanford Center for Biomedical Informatics Research at Stanford University School of Medicine. In order to build an efficient system that can be used across any given population, it is critical to begin by creating a pragmatic common ontology, to guarantee consistency (without completeness), and using the ontology’s vocabulary in statements and queries.

Attempting to create a complete mental health ontology is beyond the scope of a master thesis. However, ontologies will be developed for 16 mental disorders within the domain using the MINI
instrument. While the MINI, supported by the DSM-IV, is used to demonstrate the design theory, it should be stated that any of the reputable instruments can be used to form the knowledge base of the screening tool. The design theory ontological structure can be used with any of the established domain instruments.

1.7.2 Methodology for eliciting the system requirements specifications

The ontological method is used for several reasons, including:

- The domain of mental disorders is complex and often relies on interpretation by clinicians. Using the ontology concept allows for editing any existing ontology, such as expanding the definition of what constitutes depression, anorexia nervosa and so on.

- There is no need for any specific IT or programming skills since the domain knowledge is an independent entity.

- The artifact is intended for wide scale use, including via the internet. It is therefore necessary to allow the domain knowledge to be explicit and offer reusability, for example to join the ontologies with others in different disciplines’. This will make it possible to create a broader ontology such as all known mental disorders or health problems that affects specific sectors of society and so on.

- A common ontology provides a common language for a wide cross section of stakeholders

To build the ontology, the MINI questionnaire was divided into three sections to create/define each mental disorder with an additional entity to capture background information on the user. In order to evaluate if the overall objective of the thesis was achieved, the instantiation of the artifact was also constructed on this premise. Protégé 4.1 was used to create the ontology and then Expert System Builder 4.4 was used to create the artifact. These will be discussed in detail in Chapter 3.

1.7.3 Methodology for data acquisition

Eliciting knowledge from an expert often presents the biggest challenge when working with expert systems (Durkin, 1992). Data collection for the thesis began with speaking to experts in the domain. The domain experts work at the Department of Public Health and Caring Sciences at Uppsala Biomedicinska Centrum. They were selected to be domain experts since they are well experienced in the field, familiar with the established psychology instruments and they were interested to see how IT can assist in their domain. Professor Louise von Essen is a well establish researcher and licensed psychologist, she highlighted the problem of mental illness and the need for greater attention to be paid to mental illness in general. Martin Cernvall is a doctoral student and works with Professor von Essen. He has previously worked in the clinical environment and is familiar with the use of both the SCID and MINI instruments.
There were several unstructured interviews over a period of five months with these experts. Unstructured interviews were used to allow them to freely discuss different aspects of the domain. When certain points were emphasized I asked probing questions to determine its significance and to get a clearer understanding of the domain. At times there were gaps or conflicts in the explanations, these were identified and the experts were asked to clarify. The discussions highlighted the various tools and techniques used in screening and diagnosing of mental disorders as well as other insights into a complex domain. A review of the available tools was done to see which would be most adaptable to use when creating the screening tool. From the discussions and review of the commonly used instruments a pattern emerged in how a mental disorder was diagnosed. Aspects in the person’s life, either from the past or current, in some cases both, were examined. Some of these aspects were considered more critical than others.

The questions on the MINI instrument in particular, showed which questions were relevant to identify a particular mental disorder. Regardless of the age group or the disorder, the process was comparable. For a general screening tool a knowledge base had to be created. However, since mental disorders are such a wide domain, a large knowledge base is needed to achieve the required functions. As with any large knowledge base, it would therefore be necessary to use some sort of structure to manage and allow changes to the knowledge. I decided to explore grouping the questions by placing an order of importance to the questions since that would also make handling the knowledge base easier. While researching the idea of modularity I discovered the concept of ontology. There are different ways in which knowledge can be represented for example, rules, frames, semantic networks or logic (Durkin, 1992), and a choice had to be made in how to represent this domain’s knowledge. I then decided that the ontology concept, using rules, could be useful to simplify the structure of the knowledge base in the domain.

After analyzing the MINI instruments I decided to divide the questions into groups based on its importance. This idea was discussed with the domain experts who saw no problem with the approach. The idea was further refined after examining the different disorders on the MINI. It was possible to create three general groupings of similar questions that could be used to define each disorder. Additionally, it was also possible to represent the mental disorder knowledge in logic. Since the screening tool entailed software development I decided to use first order logic along with the ontology to define each disorder. These representations will aid in the programming process. Previous research showed that there was no existing ontology defining mental disorders using a hierarchal grouping I proposed in the design theory. Consequently, through a knowledge engineering process it was possible to design the ontologies and define the logic equations for the 16 adult mental disorders from the MINI.
1.7.4 Methodology for evaluating the results

The evaluation of the proposed theoretical design is done by creating an instantiation of the artifact, that is, a prototype of the screening tool, built using the principles discussed in the thesis, and keeping within Gregor and Jones framework. (Gregg et al., 2001; Hevner and March, 2003). The evaluation is discussed in Chapter 6.
2. Extended Background and Basic Concepts

E-health is an active area of research. There is growing use of electronic medical records (EMR) which has proven to be advantageous in primary and emergency care (Hillestad et al, 2005). Yet problems for example with file structure, code system and interfaces, continue to be encountered when trying to create a coherent patient record (McDonald, 1997). Having a common language, that is an ontology, has proven to be a means of solving some of the aforementioned challenges (Peleg et al, 2007).

Information systems have often met hurdles when trying to enter the domains of psychology and psychiatry. Clinicians can be skeptical, for various reasons, about using computer programs to deal with specific issues involving the human psyche. There has been a continuous and growing use of technology in other areas of medicine which has lead to great advancement. The same rate of growth and use cannot be said to have occurred in these two domains. Technology by itself is not the silver bullet to solve the growing global mental illness problem, but it can potentially assist in providing a solution.

Using an ontological approach allows for better knowledge management, and permit changes to be easily made, when needed (Uschold and Gruninger, 1996, Nicola et all, 2009). Domain experts can add or modify the ontology when required. This can be a way to increase the confidence of skeptical clinicians about using more technology in their practices.

In mental health there is research into creating a common mental health ontology. The Galatean Risk Screening tool (GRiST) is an ongoing project using the OWL ontology concept to create a tool to help clinicians assess ‘risk of suicide, self harm, harm to others, self neglect and vulnerability’ (GrIst, 2003). Australian researchers Hadzic and Change (2008) have also written on the benefits that the mental health domain can gain from streamlining web semantics.

Yet there still remains a need to have some sort of instrument/tool that is more generalized and not only focused on a few of the more common mental disorders and not only for specific populations. As previously mentioned, mental illness does not discriminate who it affects. The disturbing increase in mental illness calls for urgent actions. A free computerized screening tool that is easily accessible, easy to use, available online, and built on the knowledge and experiences of the current domain experts is a start to combating the problem.

In places where there is limited access to clinicians, having a screening tool can greatly assist health or social workers in taking a first step to identify possible mental illness and then to direct the individual towards getting further examinations. For families or in schools such a tool can assist in early detection of problems in children which can be treated and not allowed to linger undetected. Early detection increases the odds for positive outcomes (Saunders et all, 1993, McGorry et all, 2007, Essex et all, 2009). It also can lessen co-mobility cases and other damaging effects to both the individual and society.
Knowledge systems are used in the general health sector for various reasons such as education, diagnostics, imaging, decision support and critical care. There is also increasing use of Electronic Medical Records (EMR) for administration and as a means of quality assurance for patients, particularly in Scandinavian countries including Sweden (Openclinical, 2005). In the United States however there is slower growth in the use of EMR by physicians (Hillestad, 2005).

Educational knowledge systems such as ‘Cancer, me?’ was used by approximately 2000 people in 1989 in Canada. The system gave cancer prevention information and offered an evaluation option to users. TheraSim CS developed in the United States in 2002 is used for training medical personnel in diagnostics and treatments of various illnesses. The system combines best practice knowledge along with clinical and patient simulation data to create the specific disease knowledge base. TheraSim CS-HIV is used for HIV training and education and is used in approximately 34 countries (Therasim, 2003).

