HUMAN STRESS ONTOLOGY

Multiple Applications and Implications of an Ontology Framework in the Mental Health Domain

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Abstract: A large number of articles exist that discuss and define various concepts, terms, and theories relating to human stress. The heterogeneous and dynamic nature of this knowledge, and the growing research, highlight the need and significance of designing a coherent and sharable ontology framework for human stress domain. In response to this need, we design Human Stress Ontology (HSO) to capture stress-related concepts and their relationships in an agreed and machine readable framework. This ontology is organized according to the following five sub-ontologies: causes, mediators, effects, treatments and measurements. Development of an ontology in this field will facilitate interoperability between different information systems and enable the design of ontology-driven software programs tools and semantic web engines for intelligent access, management, retrieval and analysis of stress-related information. The derived knowledge will help identify important relationships between different concepts, and facilitate invention of more valid and consensual psychological tests and development of effective prevention and treatment strategies.

1 INTRODUCTION AND MOTIVATION

In a recent Newspoll Omnibus Survey, about 91% of adult Australians reported feelings of stress in at least one significant aspect of their lives. In this study, worries about work, finances, future, health, and personal relationships have been identified as the main stressors (Lifeline Australia, 2008).

Stress can engage a wide range of psychological and physiological mechanisms and have transient or lasting effects on different cognitive, emotional or physiological functions. The detrimental effects of chronic and intense stress on physical and mental health have been demonstrated in various studies (Harris, 1991). For example, it can interfere with the secretion of insulin resulting in susceptibility to diabetes. Stress also underpins the hypersensitivity of the limbic system resulting in subsequent arousal disorders (Everly and Lating, 2002).

Various theories have been proposed and experiments have been conducted in order to study the effects of stress as a main or mediating factor in different mental, neurophysiological, or physiological conditions. A huge range of information and data about such theories and their relevant diverse studies are stored in various data resources, yet there are ongoing controversies and arguments over conceptualization, measurement (Monroe, 2008), and classification of stress-related phenomena.

An extended range of concepts, categories, theories, and findings from stress-related studies can be found in different texts and electronic journals across various information resources. However, there are a number of issues and problems regarding effective analysis, integration, retrieval, and application of these data.

Firstly, there is a lack of shared, consensual, and precise definitions of stress-related terms and concepts in some cases which have resulted in the same concepts having different meanings in different studies, or one concept being represented by different terms across various research works. For instance, the lack of a uniform definition of the stress concept has made it difficult to integrate stress-related findings and results. There are even studies where researchers have equated stress with specific emotional states such as anxiety, fear, or anger (Lobel and Duknel-Schetter, 1990). Such

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inconsistencies in the definition of stress have culminated in ambiguous and inconsistent results in terms of measurement of stress causes and effects, as different researchers have adopted different definitions for stress (Monroe, 2008). Therefore, there is a fundamental need to clearly define differential components of each definition within their specified contexts and reach a consensual conceptualization for stress-related concepts and terms.

Secondly, there is a need to obtain a comprehensive and cohesive view of all related phenomena within our specified domain of knowledge i.e. human stress, so that we can obtain a better understanding of this phenomenon as well as a perspective of gaps and issues observed in its research field.

Thirdly, most current information resources function autonomously. It means that contents in certain information resources are developed, stored and processed independently of other information resources, making it difficult to elicit, in a precise and integrative manner, all desirable information embedded within various databases. Hence, there is a need for the information resources to be equipped with search engines with the capacity to look for the meaning of information, and not merely be limited to the appearance of a specific word in the text.

Current search engines perform keyword-based searches which make the process of information retrieval difficult and hinder the establishment of a comprehensive and inclusive view of all related phenomena within our specified domain of knowledge. For example, a search for the term *stress theories* in OvidSP database brings up more than 12900 results. This enormous number of results may also include a large amount of data about unrelated works and studies. Such a scattered collection of data about stress theories would by no means offer associations, interrelations, similarities, and differences of related concepts and theories despite the fact that all studies have elaborated on the same phenomenon, have adopted or borrowed many theory elements from one another, or are explanatory, or contradictory to each other. In order to introduce meaning and context into our search, we firstly need to design an ontology. The search engine will then use this ontology to provide meaning and context for its searches.

