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**BOUNCE**

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***Predicting Effective Adaptation to Breast Cancer to Help Women to BOUNCE Back***

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Research and Innovation Action

SC1-PM-17-2017: *Personalised computer models and in-silico systems for well-being*

**Deliverable: 3.3 Final Semantic Model**

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## 0. Document Info

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V0.1	01 Aug 2019	Starting version, template
V0.2	01 Aug 2019	Definition of ToC
V0.3	10 Oct 2019	First complete draft
V0.4	20 Oct 2019	Integrated version (send to WP members)
V0.5	25 Oct 2019	Updated version (send PCP)
V0.6	25 Oct 2018	Updated version (send to project internal reviewers)
Sign off	28 Oct 2019	Signed off version (for approval to PMT members)
V1.0	01 Nov 2019	Approved Version to be submitted to EU

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## 2. Introduction

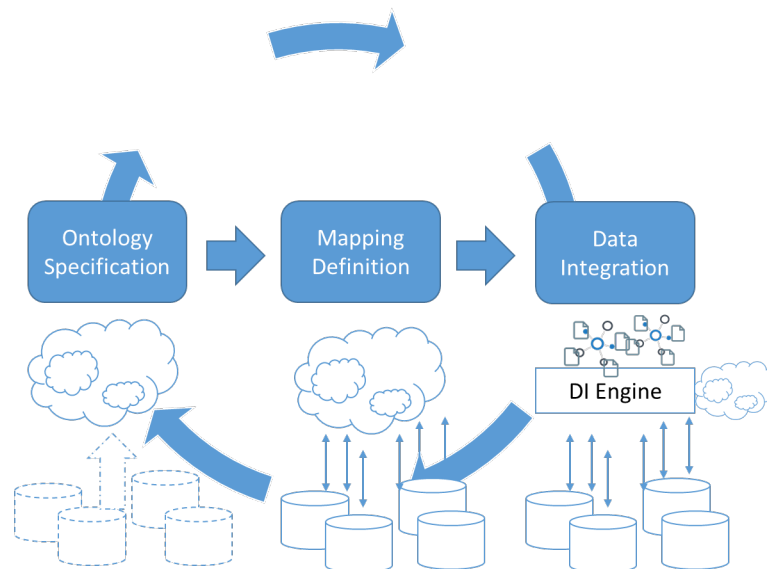
### 2.1. About task 3.2

T3.2 focuses on extracting for each domain of the BOUNCE project, a well-defined set of domain concepts that sufficiently describe the semantics of the corresponding data sources. Sources include prospective data, retrospective data and external data sources.

Initially the focus of this task was to establish the methodology for developing the semantic model of the project. Following this methodology, a first version of this semantic model was drafted based on relevant approaches able to describe both retrospective and prospective data. The result of these actions was reported in D3.2 [3]. The final version of the semantic model is delivered in this document, extending the preliminary model. The final semantic model is defined in a modular, scalable and extensive way and special attention is given on the temporal aspect of the information.

### 2.2. Purpose of the document

The purpose of this document is to report on the final version of the designed model. The designed model will be used to effectively conceptualize and homogenize all available data to be used during the BOUNCE lifetime, offering a common data model for integration and querying. The steps to integrate the available data are shown in Figure 1, showing that the semantic model is used to define the mappings, i.e. programmatic correspondences between ontological terms and the various data fields, and based on those data integration engines can automatically homogenize and semantically uplift available data. Then the semantic model is used in order to formulate the queries that the integration engine will answer.



**Figure 1. Data Integration & Homogenization through an ontology [3].**

Within D3.2 the methodology for developing the semantic model was established, explaining the following steps for constructing such a model: 1) Purpose and Scope Specifications, 2) Knowledge acquisition, 3) conceptualization, 4) implementation, 5) evaluation and 6) documentation, as shown in Figure 2. In addition in D3.2 the iManageCancer Semantic Core

Ontology was adopted and the first version of the BOUNCE psychological ontology was presented (covering partially the first four steps of the methodology).



**Figure 2. The methodology adopted for developing the BOUNCE Semantic Model**

In this deliverable, we refine the four methodological steps for developing the BOUNCE psychological ontology and we also present evaluation and documentation steps, presenting details for implementing the final version of the model.

To our knowledge **there is no other ontology available, capable of mapping and modeling psychosocial data of the extent and complexity displayed in BOUNCE**

### ***2.3. Work methods & main contents of the document***

The remaining of this deliverable is structured as follows: In Chapter 3, we present the high-level semantic model adopted for the BOUNCE project. Then in Section 4, we present the BOUNCE Psychological model and we present in detail the various methodological steps followed for its implementation. Finally, Section 5 concludes this deliverable and presents directions for future work.

### 3. Extending the IMC Semantic Core Ontology

As already stated in D3.2 [3] the development of the BOUNCE Semantic model is based on the following three principles:

- **Reuse:** Avoid “reinventing the wheel” and reuse already established high quality ontologies.
- **Granularity:** Annotations or mappings cannot be extracted from a single ontological resource. So, multiple ontologies should be used.
- **Modularity:** Create a framework where different ontologies would be able to integrate many modules through mappings between ontologies.

Ontology construction is deemed to be a labor-intensive and a time-consuming process [4]. In addition, the development of new ontologies does not necessarily tap the full potential of existing domain-relevant knowledge sources. Due to these problems the latest years the tendency is not to create new ontologies from scratch but to try to integrate high quality, domain-specific ontologies that have already prove their value. As such, within BOUNCE we intend to exploit, reuse and extend the iManageCancer Semantic Core ontology, developed by the iManageCancer project<sup>1</sup>. The ontology, is a modular ontology, with multiple modules, covering the entire cancer domain, using state-of-the-art subontologies and terminologies. The various modules are shown in Figure 3.



Figure 3. The modules of iMC Semantic Core Ontology<sup>2</sup> and the BOUNCE Psychological Ontology Module (BPO)