There are laboratory systems such as PUFF which evolved from the EMYCIN system developed in 1979 and includes features such as knowledge acquisition, rule interpreter and explanation as in the original MYCIN system. PUFF is used as a diagnostic tool in the domain of lung diseases. Other uses of knowledge systems for laboratory use include: PharmADE which screens a patient prescription to detect any possible negative interactions with medicines currently used and GermWatcher which keep a check on hospitals laboratories microbiology data to identify occurrences of infectious diseases (Laboratory Systems, 2005).

Medical imaging domain also uses knowledge systems for example PERFEX which assist in diagnosis of coronary artery disease and ISIS, which utilizes case based reasoning to aid physicians in selecting the most suited imaging procedure to use with a patient (Medical Imaging, 2005).

Another aspect of using knowledge systems in general health care is Decision Support Systems (DSS). In 1988 APACHE was the first medical DSS commercialized and first used to predict mortality rate of intensive care patients. There are other numerous DSS for example: ATHENA used in primary care for hypertension, ERA online system for support and referrals of cancer patients. Orthoplanner and Jeremiah are used by orthodontists to prepare orthodontic treatment plans. IPROB is used by midwives and obstetricians to keep patient records prenatal to postpartum (Decision Support Systems, 2005).

Knowledge systems are used for critical care systems. Examples of the uses include: Automedon, EvitaXL and SmartCare/PS are EU approved and used at many European university hospitals, manages intensive care units patients’ artificial ventilation. VIE-PNN (Vienna Expert System for Parenteral Nutrition of Neonates) is in clinical use in neonatal intensive care for administering feeding of newborn babies (Critical Care, 2005).
3. System Development Environment

Presenting the design theory is the focus on the thesis and as a result there will not be the customary discussion on the system development environment. The discussion in this chapter will be a brief introduction to the tools used for the instantiation of the artifact. There are many tools available for constructing ontology and for creating decision support systems. The prototype developed to demonstrate the proposed design uses the open source ontology software, Protégé 4.1 Alpha. The Protégé suite of tools is platform independent (Protégé, 2010). It conforms to the Web Ontology Language (OWL 2.0) specification endorsed by the World Wide Web Consortium (W3C) to promote the Semantic Web vision of common protocols to ensure interoperability (W3C, 1994). The Protégé community is very active in developing enhancements to the base product which has resulted in the availability of various plug-ins geared to enhance Protégé. One such plug in is for the feature called OWLViz which show a graphical representation of the ontology (as seen in the following chapter). If you want to use this feature then the system is required to have a small open source software called Graphviz installed. For the specific version of Protégé, a corresponding Java virtual machine is required. There are Protégé downloads with and without Java virtual machine. There is also a Jess java plug, also open source, which allow developers to build a graphical user interface using java, making the ontology available online.

The artifact is built using a freeware expert shell called Expert System Builder version 4.4(ESB). ESB is a tool that can be used to develop fuzzy decision support systems. It was developed by Paul Caswell from Dorset in the UK. Caswell is currently a chief engineer at SELEX Communications Limited. This tool is simple; it is PC Windows’s base and runs on Windows 95, 98, ME, 2000 and XP. There are 3 parts to ESB, the question editor, knowledge acquisition and user interface. There is also a javaESB that allows the tool to be used online.

Several challenges were encountered in the search for an open source alternative; the most notable problem was finding software that did not require a lot of programming, since often the software was not documented. ESB, which have limited documentation, was chosen due to its simplicity to use, but more importantly, it met the basic requirements for producing a prototype to support the thesis theory.

It should be possible to use any number of open source tool to develop the described screening tool. This is another advantage of basing the design on an ontology; it is the concept that is critical. Further explanations on the ESB and how it was used for the artifact is presented in chapter 5.
4. Design and Implementation

The design and implementation of the design theory will be presented in this chapter. First will be a presentation of the entities which forms the screening tool. This will be followed by showing how the domain knowledge could be represented and the requirements for implementation.

4.1 Entities in the design theory

A mental disorder can be defined according to a combination of factors which can be grouped into 4 entities. These groups can be viewed as levels of requirements. The design theory proposes the levels to be in a hierarchy consisting of: Background Information, Screening Questions, Pre-Requisites Questions and Other Questions. The following is a diagrammatic representation of the entities and the level they represent, the levels are explains following the diagram:

![Diagram 4.1: Composition of the Artifact](image)

Level 1 – Background Information: This entity will store information on the person who will be screened. This information will require the user to select if the screening is for themselves or on behalf of a child/adolescent, along with gender and age group. Any other background details deemed important by the domain experts can be added. For example, family data, income level and so on, which could be used to propose help options after an assessment.
Level 2 – Screening Questions: These are initial screening questions to point to the presence of a mental disorder and would be used to direct the user to a specific disorder module. The MINI Screen questions can be used for self-evaluation in a clinical setting and for demonstration of the artifact; they are used at this level. The questions call for YES/NO answers and each YES answer points to a corresponding MINI module. For example YES answers to screening questions 1 and 2 points to the Depression module, questions 2 and 3 points to the Suicidality module and so on. The following is an example of how the questions appear:

**MINI SCREEN 6.0.0**

<table>
<thead>
<tr>
<th>Patient Name:</th>
<th>Date of Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Screening:</td>
<td>IF YES, go to the corresponding MINI module</td>
</tr>
</tbody>
</table>

- Have you been depressed or down, most of the day, nearly every day, for the past two weeks? NO YES → A
- In the past two weeks, have you been much less interested in most things or much less able to enjoy the things you used to enjoy most of the time? NO YES → A
- In the past month did you think that you would be better off dead or wish you were dead? NO YES → B
- In the past month have you thought about killing yourself? NO YES → B

*Diagram 4.2: Excerpt the MINI Screen 6.0.0 questionnaire*

Level 3 – Pre-Requisites: This is the third level in the hierarchy. In the MINI these are the questions in the shaded gray area at the start of each module. The intention for this level is to zoom in to a specific disorder, pointed to from the previous level. This level should be a few questions which would gage slightly deeper than the screening questions. The interviewee would only get to this level once he/she has entered the required background information and responded YES to at least one corresponding Screening Question (from level 2). The pre-requisites are questions related to a specific mental disorder. These are also YES/NO questions and must be YES for the interviewee to go to the next level in the artifact.

Level 4 – Other questions: Having passed the previous levels it is now likely that the interviewee could have a mental disorder. In order to be certain at this level more direct questions are asked before the final assessment is given. However, it is also possible that the interviewee would not fulfill all the criteria for the disorder, but the answers from the previous levels were warning signs which may merit a clinician intervention. In the MINI the remaining questions which follow the shaded gray area are used for this Other Questions category. Co-morbidity factor possibility can also be ascertained from partial or complete fulfillment of the disorder criteria.
An example of the MINI module showing the Level 3 and Level 4 questions for Panic Disorder can be seen in the following diagram.

**D. PANIC DISORDER**

(“?” MEANS: CIRCLE NO IN DG, DG AND DJ AND SKIP TO EL)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Have you, on more than one occasion, had spells or attacks when you suddenly felt anxious, frightened, uncomfortable or uneasy, even in situations where most people would not feel that way?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Did the spells surge to a peak within 10 minutes of starting?</td>
<td>?</td>
</tr>
<tr>
<td>D2</td>
<td>At any time in the past, did any of those spells or attacks come on unexpectedly or occur in an unpredictable or unprovoked manner?</td>
<td>?</td>
</tr>
<tr>
<td>D8</td>
<td>Have you ever had one such attack followed by a month or more of persistent concern about having another attack, or worries about the consequences of the attack, or did you make a significant change in your behavior because of the attacks (e.g., shopping only with a companion, not wanting to leave your house, visiting the emergency room repeatedly, or seeing your doctor more frequently because of the symptoms)?</td>
<td>?</td>
</tr>
</tbody>
</table>

*Diagram 4.3: Showing Level 3 Pre-requisites questions and Level 4 Other questions*