Despite such issues and problems within its research field, to the best of our knowledge, there is no established ontology or ontology-based search engine for the topic of human stress and its related concepts. In this paper, we put forward the significance of establishing Human Stress Ontology (HSO) as a potential tool to address the abovementioned issues. We will present a top-layer model for the HSO which aims to capture and represent all information related to stress, its causes, mediators, effects, treatments, and measurements.

2 CHOICE OF THE ONTOLOGY DESIGN METHODOLOGY

Ontology is defined as the formal and explicit specification of a domain conceptualization (Gruber, 1993). In an ontology framework, *formal* refers to knowledge representation that is mathematically described and machine readable. A *domain conceptualization* is an abstract model of a phenomenon, i.e. an abstract view of domain concepts and relationships among them, and *explicit* expresses clear and precise definitions of concepts and their relationships.

Ontologies were basically designed to facilitate communication and interoperation between different information systems by providing a formal, agreed and shared framework for semantics of knowledge domains used by those systems. The application of ontologies within various communities such as health and biomedical areas has proved effective and operational (Ceusters et al., 2001).

It has been suggested that ontology building is more a craft than a strict engineering design (Beck and Pinto, 2002). There are different ontology building methods which can be adopted for solving different data management problems.

For the design of the HSO, we have chosen the DOGMA method. The DOGMA methodology (Spyns et al., 2008) represents a special paradigm for separating the *domain axiomatization* (the *ontology base*) from the *application axiomatization* (the *commitment layer*) in order to solve the trade-off problem observed between the usability and reusability of an ontology. The DOGMA tool has the capability to store basic concepts and their application-specific constraints in two separate layers: the ontology base and the commitment layer. By means of the DOGMA tool, we will be able to convert the elementary facts of concepts and their relationships into the *lexons* which will be placed in the ontology base. Lexons are formal binary facts with the formal description of *<Y: trem1 role1 co-role2 term2>*. The ontology commitment layer will contain additional rules, restrictions and constraints specified for the defined lexons. This advantage in

DOGMA allows domain experts and users to have multiple views and requirements for different applications while using the same stored meaning-independent conceptualization (Spyns et al., 2008). The DOGMA also offers the notion of the *context* as an identifier to confine the interpretation of each term to certain concepts within the context of that term (Jarrar and Meersman, 2008).

The notion of context is of significance particularly with regards to the maintenance of rules and lexons. It has been argued that in the maintenance phase of expert systems, the context influences the rules provided by the experts. For example, in the cases where there are inconsistent interpretations of a set of data, it is the existence of different rules in different contexts that create such inconsistencies. Respectively, the context defines to a large extent the way we answer a particular question. This statement derives from the notion that knowledge cannot be separated from the context and efforts to reach context-free fundamentals of knowledge are philosophically implausible (Compton and Jansen, 1990).

However, there are some opposite views maintaining that concepts should correspond to reality and ontology relations such as *Is-a* or *Part-of* can be established in a way that introduce real physical relations in reality. According to this view, high-quality ontologies are representations of reality and they must incorporate *universals* that exist in the real world of space and time (Smith, 2004).

This perspective though might be applicable in scientific domains such as physics and biology (where there are established scientific laws) its application in abstract domains such as human stress seems not to be realistic. In our work, we face a big variety of theory-based definitions and explanations for similar concepts where the extent to which they represent real entities in the world is unknown and arguable. For example, there are different theories to explain how stressful life events contribute to states of depression or other mental disorders, each highlighting one particular aspect of those phenomena. Or, it has been shown that during different stages of development, the individual is challenged by different types of stressors (Seiffge-Krenke et al., 2009).

For this reason we have selected the DOGMA methodology as it is important to provide a context for the HSO concepts and their relationships. This will be particularly appropriate for resolving the abovementioned inconsistencies by classifying concepts within the context of their relevant theories, where a specified context identifier can represent specific theories or explanations of the same concepts. For example, stressful life events can be classified according to the different contexts of childhood, adolescence, adulthood, and elderly, where each context is characterized by its own instances of stressful life events.

3 THE HSO STRUCTURE

In this section, we present a graphical illustration of the top-layer structure of the HSO plus a brief explanation of its sub-ontologies and the observable interrelationships existing among them.