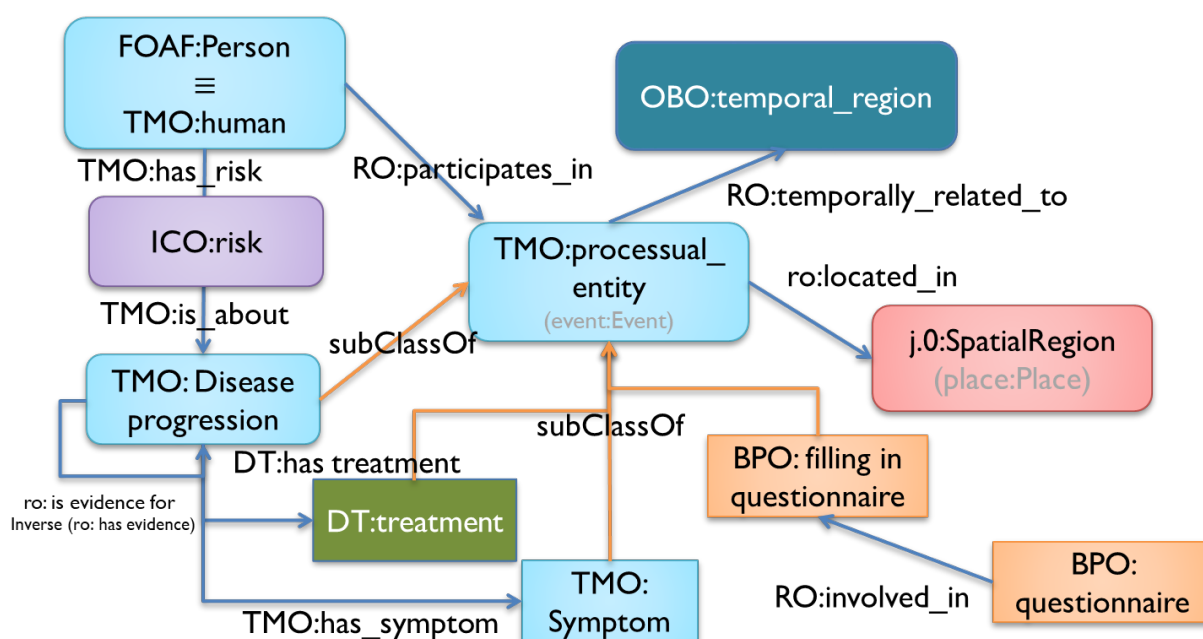
<sup>1</sup> <http://imanagecancer.eu/>

<sup>2</sup> ACGT: ACGT Master Ontology, BFO: Basic Formal Ontology, CHEBI: Chemical Entities of Biological Interest, CIDOC-CRM: CIDOC Conceptual Reference Model, CTO: Clinical Trial Ontology, DO: Human Disease Ontology, DTO: Disease Treatment Ontology, FHHO: Family Health History Ontology, FMA: Foundation Model of Anatomy, FOAF: Friend of a Friend Ontology, GALEN: Galen Ontology, GO: Gene Ontology, GRO: Gene Regulation Ontology, HDOT: Health Trunk Ontology, IAO: Information Artifact Ontology, ICD: International Classification of Diseases, ICO: Informed Consent Ontology, LOINC: Logical Observation Identifier Names and Codes, MESH: Medical Subject Headings, NCI-T: NCI thesaurus, NIFSTD: Neuroscience Information Framework Standardized ontology, NNEW: New

The ontology contains 36 sub-ontologies integrated using an extension of the Translational Medicine Ontology [5] which is used as an upper layer ontology. All other ontologies are integrated using the TMO ontology on top. The integration is achieved by introducing terms from these sub-ontologies to the TMO ontology and via relations of equivalence and subsumption from eTMO to the various ontology modules. These relations (~400) were manually identified and verified using the NCBO BioPortal<sup>3</sup>.

The aforementioned data model is able to effectively describe biomedical and eHealth concepts in the cancer domain and as such to cover the corresponding concepts from the external, retrospective and prospective datasets.

However for modelling psychological constructs only a really limited set of terms is available in existing ontologies (see D3.2 for an overview of other relevant ontologies). As such within BOUNCE we developed a novel ontology, the BOUNCE Psychological Ontology (BPO) for modelling the psychological characteristics of the scope and complexity explored in the BOUNCE project. The ontology will be detailed in the following section, however in Figure 4 we can see how the BPO ontology is interconnected with other ontologies available in the IMC Semantic Core Ontology through equivalence relations.



**Figure 4. Interconnections between BPO and other ontologies from the IMC Semantic Core ontology**

As shown, a person (*FOAF:person* which is equivalent with *TMO:human*) can participate in an event (*TMO:processual\_entity*). Such an event is an event of filling in a questionnaire (*BPO:filling\_in\_questionnaire*), and a specific questionnaire (*BPO:questionnaire*) is involved in the process. In addition, a person can have a specific risk (*ICO:risk*) about a disease (*TMO:disease\_progression*). Events occur within a specific time period (*OBO:temporal\_region*)

Weather Ontology, OBI: Ontology for Biomedical Investigation, OCRE: Ontology for Clinical Research, OMRSE: Ontology of Medically Related Social Entities, PATO: Phenotypic Quality Ontology, PLACE: Place Ontology, PRO: Protein Ontology, RO: Relation Ontology, SBO: Systems Biology Ontology, SNOMED-CT: SNOMED clinical terms, SO: Sequence Ontology, SYMP: Symptom Ontology, TIME: Time Ontology, UMLS: Unified Modeling Language System, HDOT: Health Data Ontology.

<sup>3</sup> <http://bioportal.bioontology.org/>

and are located in a specific place (*PLACE:place* or *obo:SpatialRegion*). In addition a disease can have a specific treatment (*DT:Treatment*) and can have a specific symptom (*TMO:Symptom*).



## 4. The BOUNCE Psychological Ontology (BPO)

In this chapter we present the development on the BOUNCE psychological ontology following the methodology established in D3.2 [3], an overview of which is shown in Figure 2.

### 4.1. *Scope and purpose*

The scope of the ontology is to be used by researchers participating in the BOUNCE project, supporting a unified data annotation for the psychological data of the project in both the external, the retrospective data and the prospective data collected throughout the lifetime of the project.

As such, the outcome of this effort, can be seen not as a comprehensive domain ontology, covering all concepts in the area but as an *application ontology* tailored to the needs of the BOUNCE platform. A domain ontology is an ontology that has a clear-cut and distinguishable subject matter, one unified by the kinds of objects that it contains, by the dominance of a particular set of concepts and distinctions pertinent to these objects, and often by certain characteristic methods of inquiry as well. Paradigm examples of domain ontologies include representations of basic scientific subject matters, such as anatomy, cytology, the different areas of genetics, etc. The BPO, by contrast, tackles a mixed bag of aspects arising from psychological monitoring of patients with cancer. As a result of this, a single clearly delineated domain to which it applies cannot be easily identified.

### 4.2. *Knowledge acquisition*

In order to proceed with the knowledge acquisition step, besides other ontologies identified and reported in D3.2 [3] we also collected the psychological questionnaires that exist in the retrospective data and those that will be used during the BOUNCE prospective study. We have to note that no psychological measures were identified in the external datasets. They are the following:

#### **Prospective data**

1. TIPI: Ten Item Personality Measure (brief "Big Five")
2. LOT-R: Optimism/Pessimism
3. SOC-13: Sense of Coherence
4. PCL-5: PTSD Check-List
5. Recent illness-related events
6. Recent negative life events
7. PACT: The Perceived Ability to Cope With Trauma (Flexibility in coping)
8. CERQ short: Cognitive Emotion Regulation Questionnaire
9. MAAS: Mindfulness
10. Spirituality coping - a visual bar
11. mMOS-SS: Modified Medical Outcomes Study Social Support Survey
12. F.A.R.E.: Family Resilience Questionnaire
13. Instrumental/emotional perceived social support
14. CDRISC: Connor-Davidson Resilience Scale
15. How much are you back to yourself?
16. IPQ: Illness Perception Questionnaire

17. B-IPQ: Illness Perception Questionnaire - Brief form
18. mini-MAC: mini-Mental Adjustment to Cancer
19. Single item: what has done to cope?
20. CBI-B: Cancer Behavior Inventory
21. the MOS Adherence to medical advice scale
22. A general self-efficacy item
23. PTGI: The Posttraumatic Growth Inventory - short form
24. QLQ-C30: EORTC quality of life questionnaire
25. QLQ-BR23: EORTC quality of life questionnaire breast cancer module
26. FCRI-SF: Fear of Recurrence - short form (severity scale of original FCRI)
27. HADS: Hospital Anxiety and Depression Scale
28. DT: NCCN Distress Thermometer
29. PANAS: Positive and Negative affectivity - short form

### Retrospective Data

1. POMS Depression
2. Beck Depression Inventory variable
3. Physical functioning and emotional functioning.
4. Current perceived stress level, ptsd symptoms
5. impact of event score variable

Now those psychosocial questionnaires measure multiple scales that are recorded in the following table:

**Table 1. Psychosocial scales and measured scales**

Psychosocial questionnaires	Measured Scales
TIPI: Ten Item Personality Measure (brief "Big Five")	<ul style="list-style-type: none"> <li>• <b>Extraversion:</b> Extraversion is the state of primarily obtaining gratification from outside oneself. People with high levels of extraversion tend to feel more comfortable in social situations.</li> <li>• <b>Neuroticism:</b> is a long-term tendency to be in a negative or anxious emotional state. It is not a medical condition but a personality trait.</li> <li>• <b>Conscientiousness:</b> is about how a person controls, regulates, and directs their impulses.</li> <li>• <b>Agreeableness:</b> measures a person's tendency to be kind, empathetic, trusting, cooperative, and sympathetic. It shows how well she/he harmonizes with society.</li> <li>• <b>Openness (to new experience):</b> A person with a high level of openness to experience in a personality test enjoys trying new things. Individuals who are low in openness to experience would rather not try new things.</li> </ul>
LOT-R: Optimism/Pessimism	<ul style="list-style-type: none"> <li>• <b>Optimism:</b> refers to an emotional and psychological perspective on life. It is a positive frame of mind and means that a person takes the view of expecting the best outcome from any given situation.</li> </ul>