To define a specific mental disorder an ontology was constructed for each disorder on the MINI600, using the levels described above. The following two tables show the disorders covered by the MINI, Table 4.1 shows the disorders for adults, while Table 4.2 shows disorders for children and adolescents. The adult MINI questionnaire is called the MINI600, the child and adolescent is called MINIKid and there is a third questionnaire called MINIParentKid which is used by an adult on behalf of a child or adolescent. The MINIKid and MINIParentKid contain the same questions and disorders.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Major Depressive Episode</td>
<td>I. Alcohol Dependence/Abuse</td>
<td></td>
</tr>
<tr>
<td>B. Suicidality</td>
<td>J. Substance Dependence/Abuse</td>
<td></td>
</tr>
<tr>
<td>C. Manic and Hypomanic Episode</td>
<td>K. Psychotic Disorders</td>
<td></td>
</tr>
<tr>
<td>D. Panic Disorder</td>
<td>L. Anorexia Nervosa</td>
<td></td>
</tr>
<tr>
<td>E. Agoraphobia</td>
<td>M. Bulimia Nervosa</td>
<td></td>
</tr>
<tr>
<td>F. Social Phobia (Social Anxiety Disorder)</td>
<td>N. Generalized Anxiety Disorder</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.1: Disorders covered by MINI 600 (Adults)

<table>
<thead>
<tr>
<th>A. Major Depressive Episode</th>
<th>H. Social Phobia (Social Anxiety Disorder)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Suicidality</td>
<td>I. Specific Phobia</td>
</tr>
<tr>
<td>C. Dysthymia</td>
<td>J. Obsessive-Compulsive Disorder</td>
</tr>
<tr>
<td>D. Manic and Hypomanic Episode</td>
<td>K. Posttraumatic Stress Disorder</td>
</tr>
<tr>
<td>E. Panic Disorder</td>
<td>L. Alcohol Dependence/Abuse</td>
</tr>
<tr>
<td>F. Agoraphobia</td>
<td>M. Substance Dependence/Abuse</td>
</tr>
<tr>
<td>G. Separation Anxiety Disorder</td>
<td>P. Antisocial Personality Disorder</td>
</tr>
</tbody>
</table>

Table 4.2: Disorders covered by MINI 600 (Kids) and MINI 600 (KidParent)

4.2 Knowledge representation

Domain knowledge can be represented in different ways. ‘Knowledge representation is the application of logic and ontology to the task of constructing computable models for some domain’ (Sowa, 2000). Edman (2002) proposes a system architecture structure of dividing knowledge into distinct theories since this gives the system ‘a high degree of modularity’. In addition, Edman stated that separating formal knowledge (formal theory), and contextual knowledge (informal theory) and using a metatheory (for reasoning) promotes clarity and ease in maintainability of the system (Edman, 2002).

Consequently, Edman’s architecture structure, along with previously mentioned current research in mental illness, give support for an ontological approach to the artifact’s design. Further support for using ontology in software design is seen in the book ‘New Trends in Software Methodologies, Tools and Techniques’ published the same year as Edman. The authors of one article made a very brave claim that ‘….ontologies will eventually succeed in the information system arena, the “marriage” will be happy and no computerized systems in this century will ever be designed without an ontological approach’ (Pisanelli et al, 2002).

Using the MINI as an example, I will show in the following section how an ontology can be created for each disorder and how it is possible to define a disorder using first order logic. This logic can be used in software development.
Mental disorders ontology and its corresponding logical representation were done for the 16 MINI600 disorders. For simplicity details of only 2 of the disorders is shown in the following pages. The disorders which will be discussed in detail are: Major Depressive episode, and Manic and Hypomanic episode. There is no particular raison d'être for selecting these two disorders. The ontology and logic representation for the remaining 14 mental disorders can be seen in Appendix 1. The following abbreviations are used in the diagrams:

MS = MINI Screen question(s)
PR = Pre-Requisite question(s)
OQ = Other questions

On the ontology all the MINI questions that relates to the disorder is shown, but the logic equation shows only the conditions which must be true for the disorder to be present.

To start the discussion about ontologies we begin by looking at the overall setup of the ontology in Protégé. An explanation of the setup was presented in section 1.7.3, but for the sake of clarity I will reiterate that I created these groupings of questions using the MINI instrument as the guide. The Background Information is not part of the MINI and therefore is not shown in the ontologies. In diagram 4.4, the class Thing is the general class of all things that exists. MentalDisorders is a subclass of Thing, Adult_MentalDisorders and Child_MentalDisorders are two subclasses of MentalDisorders. Then X_MentalDisorders is further divided into subclasses for each specific disorder, for example J_Substance_dependence, E_Agoraphobia or G_Obsessive_Compulsive_disorder.
For each of the disorders there exists 3 subclasses: Screening Questions, Pre-Requisite Questions and Other Questions. These are not shown in Diagram 4.4 since attempting to show it will make the diagram illegible. However, these subclasses will be seen as we discuss individual disorders in the following pages.
Diagram 4.5: Ontology for Major Depressive episode

Diagram 4.5 shows the MINI criteria that defines Depression. Q1_A and Q2_A represent the Screening Questions. A1a, A1b, A2a and A2b are the Pre-Requisite Questions and the Other Questions are A3_tot, A4, A5 and A6. A3_tot is a compound question, consisting of 7 questions. The questions as they appear on the MINI instruments are shown below in Table 4.3:

<table>
<thead>
<tr>
<th>Question Group</th>
<th>MINI questions – Major Depressive episode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screening Questions</strong></td>
<td>Q1_A – Have you been depressed or down, most of the day, nearly every day, for the past two weeks?</td>
</tr>
<tr>
<td></td>
<td>Q2_A – In the past two weeks, have you been much less interested in most things or much less able to enjoy the things you used to enjoy most of the time?</td>
</tr>
<tr>
<td><strong>Pre-Requisite Questions</strong></td>
<td>A1a – Were you ever depressed or down, most of the day, nearly every day, for two weeks?</td>
</tr>
<tr>
<td></td>
<td>A1b – For the past two weeks, were you depressed or down, most of the day, nearly every day?</td>
</tr>
<tr>
<td></td>
<td>A2a – Were you ever much less interested in most things or much less able to enjoy the things you used to enjoy most of the time, for two weeks?</td>
</tr>
<tr>
<td></td>
<td>A2b – In the past two weeks, were you much less interested in most things or much less able to enjoy the things you used to enjoy, most of the time?</td>
</tr>
</tbody>
</table>
Other Questions

A3_tot:  
A3a – Was your appetite decreased or increased nearly every day? Did your weight decrease or increase without trying intentionally (i.e., by ±5% of body weight or ±8 lb or ±3.5 kg, for a 160 lb/70 kg person in a month)?  
A3b – Did you have trouble sleeping nearly every night (difficulty falling asleep, waking up in the middle of the night, early morning wakening or sleeping excessively)?  
A3c – Did you talk or move more slowly than normal or were you fidgety, restless or having trouble sitting still almost every day?  
A3d – Did you feel tired or without energy almost every day?  
A3e – Did you feel worthless or guilty almost every day?  
A3f – Did you have difficulty concentrating or making decisions almost every day?  
A3g – Did you repeatedly consider hurting yourself, feel suicidal, or wish that you were dead? Did you attempt suicide or plan a suicide?  
A4 – Did these symptoms cause significant problems at home, at work, socially, at school or in some other important way?  
A5 – In between 2 episodes of depression, did you ever have an interval of at least 2 months, without any significant depression or any significant loss of interest?  
A6 – How many episodes of depression did you have in your lifetime?

Table 4.3: Grouping of questions from the MINI600 Depression module

The logic representation for Major Depressive Episode follows:

(Q1_A v Q2_A -> ScreenQues_A) ^ (A1a v A2a -> PreRequistQues_A) ^
(((A3a, A3b, A3c, A3d, A3e -> A3_tot) v ( A3b, A3c, A3d, A3e, A3f -> A3_tot)) v
(A3c, A3d, A3e, A3f, A3g -> A3_tot*)) ^ A4) -> OtherQues_A)

The equation above denotes, Mini screen question 1 or 2 should be answered YES by interviewee AND Pre-requisite questions A1a and A2a must be answered YES AND in Other Questions A3 there must be YES answers for at least 5 of the sub questions AND for Other Question A4 the answer must be YES.

Note: * question A3_tot consists of 7 sub questions A3a to A3g, any 5 YES answers to these 7 questions will make A3_tot YES, there are 29 possible combinations (using the number of permutations of size k=7 taken from n=5 objects) that can satisfy this requirement. In order to keep the equation simple, only 3 combinations are shown to demonstrate the principle.
Diagram 4.6: Ontology for Manic and Hypomanic episode

Diagram 4.6 shows the MINI criteria that defines Manic and Hypomanic episode. Q5_C and Q6_C represent the Screening Questions. C1a, C1b, C2a and C2b are the Pre-Requisite Questions and the Other Questions are C3_summary, C4, C5, C6, C7a, C7b and C7c. C3_summary is a compound question, consisting of 8 questions.

