MentalDisOnt: An ontology for describing different types of mental disorders.

Rafia Tehseen and Toseeq Sarwar

*Department of Computer Science and Information Technology, University of the Sargodha, Sargodha.*

*University Road, Sargodha, Punjab 40100, Pakistan.*

*E-mails:* [*rafiatehseen987@gmail.com,*](mailto:rafiatehseen987@gmail.com,%20) [*toseeq.warriach7@gmail.com*](mailto:toseeq.warriach7@gmail.com%20)

**Abstract**

Semantic descriptions of mental disorders, offered in a machine-understandable form, can provide useful information benefit in the diagnosis of disorders. In this paper, we explain the development process made to build mental disorder ontology, for describing different types of mental disorders. It could be used as a model for the development of other ontologies for developing a knowledge graph.

The terms of the MentalDisOnt ontology provide different types of information related to a mental disorder, which is reflected in distinct modules that constitute the ontology. Thus, it contains classes and properties for expressing information about disorders diagnosed till now, comorbidity, symptoms, age group, ICD codes, risk factors, and finally level of intensity of that particular disorder. The ontology development process has been carried out in close collaboration with a domain expert.

**Keywords**: Ontology, Mental Disorder, Disorders Ontology, Mental Health

1. **Introduction**

A mental disorder is characterized by a clinically significant disturbance in an individual’s cognition, emotional regulation, or behavior [1].  It is usually associated with suffering or damage in important areas of functioning. There are many different types of mental disorders. There are nearly300 mental disorders listed in the DSM-5 [2]. In 2019, about 970 million people around the world were living with a mental disorder, with anxiety and depressive disorders as the most common [3]. During the COVID-19 pandemic, these numbers increased even higher, with a 25% increase in the prevalence of mental disorders around the world [4]. Numerous studies have been conducted in the domain of mental disorders to define their symptoms, causes, and cures. Thus, to assist doctors and patients we will develop an ontology for providing a detailed description of a mental disorder. We have not found any other ontology that provides a detailed description of all the mental disorders but other existing ontology related to a single disorder will contribute significantly to our ontology.

The purpose of this paper is to present MentalDisOnt ontology. It includes terms to describe 1) Classification 2) comorbidity (disorders that can be present in a person at once) 3) symptoms 4) ICD code 5) risk factors 6) age group and 7) levels of intensity

The MentalDisOnt ontology has been implemented using OWL and Protégé [5] development environment. MentalDisOnt is in line with the classification and information of mental disorders provided in DSM-V [2] (Diagnostic and Statistical Manual of Mental Disorder). MentalDisOnt incorporates concepts given in several ontologies: Bipolar Disorder Ontology [7], which explains the main concepts related to bipolar disorder; Schizophrenia Ontology [8], which explains symptoms and types of schizophrenic disorders; Mental Disorder Classification Ontology [9], provides classification/types of mental disorder; Posttraumatic Stress Disorder Ontology [10], classifies PTSD according to causal approach; Sleep Domain Ontology [11], explain different types of sleep medicines; and Autism Spectrum Disorder Ontology [12], provides phenotype for diagnosis of the autism spectrum.

Apart from the interest in MentalDisOnt ontology in itself, the main contribution of MentalDisOnt ontology is as follows: 1) Reusability, its structure facilitates the task of developing other ontologies on different types of mental disorders and diseases. Information related to Mental Disorders that are described in this ontology could be replaced by information about any other disorder/disease; 2) Expressiveness of relation between different disorders, it incorporates a hierarchical classification of possible disorders and their relations with different factors that help in describing a mental disorder. Dealing with all this detailed description a fine-grained result could be provided for the questions related to mental disorders.

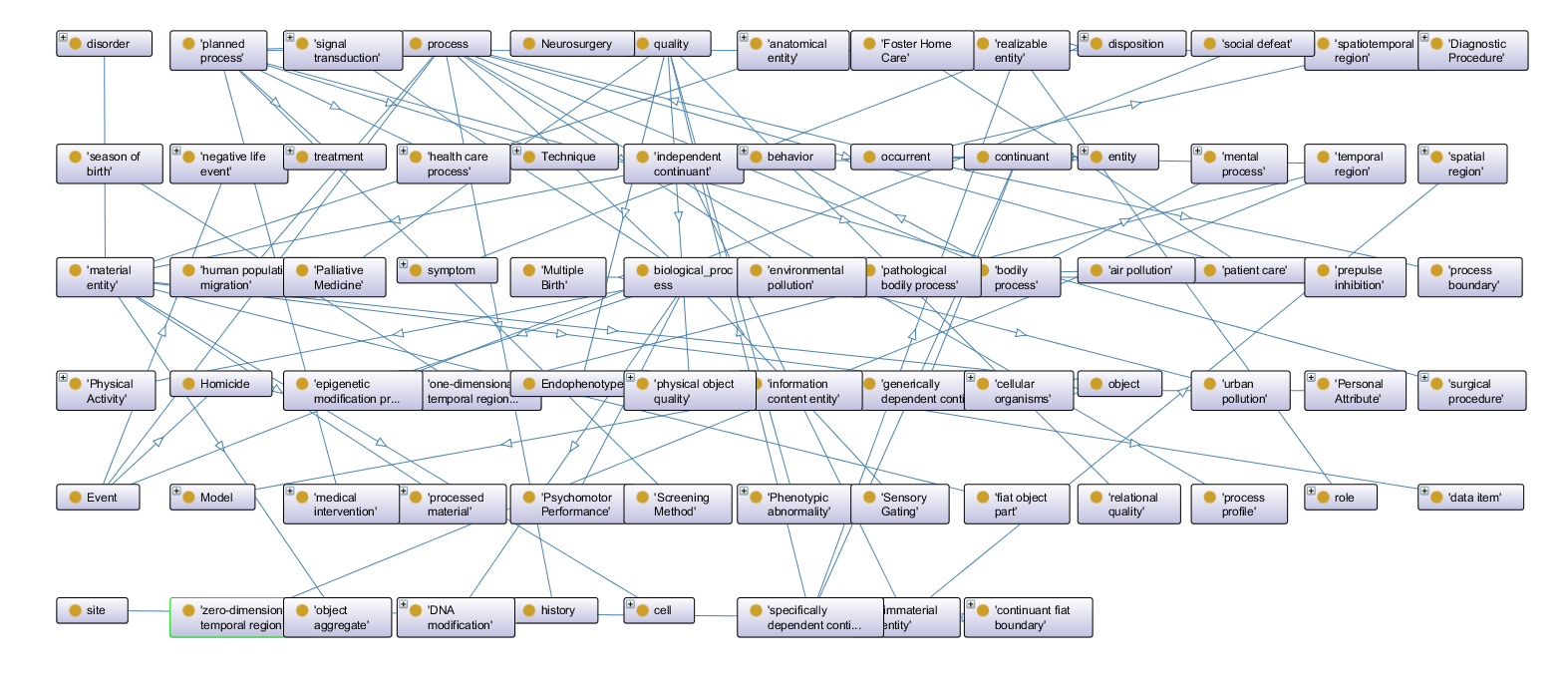
Finally, the use of MentalDisOnt ontology as the core element for the ontology-based system, developed for Smart Diagnosis, can bring several benefits. For example, the development of a Visual Query System (Expert System) will bring the following benefits to different types of users of this Mental Disorder Ontology:

* Mental health Professionals. Description of Mental Disorders will help mental health professionals in providing a diagnosis. It will speed up the process of diagnosing a mental disorder.
* Patients. This ontology will help patients with mental issues in understanding their mental conditions. It will also be able to provide an answer they might have related to different symptoms they might have noticed in themselves.

In the rest of this document, we present the first, distinct approaches that have been defined in the literature, related to the development of ontologies related to mental disorders: existing ontologies and ontology evaluation techniques. Then, we show some methodologies that have been proposed to adequately develop ontologies. Next, we illustrate the steps that we will follow to develop the MentalDisOnt ontology using the NeOn methodology [[13]](#_bookmark83) and the modules that constitute MentalDisOnt. We finish with some conclusions and future work.

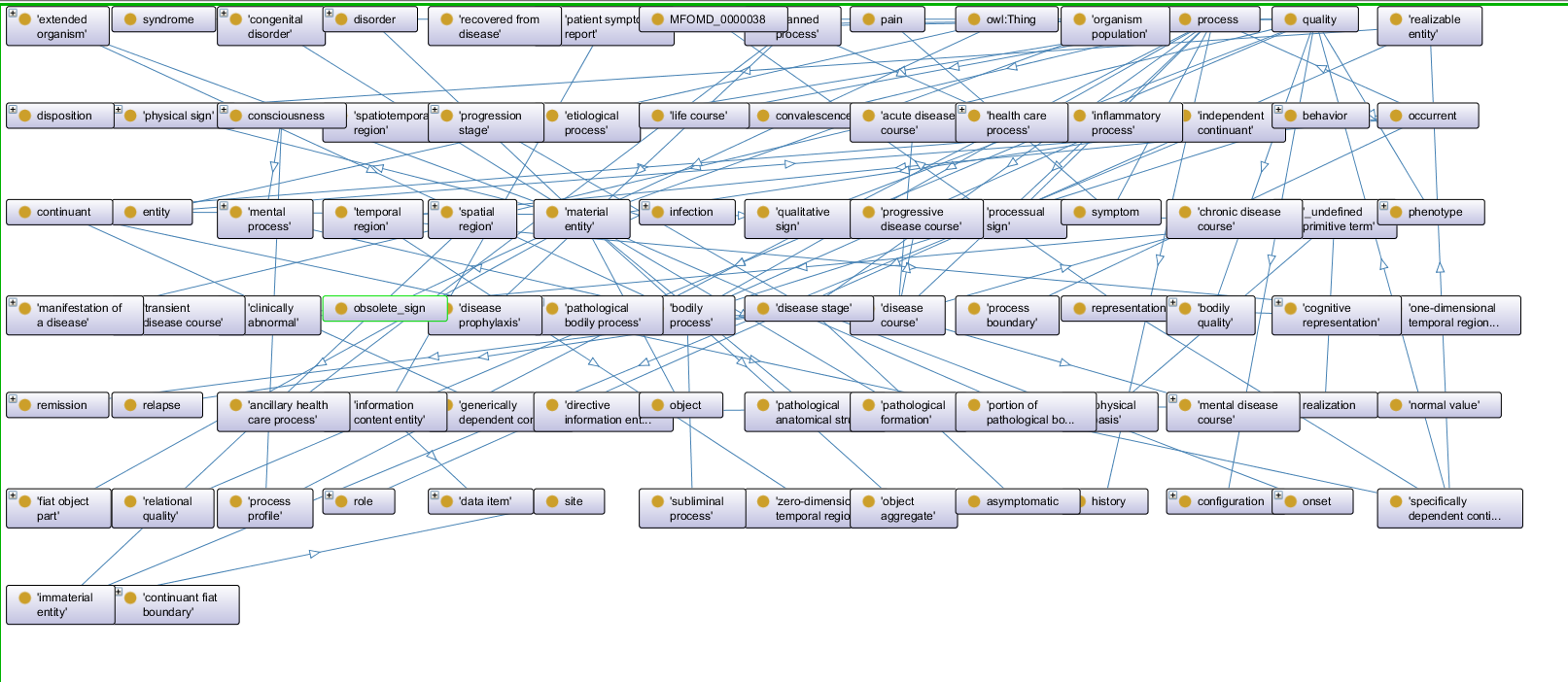
1. **Related work**

The specialized literature offers several ontologies that are focused on the domain of mental disorders. These ontologies have been developed for different purposes and therefore provide diverse information related to the specific area they cover. For example, the Bipolar Disorder Ontology [7] primarily includes concepts, terms, causes, and factors related to bipolar disorder, with a focus on the mental functions that may contribute to the development of the disorder. The core elements of this ontology consist of two main classes: continuent and occurrent. However, it does not provide detailed information about symptoms, age groups, or comorbidity associated with bipolar disorders. The Bipolar Disorder Ontology is built upon the Mental Function Ontology, which is used to describe bipolar disorder.



