A Knowledge-Based Approach to the User-Centered Design Process

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Abstract. User-Centered Design is an approach for designing usable products and systems, which encompasses a collection of techniques, procedures and methods, placing the user at the center of all of them. Our current research is focused on two methods: Personas and Usability Testing. While one is used for communicating user requirements, the other one is used to evaluate a product's ease of use by observing the users behavior. Although both methods are used to collect data regarding user needs, preferences and behavior, little research has been conducted linking the collected data with other pieces of data concerning the product development and design process. This paper considers the use of semantic web technologies, such as microdata and ontologies, in order to provide a conceptual model as a basis for structuring, extracting and linking data collected via these two methods. Our approach consists of a set of HTML5 microdata schemas and an OWL specification, which include concepts and properties used to model personas and usability testing. In order to exemplify our model and extract desired data, we made use of semantically annotated templates for personas method and usability testing.

Keywords: Knowledge Modeling, User-centered Design, Ontology, Microdata, Personas, Usability Testing.

1 Introduction

Although numerous articles exist in literature regarding the User-Centered Design (UCD) and its corresponding techniques and methods, at its core it consists the following basic principles: "Early focus on users and their tasks; Evaluation and measurement of product usage; Iterating design" [1]. With these principles in mind we will be focusing on two widely used methods from UCD: *Personas* and *Usability Testing*.

A *persona* (term initially proposed by Cooper [2]) is regarded as a user archetype which can be used to "help guide decisions about product features, navigation, interactions, and even visual design" [3]. Ultimately, this archetype represents a group of users who share common behavioral or physical characteristics, goals, frustrations and preferences. Although it encompasses all this data regarding different users, it has one goal: to develop a profile of potential users for a certain product or system.

On the other hand "usability testing employs techniques to collect empirical data while observing representative end users using the product to perform realistic tasks" [1]. Users participating in a test are selected based on a persona, in order to identify direct users of that product/system.

A. Fred et al. (Eds.): IC3K 2012, CCIS 415, pp. 165–178, 2013.

As we can denote both methods are centered around the user, and although they are part of the same UCD process, it is difficult to establish connections and integrating the collected data (from both methods).

In order to tackle these issues, we consider the adoption of semantic web technologies [4]. RDFa[1] and microdata[2] enable the publication, extraction and reuse of data (in our case, (meta)data already stored into a HTML5[3] document). Our aim is to propose a conceptual model which consists of a set of HTML5 microdata schemas to be used in the personas and usability testing methods. By providing such an infrastructure of microdata schemas, we facilitate data extraction and – at the same time – linking that data extracted with data from other sources.

We also take into account ontologies, which provide semantics for humans and formalism for machine processing and reasoning. We propose *PersonasOnto* ontology as a way of modeling personas related concepts (such as usability testing). It provides an overview of the relationships between these methods and how they integrate in the UCD process.

This paper is an updated and revised extended version of the work presented in [5].

In the following, we first summarize related work in Section 2. Section 3 illustrates HTML5 microdata schemas and corresponding templates. Section 4 presents the *PersonasOnto* ontology and Section 5 illustrates a use case of the vocabulary. The paper ends with a conclusion and an outlook on future work.

2 Related Work

Several approaches on describing persons and user profiles have been presented in the last years, with vocabularies such as FOAF[4], SIOC[5] and Person[6]. At the same, the need for software systems [6] to automatically adapt to their users has increased, this resulted in an increased attention over the user's preferences and needs, disabilities and emotional status. In order to have a better understanding of the user, a number of domain specific ontologies concerning user profiles have been developed. Although most of these vocabularies focus on how the profile of a user can be described, most of them do not incorporate important aspects regarding the user requirements and user testing from a certain product.

Work has also been done in the direction of mapping between users, accessibility concepts and accessibility scenarios, in the AEGIS ontology[7].

A number of ontologies – as [7,8] – explore the implications of user models in the context of recommender systems, while others such as [9] present a generic ontology-based user modeling architecture applied in Knowledge Management Systems. Some of

[1] http://www.w3.org/TR/rdfa-core/
[2] http://www.w3.org/TR/microdata/
[3] http://www.w3.org/TR/html5/
[4] http://xmlns.com/foaf/spec/
[5] http://rdfs.org/sioc/spec/
[6] http://schema.org/Person
[7] http://www.aegis-project.eu/

the work in this direction is concerned with providing a standard ontology for modeling user profiles in order to facilitate communications between applications [10].

The review of the related work showed that most vocabularies emphasize the importance of context awareness, more details on this aspect and other relevant user modeling issues are reviewed in [11]. Furthermore, many of the proposed vocabularies focus on the user's profile, without exploring what are the implications of the user's preferences, goals and frustrations on the product or system.