The questions as they appear on the MINI instruments are shown in Table 4.4:

<table>
<thead>
<tr>
<th>Question Group</th>
<th>MINI questions – Manic and Hypomanic episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening Questions</td>
<td>Q5_C – Have you ever had a period of time when you were feeling ‘up’ or ‘high’ or ‘hyper’ or so full of energy or full of yourself that you got into trouble, or that other people thought you were not your usual self? (Do not consider times when you were intoxicated on drugs or alcohol.)</td>
</tr>
<tr>
<td></td>
<td>Q6_C – Have you ever been persistently irritable, for several days, so that you had arguments or verbal or physical fights, or shouted at people outside your family? Have you or others noticed that you have been more irritable or over reacted, compared to other people, even in situations that you felt were justified?</td>
</tr>
<tr>
<td>Pre-Requisite Questions</td>
<td>C1a – Have you ever had a period of time when you were feeling 'up' or 'high' or 'hyper' or so full of energy or full of yourself that you got into trouble, - or that other people thought you were not your usual self? (Do not consider times when you were intoxicated on drugs or alcohol.)</td>
</tr>
</tbody>
</table>
intoxicated on drugs or alcohol.)

**C1b** – Are you currently feeling ‘up’ or ‘high’ or ‘hyper’ or full of energy

**C2a** – Have you ever been persistently irritable, for several days, so that you had arguments or verbal or physical fights, or shouted at people outside your family?

Have you or others noticed that you have been more irritable or over reacted, compared to other people, even in situations that you felt were justified?

**C2b** – Are you currently feeling persistently irritable?

<table>
<thead>
<tr>
<th>Other Questions</th>
<th>C3_summary:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During the times when you felt high, full of energy, or irritable did you:</td>
</tr>
<tr>
<td><strong>C3a</strong> –</td>
<td>Feel that you could do things others couldn’t do, or that you were an especially important person?</td>
</tr>
<tr>
<td><strong>C3b</strong> –</td>
<td>Need less sleep (for example, feel rested after only a few hours sleep)?</td>
</tr>
<tr>
<td><strong>C3c</strong> –</td>
<td>Talk too much without stopping, or so fast that people had difficulty understanding?</td>
</tr>
<tr>
<td><strong>C3d</strong> –</td>
<td>Have racing thoughts?</td>
</tr>
<tr>
<td><strong>C3e</strong> –</td>
<td>Become easily distracted so that any little interruption could distract you?</td>
</tr>
<tr>
<td><strong>C3f</strong> –</td>
<td>Have a significant increase in your activity or drive, at work, at school, socially or sexually or did you become physically or mentally restless?</td>
</tr>
<tr>
<td><strong>C3g</strong> –</td>
<td>Want so much to engage in pleasurable activities that you ignored the risks or consequences (for example, spending sprees, reckless driving, or sexual indiscretions)?</td>
</tr>
<tr>
<td><strong>C4</strong> –</td>
<td>What is the longest time these symptoms lasted?</td>
</tr>
<tr>
<td>a) <strong>3 days or less</strong></td>
<td></td>
</tr>
<tr>
<td>b) <strong>4 to 6 days</strong></td>
<td></td>
</tr>
<tr>
<td>c) <strong>7 days or more</strong></td>
<td></td>
</tr>
</tbody>
</table>

**C5** – Were you hospitalized for these problems?

**C6** – Did these symptoms cause significant problems at home, at work, socially in your relationships with others, at school or in some other important way?

**C7a** – IF MANIC EPISODE IS POSITIVE FOR EITHER CURRENT OR PAST ASK:

Did you have 2 or more of these (manic) episodes lasting 7 days or more (C4c) in your lifetime (including the current episode if present)?

**C7b** – IF MANIC OR HYPOMANIC EPISODE IS POSITIVE FOR EITHER CURRENT OR PAST ASK:

Did you have 2 or more of these (hypomanic) episodes lasting just 4 to 6 days (C4b) in your lifetime (including the current episode)?

**C7c** – IF THE PAST “HYPOMANIC SYMPTOMS” CATEGORY IS CODED POSITIVE ASK:

Did you have these hypomanic symptoms lasting only 1 to 3 days (C4a) 2 or more times in your lifetime, (including the current episode if present )?

*Table 4.4: Grouping of questions from the MINI600 Manic and Hypomanic module*
From the C_Manic_&_Hypomanic_Episode module there are three diagnoses possible. These logic equations are shown below:

a. Manic Episode:

\[
((Q5_C \lor Q6_C \rightarrow \text{ScreenQues}_C) \land (C1a \lor C2a \rightarrow \text{PreRequestQues}_C) \land
((C3a, C3b, C3c \rightarrow C3\_summary*) \land (C5 \land C6 \rightarrow \text{OtherQues}_C)) \lor
((Q5_C \lor Q6_C \rightarrow \text{ScreenQues}_C) \land (C1a \lor C2a \rightarrow \text{PreRequestQues}_C) \land
((C3a, C3b, C3c \rightarrow C3\_summary*) \land (C4c \land C6 \rightarrow \text{OtherQues}_C))
\]

b. Hypomanic Episode:

\[
((Q5_C \lor Q6_C \rightarrow \text{ScreenQues}_C) \land (C1a \lor C2a \rightarrow \text{PreRequestQues}_C) \land
(C3a, C3b, C3c \rightarrow C3\_summary*) \land (C3\_summary, C5, C6, C4b, C4c \rightarrow \text{OtherQues}_C)) \lor
((Q5\_C \lor Q6\_C \rightarrow \text{ScreenQues}_C) \land (C1a \lor C2a \rightarrow \text{PreRequestQues}_C) \land
(C3a, C3b, C3c \rightarrow C3\_summary*) \land (C3\_summary, C4b, C5, C6 \rightarrow \text{OtherQues}_C))
\]

c. Hypomanic Symptoms:

\[
((Q5\_C \lor Q6\_C \rightarrow \text{ScreenQues}_C) \land (C1a \lor C2a \rightarrow \text{PreRequestQues}_C) \land
(C3a, C3b, C3c \rightarrow C3\_summary*) \land (C3\_summary, C4a, C5 \rightarrow \text{OtherQues}_C))
\]

Note: * question C3\_summary consists of 7 sub questions C3a to C3g, any 3 or 4 YES answers to these 7 questions will make C3\_summary YES, there are 343 and 2401 possible combinations respectively, that can satisfy this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
In Protégé all ontologies are part of the super class called ‘Thing’. These parts or subclasses or entities are connected to each other via relationships. The isA relationship is used to connect the various components in the mental health ontologies. Using Diagram 4.6 as an example, the ScreenQues_C is the Level 2, the PreRequisitQues_C is level 3 and OtherQues_C is level 4. The suffix used for the levels, that is, _X represents the identity of the disorder on the MINI. In the diagram the _C is equivalent to the MINI C_Manic_and_Hypomanic_Episode.

There is no right or wrong ways to create an ontology, it is always related to the domain knowledge that one wants to capture. The mental disorders ontology in Diagram 4.4 is just one example of how the ontology can be done. Another way to represent the same domain information could be to say the subclass of Thing called MentalDisorders consists of subclasses ScreenQues, PreRequisitQues and OtherQues, as shown in Diagram 4.7. Within these three subclasses the specific disorders can be stated. It should be noted that using the MINI not all mental disorders have these 3 categories of questions. But a discussion of the MINI’s definition of each disorder is not within the scope of the thesis.

Diagram 4.7: Alternative Mental Disorder ontology design
4.3 Fundamental aspects of implementation

The ontology should represent a common language for the domain. This is necessary to allow changeability by experts as required. For the screening tool the ontology nomenclature was developed using the prefix in the MINI modules rather than trying to put a title or fix term that is language specific for the requirement. Therefore from the MINI instrument, using the ‘A’, ‘B’, ‘C’ and so on, for Depression, Suicidality and Manic/Hypomaniac disorders respectively, represents the same entity in both English and Swedish. The numbering of the questions are also the same regardless of the language used. So even though the ontology terms are quite basic, it demonstrates the adaptive possibilities of the artifact.