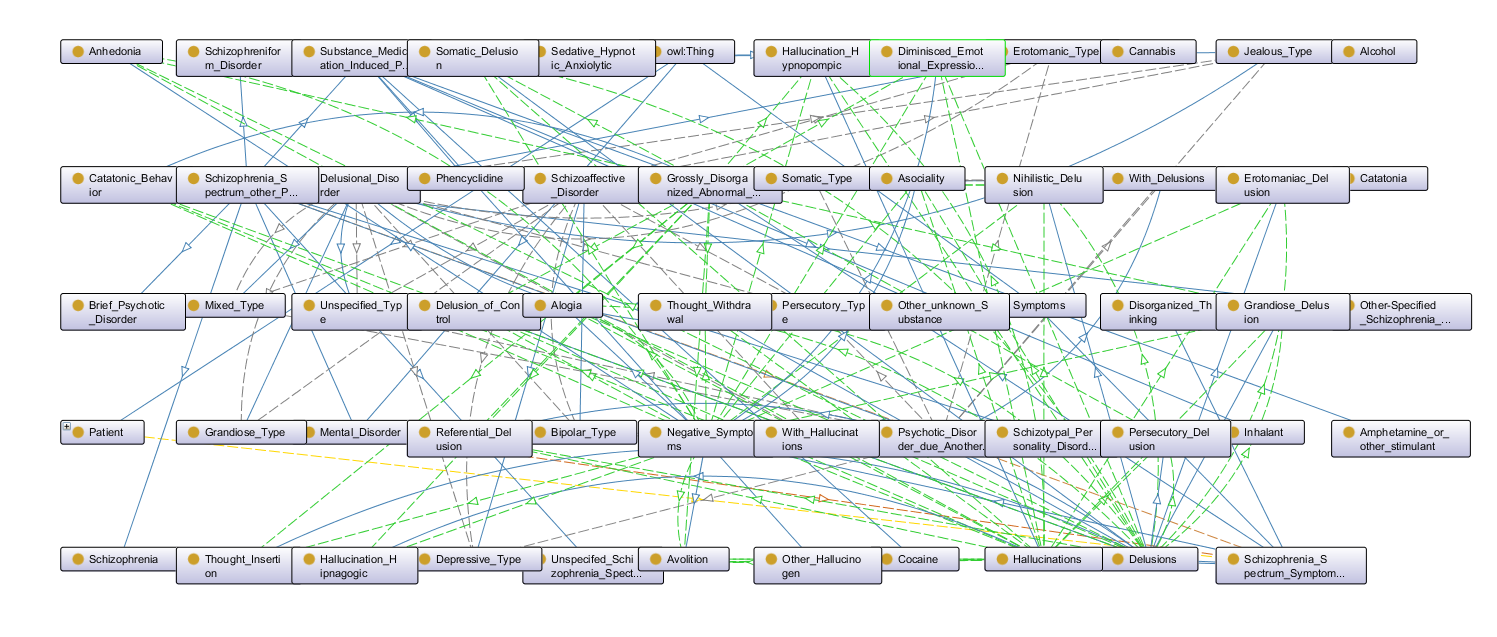
*Figure 1: Some classes and subclasses of Bipolar Disorder Ontology [7]*

The Disease Ontology [15] is a standardized ontology that aims to describe human disease terms, phenotype characters, and related medical vocabulary. The Mental Disease Ontology, within the broader scope of the Disease Ontology, explains various aspects of mental diseases such as occurrents, signs, symptoms, etc. It also integrates disease and medical vocabularies through cross-mapping with other terminologies like MeSH, ICD, NCI's thesaurus, SNOMED, and OMIM. While the Mental Disease Ontology provides comprehensive coverage of mental diseases, it does not include a graphical representation of mental disorders as explained and classified in the DSM (Diagnostic and Statistical Manual of Mental Disorders).



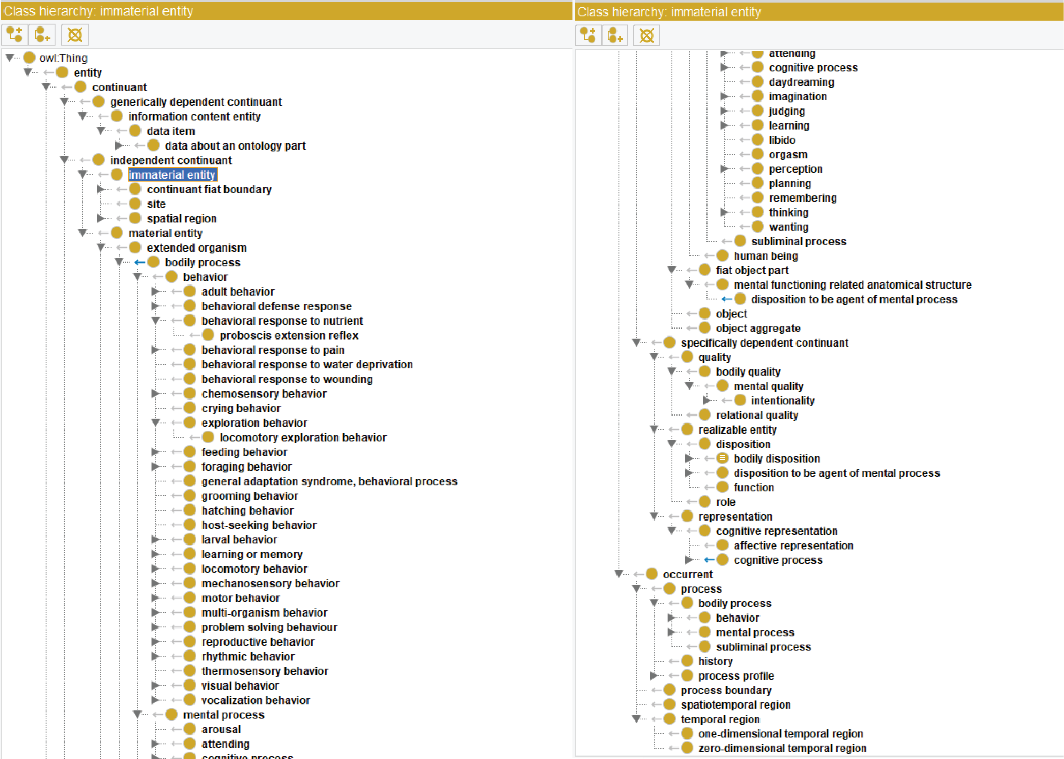
*Figure 2: Some classes and subclasses of Mental diseases ontology [5]*

The Schizophrenia Ontology [8], discussed in "Ontologies, Mental Disorders, and Prototypes" [9], focuses specifically on concepts related to schizophrenia, including different types and symptoms of the disorder. However, it lacks other essential information necessary for mapping a mental disorder, such as risk factors, age groups, and comorbidity. Similarly, the Mental Disorder Ontological classification [9] provides classification and definitions of various mental disorders based on the ICD and NIH classifications. While it offers a basic classification system, it lacks detailed information about symptoms, types, risk factors, and differential diagnosis for mental disorders.



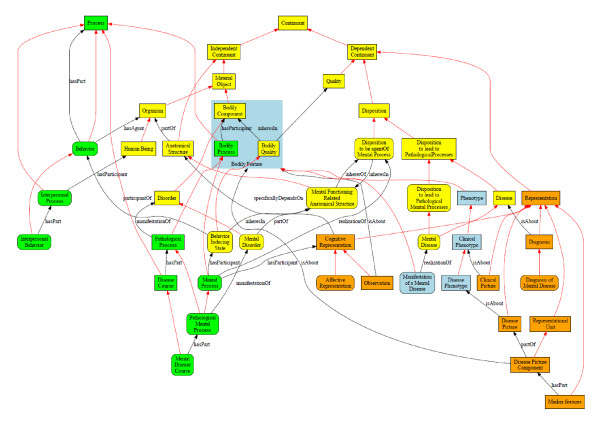
*Figure 3: Class and subclasses of Schizophrenia Disorder Ontology [8]*

The Mental Function Ontology [20] primarily describes the functions of the human mind, with its primitive classes being continuent and occurrent. However, it does not provide specific features or characteristics of mental disorders. The Mental Functioning Ontology is an overarching ontology for all aspects of mental functioning, founded on the Basic Formal Ontology (BFO) and related to the Ontology for General Medical Science (OGMS). The Mental Functioning Ontology (MF) was first described in the publication 'Foundations for a realist ontology of mental disease’ [21].



*Figure 4: Class hierarchy of mental function ontology [20]*

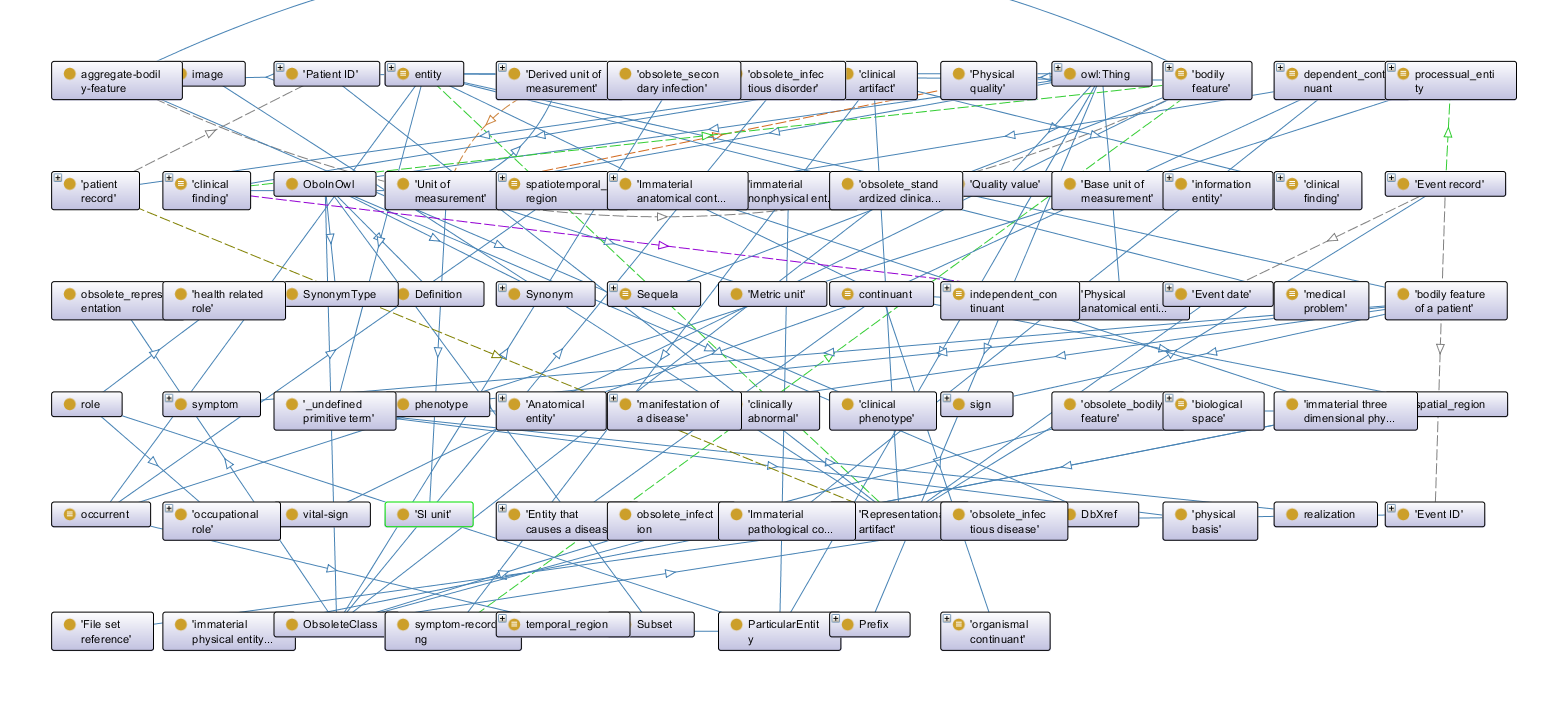
This article discusses the need for a clear understanding of terms such as 'mental disorder', 'disease', and 'illness' in the context of mental health classifications. The authors propose an ontological approach based on realism and utilize Basic Formal Ontology (BFO) and Ontology of General Medical Science (OGMS) principles to develop a formal representation of mental disease. They analyze existing statements about mental disease and identify confusions and conflations in the terminology. The article provides a framework for achieving clear and unambiguous reference to entities related to mental disease, aiming to address these confusions in the future.



*Figure 5: Foundational entities for an ontology of mental disease [21]*

The Posttraumatic Stress Disorder (PTSD) Ontology [10] approaches PTSD classification from a causal perspective, classifying different types of PTSD based on their causes (e.g., Natural Kind, Social Construction, or Causal System). However, it does not encompass information about symptoms, age groups, comorbidity, or levels of intensity associated with PTSD. This ontology is explained in article “The Ontology of Posttraumatic Stress Disorder: Natural Kind, Social Construction, or Causal System?” [10]. This article discusses the ontological status of posttraumatic stress disorder (PTSD) and explores different perspectives on its nature. It examines the debate between PTSD being considered a natural kind, a socially constructed artifact, or a causal system. The author argues for a causal system interpretation of PTSD, inspired by the work of Borsboom and colleagues, which is seen as a more scientifically fruitful approach compared to the other perspectives. The article provides insights into the controversies surrounding the conceptualization of PTSD and suggests a novel perspective rooted in causal systems analysis.