	<ul style="list-style-type: none"> <li>• <b>Pessimism:</b> the opposite of optimism</li> </ul>
SOC-13: Sense of Coherence	<ul style="list-style-type: none"> <li>• <b>Comprehensibility:</b> the cognitive dimension, refers to the extent to which one perceives internal and external stimuli as rationally understandable, and as information that is orderly, coherent, clear, structured rather than noise—that is, chaotic, disordered, random, unexpected, and unexplained.</li> <li>• <b>Manageability:</b> the instrumental or behavioral dimension, defined as the degree to which one feels that there are resources at one's disposal that can be used to meet the requirements of the stimuli one is bombarded by.</li> <li>• <b>Meaningfulness:</b> the motivational dimension, refers to the extent to which one feels that life has an emotional meaning, that at least some of the problems faced in life a face are worth commitment and dedication, and are seen as challenges rather than only as burdens.</li> </ul>
PCL-5: PTSD Check-List	<ul style="list-style-type: none"> <li>• <b>Post-traumatic stress disorder:</b> gives a total score of post-traumatic stress disorder.</li> </ul>
Recent illness-related events	Qualitative question for interim measurements
Recent negative life events	Qualitative question for interim measurements
PACT: The Perceived Ability to Cope With Trauma (Flexibility in coping)	<ul style="list-style-type: none"> <li>• <b>Perceived ability to focus on processing the trauma (trauma focus):</b> examines not the usage of a given coping strategy, but one's perceived capacity of using trauma focus coping strategies.</li> <li>• <b>Perceived ability to focus on moving beyond the trauma (forward focus):</b> examines not the usage of a given coping strategy, but one's perceived capacity of using forward focus coping strategies.</li> <li>• <b>Single flexibility score:</b> Represents the ability to use both types of coping (on processing the trauma and on moving beyond the trauma).</li> </ul>
CERQ: Cognitive Emotion Regulation Questionnaire	<ul style="list-style-type: none"> <li>• <b>Self-blame:</b> referring to thoughts of blaming yourself for what you have experienced.</li> <li>• <b>Acceptance:</b> referring to thoughts of resigning to what has happened.</li> <li>• <b>Rumination:</b> referring to thinking all the time about the feelings and thoughts associated with the negative event.</li> <li>• <b>Positive Refocusing:</b> which refers to thinking of other, pleasant matters instead of the actual event.</li> <li>• <b>Refocus on Planning:</b> thinking about what steps to take in order to deal with the event.</li> <li>• <b>Positive Reappraisal:</b> thinking of attaching a positive meaning to the event in terms of personal.</li> </ul>

	<ul style="list-style-type: none"> <li>• <b>Putting into Perspective:</b> thoughts of playing down the seriousness of the event when compared to other events.</li> <li>• <b>Catastrophizing:</b> referring to explicitly emphasizing the terror of a potential catastrophe.</li> <li>• <b>Other-blame:</b> referring to thoughts of putting the blame for what you have experienced on others.</li> </ul>
MAAS: Mindful Attention Awareness Scale	<ul style="list-style-type: none"> <li>• <b>Dispositional mindfulness:</b> open or receptive awareness of and attention to what is taking place in the present.</li> </ul>
Spirituality coping - a visual bar	<ul style="list-style-type: none"> <li>• <b>A single item with a single score of spirituality coping</b></li> </ul>
mMOS-SS modified Medical Outcomes Study Social Support Survey	<ul style="list-style-type: none"> <li>• <b>Instrumental social support:</b> measures assistance received from others that is tangible.</li> <li>• <b>Emotional social support:</b> measures support from others that makes us feel loved.</li> </ul>
F.A.R.E. Family Resilience Questionnaire	<ul style="list-style-type: none"> <li>• <b>Communication and cohesion:</b> corresponds to the ways in which family members inform each other about things that need to be done and to the ways in which family members show each other love and support.</li> <li>• <b>Perceived family coping:</b> Coping is a conscious intentional response to stress. Coping is often invoked to represent competence and resilience.</li> </ul>
Instrumental/emotional perceived social support	<ul style="list-style-type: none"> <li>• <b>Single item with a single score of perceived emotional support</b></li> </ul>
CDRISCCConnor-Davidson Resilience Scale	<ul style="list-style-type: none"> <li>• <b>Overall, single score of resilience</b></li> </ul>
How much are you back to yourself?	<ul style="list-style-type: none"> <li>• <b>Single item with a single Percentage score of resilience:</b> To what extent did you bounce back to your ordinary life (before illness).</li> </ul>
IPQ Illness Perception Questionnaire	<ul style="list-style-type: none"> <li>• <b>Timeline:</b> the perceived duration of the illness</li> <li>• <b>Timeline-cyclical:</b> beliefs about the predictability or cyclic nature of illness.</li> <li>• <b>Personal control:</b> the extent to which an individual has control over illness.</li> <li>• <b>Treatment control:</b> beliefs about treatment effectiveness.</li> <li>• <b>Illness coherence:</b> extent to which an individual has a clear understanding of illness.</li> <li>• <b>Consequences:</b> the expected effects of the illness.</li> <li>• <b>Emotional representations:</b> the emotional reactions to illness.</li> <li>• <b>Biological:</b> biological factors that heighten the odds of illness or impede recovery.</li> <li>• <b>Psychological/stress:</b> psychological factors that heighten the odds of illness or impede recovery.</li> <li>• <b>Environmental:</b> environmental factors that heighten the odds of illness or impede recovery.</li> <li>• <b>Health behaviors:</b> actions that heighten the odds of illness or impede recovery.</li> </ul>

B-IPQ Illness Perception Questionnaire - Brief form	<ul style="list-style-type: none"> <li>• <b>Personal control:</b> a high personal control score means that the participant perceives having good control of the illness.</li> <li>• <b>Treatment control:</b> a high treatment control score means that the participant believes the treatment is extremely helpful in managing the illness.</li> </ul>
mini-MAC mini-Mental Adjustment to Cancer	<ul style="list-style-type: none"> <li>• <b>Helplessness/hopelessness:</b> state in which a person feels an irreparable loss, the threat of death, and a lack of over the situation.</li> <li>• <b>Anxious preoccupation:</b> where the disease presents itself as a threat but where there is some doubt as to the possibility of exercising some control over the situation and its implications.</li> <li>• <b>Fighting spirit:</b> where the disease is perceived as a challenge and where the patient believes he or she can exert some control over the situation.</li> <li>• <b>Cognitive avoidance:</b> characterized by minimization of the threat and downplaying the need for personal control.</li> <li>• <b>Fatalism:</b> characterized by an attitude of passive acceptance of the disease, which the patient considers impossible to control.</li> </ul>
Single item: what has done to cope	<ul style="list-style-type: none"> <li>• <b>Reappraisal.</b></li> <li>• <b>Social support</b></li> <li>• <b>Relaxation.</b></li> <li>• <b>Distraction.</b></li> <li>• <b>Spiritual coping.</b></li> <li>• <b>Exercise.</b></li> <li>• <b>Emotion expression.</b></li> </ul>
CBI-B Cancer Behavior Inventory	<ul style="list-style-type: none"> <li>• <b>Single overall score of coping self-efficacy</b></li> </ul>
A general self-efficacy item	<ul style="list-style-type: none"> <li>• <b>Single overall score of coping self-efficacy</b></li> </ul>
MOS Adherence to medical advice scale	<ul style="list-style-type: none"> <li>• <b>Single item and a single score of adherence to medical advice</b></li> </ul>
PTGI The Posttraumatic Growth Inventory-short form	<ul style="list-style-type: none"> <li>• <b>Relating to Others</b></li> <li>• <b>New Possibilities</b></li> <li>• <b>Personal Strength</b></li> <li>• <b>Spiritual Change</b></li> <li>• <b>Appreciation of Life</b></li> </ul>
QLQ-C30 EORTC quality of life questionnaire	<ul style="list-style-type: none"> <li>• <b>Global quality of life:</b> is the general well-being of individuals, outlining negative and positive features of life.</li> <li>• <b>Physical functioning:</b> is conceptualized as being supported by physical abilities such as walking, reaching, vision, and hearing, as well as by those in the cognitive domain such as spatial orientation, short-term memory, intelligible speech, and alertness.</li> <li>• <b>Role functioning:</b> assesses a patient's ability to perform daily activities, leisure time activities, and/or work.</li> </ul>

