

# Developing the BOUNCE Psychological Ontology<sup>1</sup>

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**Abstract.** It is well known that the mental and emotional state of cancer patients plays an important role in the treatment of their disease. As such, for building prediction tools, patient's psychology should also be considered, along with medical, clinical, biological and lifestyle data. However, for modelling patients psychological status, only a limited set of terms is available in existing ontologies. The BOUNCE Psychological Ontology (BPO) is an attempt to model all relevant psychological constructs, for cancer patients, effectively capturing patients' emotional and mental disposition in order to further study methods for coping with and recovering from the disease.

**Keywords:** psychological; ontology; health

## Introduction

Coping with breast cancer has increasingly become a major socio-economic challenge, among others, due to its constantly increasing incidence in the developing world. The BOUNCE EU project (<https://www.bounce-project.eu/>), takes into consideration clinical, cancer-related biological, lifestyle, and psychosocial parameters in order to predict individual resilience trajectories throughout the cancer continuum. Eventually the target is to increase resilience in breast cancer survivors and help them remain in the workforce and enjoy a better quality of life.

In order for such prediction tools to be implemented, a unified view over all available data sources is essential, effectively integrating medical, clinical, biological, lifestyle and psychosocial parameters, collected from four clinical sites across Europe, effectively enabling the informed secondary use of patient's personal data [1, 2]. Although multiple ontologies are already available, integrating and modelling clinical, biological and lifestyle data [3], when coming into psychological constructs, the available ontologies (e.g. Psychological Ontology for Breast Cancer Patients, Mental Functioning Ontology, Emotion Ontology [4]) offer really limited relevant terms, covering only skin deep the aforementioned domain. However, within the BOUNCE project, more than 25

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psychological questionnaires are used, (e.g. the Ten item Personality measure, PTSD Checklist, Connor Davidson Resilience Scale, Family Resilience Questionnaire, NCCN Distress Thermometer), measuring more than 100 psychological parameters, dictating a more detailed and extensive model. The model should be able not only to model constructs captured by these questionnaires, but also the interrelations between those constructs, requiring and capturing knowledge available mostly to domain experts.

To this direction, in this paper, we present the process we followed to develop the BOUNCE Psychological Ontology (BPO) and present a glimpse of the current status of the developed ontology. The ontology is an OWL ontology developed using Protégé and a first version is already available online<sup>2</sup>.

## Methodology

There are several methodologies for developing an ontology. These methodologies provide a guideline on how to carry out the activities specified in the ontology development process and the type of techniques that are most appropriate for each activity. In our case we relied on a methodology similar to [5] and [6] including purpose & scope specification, knowledge acquisition, conceptualization, implementation, evaluation and documentation as shown in Fig. 1



**Fig. 1.** The methodology adopted for developing the BOUNCE Semantic Model.

After defining the *purpose and the scope* of the developed ontology, in the *knowledge acquisition step* we a) identified other relevant ontologies including psychological constructs; b) studied the already available retrospective datasets from the participating clinical centers; and c) collected the relevant patient reported questionnaires used during the BOUNCE prospective study. Unfortunately, no existing ontology was able to cover the plethora and the diversity of the required psychological constructs (see [4] for a detailed review of relevant ontologies).

In the next phase of *conceptualization*, we collected, analyzed and conceptualized the necessary psychological terms. Then interrelations between those were captured after constant interaction with clinical psychologists, exploiting their domain knowledge, based on relevant publications.

Next, we *implemented* the ontology as an OWL ontology using Protégé. At the moment, the ontology contains 310 classes, 106 object properties and 10 data properties. BPO is a module of the IMC Semantic Core Ontology, which also covers medical, clinical, biological, lifestyle constructs. As such, BPO adopts at the upper level the basic formal ontology (BFO), the upper level ontology upon which OBO Foundry on-

<sup>2</sup> <https://cbml-gitlab.ics.forth.gr/kondylak/the-bounce-psychological-ontology>

tologies are built. The high-level classes of the BPO ontology, their main interconnections with BFO and some examples, are shown in Fig. 2. For the development of the BPO it was crucial to be able to represent both the clinical reality and the various kinds of questionnaires of the clinical reality in the domain of our research. To achieve this goal our ontology includes a questionnaire class (*BPO:Questionnaire*), modelling the various questionnaires used in the project.

For example, the BR23 and C30 EORTC quality of life questionnaires, require instantiation in some paper or electronic bearer (e.g., a printed questionnaire or a pdf file), but they are not particularly important for the existence of the questionnaire for which a particular bearer can instantiate it.