Stating that the artifact will work is not sufficient to support the design theory. It is important to show why the design will work. It should also be possible to test the proposal made in the design theory via an instantiation. To exemplify the instantiation, the interviewee’s background information is necessary, for example age, gender and if the screening is for the interviewee or on behalf of a child/adolescent. This will then direct the artifact to ask the Screening Questions, if applicable, for the specific age group. For all positive answers to these Screening Questions by the interviewee, the artifact will direct the interviewee to the Pre-Requisite Questions for adults and Other Questions for a child/adolescent. For adults who respond positively to the Pre-Requisites Questions the artifact will move to the Other Questions. In either case, the artifact will deliver a result showing the likelihood that the interviewee has one of the specified mental disorders.
5. Prototype of the artifact

The design theory explained in detailed in the preceding chapters may or may not appear feasible on paper, however to validate the theory it is necessary to present what Gregor and Jones (2007) refer to as the ‘expository instantiation of the artifact’.

ESB Question Editor was used to enter all questions from the MINI forms. The background questions of who the screening is for, as well as the interviewee’s age and gender are also entered here. The following screen shot shows what the ESB question editor looks like:

![ESB Question Editor](image)

Figure 5.1: ESB Question Editor

ESB question editor is used to enter domain knowledge. This is done by building the base of questions and corresponding responses. If required, the importance of the question can be indicated from a scale of normal, medium or high. There is the option to create reliance, that is, dependence relationships between questions, for example, getting to question number 27 depends on the reply to question number 3. While building the question base it is also possible to add links to HTML pages. The create
reliance function was used to create the links to allow navigating from Background Information to Screening Questions to Pre-requisite Questions to Other Questions.

The next stage of constructing the artifact is to use the questions and responses to create and define a specific mental disorder. This is done using ESB Knowledge Acquisition. All possible results or solutions can be defined covering any likely scenario. In other words, where a specific mental disorder is defined, using the logic from the equations described in Section 4.2. Optimal user response is included so that ESB can give a percentage certainty of the results from the user responses. Figure 5.5.2 shows a screen print of the Knowledge Acquisition interface:

![Figure 5.2: ESB Knowledge Acquisition](image)

The third sub-program in ESB is the User Interface. This is what the user of the screening tool will interact with. The function of this sub-program is to collate the information from the question editor and knowledge acquisition components and present the user with questions and answer options. The questions are posed based on the user response to the current question and any reliance that exists between questions. For example, if the user selects the option for the interviewee as Myself (over 21 years) then they will be directed to the question about their gender. However, if they select On behalf of
a child or adolescent they will be directed to a question asking about the child’s or adolescent’s gender. Figure 5.3 shows a screen shot of the user interface:

![Screen Shot of ESB User Interface](image)

*Figure 5.3: ESB User Interface*

After the user has answered all the relevant questions then the results will be displayed. The result will display an ordered list showing a confidence factor rating for all likely disorders. ESB User Interface has its own built in fuzzy logic inference engine that controls which questions are asked and what interpretation is given at the end of the screening.

Now that we have seen how the artifact is construction it is necessary to explain how the logic works. For clarity and simplicity, this explanation is shown in the following steps listed hereunder with relevant screen shots:

a) The artifact is invoked and the user is required to make a selection to indicate who the screening is for. (refer to Figure 5.3 above)

b) The next question is to select the gender of the interviewee.
c) Then an age range has to be selected
d) If the screening is for an adult then a series of screening questions will be asked. These questions are based on the MINI Screen instrument. Figure 5.6 shows the first Screening question, in total there are 25 Screening questions:

![Figure 5.6: Screenshot of example Screening question for Depression](image)

e) If any Screening Question(s) are answered YES then at the end of these questions the interviewee will be directed to the mental disorder module to which he or she responded YES to.

f) The interviewee will now be required to answer the Pre-Requisite question(s) related to that specific module. If YES was answered to Screening Questions that relates to several modules, then the assessment will begin with the Pre-Requisite Questions for the first YES answer. The complete assessment for the disorder will be done, that is, if the Pre-Requisite Questions are fulfilled then the Other Questions will be shown. Afterwards, the screening will continue with any other YES answers given for the Screening Questions.

g) If the interviewee is a child or adolescent or done on behalf of a child or adolescent, there are no Screening Questions. The interviewee will get straight to the first module and will have to answer the Pre-Requisite Questions for that module.
h) In both adult, and child and adolescent categories, the next step is either to continue onto the Other Questions level or the screening will end. In order to continue to the Other Questions level the interviewee must have answered YES to the Pre-Requisite Questions. If the interviewee answers NO to the Pre-Requisite Questions then it is an indication that it is not likely that he or she is positive for that mental disorder, based on the MINI criteria.
i) After all the relevant questions have been answered, the result of the screening will show a list with disorder(s), if any, the interviewee is likely to have. The list will also show a confidence factor for each disorder, as shown in Figure 5.9. This is where probable co-morbidity could be identified.

![Figure 5.9: Screenshot of example results for Depression with co-morbidity for Social Phobia and Suicidality](image)
Figure 5.10 shows an example of how the result was arrived at. This explanation can be seen by clicking the ‘Explain’ button on the results window:

<table>
<thead>
<tr>
<th>Question 1</th>
<th>Importance = NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is the interviewer for? Type = Single</td>
<td></td>
</tr>
<tr>
<td>--- Myself (over 21 years) [YES]</td>
<td></td>
</tr>
<tr>
<td>--- Myself (under 21 years) [NO]</td>
<td></td>
</tr>
<tr>
<td>--- On behalf of a child or adolescent [NO]</td>
<td></td>
</tr>
<tr>
<td>Resultant Score = 10.00 From a MAX of 10.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 2</th>
<th>Importance = NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background: What is the child/adolescent's gender? Type = Single</td>
<td></td>
</tr>
<tr>
<td>[This question was NOT asked/answered]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 3</th>
<th>Importance = NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your gender? Type = Single</td>
<td></td>
</tr>
<tr>
<td>--- Male [NO]</td>
<td></td>
</tr>
<tr>
<td>--- Female [YES]</td>
<td></td>
</tr>
<tr>
<td>Resultant Score = 10.00 From a MAX of 10.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 4</th>
<th>Importance = NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background: What age group is the child/adolescent in? Type = Single</td>
<td></td>
</tr>
<tr>
<td>[This question was NOT asked/answered]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 5</th>
<th>Importance = NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background: What age group are you in? Type = Single</td>
<td></td>
</tr>
<tr>
<td>--- 20 to 29 [NO]</td>
<td></td>
</tr>
<tr>
<td>--- 24 to 30 [YES]</td>
<td></td>
</tr>
<tr>
<td>--- over 30 [NO]</td>
<td></td>
</tr>
<tr>
<td>Resultant Score = 10.00 From a MAX of 10.00</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5.10: Screenshot of example of result explanation*
6. Evaluation

The evaluation of the design theory is two-fold, first is the task of evaluating the knowledge base and second is to evaluate the instantiation of the artifact. The knowledge base was constructed using an establish psychology instrument and with guidance from trained clinicians. The logic equations derived from the MINI, where shown to and discussed with the clinicians. The logic was agreed, but there were some concerns regarding how clinical judgment can be ascertained. However since the artifact is meant as a screening tool and not a diagnostic tool, the logic approach is acceptable. It was possible to create a prototype using the information system design proposed, and the tools described in Chapter 3 of the thesis. Protégé was used to create the ontology for the disorders. In section 4.2 diagrammatic representation of the ontology in Protégé was shown. As was also mentioned in Chapter 3, Protégé follows the W3C semantic web vision. It is therefore possible with Protégé to automatically generate the RDF/XML and OWL/XML code representation for the ontology. These codes can be used by developers for software development or for reuse of the ontology. The following is a small sample extract of these codes:

**RDF/XML:**

```xml
<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A1a -->
<Class rdf:about="&MentalDisorders;A1a">
  <rdfs:subClassOf rdf:resource="&MentalDisorders;PreRequistQues_A"/>
</Class>

<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A1b -->
<Class rdf:about="&MentalDisorders;A1b">
  <rdfs:subClassOf rdf:resource="&MentalDisorders;PreRequistQues_A"/>
</Class>

<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A3_tot -->
<Class rdf:about="&MentalDisorders;A3_tot">
  <rdfs:subClassOf rdf:resource="&MentalDisorders;OtherQues_A"/>
</Class>

<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A3a -->
<Class rdf:about="&MentalDisorders;A3a">
  <rdfs:subClassOf rdf:resource="&MentalDisorders;A3_tot"/>
</Class>

<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A6a -->
<Class rdf:about="&MentalDisorders;A6a">
  <rdfs:subClassOf rdf:resource="&MentalDisorders;OtherQues_A"/>
</Class>

<!-- http://www.semanticweb.org/ontologies/2010/3/16/MentalDisorders.owl#A_Major_Depressive_Episode -->
<Class rdf:about="&MentalDisorders;A_Major_Depressive_Episode"/>
```
<rdfs:subClassOf rdf:resource="&MentalDisorders;Adult_MentalDisorders;"/>

<rdfs:comment>A. Major Depressive Episode: (MS1=Y and/or MS2=Y) ^ (PR A1a=Y ^ PR A2a=Y) ^ (OQ A3=Y &gt;= 5) ^ (OQ A4=Y)</rdfs:comment>

<rdfs:comment>0 is used to mean NO</rdfs:comment>

1 is used to mean YES</rdfs:comment>
</Class>

<owl:xml>
<?xml version="1.0"?>
<!DOCTYPE Ontology [ 
<!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
<!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
<!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
<!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" > ]>


  <Class IRI="#ScreenQues_P"/>
</ObjectPropertyRange>

<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#A_Major_Depressive_Episode</IRI>
  <Literal>0 is used to mean NO</Literal>
  1 is used to mean YES</Literal>
</AnnotationAssertion>

<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#A_Major_Depressive_Episode</IRI>
  <Literal>A. Major Depressive Episode: (MS1=Y and/or MS2=Y) ^ (PR A1a=Y ^ PR A2a=Y) ^ (OQ A3=Y &gt;= 5) ^ (OQ A4=Y)</Literal>
</AnnotationAssertion>

<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#B_Suicidality</IRI>
  <Literal>0 is used to mean NO</Literal>
  1 is used to mean YES</Literal>
</AnnotationAssertion>

<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#B_Suicidality</IRI>
  <Literal>B. Suicidality: (MS3=Y and/or MS4=Y) ^ (OQ B2 to B13=y &gt;= 1)</Literal>
</AnnotationAssertion>
The artifact is created to screen for some of mental disorders from the MINI to demonstrate the design theory, these disorders are show below:

<table>
<thead>
<tr>
<th>Adult</th>
<th>(A)Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(B)Suicidality</td>
</tr>
<tr>
<td></td>
<td>(F)Social Phobia</td>
</tr>
<tr>
<td></td>
<td>(H)Posttraumatic Stress Disorder</td>
</tr>
<tr>
<td></td>
<td>(I)Alcohol Abuse</td>
</tr>
<tr>
<td>Child or adolescents</td>
<td>(A)Depression</td>
</tr>
<tr>
<td></td>
<td>(G)Separation anxiety</td>
</tr>
<tr>
<td></td>
<td>(X)Pervasive development</td>
</tr>
<tr>
<td></td>
<td>(N)TICS – Tourette disorder</td>
</tr>
<tr>
<td></td>
<td>-Motor Tic disorder</td>
</tr>
<tr>
<td></td>
<td>-Vocal tic disorder</td>
</tr>
<tr>
<td></td>
<td>-Transient tic disorder</td>
</tr>
</tbody>
</table>

| On behalf of a child or adolescent | (A)Depression |

*Table 6.1: Disorders used to demonstrate the design theory in the artifact*

The instantiation of the artifact is one method of verifying and validating the proposal for an ontological approach for creating the mental disorder screening tool. In essence, the screening tool should act in an intelligent way exemplifying some of the methods a clinician would use in conducting a similar mental health screening interview. Therefore, feedback from the clinicians who have been domain experts for the thesis can further validate the construct of the artifact.

The feedback received from the domain expert was positive and encouraging. The logic and method of construction was said to be understandable and were within the MINI instrument description. The domain expert pointed out how a screening tool can be beneficial for example, allowing people who might be concerned about their mental health to do the screening, and then seek professional help based on the screening results. It can also be valuable for families who are concerned about a child’s behavior. The tool can be used as an indicator of the need for professional care.

In the discussions with the domain expert on the pros and cons of the screening tool, a concern was expressed about how the interviewee’s could react to the results. For example, if a person is depressed and the results show depression and perhaps the presence of a co-morbidity disorder, this can sometimes worsen the depression. Another scenario of a possible disadvantage of a screening tool is the possibility of creating anxiety in the parent of a child whose screening results show that a mental disorder is likely to be present.
Another issue which was discussed was how the feedback from the screening would be presented to the user. This is related to the design of the user interface. Much care has to be taken in how for example a result with co-morbidity is displayed. Persons vulnerable to mental illness can be sensitive to receiving negative feedback, for example will be necessary to emphasize that the results are based on a screening and only a trained clinician can provide an accurate diagnosis. Where there are co-morbidity results, it could be user friendly to display as a sentence there is a risk for other disorders and show the names rather than in a hierarchal list with certainty values. There are different approaches to the user interface design, to find the most suitable further deliberations with the clinicians is necessary, however design considerations is not within the scope of this thesis.

Overall the domain expert believe that a screening tool could work towards normalizing the problem of mental disorders, that is, it can remove the stigma and increase acceptance that mental disorders is treatable and there should not be any shame in seeking treatment as you would for any other physiological disease.
7. Epilogue

7.1 Conclusions

The information system design theory proposed that it could be possible, using an ontological approach, to create a general screening tool for mental disorders. The entities required to accomplish this was shown on diagram 4.1. Using the design theory an artifact was produced to provide the proof of concept. Providing the level of mental health cover required is unprecedented for any country. But the consequences of continuing to neglect or turning a blind eye to the increasing problem will have great future costs. These costs are more than financial. Therefore it is important that all possible solutions be investigated to find one that works for a particular society or for several societies. Technology has proven to be able to assist in many other health and environmental problems. While there is a significant amount of work necessary to get the psychology domain to embrace technology in its daily functions, it is not an impossible task. The basic tools are currently available, such as the DSM-IV, SCID and MINI, and with the guidance of domain experts it is possible for information systems specialists to provide greater support for this domain.

The artifact created is an example of how it is possible to develop a tool, using the MINI (a common instrument), that will not likely intimidate the non-technically inclined. Intimidation or ignorance can be bona fide barriers to the use of technology in any domain. Consequently, the ontology concept can work to address this problem, since there is some familiarity as it is based on using the language of the domain. The domain experts themselves are encouraged to maintain the ontology.

7.2 Discussion

It was very interesting to work in the psychology domain using my information system knowledge to develop an artifact that represents a point where both domains intersect. It was possible to present the design theory and support it by creating an instantiation. The methodology used can be supported by Gregor and Jones (2007) ‘Anatomy of a Design Theory’ model, which was shown in Table 1.1. The eight components proposed in their design can be recognized in the design of the mental disorders screening tool. In the following sections I will summarize the thesis design theory in accordance with Gregor and Jones’s anatomy components, using these components terms as the section heading. The purpose and scope component was discussed in the thesis introduction and will not be repeated here.

7.2.1 Constructs

The proposed structure of the screening tool is a system constructed with four main entities: background questions, screening questions, pre-requisite questions and other questions. These entities can be viewed as different levels, where particular requirements which must be fulfilled in order to move to the next level. To demonstrate this, the entities were constructed using the MINI. Since the MINI does not capture background information, the background entity is added specifically to capture
background information. Diagram 4.1 showed these entities which formed the artifact and the entities were discussed in detail in section 4.1.

7.2.2 Principle of form and function
The domain of mental disorders is complicated and uncertainty exists. Therefore to have any efficient screening tool the knowledge base must be given some structure that is able to handle new discoveries or amendments to existing theories. The MINI instrument gives a clear indication of what defines a specific disorder, in keeping with the DSM-IV standard. It is therefore possible to define each disorder using first order logic and to represent the entities ontologically. This was shown in section 4.2.