The HSO consists of five sub-ontologies including: 1. Stress Causes, 2. Stress Mediators, 3. Stress Effects, 4. Stress Treatments, and 5. Stress Measurements. All concepts which can be found within the domain knowledge of human stress will be placed under their related categories which fall under the above sub-ontologies. Each sub-ontology encapsulates its related categories and concepts; however, the categories and concepts are not mutually exclusive and there might be some interrelations among them in certain contexts in which they appear. Following, is a brief explanation of each sub-ontology branch and some of their defined categories. We will extend this ontology model to incorporate all stress-related concepts and theories.

3.1 Stress Causes (Stressors)

Overall, there are three general classifications for stress-inducing factors regarding their relativity, objectivity, and duration:

I. One classification system (Lupien et al., 2007) classifies stressors into two groups based on their relativity: a) Psychological (relative), and b) Biogenic (absolute).

II. Another classification system (Pervin, 1978) classifies stressors into two groups based on their objectivity: a) Objective, and b) Subjective.

III. In one more popular division (Baum, 1990) stressors are categorized into two groups according to their duration: a) Acute, and b) Chronic.

3.2 Stress Mediators

The path from exposure to the stressor to stress experience is not a direct path. In fact, a combination of neurophysiological, psychological, and situational factors mediates the link between stress causes stress feelings, and consequent stress effects. We,