	<ul style="list-style-type: none"> <li>• <b>Emotional functioning:</b> refers to the ability to develop and apply self-awareness, self-management and relationship management skills which enable people to understand and manage their own and others' emotions.</li> <li>• <b>Cognitive functioning:</b> any mental process that involves symbolic operations (i.e. perception, memory, creation of imagery, and thinking). Encompasses awareness and capacity for judgment.</li> <li>• <b>Social functioning:</b> defines an individual's interactions with their environment and the ability to fulfill their role within such environments as work, social activities, and relationships with partners and family.</li> </ul>
QLQ-BR23 EORTC quality of life questionnaire breast cancer module	<ul style="list-style-type: none"> <li>• <b>Functional scales:</b> <ul style="list-style-type: none"> <li>○ <b>body image sexual functioning</b></li> <li>○ <b>sexual enjoyment</b></li> <li>○ <b>future perspective</b></li> </ul> </li> <li>• <b>Symptoms scales:</b> <ul style="list-style-type: none"> <li>○ <b>systemic therapy side effects</b></li> <li>○ <b>breast symptoms</b></li> <li>○ <b>arm symptoms upset by hair loss</b></li> </ul> </li> </ul>
FCRI-SF Fear of Recurrence - short form (severity scale of original FCRI)	<ul style="list-style-type: none"> <li>• <b>Severity of fear or recurrence.</b></li> </ul>
HADS Hospital Anxiety and Depression Scale	<ul style="list-style-type: none"> <li>• <b>Anxiety levels:</b> measure levels of anxiety.</li> <li>• <b>Depression:</b> measure levels of depression.</li> </ul>
DT NCCN Distress Thermometer	<ul style="list-style-type: none"> <li>• <b>Single item with a single score of distress</b></li> </ul>
PANAS Positive and Negative affectivity - short form	<ul style="list-style-type: none"> <li>• <b>Positive mood:</b> measure positive feelings.</li> <li>• <b>Negative mood:</b> measure negative feelings.</li> </ul>
POMS Profile of Mood States	<ul style="list-style-type: none"> <li>• <b>Tension or Anxiety</b></li> <li>• <b>Anger or Hostility</b></li> <li>• <b>Vigor or Activity</b></li> <li>• <b>Fatigue or Inertia</b></li> <li>• <b>Depression or Dejection</b></li> <li>• <b>Confusion or Bewilderment</b></li> </ul>
Beck Depression Inventory	<ul style="list-style-type: none"> <li>• <b>Depressiveness</b></li> </ul>
Impact of Events Scale (IES)	<ul style="list-style-type: none"> <li>• <b>Event-specific distress</b></li> </ul>

### 4.3. Conceptualization & Implementation

For implementing the BOUNCE psychological ontology we used Protégé<sup>4</sup>, whereas the developed ontology is an RDF/S ontology. A screenshot of the high-level description of ontology out of the Protégé tool is shown in Figure 5.

**Ontology header:**

Ontology IRI: <https://www.bounce-project.eu/BPO.owl>

Ontology Version IRI: <https://www.bounce-project.eu/BPO.owl>

**Annotations:**

rdfs:comment  
A knowledge model for describing how the psychological factors affect on breast cancer

Creator  
Haridimos Kondylakis (kondylak@ics.forth.gr)

owl:versionInfo [type: xsd:decimal]  
1.0

**Ontology metrics:**

**Metrics**

Axiom	7156
Logical axiom count	1802
Declaration axioms count	1082
Class count	288
Object property count	665
Data property count	2
Individual count	5
Annotation Property count	129

**Class axioms**

SubClassOf	308
EquivalentClasses	0
DisjointClasses	41
GCI count	1
Hidden GCI Count	0

**Object property axioms**

SubObjectPropertyOf	685
EquivalentObjectProperties	0
InverseObjectProperties	106
DisjointObjectProperties	10
FunctionalObjectProperty	17
InverseFunctionalObjectProperty	1
TransitiveObjectProperty	47
SymmetricObjectProperty	77
AsymmetricObjectProperty	2
ReflexiveObjectProperty	0
IrreflexiveObjectProperty	7

**Ontology prefixes:**

Prefix	Value
BPO	<a href="http://www.semanticweb.org/BPO.owl#">http://www.semanticweb.org/BPO.owl#</a>
cito	<a href="https://www.bounce-project.eu/BPO.owl#">https://www.bounce-project.eu/BPO.owl#</a>
dc	<a href="http://purl.org/dc/terms/">http://purl.org/dc/terms/</a>
foaf	<a href="http://xmlns.com/foaf/0.1/">http://xmlns.com/foaf/0.1/</a>
obo	<a href="http://purl.obolibrary.org/obo/">http://purl.obolibrary.org/obo/</a>
obolnOwl	<a href="http://www.geneontology.org/formats/obolnOwl#">http://www.geneontology.org/formats/obolnOwl#</a>
obolnOwl1	<a href="http://www.geneontology.org/formats/obolnOwl1#">http://www.geneontology.org/formats/obolnOwl1#</a>
owl	<a href="http://www.w3.org/2002/07/owl#">http://www.w3.org/2002/07/owl#</a>
rdf	<a href="http://www.w3.org/1999/02/22-rdf-syntax-ns#">http://www.w3.org/1999/02/22-rdf-syntax-ns#</a>
rdfs	<a href="http://www.w3.org/2000/01/rdf-schema#">http://www.w3.org/2000/01/rdf-schema#</a>
subsets	<a href="http://purl.obolibrary.org/obo/ro/subsets#">http://purl.obolibrary.org/obo/ro/subsets#</a>
scio	<a href="http://purl.org/scio/ontology/terms/">http://purl.org/scio/ontology/terms/</a>

**Figure 5. A overview from Protege of the high-level description of the BPO ontology**

At the moment, the ontology contains 310 classes, 106 object properties and 10 data properties. Such an ontology is difficult to be completely presented in a deliverable and the interested reader is referred to the corresponding git repository<sup>5</sup> for further exploration.

Figure 6 illustrates the upper levels of the ontology showing which parts come from the basic formal ontology (BFO). BFO is the upper level ontology upon which OBO Foundry ontologies are built and is part of the IMC Semantic Core Ontology. At the top level, BFO introduces a distinction between continuants and occurrents. Occurrents are processes and other entities that unfold in time, i.e. entities that have temporal parts. Continuants, on the other hand, are those things that exist in full at all times that they exist, have no temporal parts, and continue to exist over an extended period of time. Within continuants, BFO further distinguishes between those entities that are independent and those that are dependent. Independent continuants can exist by themselves, while dependent continuants are those sorts of things that need a “bearer” in order to exist, such as colours, social roles, or behavioural dispositions that are realized in behaviour, a concurrent entity. In addition dependent continuants are also distinguished between generically dependent continuants and specifically dependent continuants. Specifically

<sup>4</sup> <https://protege.stanford.edu/>

<sup>5</sup> <https://cbml-gitlab.ics.forth.gr/kondylak/the-bounce-psychological-ontology>



dependent continuants, such as headaches or talents, cannot migrate from one bearer to another, as contrasted with generically dependent continuants, such as the pdf file on your laptop, which can exist in a multiplicity of bearers.