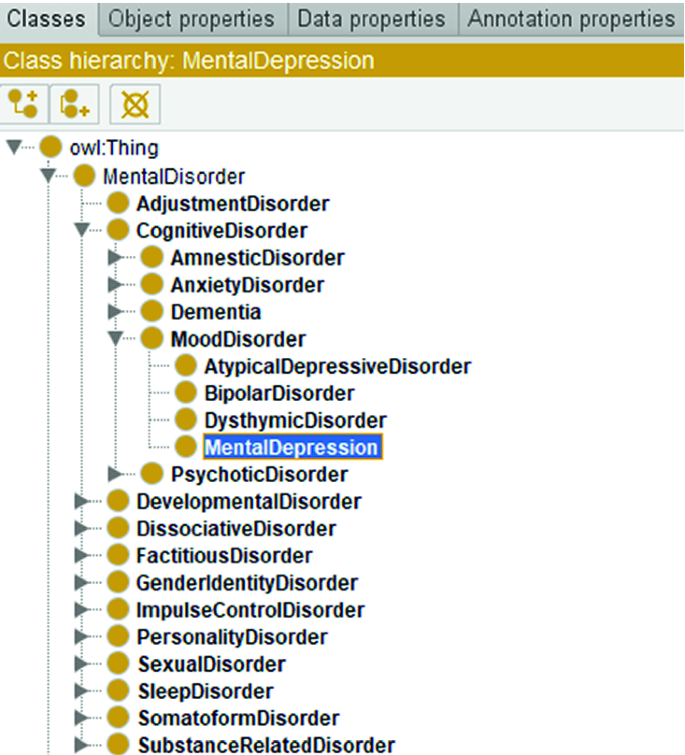
The Sleep Domain Ontology [31] focuses on explaining different sleep medicines, including their unit of measurement, recommended quantities, and roles. Additionally, it describes the symptoms of different types of sleep-domain disorders/diseases. However, it does not provide a clear classification system, risk factors, age groups, or comorbidity information.



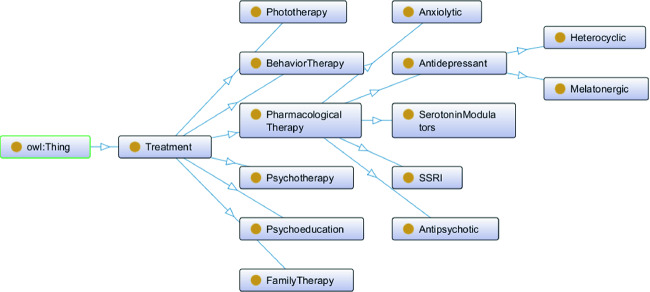
*Figure 6: Graphical representation of Sleep Domain Ontology [31]*

The Autism Spectrum Disorder (ASD) Ontology [12] specifically provides phenotype information for diagnosing autism spectrum and related neurodevelopmental disorders, incorporating their classification, risk factors, and comorbidity. It could be extended to include additional details such as intensity levels, age groups, and ICD codes for disorders.

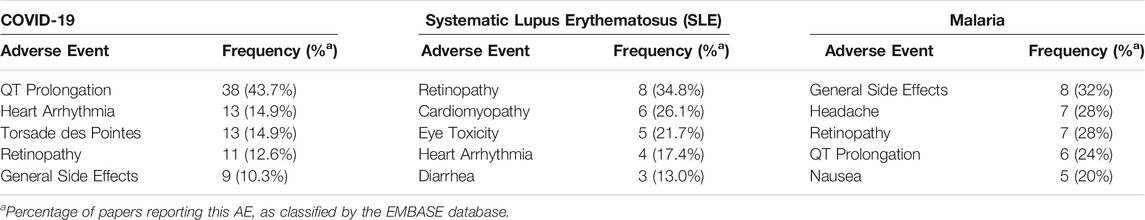
In the realm of clinical decision support for mental health disorders, the Ontology-Based Clinical Decision Support for Mental Health Disorders [40] discusses the utilization of ontologies to enhance clinical decision-making. The paper presents results related to depression-related inferences, showcasing the potential of ontologies to improve the accuracy and efficiency of clinical decision-making in the field of mental health disorders.



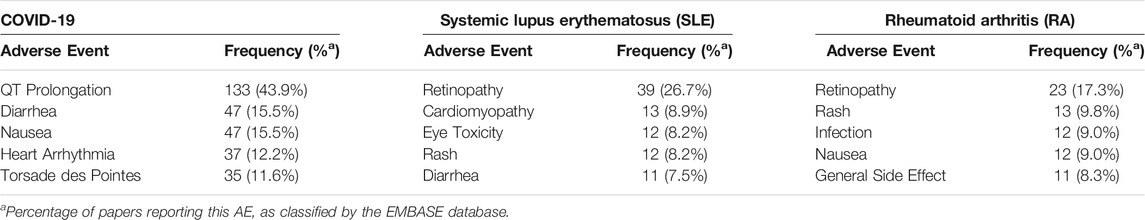
*Figure 7: Mental depression entity [40]*



*Figure 8: Structure of treatments for depression [40]*

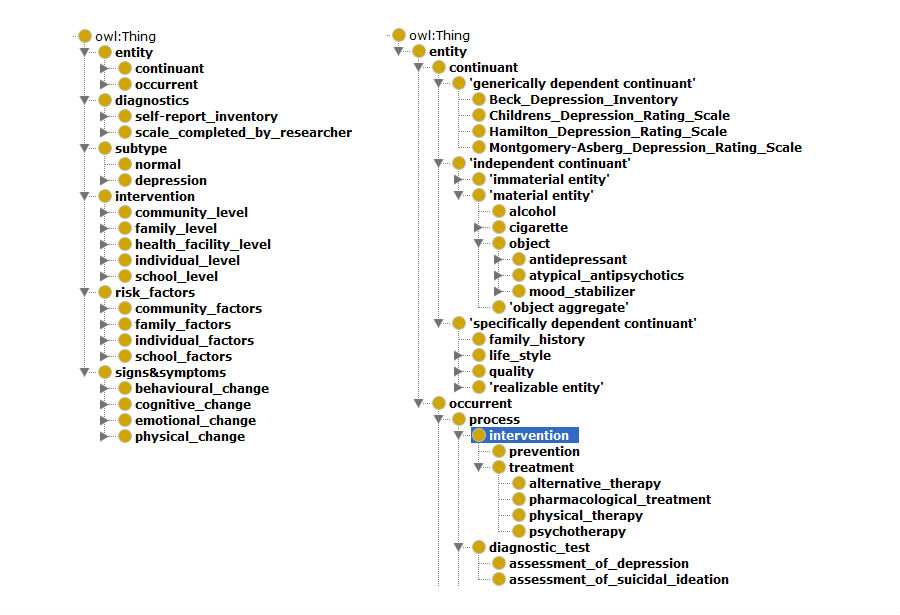
"Ontology-Based Classification and Analysis of Adverse Events Associated with the Usage of Chloroquine and Hydroxychloroquine" [42] explores the application of ontology in classifying and analyzing adverse events (AEs) related to the use of chloroquine (CQ) and hydroxychloroquine (HCQ). The study evaluates AE data from multiple sources, including US Prescribing Information (USPIs), the FDA Adverse Event Reporting System (FAERS), and literature from PubMed/EMBASE. The Ontology of Adverse Events (OAE) is used to classify and model the AEs. The analysis reveals that the AE profiles of CQ and HCQ are similar, but HCQ is associated with fewer types of cardiovascular, nervous system, and musculoskeletal AEs. The study also demonstrates how patient population characteristics and the disease being treated can impact the manifestation of AEs. The methodology presented in the article can be applied to other drugs and indications to identify vulnerable patient populations prone to AEs.

*Figure 9: Five AEs most frequently discussed in papers describing chloroquine use in various disease states [42]*



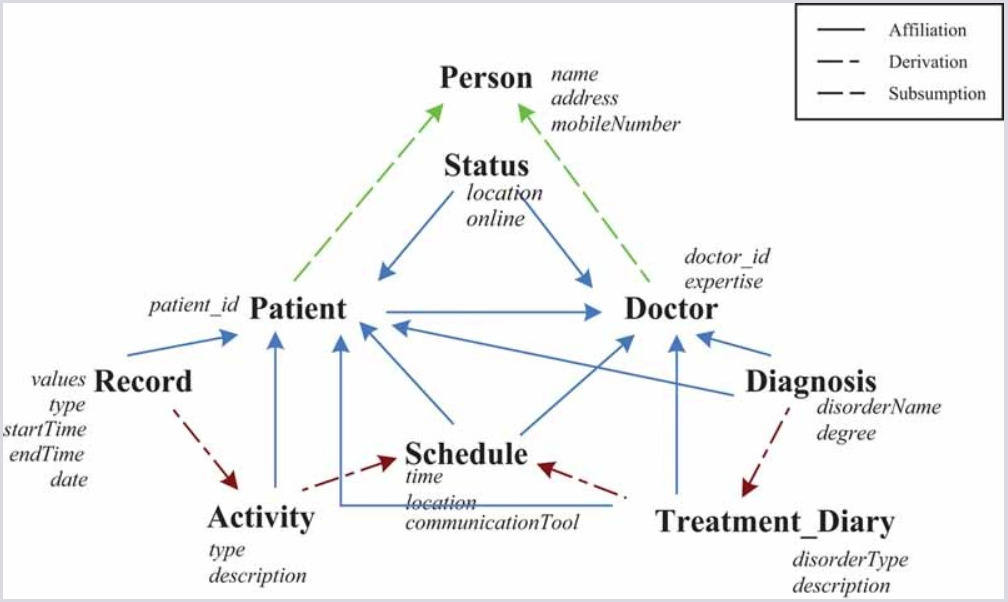
*Figure 10: Five AEs most frequently discussed in papers describing hydroxychloroquine (HCQ) use in various disease states [42]*

The article “Ontology-Based Approach to Social Data Sentiment Analysis: Detection of Adolescent Depression Signals” [32] discusses an ontology-based approach to analyzing social media data for detecting signals of adolescent depression. The authors refine an ontology and terminology specific to adolescent depression, which serves as a semantic framework for analyzing social media postings. They collect concepts from clinical guidelines, literature, and social media posts, define class concepts and their relationships, and design the internal structure of the ontology using the entity-attribute-value (EAV) data model. The ontology is evaluated for description logics and validated by examining sentiment phrases and conducting sentiment analysis of social media data. The developed ontology provides a foundation for analyzing social media data related to adolescent depression, but it requires regular updates to incorporate evolving terminology and additional attributes reflecting depression-related sentiments.



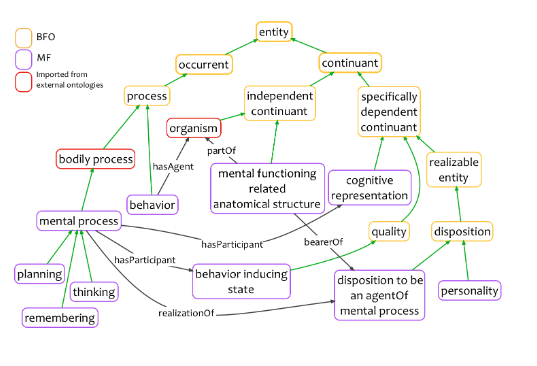
*Figure 11: Super classes in an adolescent depression ontology alongside the basic formal ontology (BFO, left) and example classes in the BFO positions (right). [32]*

"Ontology-Based Ubiquitous Monitoring and Treatment Against Depression" [6] is an innovative approach that combines ontological principles and ubiquitous computing technologies to monitor and provide treatment for depression. By utilizing ontologies to organize and understand data related to depression, and leveraging ubiquitous monitoring through various devices and sensors, this approach enables continuous and personalized monitoring of individuals' mental health. The collected data is analyzed using intelligent systems and algorithms, which can provide tailored interventions and support for managing depression. This framework aims to enhance the understanding, monitoring, and treatment of depression, ultimately improving the well-being of individuals affected by this mental health condition.