7.2.3 Artifact mutability
The modularity of the artifact facilitates any necessary changes to the definition of a mental disorder. So it is possible for domain experts to edit any (or all) of the three entities, that is, if for example, additional pre-requisites or screening questions are needed it can be easily added.

This artifact represents a small part of the mental illness domain and can be described as an evolving artifact, a term used by Simon (1996), where flexibility and adaptability are necessary for artifact mutability. The knowledge captured and represented here can be compared to a piece of the puzzle which when completed shows the whole picture.

7.2.4 Testable propositions
The design theory can be summarized in a testable proposition. If you want to know the possibility that an individual (adult, child/adolescent), has a mental disorder then you can perform a simple screening examination. This proposition is tested through an instantiation of the artifact.

7.2.5 Justificatory knowledge
Justificatory knowledge is mentioned throughout the thesis. However, it can be summarized by saying the ontological design using Protégé provides several benefits. First it allows the domain experts to maintain the ontology as required. Being open source, it inherits the benefits of open source mentioned earlier. It supports the Web Ontology Language and follows the Semantic Web rules. Dividing the knowledge base into modules is supported by previous research since it adds clarity and separates the knowledge from the reasoning.

7.2.6 Principles of implementation
There are two parts of the implementation of the system, the process and the product (Gregor and Jones, 2007). Sommerville (2001) proposes a generic four step model for a prototyping process. The process that gave rise to the design theory and its evolution into the instantiated artifact can be discussed within the dimensions of Sommerville’s model. The first step is to establish the objectives, which is primarily to use information systems as part of the solution to a growing mental health
dilemma. Other objectives are to create a screening tool for general use, that is free to use, that is easily accessible worldwide for example via the internet. The second step is to define functionality. The required functionalities include a prototype that is reasonable simple and easy to use but most importantly is able to provide accurate results. The third step in the prototyping process is to develop the prototype. The fourth and final step is evaluation. The evaluation is two-fold, evaluating the process of extracting the knowledge to create the knowledge base and evaluating the tool representing the proposed design theory.

7.2.7 Expository instantiation

The design of the instantiation was done using Protégé to create ontologies for each disorder, as shown in section 4.2. The artifact was built using the constructs described in section 4.1. For an adult screening the constructs are: background questions, screening questions (if any), pre-requisites questions (if any) and other questions. The child and adolescent construct, based on the MINI, is similar but excludes screening questions.

If necessary, the domain expert can add, delete or edit the questions in these modules. As previously mentioned, this design allows for easy modifications or redefinition of existing knowledge. New disorders can also be defined from a combination of criteria from these existing modules. There is a high degree of flexibility in this method.

The freeware called Expert System Builder (ESB) was used to develop the artifact. ESB comprises of three sub-programs: ESB Question Editor, ESB Knowledge Acquisition and ESB User Interface. The details for the artifact’s prototype were shown in section 4.4.

7.2.8 Challenge of knowledge acquisition and software

Answering the research question and accomplishing the purpose of the thesis did not come without its share of challenges. Acquiring the domain knowledge was problematic at times since domain experts have been hesitant in using IT for crucial tasks that require clinical judgment. This is not unreasonable, but hopefully over time IT can show that with support from psychology domain experts it is possible to have more IT involvement not to replace, but support decisions that rely on clinical judgments. The governing body that holds the copyright for key psychology instruments such as the SCID has to be convinced to allow developers access to use the material. Currently no authorization is given to use the SCID instrument online or in any software development. As previously mentioned this was one of the reasons that led to the MINI being used for the design of the screening tool.

One of the biggest challenges is related to my choice to use open source software. The choice was justified and supported in the methodology section of the thesis. Nevertheless, there was the problem of getting user support for the software, which led to unnecessary and significant loss of time. There is a lot of very useful open source software which were more appropriate for constructing the artifact, for example eXpertise2go. However, like many of the available choices there was lack of documentation, or
an inactive user forum, or as in the case of eXpertise2go, was maintained by one person who was unable to provide support due to illness. This is unfortunate, and I think that it can be a deterrent to using open source software. So perhaps parallel to the EU or the Swedish government drive to use open source, there should be some form of motivation for developers to document their software. An experiment to create an open source software ontology could also be interesting.

My research and use of Protégé showed it to be a powerful and useful open source tool. The ontologies created for the thesis represent a small part of the capabilities of this software. Developers who are designing knowledge base or intelligent systems can benefit from the wealth of support available (from almost 150,000 registered users), and the versatility of the software itself via the numerous plug-ins.

7.3 Future Work

Maintaining the ontology is a key aspect to the success of the screening tool. Since the domain experts should be responsible for this task, future work should explore different strategies to accomplish this, for example the implementation of formal training. ESB sufficed for the instantiation of the artifact, since the focus of the thesis was on the design theory. However, exploring other open source software alternatives, for example Protégé, could be done to get a more suitable option that would for example simplify the construct of the knowledge base, and focus on usability issues. Following this would be to actually have the screening tool tested in a clinical environment where the logic and inferences can be further refined by additional input from the domain experts. Then to eventually test the screening tool’s effectiveness in screening for mental disorders in different groups and countries.
8. References


Edman, A., 2001. Combining knowledge systems and hypermedia for user co-operation and learning, PhD thesis, Computer Science, Uppsala University, Uppsala, Sweden


M.I.N.I. Available at: https://medical-outcomes.com/HTMLFiles/MINI/MINI.htm [Accessed 22 March 2010]


Nora D. Volkow, 2008. M.D. Director National Institute on Drug Abuse: Comorbidity: Addiction and Other Mental Illnesses


Appendix 1

Diagram 1: Ontology for Suicidality

B_Suicidality:

( Q3_B v Q4_B -> ScreenQues_B) ^ (( B2 v B3 v B4 v B5 v B6 v B7 v B8 v B9 v B10 v B11 v B12 v B13) -> OtherQues_B)

Note: There are no pre-requisite questions on the MINI for Suicidality. However, if clinicians determine there should be pre-requisites in the future, then it can be easily added.
Appendix 1

Diagram 2: Ontology for Panic Disorders

D_Panic Disorder:

The diagnosis from Panic Disorder can be either current or lifetime, both are shown below:

a. Lifetime:
   (Q7_D v Q8_D -> ScreenQues_D) ^ (D1a, D1b -> PreRequistQues_D) ^
   (D4a, D4b, D4c, D4d -> D4_tot*) ^ (D2, D4_tot -> OtherQues_D)

b. Current:
   (Q7_D v Q8_D -> ScreenQues_D) ^ (D1a, D1b -> PreRequistQues_D) ^
   (D4a v D4b v D4c v D4d v D4e v D4f v D4g v D4h v D4i v D4j v D4d v D4d v D4d -> D4_tot)
   ^ (D2, D4_tot, D7 -> OtherQues_D)

Note: * question D4_tot consists of sub questions D4a to D4m, any 4 YES answers to these 13 questions will make D4_tot YES, there are 28,561 possible combinations that can satisfy this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle

~ 2 ~
Appendix 1

Diagram 3: Ontology for Agoraphobia

E_Agoraphobia:

This disorder could exist with or without Panic disorder, as shown below:

a. With panic disorder:
   (Q9_E -> ScreenQues_E) ^ (E1 -> PreRequistQues_E) ^ (E2 -> OtherQues_E) ^
   (D7 -> OtherQues_D*)

b. Without panic disorder:
   (Q9_E -> ScreenQues_E) ^ (E1 -> PreRequistQues_E) ^ (D7 -> OtherQues_D*)

c. Without history of panic disorder:
   (Q9_E -> ScreenQues_E) ^ (E1 -> PreRequistQues_E) ^ (E2 -> OtherQues_E) ^
   (D5 -> OtherQues_D*)

d. Agoraphobia current:
   (Q9_E -> ScreenQues_E) ^ (E1 -> PreRequistQues_E) ^ (E2 -> OtherQues_E)

Note: *response from Panic Disorder
Appendix 1

Diagram 4: Ontology for Social Phobia

F_Social_Phobia:

\( (Q10_F \rightarrow \text{ScreenQues}_F) \land (F1 \rightarrow \text{PreRequestQues}_F) \land (F2, F3 \rightarrow \text{OtherQues}_F) \)
Diagram 5: Ontology for Obsessive Compulsive disorder