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 document class (*BPO:InformationObject*), which includes the various questionnaires used in the project. We choose to make *BPO:InformationObject* a subclass of *bfo:GenericallyDependentContinuant*. For example, the MAAS questionnaire (generically dependent continuant *D*) requires instantiation in some paper or electronic bearer (e.g., a printed questionnaire or a pdf file) *C*, but it is not particularly important for the existence of the questionnaire for which a particular bearer can instantiate it. Figure 7 lists the available questionnaires.

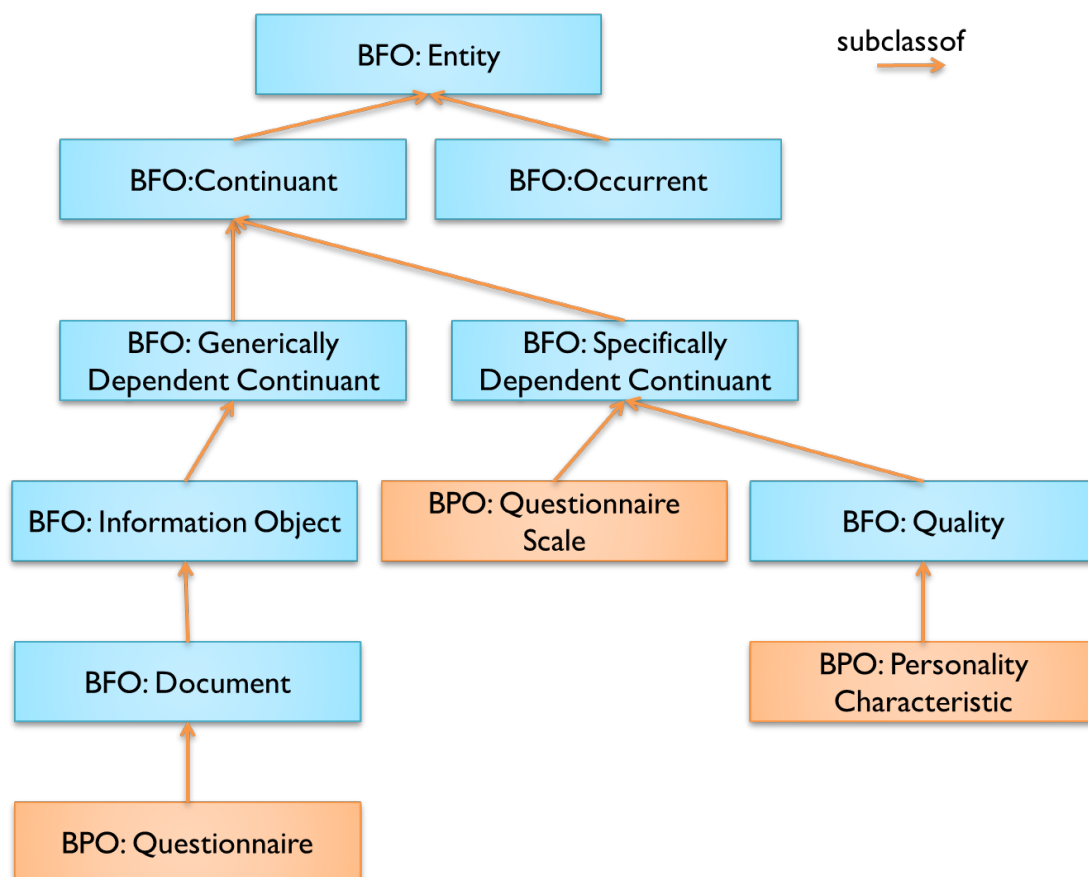


Figure 6. The Questionnaire class as subclass of the Information Object





Figure 7. The available questionnaires

Further, the ontology specifies the underlying concepts that those questionnaires measure, as shown in Figure 8. All scales have been placed as subclasses of the *BFO:SpecificallyDependentContinuant*, as according to its definition a specifically dependent continuant is a continuant that inheres in or is borne by other entities. Every instance of A requires some specific instance of B which must always be the same. Subscales within each questionnaire are also defined. For example the scales measured by the TIPI questionnaire are *BPO:Agreeableness*, *BPO:Conscientiousness*, *BPO:Extraversion*, *BPO:Neuroticism* and *BPO:Openness*.

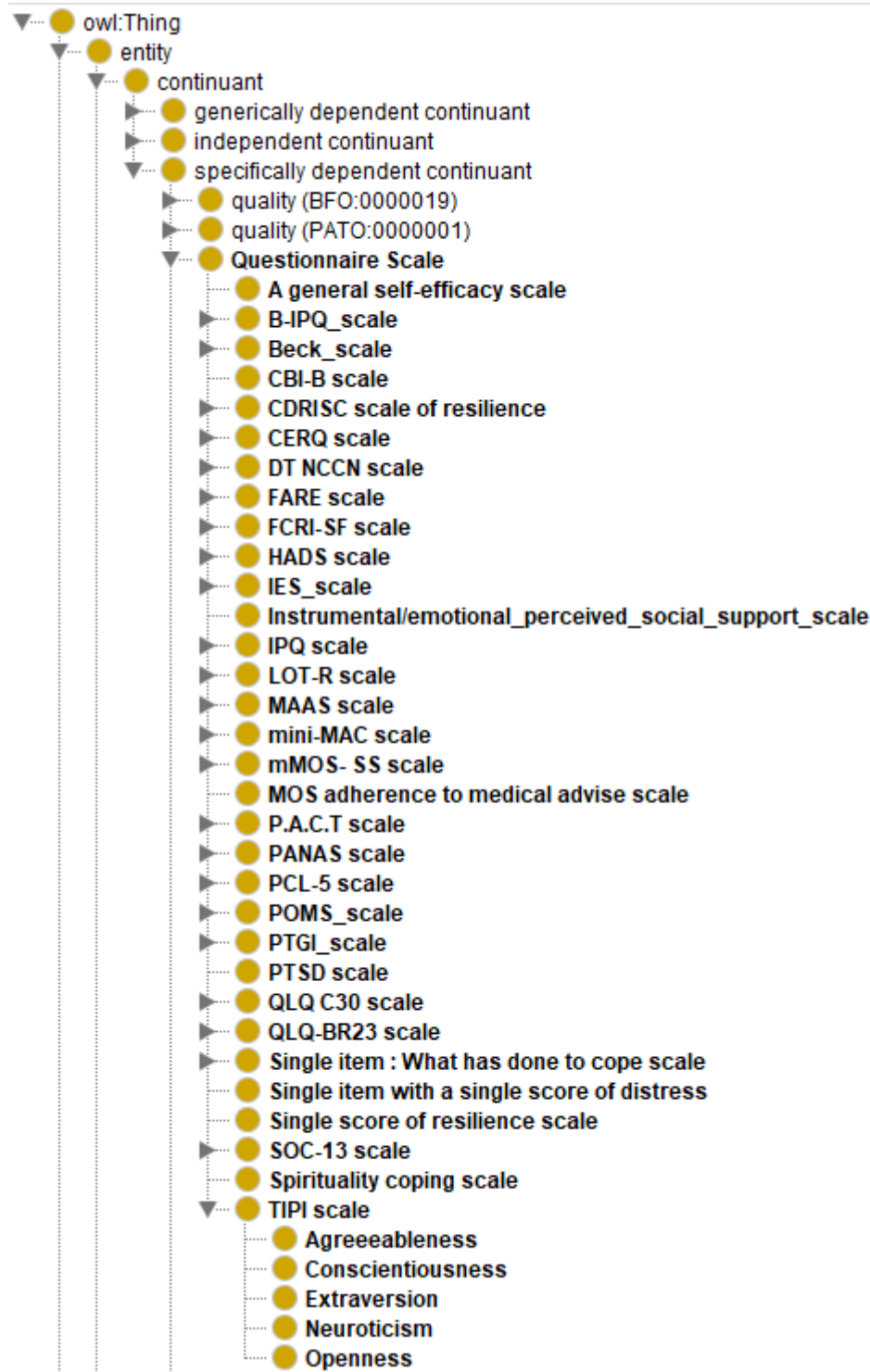


Figure 8. The scales measured by the questionnaires

Next we need to create the object properties connecting the questionnaires and the various scales. This is implemented using the appropriate object properties shown in Figure 9, whereas in Figure 10 we can see the way the questionnaires are linked with the object properties to the corresponding measured factors. For the following examples we omit the prefixes (e.g BPO) for readability reasons.