*Figure 12: Top level structure of ontology used in Ontology-Based Ubiquitous Monitoring and Treatment Against Depression [6]*

The article "Representing Mental Functioning: Ontologies for Mental Health and Disease" [47] discusses the development of two ontologies: the Mental Functioning Ontology (MF) and the Mental Disease Ontology (MD). These ontologies aim to provide structured and formal representations of human mental functioning and mental diseases. The article highlights the importance of ontologies in facilitating data aggregation, comparison, and automated reasoning in the field of mental health. It discusses the structure and upper levels of the ontologies, along with preliminary application scenarios. The article also acknowledges the challenges and open questions in developing these ontologies. Overall, the article emphasizes the potential of ontologies to enhance the understanding and management of mental disorders by providing a standardized and computationally accessible framework.



*Figure 13: The Mental Functioning Ontology upper level aligned to BFO.* [47]

While some of the mentioned ontologies contain general terms for representing mental disorder concepts (e.g., Classification of mental disorders, Mental Function Ontology, and Ontology of General Medical Sciences), further specialization and detailed characteristics are needed to adequately describe all mental disorders. Despite searching various ontology repositories (e.g., LOV, Swoogle, ODP, OGMS), no existing ontology covering the desired level of detail for mental disorders was found. Therefore, the MentalDisOnt ontology was developed following a well-established methodology to fulfill this purpose.

In order to ensure the quality and correctness of developed ontologies, evaluating them has become a crucial aspect. The specialized literature offers various evaluation methods that depend on the specific goals of the evaluation. The NeOn guidelines, which provide a framework for ontology evaluation [25], highlight key evaluation goals, including domain coverage, quality of modeling, suitability for specific applications or tasks, and adoption and use. These goals guide the selection of appropriate evaluation approaches.

Several evaluation approaches have been proposed in the literature. One common approach is comparing the ontology under evaluation to a gold standard ontology [26]. This involves assessing the degree of similarity, coverage, and accuracy between the two ontologies. Another approach involves comparing the ontology to unstructured or informal data sources [27]. This helps determine the ontology's ability to capture and represent information from real-world data.

Human assessments are another valuable approach in ontology evaluation [28]. This involves involving domain experts or users to evaluate the ontology's usefulness, clarity, and relevance to the intended application. Additionally, reasoners can be employed to assess the logical correctness of the ontology [29]. Reasoning engines analyze the ontology's axioms and infer logical consequences, identifying any inconsistencies or contradictions.

A relevant work in ontology evaluation [30] presents a comprehensive framework that considers various quality criteria. These criteria include accuracy, adaptability, clarity, completeness, computational efficiency, conciseness, consistency, and organizational fitness. These criteria provide a holistic perspective on the ontology's overall quality and fitness for purpose.

During the evaluation process of the MentalDisOnt ontology, several aspects from these evaluation works were taken into account. The ontology was assessed for its domain coverage, modeling quality, suitability for specific applications, and adherence to quality criteria such as accuracy, clarity, and completeness.

In summary, ontology evaluation is crucial for ensuring the quality, correctness, and fitness for purpose of developed ontologies. The literature provides various evaluation methods, including comparing to gold standard ontologies, utilizing unstructured data sources, human assessments, and reasoning engines. The evaluation criteria outlined in existing works help assess different aspects of ontology quality. These evaluation approaches and criteria were considered during the evaluation of the MentalDisOnt ontology.

1. **Design Methodologies**

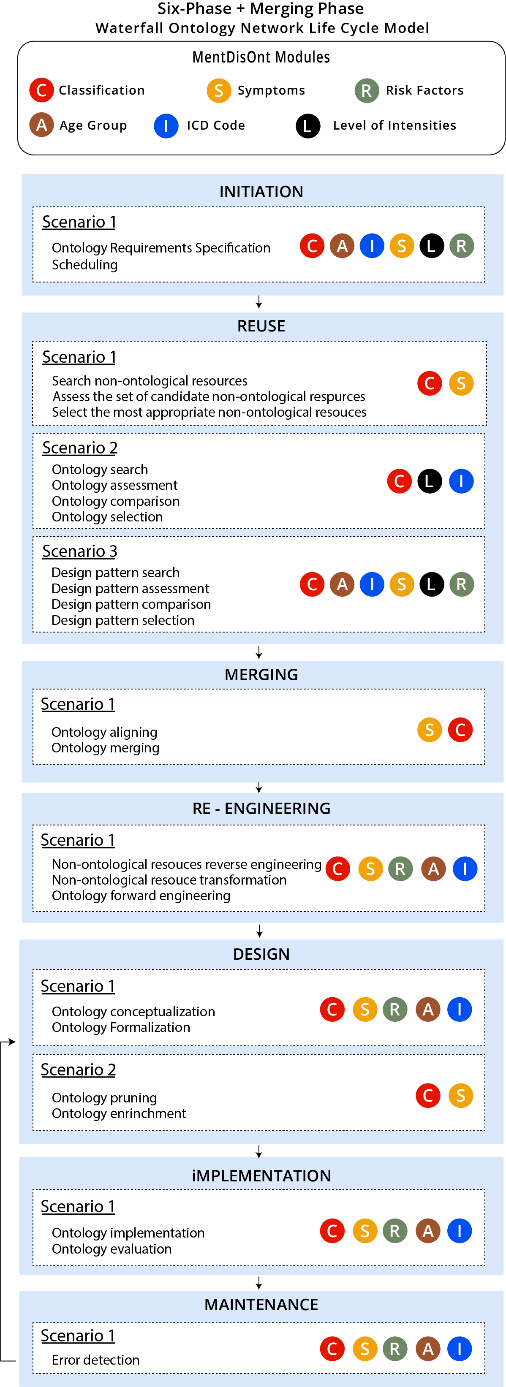
The literature presents several methodologies for ontology development, such as On-To-Knowledge, Diligent, and NeOn. On-To-Knowledge proposes a structured approach consisting of five main steps. Firstly, a feasibility study is conducted to determine whether it is appropriate to begin developing the ontology. Secondly, the kickoff step specifies the requirements and develops a semi-formal ontology description. Thirdly, the refinement step formalizes and refines the semi-formal ontology description to obtain the target ontology. Fourthly, the evaluation step assesses the ontology, and finally, the application and evolution step involve the application and maintenance of the ontology in the target system. Although On-To-Knowledge recommends the reuse of ontologies if available during the kickoff step, it does not provide any specific guidelines for doing so. Furthermore, On-To-Knowledge does not address non-ontological resources or ontology design patterns.

Diligent proposes a distributed ontology development process consisting of five steps. The first step involves building an initial version of the ontology by various stakeholders such as domain experts, users, and knowledge and ontology engineers. The second step, local adaptation, involves users adopting the ontology for their specific purposes. In the third step, analysis, a control board analyzes the local versions to identify similarities and determine which changes and requests should be added to the next shared version of the ontology. The fourth step, revision, involves the control board revising the new version of the shared ontology. The final step, local update, enables users to update their local ontologies with information from the new version. However, Diligent does not provide detailed guidance on the activities that should be followed during the build step, and it does not include guidelines for using ontological or non-ontological resources in the development process.

NeOn offers a more complex methodology than the previous two approaches, describing nine possible scenarios that may arise during ontology development. NeOn also provides several ontology network life cycle models, including the Four phase model, which consists of initiation, design, implementation, and maintenance. NeOn emphasizes the importance of reusing and re-engineering both ontological and non-ontological knowledge resources. The methodology provides detailed guidance on how to perform each activity in each phase of the ontology development process, as well as recommendations for tools and techniques to support each step. Additionally, NeOn includes further versions of the basic model, such as the Five-phase model and the Six-phase + Merging model, which include additional phases such as reuse, reengineering, and merging to accommodate a range of paths to ontology development.

1. **Development of MentalDisOnt Ontology**

To develop the MentalDistOnt ontology we selected the NeOn methodology. In our opinion, NeOn beats the other methodologies in these two aspects: on the one hand, the variety of scenarios that it takes into account, which results in a more flexible methodology, and on the other hand, the great detail in the description of the activities that need to be carried out when building the ontology. Furthermore, due to the requirements of MentalDisOnt, which include the reuse of ontological and no-ontological resources, re-engineering, merging, aligning with domain ontologies, implementation, and evaluation among others, its development process fits with the Six-Phase + Merging Phase Waterfall Ontology Network Life Cycle Model. In figure 1 the phases of the aforementioned life cycle model along with scenarios, activities, and modules of the MentalDisOnt ontology involved in each scenario are indicated. These modules and their purpose are explained in section 5. The different phases of the life cycle model are explained below.

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*Figure**14: Six phase + merging phase waterfall ontology network life cycle model*

***4.1. Initiation:***

In collaboration with Ms. Sadia Shadab, Psychologist, and Mr. Fahad Maqbool, our supervisor, we created the Ontology Requirements Specification Document (ORSD) that contains among others, the purpose of the MentalDisOnt ontology, its scope and the Competency Questions (CQs), see Table 1. After a detailed analysis of those questions, it was noticed that they referred to five different dimensions regarding information related to Mental Disorders. Thus, the questions were classified into the following seven groups, one for each aspect, type, ICD codes, symptoms, comorbidity, risk factors, severity levels, and age group. (Scenario 1).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mental Disorder Ontology | | | | |
| SEEMP Reference Ontology Requirements Specification Document | | | | |
| **1** | **Purpose** | | | |
|  | The purpose of building the Mental Disorder Ontology is to provide a consensual knowledge model of the different types of mental disorders to be used by different users. | | | |
| **2** | **Scope** | | | |
|  | The ontology has to focus just on the different types of mental disorders, their types, symptoms, relevance, risk factors, and level of intensity. The level of granularity is directly related to the competency questions and terms identified. | | | |
| **3** | **Implementation Language** | | | |
|  | The ontology has to be implemented in OWL language. | | | |
| **4** | **Intended End-Users** | | | |
|  | . User 1. Mental health professionals.  User 2. People with Mental issues. | | | |
| **5** | **Intended Uses** | | | |
|  | Use 1. For gaining knowledge about mental disorders.  Use 2. To improve people's knowledge of different mental health problems/disorders.  Use 3. Gather information about different mental disorders.  Use 4. To help make the optimal diagnoses for a person.  Use 5. To describe different types of mental disorders. | | | |
| **6** | **Ontology Requirements** | | | |
|  | **a. Non-Functional Requirements** | | | |
|  | NFR1. The ontology must be consistent and should be able to answer all the competency questions.  NFR2. The ontology must satisfy the FAIR (Findable, Accessible, Interoperable, Reusable) principle. | | | |
|  | **b. Functional Requirements: Groups of Competency Questions** | | | |
|  | Group 1: Classification/Types  CQ1. Is a schizotypal personality disorder a type of schizophrenia spectrum disorder?  CQ2. How many types of Paraphilic Disorders are there?  Group 2: Code  CQ1. What is the ICD code of Fetishistic Disorder?  CQ2. What is the code of intellectual disability disorder if it has a profound level of intensity?  CQ3. Which mental disorder has the “F80.81” ICD code?  Group 3: Symptoms  CQ1. List the name of disorders that have breathing problems as their symptoms.  CQ2. What are the symptoms of Speech Sound Disorder?  CQ3. Is sleepwalking a sign of a mental disorder?  CQ4. Which disorder has trembling, palpitation, and chest pain as symptoms?  CQ5. How many symptoms a person must have to diagnose development coordination disorder?  Group 4: Correlation(comorbidity)  CQ1. Which disorders are correlated to schizophrenia disorder?  CQ2. Is cyclothymic disorder correlated to bulimia nervosa disorder?  CQ3. Could anxiety and depression occur together?  Group 5: Risk Factors  CQ1. What are the risk factors of posttraumatic stress disorder?  CQ2. Is Language disorder affected by genetic factors?  Group 6: Level of intensity /severity level  CQ1. What are the severity levels of intellectual disability disorder?  CQ2. How many symptoms a patient must have to diagnose a profound level of stress disorder  Group 7: Age Group  CQ1. Name the disorders that can only occur in children.  CQ2. Could neurocognitive disorder occur after the age of 50?  CQ3. Which are the minimum age criteria for the diagnosis of Alzheimer's disorder? | | | |
| 7 | **Pre-Glossary of Terms** | | | |
|  | **Terms from Competency Questions** | | | |
|  | Types  Disorder  Mental disorder  Symptoms  Genetic Factors  Severity Level  Diagnoses |  | Correlation  Comorbidity  Risk factors  Environmental factor  Temporal Factor  Level of intensity  Age group |  |

*Table 1: Ontology requirement specification document*

***4.2. Reuse:***

As it was not possible to find a single ontology that encompassed all the dimensions, our search efforts were directed toward exploring both ontological and non-ontological sources for each dimension.

In this subsection, we present the non-ontological and ontological resources used to describe the aforementioned dimensions.