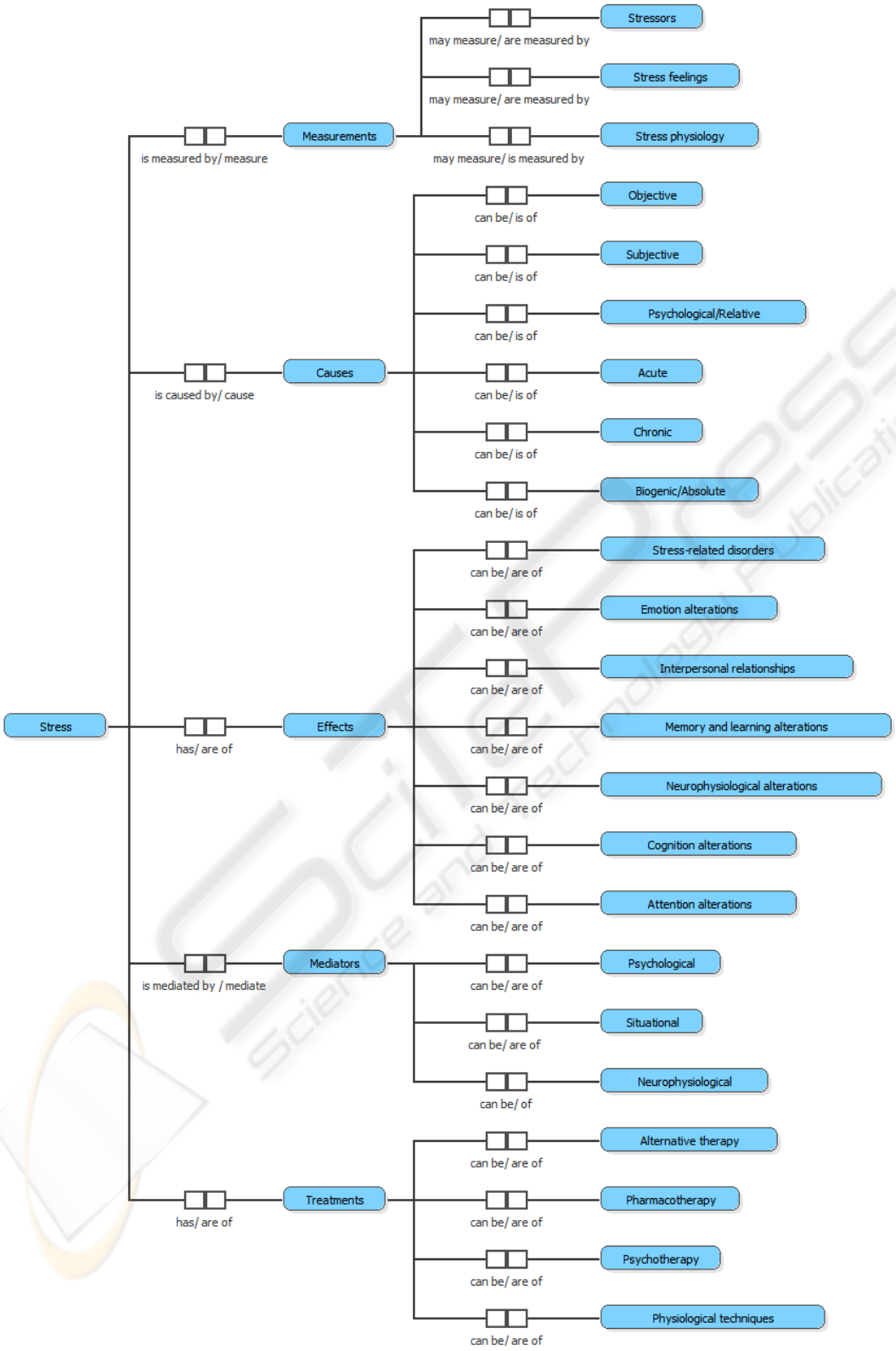

Figure 1: The top-level hierarchy of Human Stress Ontology (HSO) and its five sub-ontologies.

classify the stress mediators into the following three categories with their corresponding sub-concepts:

I. Psychological mediators: a) Coping patterns, b) Personality factors, c) Developmental factors, d) Gender-related factors (Seiffge-Krenke et al., 2009), and e) Cognitive factors (Sarafino, 1998).

II. Neurophysiological mediators: a) The HPA axis, b) Limbic system reactions, c) Stress hormones, and d) Stress-hormone receptors (Lupien et al., 2007).

III. Situational mediators: a) Socioeconomic factors, b) Cultural factors (Kopp et al., 1998a).

3.3 Stress Effects

The HSO classifies all functional and structural stress-related alterations in the organism under seven subclasses of: a) Stress-related disorders, b) Neurophysiological alterations, c) Cognition alterations, d) Emotion alterations (Lupien et al., 2007), e) Learning and Memory (working, declarative, emotional, long-term) alterations (Lupein and McEwen, 1997), f) Attention alterations (Ritter et al., 2007), and g) Effects on Interpersonal relationships (Lindy, 1985).

3.4 Stress Treatments

Treatment of stress-related disorders draws on many psychotherapy techniques, psychiatric interventions, physiological techniques, and a wide range of complementary therapies. These include: a) Psychotherapy, b) Pharmacotherapy, c) Physiological techniques, and d) Alternative therapies (Everly and Lating, 2002).

3.5 Stress Measurements

If we are to effectively evaluate stress and its effects on health, we need to correctly define the fundamental variables of stress. Definition and designation of such variables, as well as experimental research on stress, necessitate the design or creation of efficient measurement tools.

However, due to the existence of various definitions for stress, inconsistent and superfluous measurement tools for quantification of this phenomenon have been created that consequently resulted in phenomenological and methodological mistakes. For example, some frequently used instruments such as *The Life Stressor Checklist-Revised* (Wolfe and Kimerling, 1998) focus more on evaluating the stressors, not specifically addressing other mediating factors which might affect the stress response. Therefore, such measures do not measure the stress response accurately (Everly and Lating, 2002).

In general, stress measurement tools can be classified into three categories: a) Measurement of stressors, b) Measurement of stress feelings, and c) Measurement of physiology of stress response (Everly and Lating, 2002).

4 EVALUATION OF THE HSO

For the evaluation of the HSO we will use the conceptual coverage technique (Hartmann et al., 2005) as follows: a test set (for example a set of 30 article abstracts randomly selected from various psychology databases) will be used to evaluate the designed ontology. The knowledge abstracted from this test set will be encoded by means of the designed ontology. Then, we will calculate the percentage of sentences within this test set that can be represented by the developed ontology. Depending on the percentage of the covered text, new concepts will be added and the created concepts then will be further refined to ensure the HSO meet criteria such as consistency, coherence, and correctness.

Additionally, we have mapped the HSO to the MeSH (Medical Subject Headings, 2008), the National Library of Medicine's controlled vocabulary thesaurus, to examine the degree to which concepts in the HSO match the MeSH's stress-related concepts. Our mapping evaluation demonstrated that for most concepts in the HSO, there is no equal or even synonymous concept in the MeSH as the MeSH is a generic medical thesaurus and is not detailed enough to capture specific knowledge domains such as human stress.

5 SIGNIFICANCE OF THE HSO

The HSO sub-ontologies have the potential to offer a cohesive and coherent view of various stress-related concepts. By considering the illustrated HSO figure, some formerly unseen relationships among different aspects of this phenomenon may be revealed, motivating researchers to carry out additional studies on these interesting and important topics. Researchers can observe the interconnectedness of different categories of stressors with multiple aspects of stress response or stress mediators. For example, the HSO suggests that there can be specific

links between biogenic stressors and cognitive alterations which might be different from associations between psychological stressors and subsequent cognitive processes.