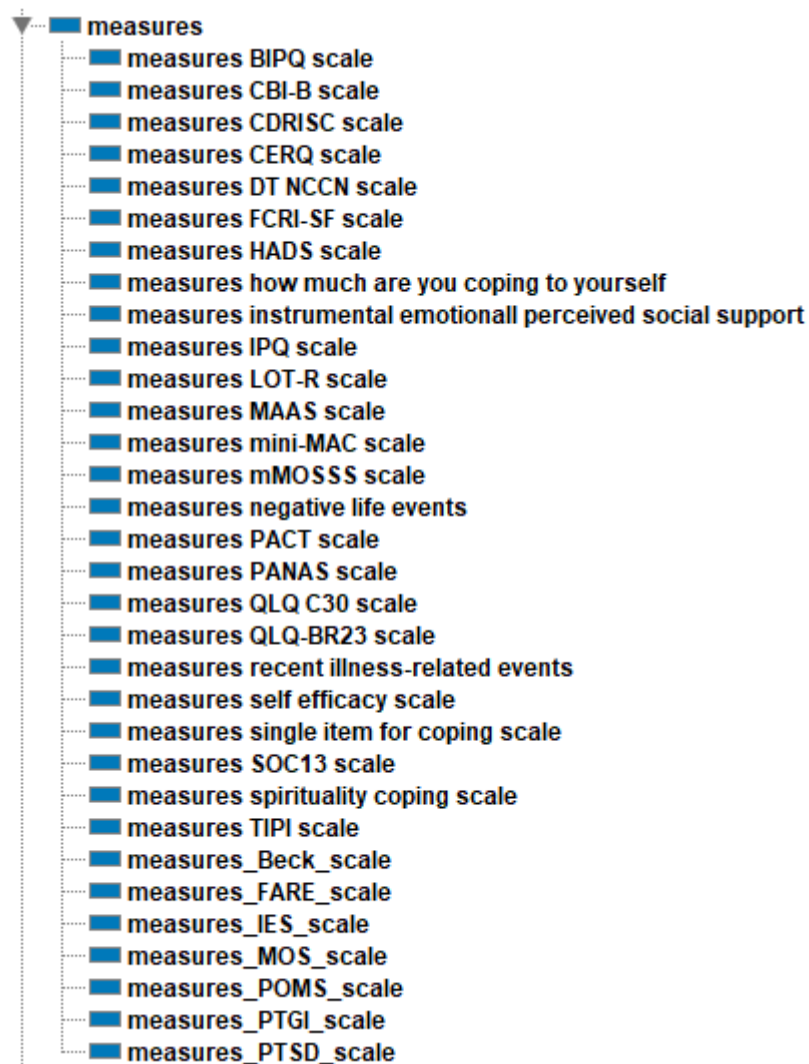


Figure 9. Object properties for linking questionnaires with measured scales

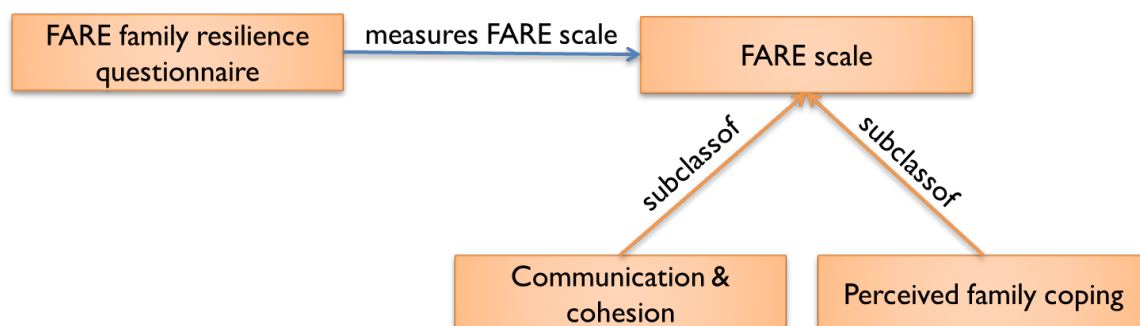
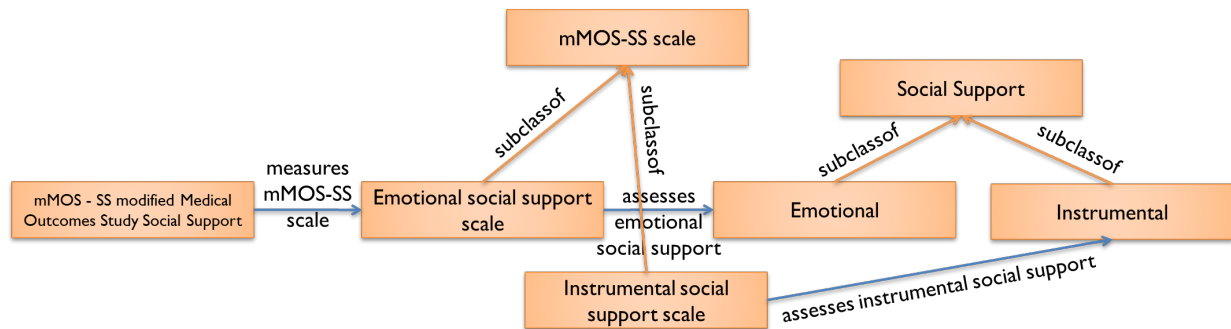


Figure 10. Object properties for linking questionnaires with measured scales

Finally, specific links between several personality and other psychosocial characteristics have been incorporated into the ontology based on the extant literature captured through discussions with the experts. These personality characteristics have been placed under the *BPO:Quality* class.