* ***Classification of mental disorder***: To describe the components, we relied on the one hand, on non-ontological resources existing in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [2]. The DSM-5 provides a standardized classification system for mental disorders, which includes diagnostic criteria and descriptive text for each disorder. This information can be used to identify and classify mental disorders based on specific symptoms and characteristics (Scenario 1). Moreover, due to the complexity of mental disorders classification we also use mental disorder classification [9] as a reference ontology to define the classification of mental disorders (Scenario 2). On the other hand, the Classification [33] ontology design pattern was selected in order to specify classification of different mental disorder (Scenario 3).
* ***Symptoms of mental disorder***: To describe the symptoms of mental disorders, we had used different ontologies available for a particular mental disorder (Schizophrenia Disorder Ontology, Bipolar Disorder Ontology, Posttraumatic Stress Disorder) as explained in able sections (Scenario 2). We use DSM-5 as a manual to add the symptoms of mental disorders in our ontology (Scenario 1). On the other hand, Co-Participation [34] design pattern was selected to describe the participation of more than one symptom in the diagnosis of mental disorder. Criterion [35] design pattern was also helpful in specifying symptoms of mental disorders (Scenario 3).
* ***Risk Factors***: As no ontologies were found that map risk factors of mental disorders in an ontology, we use DSM-5 as a non-ontological resource (Scenario 1) to extract this information related to mental disorder. We also use Co-Participation [34] design pattern as risk factor also plays an important role in diagnosis and development of a mental disorder (Scenario 3).
* ***Age Group***: To describe the age group of the person having mental disorder we relied on non-ontological resources existing in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (Scenario 1). Based on our research no other ontologies were found to map this criterion of mental disorder. We ConceptGroup [36] design pattern to specify different age groups of each mental disorder (Scenario 3). We use Age Ontology described in The Age-Phenome Knowledgebase [37] to describe age groups (Scenario 2).
* ***Level of Intensities***: To explain the level of intensities of different mental disorder we relied on Diagnostic and Statistical Manual of Mental Disorder (DSM-5) (Scenario 1). We also use ObjectWithState [38] design pattern to explain different states of mental disorders (Scenario 3).
* ***ICD Code***: To map ICD code of all the disorders we solely relied on Diagnostic and Statistical Manual of Mental Disorder as a non-ontological resource (Scenario 1).

***4.3. Merging:***

To guarantee semantic interoperability, Classification of Mental disorder [9] is used in MentalDisOnt ontology. Mental Disorder Ontological classification [9] provides classification and definition of different mental disorders according to ICD [18] and NIH [19] respectively. This ontology only explains the basic classification of mental disorders. It does not have any details related to mental disorders like their symptoms, types, risk factors, differential diagnosis, etc. Despite the presence of some general terms related to mental disorders in certain ontologies, such as the Classification of Mental Disorders, Mental Functions Ontology, and Ontology of General Medical Sciences [21], further specification and detail are required to achieve our goal of describing all mental disorders comprehensively. Our search for an ontology that covers this domain on various ontology repositories, including LOV[22], Swoogle[23], ODP[24], and OGMS[21] proved unsuccessful. As a result, we developed the MentalDisOnt ontology using a well-established methodology.

***4.5. Re-engineering:***

In (Scenario1), the non-ontological resources mentioned earlier underwent a re-engineering process to convert them into conceptual models. This involved analyzing the structure of the resources, including chapters, subsection, and order. After creating a conceptual model for each resource, they were then utilized as input during the design phase.

***4.6. Design:***

Modularizing ontologies offers several benefits, including facilitating the development, reuse, and maintenance of the ontology. Furthermore, it aligns with the dimensionality approach derived from the ORSD analysis. As a result, each of the six dimensions was represented by its own module: the classification of mental disorder(Classification), Symptoms of mental disorder (Symptoms), risk factor involved in diagnosis of mental disorders (Risk\_Factor), level of severity of a mental disorder(Level\_of\_Severity), person which has mental disorder(Person) and age group of the person diagnosed with mental disorder (Age\_Group) which altogether form the different ontological and non-ontology resources (Scenario 1). The key features of each module are presented in depth in section 5.

PostTramtic, sleepDomain, bipolarDisorder and schizophreniaDisorder ontologies contain wide range of concepts that belong to that specific topic and mental disorder domain

***4.7. Implementation:***

In (Scenario 1), a formal model was created using Description Logic and implemented in OWL 2 DL Web Ontology Language using Protégé [23]. Subsequently, an extensive evaluation of the ontology was conducted, as detailed in section 6, outlining the various approaches that were considered and described.

***4.8. Maintenance:***

Currently, the maintenance phase is in progress, and if any errors are identified within the ontology, it will be transitioned to the design phase for correction. This process adheres to the guidelines outlined in the Waterfall ontology network life cycle model.

1. **Ontology modules**

As said before, MentalDisOnt is divided into six modules aiming to describe mental disorders (see Figure 2).

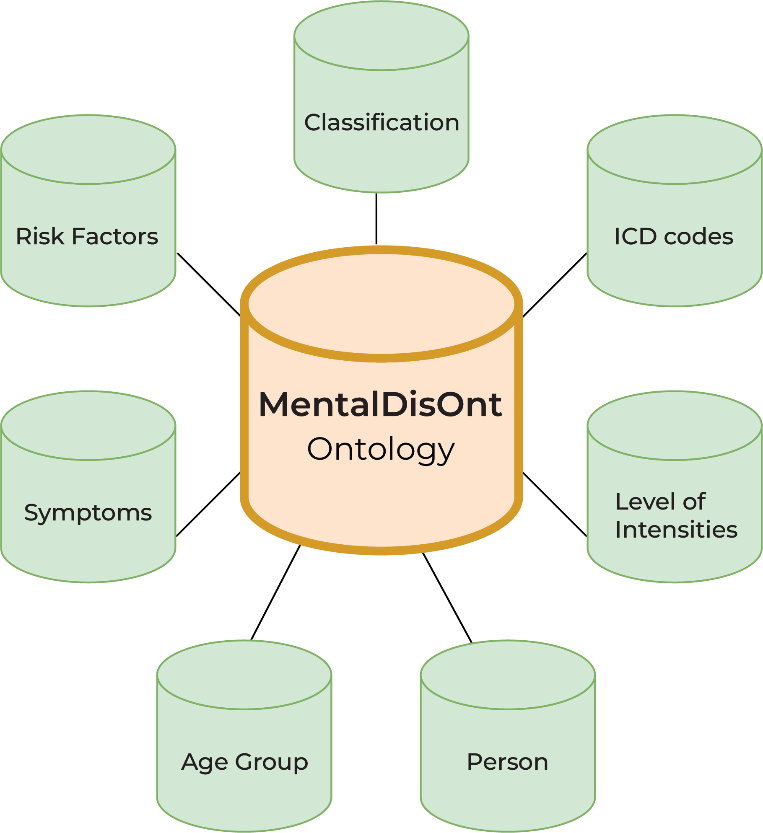


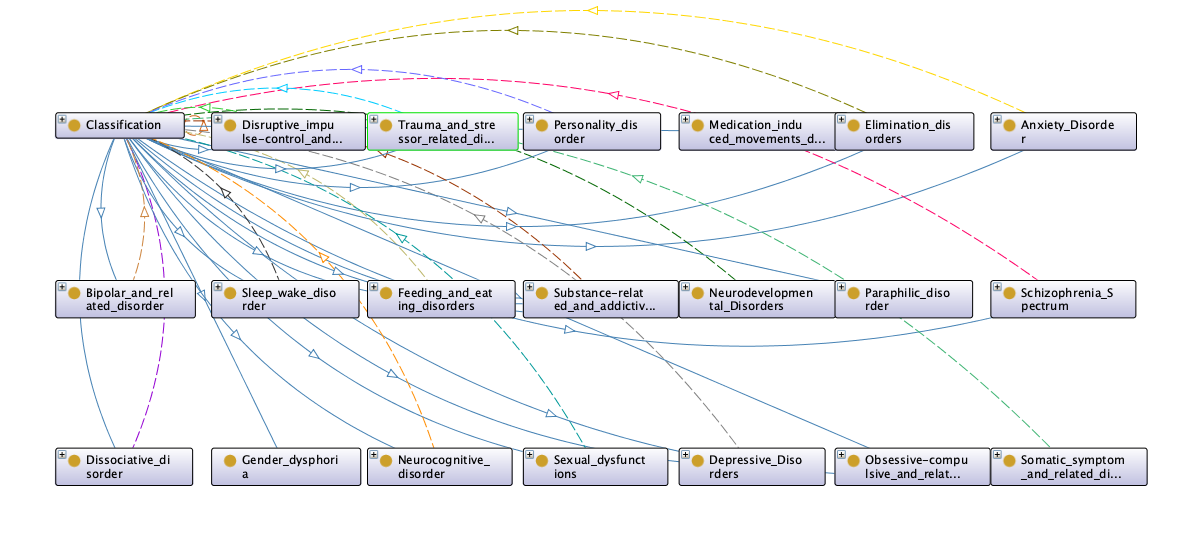
Figure 15: *Different modules of mental disorder ontology*

In the following, the key features of each module are presented.

***5.1. Classification:***

The Classification module is the main module of MentalDisOnt ontology and is intended to describe the types and subtypes of mental disorders. According to DSM-IV, 20 major types of disorders can be distinguished:

* Anxiety disorder
* Bipolar and related disorder
* Depressive disorders
* Disruptive impulse-control and conduct disorder
* Dissociative disorder
* Elimination disorders
* Feeding and eating disorders
* Gender dysphoria
* Medication induced movements disorders and adverse effects of medication
* Neurocognitive disorder
* Neurodevelopmental Disorders
* Obsessive-compulsive and related disorder
* Paraphilic disorder
* Personality disorder
* Schizophrenia Spectrum
* Sexual dysfunctions
* Sleep wake disorder
* Somatic symptom and related disorders
* Substance-related and addictive disorder
* Trauma and stressor related disorder

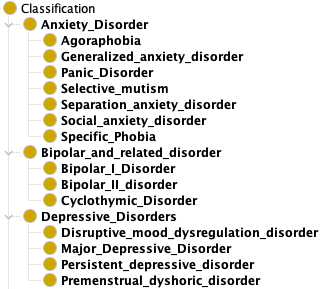
Moreover, subtypes of each disorder are explained. For example, anxiety disorder has further 7 subtypes i.e., Agoraphobia, Generalized anxiety disorder, Panic Disorder, Selective mutism, Separation anxiety disorder, Social anxiety disorder, Specific Phobia. This classification of mental disorders are used as a based for creating a ontology to describe a mental disorder.

*Figure 16: Components of class Classification*

The subtypes of different disorders was represented using *rdfs:subClassOf* relation. An example is illustrated in Figure 4. All the classification of mental disorders could be found in DSM-IV [2] which was used to provide detailed information of mental disorders.

Among other, these are the competency questions that are related to Classification module:

* CQ1. How many types of anxiety disorders are there?
* CQ2. Is a schizotypal personality disorder a type of schizophrenia spectrum disorder?
* CQ3. Name the types of anxiety disorder?