G_Obsessive_Compulsive_disorder:

a. Obsessive:
   \[(Q11_G \lor Q12_G \rightarrow \text{ScreenQues}_G) \land (G1 \rightarrow \text{PreRequistQues}_G) \land (G3 \rightarrow \text{OtherQues}_G)\]

b. Compulsive:
   \[(Q11_G \lor Q12_G \rightarrow \text{ScreenQues}_G) \land (G1 \rightarrow \text{PreRequistQues}_G) \land (G2, G4 \rightarrow \text{OtherQues}_G) \lor (Q11_G \lor Q12_G \rightarrow \text{ScreenQues}_G) \land (G1 \rightarrow \text{PreRequistQues}_G) \land (G4 \rightarrow \text{OtherQues}_G)\]

c. Current:
   \[(Q11_G \lor Q12_G \rightarrow \text{ScreenQues}_G) \land (G1 \rightarrow \text{PreRequistQues}_G) \land (G5, G6 \rightarrow \text{OtherQues}_G)\]
H_Post_Traumatic_Stress_Disorder:

\[(Q13_H \lor Q14_H \lor Q15_H \rightarrow \text{ScreenQues}_H) \land (H1, H2, H3 \rightarrow \text{PreRequistQues}_H) \land (H4a, H4b, H4c \rightarrow H4_{tot*}) \land (H5a, H5b \rightarrow H5_{tot*}) \land (H4_{tot}, H5_{tot}, H6 \rightarrow \text{OtherQues}_H)\]

Note: *questions H4_tot and H5_tot consists of sub questions H4a to H4g and H5a to H5e any 3 and 2 YES answers respectively, to these questions will make H4_tot and H5_tot YES, there are 343 and 25 possible combinations for each that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
Appendix 1

Diagram 7: Ontology for Alcohol Dependence/Abuse

I_Alcohol_Dependence:

Dependence and Abuse is shown as two separate disorders. However, if Dependence is established then it is not necessary to check for Abuse, since Dependence infer Abuse:

a. Dependence:
   \( (Q16_1 -> \text{ScreenQues}_1) ^ (I1 -> \text{PreRequistQues}_1) ^ (I2a, I2b, I3c -> I2\_tot*) ^ (I2\_tot -> \text{OtherQues}_1) \)

b. Abuse:
   \( (Q16_1 -> \text{ScreenQues}_1) ^ (I1 -> \text{PreRequistQues}_1) ^ (I3a v I3b v I3cv I3d -> I3\_tot) ^ (I3\_tot -> \text{OtherQues}_1) \)

Note: *question I2\_tot consists of sub questions I2a to I2g and 3 YES answers to these questions will make I2\_tot YES, there are 343 possible combinations that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
Appendix 1

Diagram 8: Ontology for Substance Dependence/Abuse

J_Substance_dependence:

As with Alcohol, Substance Dependence and Abuse is shown as two separate disorders. However, if Dependence is established then it is not necessary to check for Abuse, since Dependence infer Abuse:

a. Dependence:
   (Q17_J -> ScreenQues_J) ^ (J1a -> PreRequistQues_J) ^ (J2a, J2b, J3c -> J2_tot*) ^ (J2_tot -> OtherQues_J)

b. Abuse:
   (Q17_J -> ScreenQues_J) ^ (J1a -> PreRequistQues_J) ^ (J2a v J2b v J2c v J2d v J2e v J2f v J2g -> J2_tot) ^
   (J3a v J3b v J3c v J3d -> J3_tot) ^
   (J3_tot -> OtherQues_J)

Note: *question J2_tot consists of sub-questions J2a to J2g and 3 YES answers to these questions will make J2_tot YES, there are 343 possible combinations that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
Appendix 1

Diagram 9: Ontology for Psychotic disorders
Appendix 1

K_Psychotic_disorders_&_mood_disorders_with_psychotic_features:

Psychotic disorders can be current or lifetime, equations are shown for both:

a. Lifetime:
   \((Q_{18\_K} \lor Q_{19\_K} \lor Q_{20\_K} \rightarrow \text{ScreenQues\_K}) \land (K_{1b} \lor K_{2b} \lor K_{3b} \lor K_{4b} \lor K_{5b} \lor K_{6b} \rightarrow \text{OtherQues\_K}) \lor (Q_{18\_K} \lor Q_{19\_K} \lor Q_{20\_K} \rightarrow \text{ScreenQues\_K}) \land (K_{1b}, K_{2b} \rightarrow \text{OtherQues\_K}^*)\)

b. Current:
   \((Q_{18\_K} \lor Q_{19\_K} \lor Q_{20\_K} \rightarrow \text{ScreenQues\_K}) \land (K_{1a} \lor K_{2a} \lor K_{3a} \lor K_{4a} \lor K_{5a} \lor K_{6a} \rightarrow \text{OtherQues\_K}) \lor (Q_{18\_K} \lor Q_{19\_K} \lor Q_{20\_K} \rightarrow \text{ScreenQues\_K}) \land (K_{1a}, K_{2a} \rightarrow \text{OtherQues\_K}^*)\)

Note: *OtherQues\_K consists of sub questions K1a to K12a and K1b to K14b and 2 YES answers to these questions will make OtherQues\_K YES, there are numerous possible combinations that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
Appendix 1

Diagram 10: Ontology for Anorexia Nervosa

L_Anorexia_Nervosa:

a. Women:
   \[(Q21_L \lor Q22_L \rightarrow \text{ScreenQues}_L) \land (L1 \rightarrow \text{PreRequistQues}_L) \land (L4a \lor L4b \lor L4c \rightarrow L4_{\text{tot}}) \land (L4_{\text{tot}}, L2, L3, L5, L6 \rightarrow \text{OtherQues}_F)\]

b. Men:
   \[(Q21_L \lor Q22_L \rightarrow \text{ScreenQues}_L) \land (L1 \rightarrow \text{PreRequistQues}_L) \land (L4a \lor L4b \lor L4c \rightarrow L4_{\text{tot}}) \land (L4_{\text{tot}}, L2, L3, L5 \rightarrow \text{OtherQues}_F)\]
Appendix 1

Diagram 11: Ontology for Bulimia nervosa

M_Bulimia_nervosa:

a. Current:
   \((Q22\_M \rightarrow \text{ScreenQues}\_M) \land (M1 \rightarrow \text{PreRequestQues}\_M) \land (M3, M4, M5 \rightarrow \text{OtherQues}\_M)\)

b. Anorexia nervosa binge eating/purging type current:
   \((Q22\_M \rightarrow \text{ScreenQues}\_M) \land (M1 \rightarrow \text{PreRequestQues}\_M) \land (M2, M3, M4, M5, M6, M7 \rightarrow \text{OtherQues}\_M)\)
Diagram 12: Ontology for Generalized Anxiety disorders

N_Generalized_Anxiety_Disorder:

\[(Q_{23N} \lor Q_{24N} \rightarrow \text{ScreenQues}_N) \land (N_{1a}, N_{1b1} \rightarrow \text{PreRequistQues}_N) \land (N_{3a}, N_{3b}, N_{3c} \rightarrow N_{3\_tot}) \land (N_{2}, N_{3\_tot}, N_{4} \rightarrow \text{OtherQues}_N)\]

Note: *question N_{3\_tot} consists of sub questions N_{3a} to N_{3f} and 3 YES answers to these questions will make N_{3\_tot} YES, there are 216 possible combinations that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.
Appendix 1

Diagram 13: Ontology to rule out medical, organic or drug causes for disorders

O_Rule_out_medical_organic_or_drug_causes_for_all_disorders:

(Q25_O -> ScreenQues_O)
Appendix 1

Diagram 14: Ontology for Antisocial Personality disorders

P_Antisocial_Personality_disorder:

(P1a, P1f -> P1_tot*) ^ (P2a, P2b, P2c -> P2_tot*) ^ (P1_tot, P2_tot -> OtherQues_G)

Note: *questions P1_tot and P2_tot consists of sub questions P1a to P1f and P2a to P2f any 3 and 3 YES answers respectively, to these questions will make P1_tot and P2_tot YES, there are 36 and 216 possible combinations for each that satisfies this requirement. In order to keep the equation simple, only 1 combination is shown to demonstrate the principle.