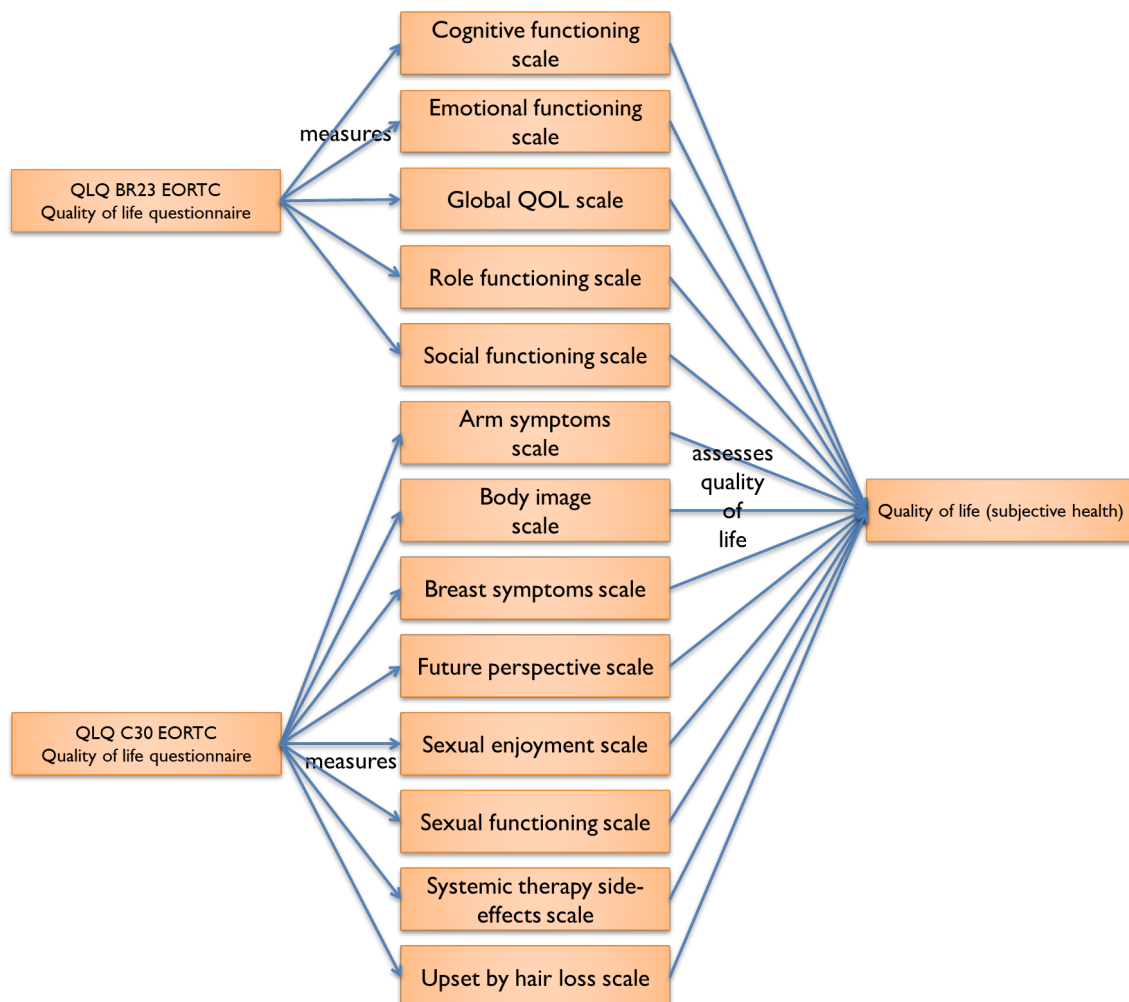
An example, illustrated in Figure 11, shows that social support entity can be conceptualized as two partially distinct dimensions: emotional support (measured by the emotional social support

scale) and instrumental support (measured by the instrumental social support scale) both measured through the mMOS-SS questionnaire.



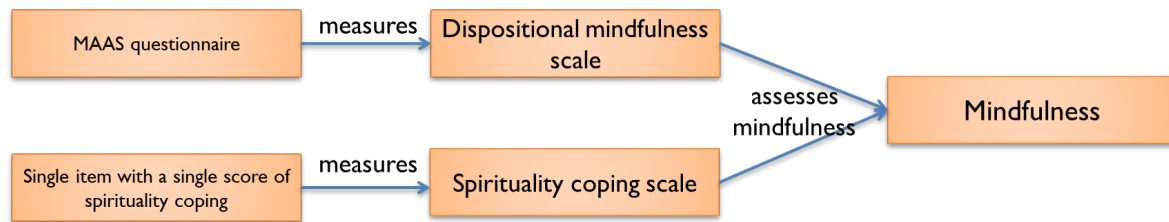
**Figure 11. Assessing emotional and instrumental social support through the mMOS-SS questionnaire**

On the other hand quality of life, as shown in Figure 12 is assessed by multiple scales, measured by two EORTC questionnaires.



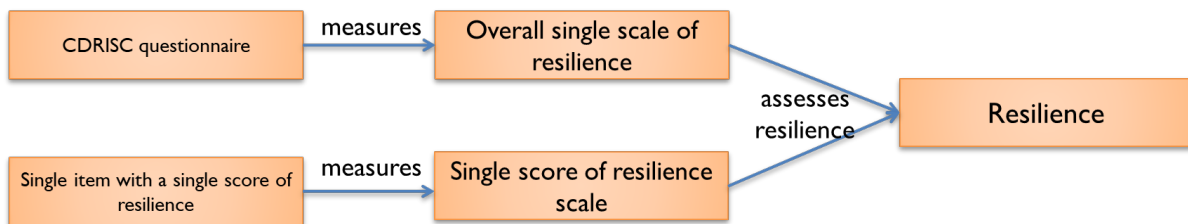
**Figure 12. Assessing quality of life through two questionnaires**

Regarding mindfulness, as shown in Figure 13, it is similarly assessed by multiple scales, measured by two questionnaires, the MAAS questionnaire and the spirituality coping questionnaire.



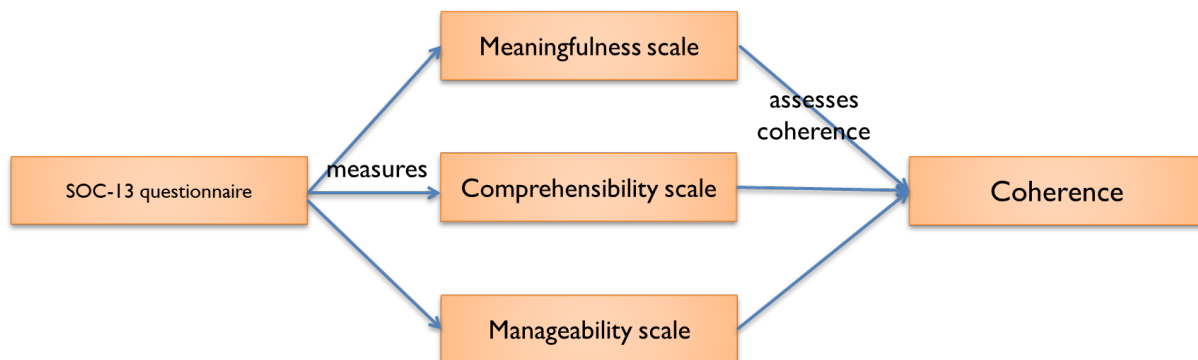
**Figure 13. Assessing mindfulness through two questionnaires**

Regarding resilience, as shown in Figure 14, it is assessed by multiple scales, measured by two questionnaires, the CDRISC questionnaire and the single item with a single scope of resilience questionnaire.



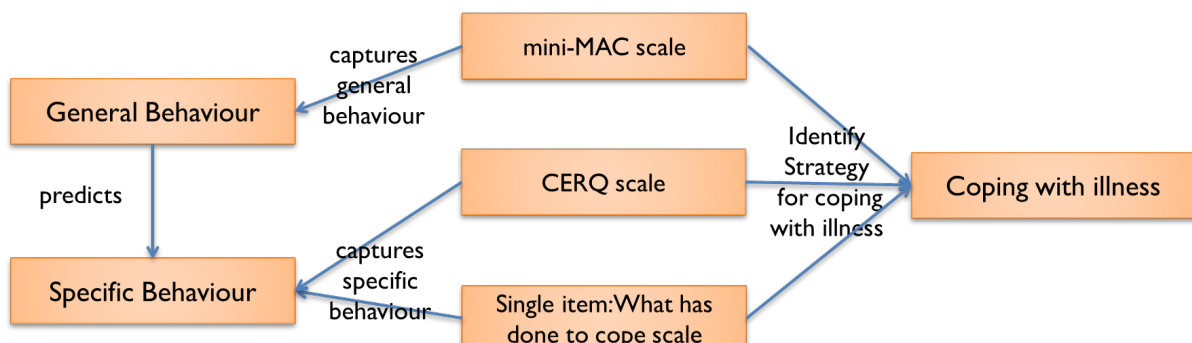
**Figure 14. Assessing resilience through two questionnaires**

Regarding coherence, as shown in Figure 15, it is assessed by multiple scales, measured by the SOC-13 questionnaire.