*Figure 17: Excerpt of the class hierarchy of Classification*

A SPARQL query to answer the competency question CQ1 is as follow:

*PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>*

*PREFIX owl: <http://www.w3.org/2002/07/owl#>*

*PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>*

*PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>*

*PREFIX mont: <http://www.semanticweb.org/computerhouse/ontologies/2022/9/untitled-ontology-18#>*

*PREFIX : <http://www.semanticweb.org/computerhouse/ontologies/2022/9/untitled-ontology-18#>*

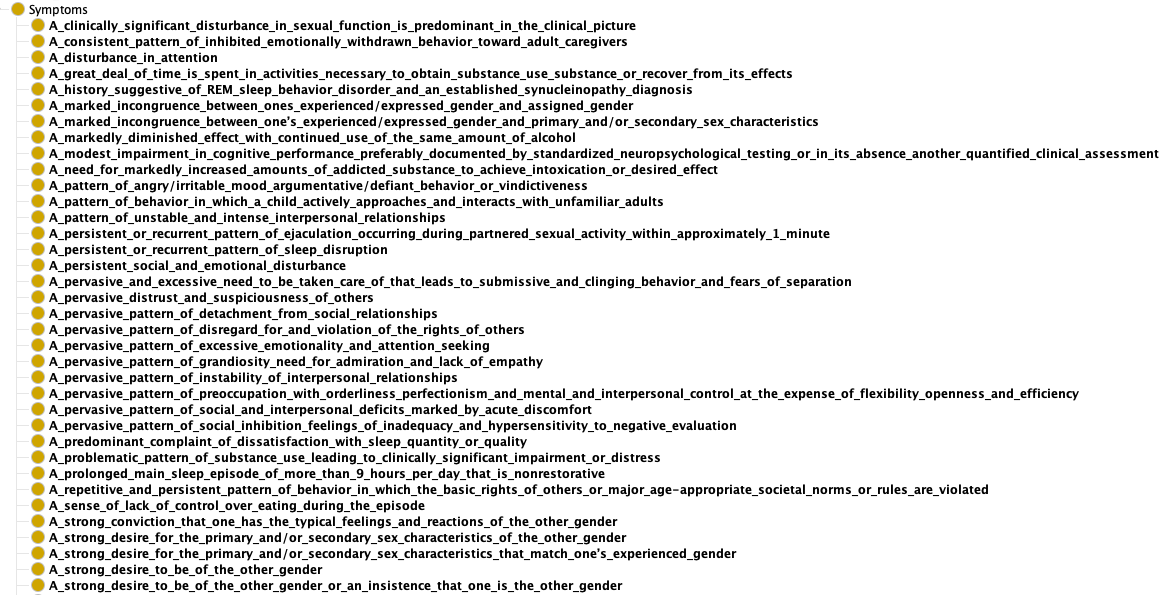
*SELECT (STR(count(?subject)) as ?count)*

*WHERE { ?subject rdfs:subClassOf mont:Anxiety\_Disorder }*

As a result, classification of different mental disorder in MentalOntDis ontology will help novice healthcare workers and patients in identifying different types of mental disorders and there subtypes. In addition, having knowledge of the disorders and their types empowers domain experts to construct queries that cater to their specific requirements regarding the type and specific attributes of the mental disorder.

***5.2. Symptoms***

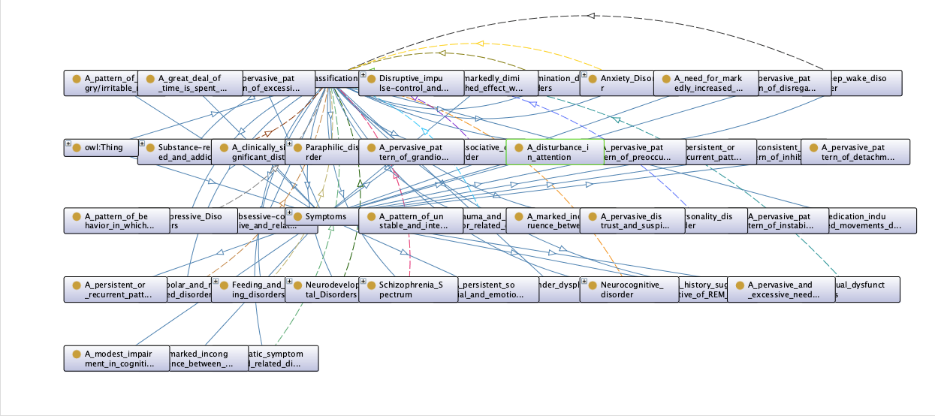
Symptoms module of MentalDisOnt ontology contain all the symptoms of mental disorder described as diagnostic criteria in DSM-V [2]. To enhance the ontology with symptom information, each disorder can be associated with its characteristic symptoms. This addition allows for a comprehensive representation of mental disorders by incorporating both diagnostic classifications and symptomatology.



*Figure 18: Symptoms class of MentalDisOnt*

By including symptoms of mental disorders, domain experts and healthcare professionals can benefit from an enriched ontology. They can now formulate queries based on specific symptoms, allowing for more targeted investigations and assessments. For example:

* CQ1: List the name of disorders that have difficulty concentrating as their symptoms.
* CQ2: Identify the anxiety disorders that manifest symptoms such as fear of specific objects or situations.
* CQ3. What are the types of anxiety disorders characterized by symptoms such as excessive anxiety and worry about events or activities and restlessness?
* CQ4. What are the symptoms of Speech Sound Disorder?
* CQ5. Is sleepwalking a sign of a mental disorder?
* CQ6. Which disorder has trembling, palpitation, and chest pain as symptoms?
* CQ7. How many symptoms a person must have to diagnose development coordination disorder?



*Figure 19: Class hierarchy of symptom module*



*Figure 20: Object properties connecting symptoms modules*

A SPARQL query to answer CQ1 is as follow:

*PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>*

*PREFIX owl: <http://www.w3.org/2002/07/owl#>*

*PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>*

*PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>*

*PREFIX mont: <http://www.semanticweb.org/computerhouse/ontologies/2022/9/untitled-ontology-18#>*

*PREFIX : <http://www.semanticweb.org/computerhouse/ontologies/2022/9/untitled-ontology-18#>*

*SELECT ?subject*

*WHERE {*

*?subject ?object mont: Difficulty\_concentrating.*

*}*

This incorporation of symptom information into the Classification module not only aids novice healthcare workers and patients in understanding different mental disorders and their subtypes but also enables more precise and tailored queries to be formulated, accommodating the requirements of domain experts in exploring mental disorders based on specific symptoms.

***5.3. Diagnosis\_Age***

The Age Group module in the MentalDisOnt ontology focuses on incorporating age-related information for different mental disorders. It aims to provide a framework for categorizing mental disorders based on age groups, enabling more targeted analysis and understanding of the prevalence, characteristics, and treatment options for specific age demographics.

The module expands the existing classification system by including age-specific properties and classes within the ontology's structure. These additions allow for the representation of age groups and their relationships to various mental disorders.

For example, a class hierarchy was established to represent different age groups, such as "Child," "Adolescent," "Adult," and "Infant." Each age group is further be associated with specific mental disorders or subtypes that are more prevalent or have distinct manifestations within that particular demographic.



Figure 21: *Diagnosis Age class of MentalDisOnt*

Additionally, properties can be introduced to capture age-related information, such as "minimumAge" and "maximumAge," to define the age range for each mental disorder or subtype. These properties provide a means to specify the age criteria associated with particular disorders.

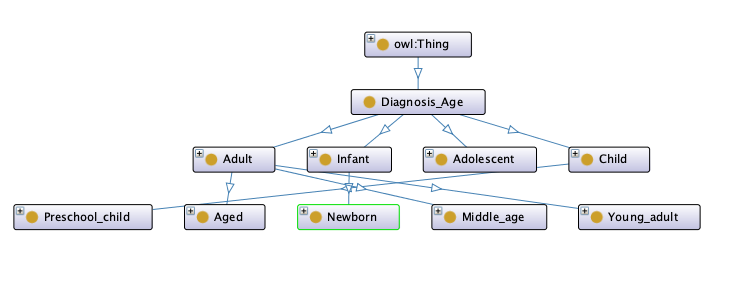
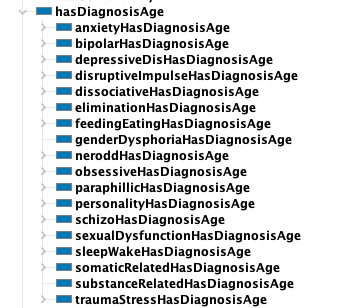


Figure 22: *Class hierarchy of diagnosis age module*

The Age Group module also enables queries and analysis related to specific age groups. Competency questions pertaining to age groups can be addressed using SPARQL queries and the ontology's age-related properties. Among other, these are the competency questions that are related to diagnosis age module:

* CQ1. Name the disorders that can only occur in children.
* CQ2. Could neurocognitive disorder occur after the age of 50?
* CQ3. Which are the minimum age criteria for the diagnosis of Alzheimer's disorder?
* CQ4. What are the prevalent mental disorders among adolescents?
* CQ5. Which mental disorders are more commonly observed in the elderly population?

Integrating the Age Group module within the MentalDisOnt ontology enriches its ability to provide targeted information and support decision-making processes in mental healthcare. It allows healthcare professionals, researchers, and stakeholders to explore the relationship between age and mental disorders, consider age-specific risk factors, and tailor treatment strategies accordingly.



*Figure 23: Object properties connecting diagnosis age modules*

By incorporating the Age Group module, the MentalDisOnt ontology becomes a more comprehensive and valuable resource for understanding the complexities of mental disorders across different age groups, facilitating improved diagnosis, intervention, and care for patients of varying ages.

***5.4. Risk Factors***

The Risk Factor module in the MentalDisOnt ontology focuses on incorporating information related to risk factors associated with mental disorders. It aims to provide a comprehensive framework for capturing and analyzing the various risk factors that contribute to the development, onset, or exacerbation of different mental disorders.

The module expands the existing ontology structure by introducing properties and classes specific to risk factors. These additions allow for the representation of different types of risk factors and their relationships to specific mental disorders or subtypes.

For example, a class hierarchy can be established to represent different categories of risk factors, such as "Genetic and Psychological Factors," "Environmental Factors," "Temperamental Factors," and "Course Modifiers." Each category can be associated with specific mental disorders or subtypes that are influenced by those risk factors.



Figure 24: *Risk factors class of MentalDisOnt*

Properties were introduced to capture information related to risk factors, such as "hasRiskFactor" to define the relationship between a mental disorder and a specific risk factor. These properties provide a means to specify the association between a risk factor and a particular disorder.



*Figure 25: Object properties connecting risk factors modules*

The Risk Factor module also enables queries and analysis related to specific risk factors. Competency questions pertaining to risk factors can be addressed using SPARQL queries and the ontology's risk factor-related properties.Among other, these are the competency questions that are related to risk factor module:

* CQ1. What are the risk factors of posttraumatic stress disorder?
* CQ2. Is Language disorder affected by genetic factors?
* CQ3. What are the risk factors associated with schizophrenia?
* CQ4. Which factors contribute to the development of bipolar disorder?

Integrating the Risk Factor module within the MentalDisOnt ontology enriches its ability to provide targeted information on the various factors that contribute to the etiology and progression of mental disorders. It allows healthcare professionals, researchers, and stakeholders to explore the relationships between risk factors and mental disorders, understand the interplay between different factors, and identify potential prevention or intervention strategies.

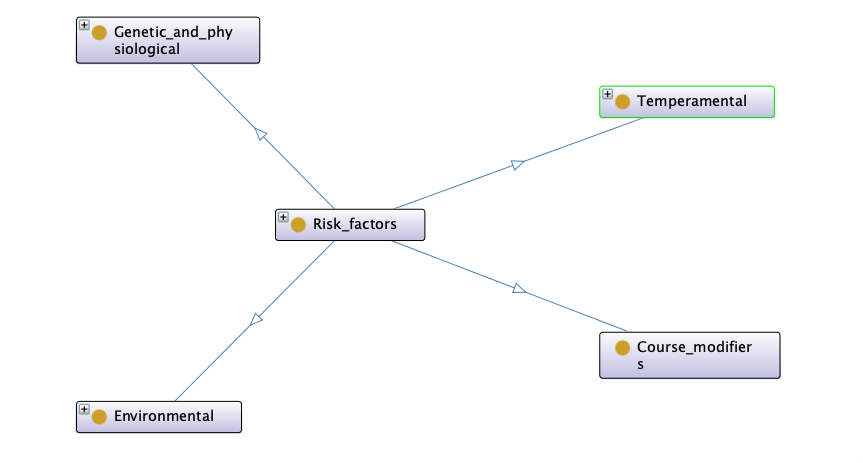


Figure 26: *Class hierarchy of risk factors module*

By incorporating the Risk Factor module, the MentalDisOnt ontology becomes a valuable resource for understanding the complex nature of mental disorders and the factors that contribute to their occurrence. It supports evidence-based decision-making, risk assessment, and the development of tailored interventions based on specific risk factors associated with different mental disorders.

***5.5. Level of Severity***

The Level of Severity module in the MentalDisOnt ontology focuses on incorporating information related to the severity levels of different mental disorders. It aims to provide a comprehensive framework for capturing and analyzing the various levels of severity associated with mental disorders, enabling a more nuanced understanding of the impact and intensity of specific disorders.

The module expands the existing ontology structure by introducing properties and classes specific to severity levels. These additions allow for the representation of different categories or levels of severity and their relationships to specific mental disorders or subtypes.

For example, a class hierarchy can be established to represent different severity levels, such as "Mild," "Moderate," "Severe," and "Profound." Each severity level can be associated with specific mental disorders or subtypes that exhibit varying degrees of severity within that particular category.