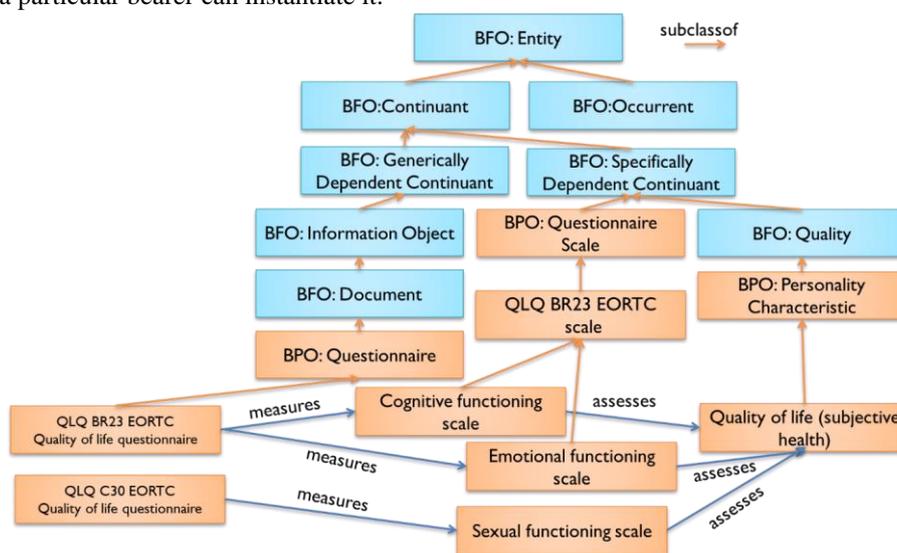


Fig. 2. The Questionnaire class as subclass of the Information Object.

As shown in the example, for assessing the perceived quality of life of a patient, there are multiple scales (three of them are shown in the example) that can be measured using BR23 and C30 questionnaires developed for cancer patients. The introduced classes and properties have been *documented* adding relevant useful information using multiple annotation properties, providing also the links to relevant publications.

To evaluate an ontology there have been proposed several methods. Independent of the specific methods employed, two main lines of evaluation process are usually adopted, usually seen as complementing each other: The “glass box” or “component” evaluation and the “black box” or “task-based” evaluation, each one evaluating different ontology qualities. We evaluated the BPO ontology using the following glass box methods:

*Logical consistency*: Logical soundness assesses the ontology for logical consistency, detecting contradictory statements. As the ontology has been developed using the Protégé tool, logical consistency, subsumption and satisfiability is automatically and constantly checked using the Pellet and the Hermit reasoners.

*Common pitfalls in ontology development:* Next, we employed an automated web-based tool, namely OOPS! [7], to automatically identify common errors in ontology development that could lead to modelling errors. We used the tool to evaluate the structural, functional, and usability-profiling dimensions of our ontology as well as to evaluate its consistency, completeness and conciseness. The results were very good with only some minor pitfalls noted, due to the fact that is not yet used by others, besides the creators.

*Application domain coverage & task orientation:* Finally, validating domain coverage is crucial to ensuring the usability of an ontology. The ontology is used by technology experts to generate (via mappings [8, 9]) a unified data access layer, effectively integrating all external, retrospective and the prospective data collected throughout the lifetime of the project. Then it is used by psychologists to query the available data and visualize them through an advanced data analysis tool [10] and by modelers to generate AI models [11, 12] on top effectively querying the homogenized, integrated data. As such, the ontology was able to answer all clinical and modeling questions involving such data, and to generate effective recommendation [13, 14] for cancer patients based on the predictions and their correlations with the available data.

## Conclusions

In this paper, we present the BOUNCE psychological ontology, explaining the methodology followed for developing, presenting in short the modelling choices made, and providing a glimpse of the developed model. We also described the process followed for its glass box evaluation. BPO cannot be seen as a complete domain ontology, but rather an application ontology tailored to the needs of the BOUNCE platform. However, it succeeds in modeling all psychological parameters used today for cancer patients.

Nevertheless, we have to note that ontologies are living artefacts and subject to continuous change [15, 16]. As such, although ontology development within the BOUNCE project is complete, actually it will continue till the end of the project and beyond that, as long as there are people using it, continuously extending and adapting the model to fit their needs. We expect that, as we understand more on the psychological concepts under study, we will be able to refine classes and terms included in the ontology and to improve the mapping to the data sources.

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