3 Using Microdata to Structure Information

Even though a persona represents a fictional individual, it is created based on a group of persons. In most instances each person is interviewed, in order to establish the specific group it belongs to [12]. The data collected during these interviews is included into the persona document [13]. In this document, each archetype is developed in greater detail, along with scenarios which describe how it might interact with a product. The persona and their associated scenarios form the basis for specifying how users want to experience and interact with a certain product or application.

As with the *persona* method usability tests are based mainly on user interviews and observations, and are traditionally conducted with one test participant at a time ([14]), in the same manner as a controlled experiment. This data is compiled and interpreted using statistics or presented as is.

3.1 Personas and Usability Test Templates

As a first layer to structuring the information, we developed HTML5 templates for both the personas[8] and usability test[9], following existing guidelines [15,12,16] and the standards for usability test[10]. Both HTML documents contain information which can be semantically annotated by using microdata/RDFa, thus facilitating publication, consumption, and reuse of information.

The personas template is structured as follows:

1. *Type and Background Information* – contains details regarding the persona type and fictional background information such as birthday, name, gender, location and other information of interest;
2. *Main Details* – consists of a detailed description regarding this persona along with some characteristics (main points), goals and frustrations;
3. *Scenarios* – includes either a description of scenario tasks or images depicting scenarios;
4. *Other Details* – contains other relevant notes regarding the persona.

On the other hand, the usability test template is more complex focusing on of two main components:

[8] Publicly available at: `http://blankdots.com/open/personas/`
[9] Publicly available at: `http://blankdots.com/open/usability/`
[10] ISO/IEC 25062:2006 "Common Industry Format (CIF) for usability test reports".

1. *Test Plan* – contains usability testing procedures and objectives, tasks and scenario;
2. *Test Report* – includes findings, objectives achieved, answers to user questions, task completion time etc.

The *Test Plan* component is structured as follows:

1. *Main Details*: contains details regarding which component of a certain product or software application is being tested, the persona ([16,13]) type tested, context and duration of a test. Additional information regarding the tested person is gathered at this stage via the *User Background Information Form*;
2. *Overall Objectives*: consists of a list of objectives of a test, what we want to study or to evaluate;
3. *Scenario*: includes either a description of scenario tasks or images depicting a scenario;
4. *User Tasks and Post-Test Questions*: contains user tasks description and estimated completion time along with a series of post-test questions (which later will help to conclude the findings of the test);
5. *Other Notes*: denotes other details regarding the way this usability test is conducted.

The second component *Test Report* contains the following:

1. *Success Criteria*: the usability test is considered successful only if a certain percentage of users completed a pre-established criteria (for example: a certain task was completed in 2 minutes);
2. *Summary*: consists of a list of major findings/observations done by the test observer;
3. *Demographics*: includes personal details of the users that participated in the usability test;
4. *Interaction Notes*: a detailed descriptions of the participants' interactions. The notes can be separated by task, category, or whatever makes most sense for this test;
5. *Post-test Questions Answers*: answers to the post-test questions;
6. *Test Observations*: notes attached to the usability test (written, video or audio);
7. *Potential Design Improvements*: a list of potential design improvements as proposed by the tested user.

In the next section we will discuss how we can make use of this HTML template and annotate relevant data using existing vocabularies and our proposed vocabulary.

3.2 Microdata Schema

One advantage of the HTML5 microdata is that it is designed such that each piece of information in a document has assigned types from a single vocabulary, though each entity may have several types and properties from other vocabularies[11].

Because `schema.org` allows the extension of existing schemas, we made use of them in this section by proposing the Personas and Usability Testing schema[12] extension. As represented in Table 1, we proposed a set of new properties such as *personaType*, *tagLine*, *mainPoint*, *frustrationPoint*, *endGoal*, *scenario*, *context* and other.

Table 1. Persona Schema Properties and Description

Property	Expected Type	Description
personaType	Text	The type of Persona: Primary, Secondary, Negative, Supplemental, Served or Customer.
experienceGoal	Text	Experience goals are simple, universal, and personal.
endGoal	Text	End goals represent the user's motivation for performing the tasks associated with using a specific product.
lifeGoal	Text	Life goals represent personal aspirations of the user that typically go beyond the context of the product being designed.
businessGoal	URL or Text	Business goals represent the goals of the organization the persons works for.
technicalGoal	Text	Technical goals reflect technical aspects regarding an application/product for example: run in a variety of browser, data privacy etc.
disability	Disability or Text	A persona disability/disabilities relevant to accessibility aspects of the application/product.
myersBriggs	Personality or Text	Inspired by FOAF Myers Briggs personality classification which includes 16 4-letter textual codes [17].
topicInterest	Thing	A thing of interest for a certain persona, inspired by FOAF topic interest.
affectiveState	Emotion or Text	The affective state of the user at a certain moment, if a proper schema is not used, please provide a certain emotion using text format.
frustrationPoint	Text	Elements of a UI/UX or certain characteristics that frustrate the user or (s)he sees as pain points. These elements will help in usability evaluation.
userRole	Text	The role of the user in the application/product (if necessary – for example: admin, basic user etc.).
scenario	Scenario or URL	The scenario where the users represented by this persona will be used to test the usability.
context	Context	Description of the context that best fits a scenario recommended values: Physical/Virtual.