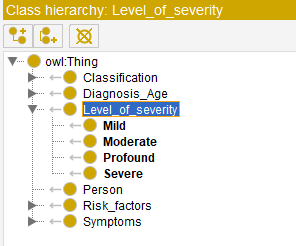


Figure 27: Hierarchy of Level of Severity class

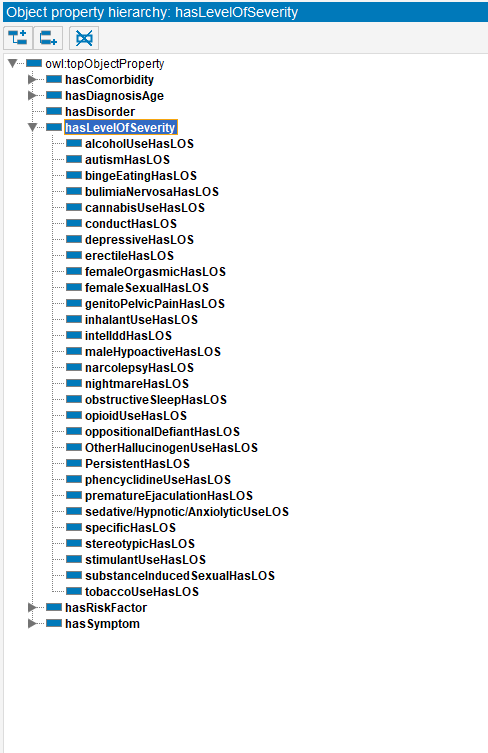
Properties was introduced to capture information related to severity levels, such as "hasLevelOfSeverity" to define the relationship between a mental disorder and its corresponding level of severity as shown in *figure 17*. These properties provide a means to specify the intensity or impact of a disorder based on its severity level.

The Level of Severity module also enables queries and analysis related to specific severity levels. Competency questions pertaining to severity levels can be addressed using SPARQL queries and the ontology's severity level-related properties.

CQ1. What are the severity levels of intellectual disability disorder?

CQ2. How many symptoms a patient must have to diagnose a profound level of stress disorder

CQ3. Which mental disorders are classified as severe?



*Figure 28: Object properties defining relation between Level of Severity and Mental Disorders*

Integrating the Level of Severity module within the MentalDisOnt ontology enriches its ability to provide targeted information on the severity of mental disorders. It allows healthcare professionals, researchers, and stakeholders to understand the varying degrees of impact and functional impairment associated with different disorders, tailor treatment approaches accordingly, and assess the effectiveness of interventions based on severity levels.

By incorporating the Level of Severity module, the MentalDisOnt ontology becomes a valuable resource for understanding the gradations of severity within mental disorders. It supports evidence-based decision-making, treatment planning, and outcome assessment, facilitating improved care and management of individuals with different levels of severity within specific mental disorders.

1. **Evaluation**

The MentalDisOnt ontology was evaluated for its quality using two main goals: domain coverage and modeling quality. Additionally, the suitability for specific applications/tasks and the adoption and use of the ontology were considered as future evaluation goals. The evaluation process involved input from three individuals:

1. A psychologist who is experience in field of mental disorders. This individual provided real data from her patients and worked closely with the ontology developers, offering valuable insights into the ontology's practical application in the industry.
2. An academic researcher specializing in ontology engineering and knowledge representation. This researcher brought expertise in ontology development and provided a critical evaluation of the ontology's design and development process.

By involving these different stakeholders, the evaluation aimed to comprehensively assess the MentalDisOnt ontology from various angles, ensuring its effectiveness, applicability, and robustness. Thus, psychologist constitute a fundamental agent in industrial scenarios where there is an interest in developing smart applications for diagnosis of mental disorders and an expert provide knowledge about developing and designing an comprehensive ontology in a domain.

***6.1. Domain coverage:***

The initial version of the MentalDisOnt ontology was developed by utilizing non-ontological resources and incorporating relevant existing ontologies related to the ontology's dimensions. After a rigorous discussion process involving the three experts, the ontology was refined. The experts evaluated the correctness and usefulness of the information in the ontology, leading to the incorporation of new terms and the elimination of others.

The psychologist, leveraging their knowledge of the diagnosis process of mental disorder, evaluated the semantic quality of the ontology. They suggested eliminating several types of information related to mental disorders. This adjustment aimed to eliminate unnecessary information in the representation.

The ontology expert evaluated the quality of alignments with existing ontologies. They recommended aligning with Classification of mental disorder developed by NIH (National Library of Medicines), which was the initial approach. This adjustment aimed to enhance the ontology's alignment with relevant standards.

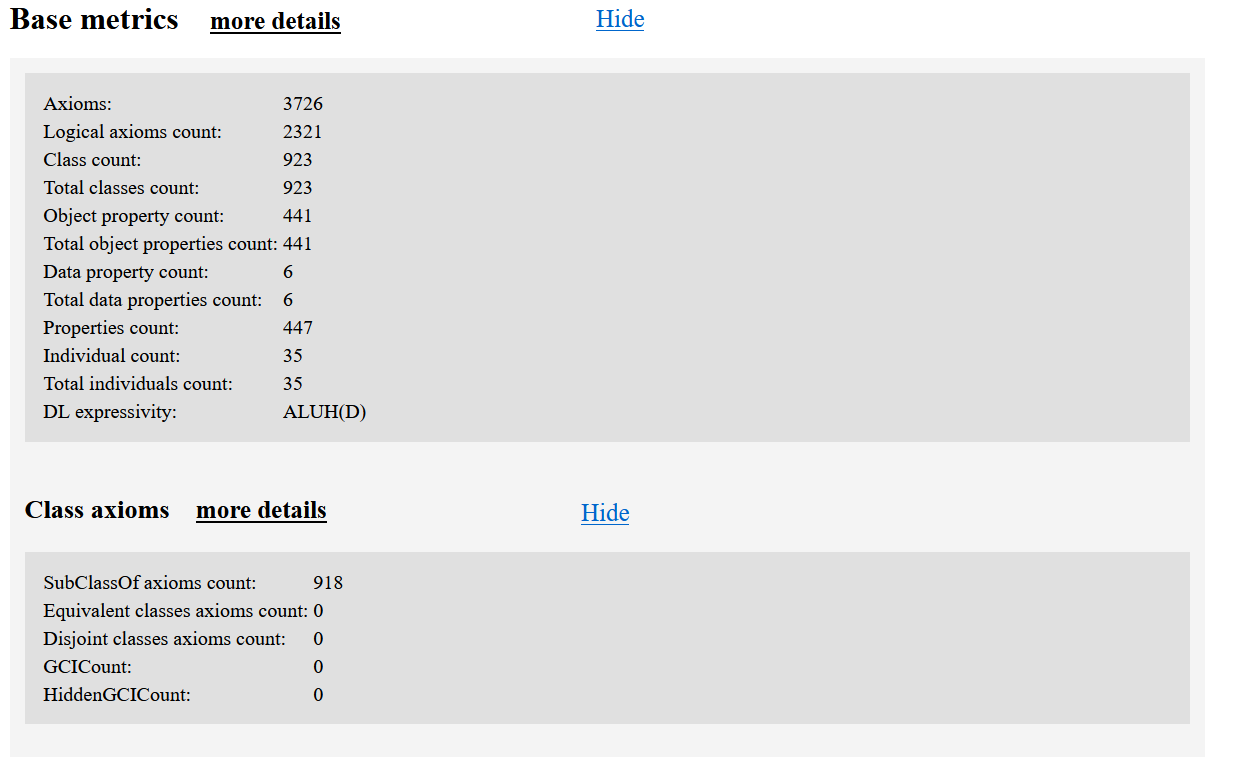
The final version of the Mental Disorder ontology included 923 terms related to the main concepts described in the non-ontological resources, as well as 181 terms specifically related to the classification of mental disorder. This coverage accounted for 90% of the vocabulary, with the remaining 10% consisting of terms outside the ontology's scope or lacking significant value, such as diagnostic features, specifiers, development ad course. Unfortunately, conducting an evaluation against a gold standard was not feasible as no suitable gold standard source could be identified despite an exhaustive search. It is prudent to persist in the search process until a suitable gold standard source is discovered. Once found, conducting an additional evaluation step will strengthen the assessment of the ontology's adaptability and reusability.