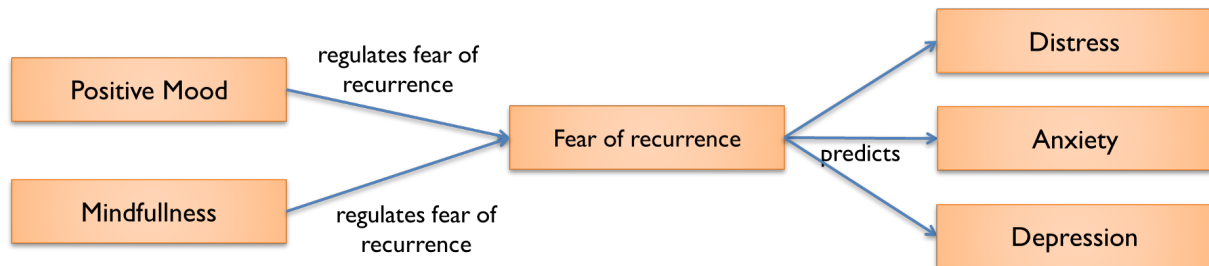
**Figure 15. Assessing Coherence**

To identify strategies for coping with illness, as shown in Figure 16, we can use mini-MAC scales, CERQ scales and scales provided by the “Single item: What has done to cope” questionnaire. mini-Mac scales capture general behaviours, whereas CERQ and “Single item: What has done to cope” scales capture specific behaviours. In addition, general behaviours can predict specific behaviours according to the extant bibliography.



**Figure 16. Identify strategies for coping with illness**

Finally there are multiple relationships between personality characteristics, implemented through various object properties. An example is shown in Figure 17 where positive mood and mindfulness regulate the fear of recurrence. On the other hand the fear of recurrence predicts distress, anxiety and depression.

**Figure 17. Example of interconnections between personality characteristics**

#### 4.4. Documentation

Beck Depression Inventory (BDI) — [https://www.bounce-project.eu/BPO.owl#Beck\\_Depression\\_Inventory](https://www.bounce-project.eu/BPO.owl#Beck_Depression_Inventory)

Class Annotations
Class Usage

Annotations: Beck Depression Inventory (BDI)

Annotations +

**rdfs:label** [language: en]

Beck Depression Inventory (BDI)

**rdfs:comment** [language: en]

Description of Measure: The Beck Depression Inventory (BDI) is a 21-item, self-report rating inventory that measures characteristic attitudes and symptoms of depression (Beck, et al., 1961). The BDI has been developed in different forms, including several computerized forms, a card form (May, Urquhart, Tarran, 1969, cited in Groth-Marnat, 1990), the 13-item short form and the more recent BDI-11 by Beck, Steer & Brown, 1996. (See Steer, Rissmiller & Beck, 2000 for information on the clinical utility of the BDI-11.) The BDI takes approximately 10 minutes to complete, although clients require a fifth - sixth grade reading level to adequately understand the questions (Groth-Marnat, 1990).

Internal consistency for the BDI ranges from .73 to .92 with a mean of .86. (Beck, Steer, & Garbin, 1988). Similar reliabilities have been found for the 13-item short form (Groth-Marnat, 1990). The BDI demonstrates high internal consistency, with alpha coefficients of .86 and .81 for psychiatric and non-psychiatric populations respectively (Beck et al., 1988).

References

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Beck, A. T., Steer, R.A., & Garbin, M.G. (1988) Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. Clinical Psychology Review, 8(1), 77-100.

Groth-Marnat G. (1990). The handbook of psychological assessment (2nd ed.). New York: John Wiley & Sons.

Hojat, M., Shapurian, R., Mehrya, A.H., (1986). Psychometric properties of a Persian version of the short form of the Beck Depression Inventory for Iranian college students, Psychological Reports, 59(1), 331-338.

Steer, R. A., Rissmiller, D. J. & Beck, A.T., (2000) Use of the Beck Depression Inventory with depressed geriatric patients. Behaviour Research and Therapy, 38(3), 311-318.



**Figure 18. Documenting BDI class.**

The introduced classes and properties have been documented adding relevant useful information using the *rdfs:comment* annotation property. An example is shown in Figure 18, where the class Beck Depression Inventory is documented, providing a description of the questionnaire and proper references.

## 4.5. Evaluation

Although the quantity of the available ontologies on the web has dramatically increased, assessing their quality and suitability for specific applications remains a difficult task. To this purpose a variety of frameworks and metrics have been defined [6]. Independent of the specific methods employed, two principal, complementary evaluation methods are usually adopted: The “glass box” or “component” evaluation and the “black box” or “task-based” evaluation, each assessing distinct ontology properties.

Glass box evaluation assesses the adequacy of the ontology as a logically structured representation of some domain of reality [7]. It evaluates domain coverage, task orientation and logical/structural assessment of the ontology, including the submodules from which the ontology is consisted of. Black box evaluation on the other hand, focuses on the completeness of the ontology as a functional computational system, evaluating its effective application on specific tasks, user-friendliness and agreement of domain experts on the terms adopted. The black box evaluation is carried out by end-users. In this deliverable we will focus on the glass box evaluation as complete experiences from using the ontology will be reported in D3.4, presenting in detail experiences from ontology usage for data harmonization.

In this context we propose to employ the following glass box methods to evaluate the BPO ontology:

- Logical soundness
- Application domain coverage & task orientation
- Re-use of existing ontologies
- Common pitfalls in ontology development

### 4.5.1.1. Logical soundness

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 [8] and the Hermit [9] reasoners. Constant consistency checks during the development process are highly important in order to facilitate troubleshooting, once inconsistencies occur, and to facilitate the tracking down of erroneous logical definitions.

### 4.5.1.2. Application domain coverage & task orientation

Validating domain coverage is crucial to ensuring the usability of an ontology. For the BPO ontology we questionnaires and scales were restricted to those specified by the domain experts in the BOUNCE group following extensive discussions. As such we expect that the ontology is able to completely model the psychological data available within the project. The ontology is going to be used for generating the mappings between the ontology and the data sources. As

soon as those mappings are available, the data can be automatically integrated and homogenized, enabling access to them through a standard terminology service as linked data. Nevertheless this is yet to be verified as the mapping process between the ontology and the available data will be finalized during the following months. The process for mapping ontology to the sources will be described in detail in D3.4.

#### *4.5.1.3. Re-use of existing ontologies*

The BPO re-uses two ontologies of the OBO Foundry [10], which is a library of ontologies built to meet the same quality criteria and to provide ontological reference for different domains of the life sciences. As already explained those are the Basic Formal Ontology (BFO) and the Relation Ontology (RO). The OWL implementations of BFO and RO are directly imported into the OWL file of the ontology and the two related files are also provided in the git repository.

#### *4.5.1.4. Common pitfalls in ontology development*

Finally, we employ an automated web-based tool, namely OOPS!, to automatically identify common errors in ontology development that could lead to modelling errors [11]. 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.



## 5. Conclusions

In this deliverable, we present the final version and modules of the BOUNCE semantic model, focusing on the novel module developed specifically for modelling BOUNCE psychological data. As such we explained in detail the methodology followed for developing BPO, presenting the modelling choices made, and showing several modelling examples. Then we described how the ontology is documented and we presented its glass box evaluation results.

We have to note that ontologies are living artefacts and subject to continuous change. As such, although the title of this deliverable implies that ontology development within BOUNCE 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.

The ontology developed will be used to generate mappings to the prospective data sources in order to be subsequently homogenized, integrated and semantically uplifted (external data do not contain psychological variables and retrospective do not contain scales that can be combined with the prospective data). The results of this process will be described in D3.4 Solutions for Data Aggregation, Cleaning, Harmonization & Storage.

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