The HSO will potentially help identify and unify the existing differences observed in definitions of stress-related terms and concepts, representing formal, elaborated, precise, and consensual definitions for them, and thereby, facilitating communication and interoperation across different applications.

It will have the potential to provide an overview of prominent research subjects such that different subjects and concepts can be placed under their appropriate categories and viewed as interrelated and interwoven manifestations of one phenomenon, i.e. human stress. Therefore, through the cohesive and coherent structure of the HSO, some hitherto unseen relationships among different aspects of human stress may be revealed, motivating researchers to carry out additional studies on perceived gaps or other latent issues across entities and theories. The HSO will also be a motivation for the establishment of other ontologies in psychology and psychiatry.

The HSO can be used to integrate heterogonous information resources within the human stress domain and manage contents of different databases in relation to each other. It will facilitate interoperability between different information systems and enable the design of ontology-driven software programs tools and semantic web engines for intelligent access, management, retrieval, and analysis of stress-related information.

The subsequently derived knowledge may also help in the development of effective prevention and intervention strategies in the field of mental heath. Representation and description of various stress causes, mediators, and their mechanisms in the form of classified binary facts can facilitate the process of formulating more *evidence-based* and effective intervention strategies. Experts can store and organize knowledge and scientific explanations of the factors and mechanisms contributing to causation and precipitation of stress-related disorders in distinctive contexts according to their underling theories. Different intervention and treatment strategies, therefore, in the same fashion, can be structured in their relevant contexts where links between them, their underpinning theories, and related pathological explanations can be recognizable in an effective way. Given that intervention strategies apply their effects differently from situation to situation and individual to individual, an HSO-based agent system is likely to play an important role in defining the best treatment technique for a specific situation or individual. This will be possible by considering different situations or personality characteristics as distinctive contexts for which there are suggested or prescribed treatment techniques available.

Another intriguing application of the HSO in the mental health domain relates to its potential for facilitating the establishment and implementation of various stress-related psychometric tests and inventories. By obtaining consensual and shared definitions of stress-related concepts and terms, researchers and clinicians will gain a more coherent and realistic understanding of what exactly they aim to measure. For example, current differences and disagreements on whether a certain test measures stress responses, stress feelings, or stress-inducing factors are likely to be resolved by linking each item of the test to their relevant conceptualizations embedded in the ontology framework. The context-based binary facts in the HSO can be used as a basis for development of more valid stress-related psychological tests and inventories. For example, test inventors aiming to capture specific test-items for measurement of stress-response will acquire a more accurate and consensual view of relevant items by mapping those items to their formal definitions in their related contexts within the HSO. In this way, obscure, intrusive, or irrelevant items such as stress-stimuli measuring items can be recognized and separated out by juxtaposing them with items in targeted contexts. This application of the HSO can be an intriguing progress in the process of test invention and validation in psychology, psychiatry, and mental health domains in general. On this ground, we will also be able to develop specific intelligent agents to practise the process of test invention and validation in an automated way. For instance, an automated agent as such may have the potential to help researchers calculate the degree to which a certain test is related to a specified concept.

6 CONCLUSIONS

In this paper, we explained the significance, possible applications, and implications of the Human Stress Ontology (HSO) for the mental health domain. The HSO will facilitate intelligent retrieval and analysis of stress-related information. This ontology framework is likely to help researchers increase their understanding of the related concepts, their definitions and possible associations in various areas

of stress-related research by discovering some formerly unseen relationships among different aspects of this phenomenon.

We also highlighted the significant role of context-based conceptualization and classification of stress-related phenomena for various psychological test invention and validation purposes, as well as intervention and prevention strategies. It was suggested that the notion of context in the HSO framework may resolve the problem of having different theories, definitions, and explanations for similar concepts within the domain of human stress.

We are in the process of introducing ontology as an auxiliary and complementary method to mental health research and study. The HSO project can be considered as the emergence of a new method in psychology and psychiatry research, inspiring researchers to consider ontology as an effective tool for studying various topics of those areas of science and art. Our future work on the application of the HSO in psychometrics and intervention strategies is expected to have significant implications for mental health researchers and clinicians.

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