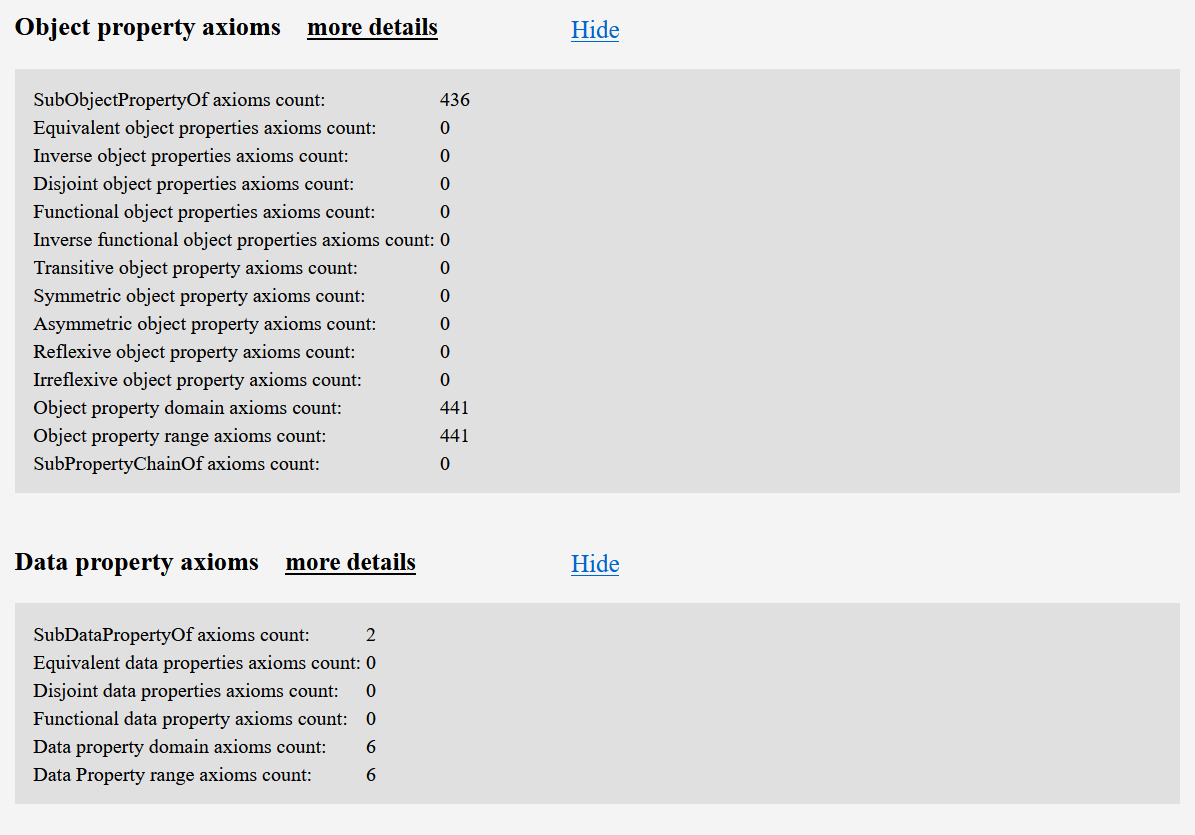
***6.2. Quality of the modeling***

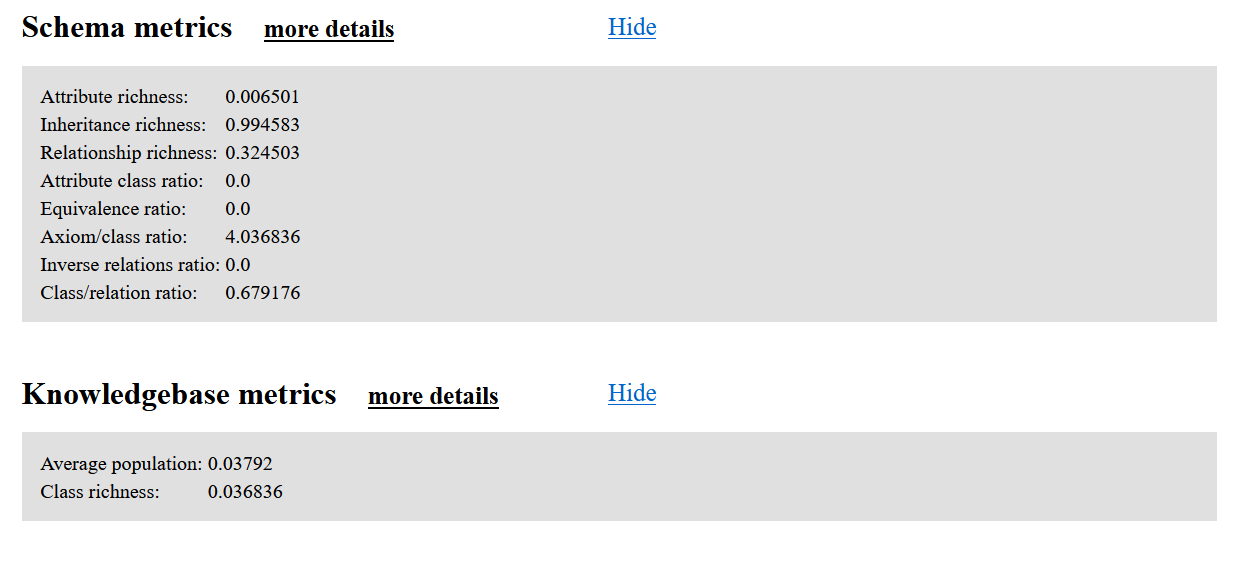
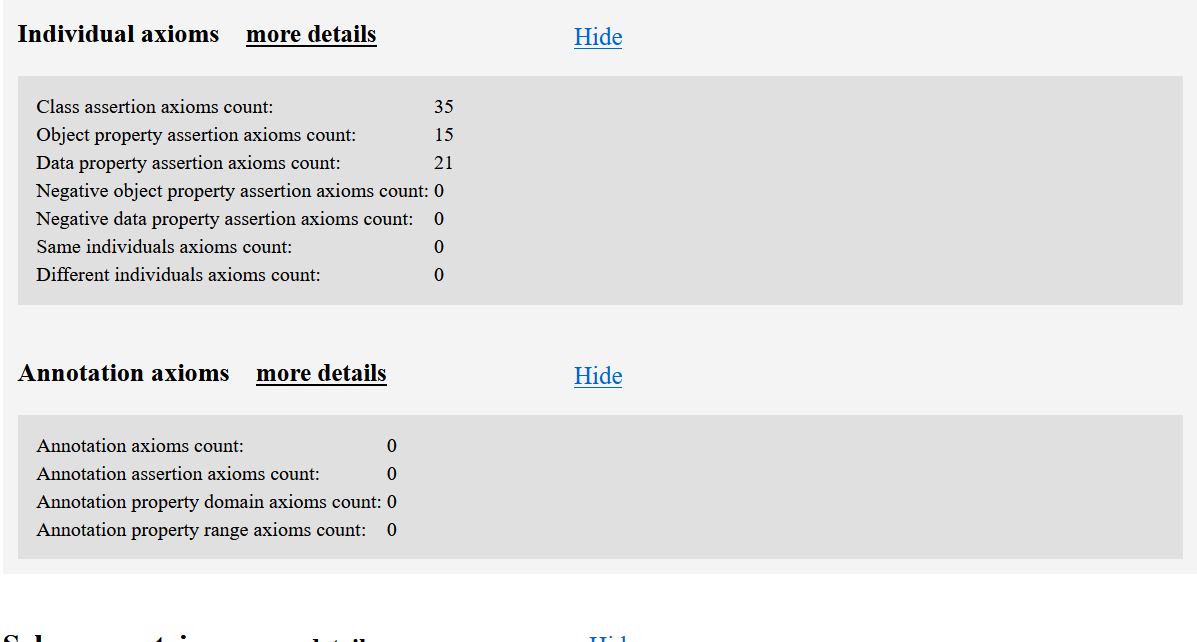
To evaluate the quality of the ontology, we consider multiple approaches in this section. Our focus lies on ontology metrics, identifying common pitfalls in the ontology development process, and comparing specific criteria used for evaluating the ontology during its development. By employing these three approaches, we can obtain a thorough understanding of the ontology's overall quality.

*6.2.1. Ontology metrics*

Table 2 presents the basic ontology metrics, which include the number of axioms, classes, properties, and individuals in the ExtruOnt ontology. These metrics were extracted using Protégé. Additionally, Table 3 provides a comparison of schema and graph metrics between MentalDisOnt and other well-known ontologies in the manufacturing domain. The data for this comparison was obtained using OntoMetrics[39].







*Figure 29: MentalDisOnt Ontology metrices*

Upon examination, it is evident that the metrics for MentalDisOnt fall within the range of values observed in other established mental disorder domain ontologies. Metrics such as Inheritance Richness and Equivalence Ratio demonstrate a moderately high value, reflecting the achieved level of semantic interoperability through ontology reuse.

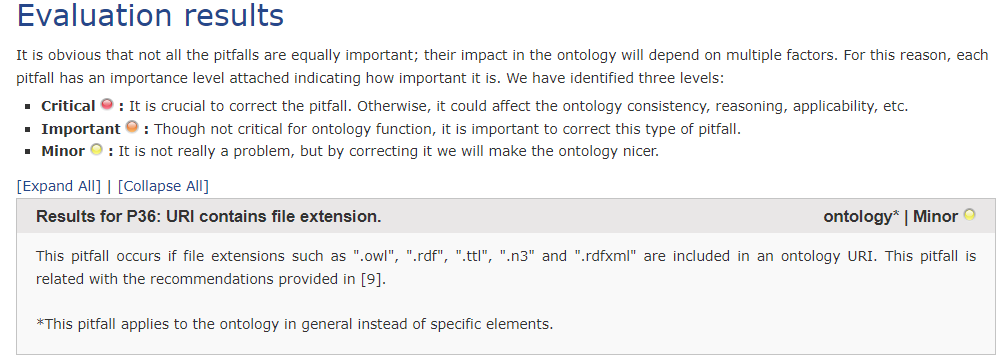
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Schema Metrics | MentalDisOnt Ontology | Bipolar Ontology | Sleep Domain Ontology | Schizophrenia Ontology | Mental Disease Ontology |
| Attribute richness: | 0.006501 | 0.0 | 0.016643 | 0.0 | 0.0 |
| Inheritance richness: | 0.994583 | 1.054579 | 1.786541 | 0.948276 | 0.461538 |
| Relationship richness: | 0.324503 | 0.016393 | 0.076319 | 0.112903 | 0.647059 |
| Attribute class ratio: | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Equivalence ratio: | 0.0 | 0.0 | 0.03835 | 0.0 | 0.0 |
| Axiom/class ratio: | 4.036836 | 16.509713 | 5.560781 | 3.293103 | 2.153846 |
| Inverse relations ratio: | 0.0 | 0.0 | 0.223529 | 0.0 | 0.0 |
| Class/relation ratio: | 0.679176 | 0.932701 | 0.517022 | 0.935484 | 0.764706 |
| Graph Metrics | | | | | |
| Absolute root cardinality: | 6 | 1 | 31 | 3 | 7 |
| Absolute leaf cardinality: | 878 | 725 | 902 | 46 | 7 |
| Absolute sibling cardinality: | 923 | 1081 | 1380 | 58 | 13 |
| Absolute depth: | 2070 | 10993 | 13641 | 203 | 19 |
| Average depth: | 2.24036 | 9.160833 | 9.552521 | 3.5 | 1.461538 |
| Maximal depth: | 4 | 15 | 20 | 4 | 2 |
| Absolute breadth: | 924 | 1200 | 1428 | 58 | 13 |
| Average breadth: | 20.086957 | 3.149606 | 2.90835 | 4.461538 | 1.857143 |
| Maximal breadth: | 668 | 51 | 48 | 11 | 7 |
| Ratio of leaf fan-outness: | 0.951246 | 0.670675 | 0.652677 | 0.793103 | 0.538462 |
| Ratio of sibling fan-outness: | 1.0 | 1.0 | 0.998553 | 1.0 | 1.0 |
| Tangledness: | 0.001083 | 0.049954 | 0.434877 | 0.0 | 0.0 |
| Total number of paths: | 924 | 1200 | 1428 | 58 | 13 |
| Average number of paths: | 231.0 | 80.0 | 71.4 | 14.5 | 6.5 |

*Table 2: Comparison of MentalDisOnt ontology metrices with number of other ontologies of same domain*

However, it would be unfair to directly compare specific metrics like tCardinality, Depth, and xtBreadth, as the compared ontologies may differ significantly in terms of their level of abstraction.

*6.2.2. OOPS! Evaluation*

The Ontology Pitfall scanner (OOPS!) is utilized to evaluate the ontology by detecting design pitfalls commonly encountered during the ontology development process. OOPS! relies on a catalogue of 41 pitfalls, categorized into three levels: critical, important, and minor. The tool can automatically identify 33 out of the 41 pitfalls. During the initial evaluation of MentalDisOnt, some flaws were detected and subsequently addressed. However, there is one remaining minor pitfall related to the presence of file extensions in URLs. Figure 3 provides a summary of the evaluation conducted by OOPS!



*Figure 30: OOPS! Evaluation results by ontology pitfall scanner*

*6.2.3. Evaluation criteria during the development process*

During the development process of the MentalDisOnt ontology, the evaluation criteria outlined in "A Snapshot of Ontology Evaluation Criteria and Strategies" [41] were applied. These criteria, which are summarized below, were utilized to assess the ontology's quality and effectiveness:

* ***Accuracy***: MentalDisOnt aimed to accurately represent various aspects of mental disorders, such as symptoms, diagnoses age, level of severity, and risk factors, ensuring a correct reflection of the real-world domain.
* ***Adaptability***: The ontology was designed to be adaptable, allowing for easy modifications and updates to incorporate new knowledge, changes in diagnostic criteria, and advancements in the field of mental health.
* ***Clarity***: MentalDisOnt focused on effectively communicating the intended meaning of defined terms, employing clear and unambiguous definitions to facilitate understanding and prevent ambiguity.
* ***Cognitive Adequacy***: The ontology aimed to match the formal representation with the cognitive semantics of mental disorders, ensuring alignment with how people naturally think and reason about these conditions.
* ***Completeness***: MentalDisOnt strived to provide appropriate coverage of the mental health domain, encompassing a wide range of mental disorders, symptoms, and associated information to offer a comprehensive view.
* ***Conciseness***: The ontology aimed to avoid unnecessary or redundant definitions and axioms, ensuring a concise representation that contained relevant and essential information without unnecessary complexity.
* ***Consistency***: MentalDisOnt was designed to maintain consistency by ensuring logical coherence and avoiding contradictory conclusions from valid input data.
* ***Expressiveness***: The ontology's design focused on providing an expressive framework that could answer a variety of competency questions related to mental disorders, enabling users to obtain meaningful insights and information.

These criteria were utilized to evaluate and ensure the quality of MentalDisOnt throughout its development process, promoting accuracy, adaptability, clarity, cognitive adequacy, completeness, conciseness, consistency, and expressiveness in the resulting ontology.

1. **Conclusion and Future Work**

The purpose of this paper is to present the MentalDisOnt ontology, which contains terms to describe different types of mental disorders. The ontology is organized into several modules: Symptoms for representing the symptoms associated with each disorder, Risk\_Factors for representing the potential causes or risk factors, Diagnosis\_age for representing the age group when a disorder might be diagnosed, Level\_of\_Severity for representing severity levels of a mental disorder and comorbidities for representing the co-occurring disorders.

The MentalDisOnt ontology aims to provide a comprehensive framework for describing mental disorders, allowing users to better understand and navigate the complexities of mental health. It facilitates interoperability and knowledge sharing among different stakeholders in the field of mental health, including researchers, clinicians, and patients.

The descriptions contained in the MentalDisOnt ontology enable users to access information about various mental disorders, including their symptoms, potential causes, diagnosis age, level of severity, and common comorbidities. This comprehensive representation of mental disorders allows for a more holistic understanding of these conditions and supports informed decision-making in diagnosis, treatment planning, and research.

The MentalDisOnt ontology has undergone evaluation to assess its domain coverage and the quality of its modeling. The evaluation involved both human experts in the field of mental health and software artifacts. The results of the evaluation demonstrate that MentalDisOnt effectively captures the necessary knowledge to answer competency questions related to mental disorders and meets the specified requirements. It has also been aligned with related ontologies, promoting interoperability and facilitating integration with other knowledge resources.

In future work, in addition to the ongoing maintenance of the ontology, we plan to develop two software artifacts that leverage the MentalDisOnt ontology. The first artifact will be a Decision Support System that assists clinicians in diagnosing mental disorders by leveraging the structured knowledge in MentalDisOnt. The system will help clinicians make informed decisions based on symptom profiles, potential causes, and other information. The second artifact will be a personalized recommendation system for mental health interventions. It will consider individual patient characteristics, such as symptoms, comorbidities, and treatment history, to suggest suitable interventions and customized treatment plans based on the information available in MentalDisOnt.

By leveraging the MentalDisOnt ontology in these software artifacts, we aim to improve the efficiency and effectiveness of mental health assessment, treatment planning, and patient care, ultimately contributing to better outcomes for individuals with mental disorders.

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