Some properties like *myersBriggs* and *topicInterest* were inspired from the FOAF vocabulary.

Properties like *minHeigh*, *maxWeight*,*minFeetSize* (along with others presented in Personas and Usability Testing schema) refer to a persona body measurement such as height, weight, bust size, waist size, and feet size. We used min and max values instead of a range, due to the fact that they are more precise than a range.

Along with some of the new properties, we proposed several additional schemas like *Disability*, *Personality*, *Emotion*, *Scenario* and *Context* (some of which are also used by the *UsabiliyTest* schema), in order to provide a more detailed vocabulary which fits our purposes. These schemas themselves come along with new properties and a range which specifies expected data types.

[11] `http://www.w3.org/TR/html-data-guide/`

[12] Publicly available at: `http://blankdots.com/open/schema/`

The *Scenario* schema has the following new properties and expected data types:

- *product*: A product (subject of a given usability test); for example, a software application or even a physical product such as mobile phone or car. Expected Type: Product or Application;
- *scenarioName*: Scenario name. Expected Type: Text;
- *userTask*: Tasks to be performed by the user. Expected Type: Text;
- *productTask*: Task performed by the product in response to the user. Expected Type: Text;
- *interactionMedium*: The medium of interaction; for example, Touch, Gestural, Mouse+keyboard etc. Expected Type: Text;
- *description*: Description of the scenario. Expected Type: URL or Text;
- *context*: Scenario context. Expected Type: Context;
- *participant*: Participants to this scenario. Expected Type: Person;
- *usabilityTest*: Usability test. Expected Type: UsabilityTest or Text;
- *evaluatedElements*: Focus/key elements in this scenario, tested later on, for example notifications element from the user interface. Expected Type: Text.

The *Disability* schema contains the following properties: *visualImpairment*, *hearingImpairment*, *gustatoryImpairment*, *somatosensoryImpairment*, *intellectualImpairment*, *mentalEmotionalDisorder*, *developmentalDisability*.

The *Context* schema has the following properties:

- *contextType*: Context type – recommended values: Physical/Virtual or Tangible/Intangible;
- *location*: Useful information about the location;
- *event*: An event has a location and a time;
- *geo*: The geographical coordinates of the context;
- *sensorData*: Sensors context data;
- *photos*: Photographs regarding the context;
- *reviews*: A set of reviews regarding the context.

The core of the *Usability Testing* described in Table 2. We introduced the *expectedAnswer* and *givenAnswer* properties, as some usability test scenarios require *control answers*, which can used as a reference point in order to compare them with the answers received during the usability test.

Alongside the core of the usability test schema, we identify the following properties for the *Task* schema (which in a bigger picture is part of the Workflow class):

- *taskType*: Could be an interactive task (performed by the user) or a non-interactive task (e.g. a feedback from the product/application).
- *taskPerformer*: A task could be performed by a Person, Product or Software Application.
- *estimatedTime*: The estimated length of time it takes to do the task, in ISO 8601 duration format.
- *completionTime*: The completion time of a task, in ISO 8601 duration format.
- *action*: A user or software/product performed action.
- *inputValue*: A user or software/product input value.
- *taskResult*: A user can complete the task, skip it or have trouble with it.

Table 2. Usability Testing Schema Properties and Description

Property	Expected Type	Description
productTested	Product or Application	A product is used in this scenario, it could be a software application or even a physical product (e.g. laptop or mobile phone).
componentTested	Text	A component of the product/sofware application that is being tested.
personaTested	Persona	The *persona* to be tested.
inspectionMethod	Text	Guidelines for examining the usability aspects of a UI design – inspired by [18].
testingMethod	Text	Method used for testing – inspired by [18].
participant	Person	Participant to the test (observer or user).
testDuration	Duration	The length of time it takes to do the test – ISO 8601 duration format.
context	Context	Description of the context that best fits a scenario.
scenario	Scenario	The scenario where the users represented by this persona will be used in the usability tests.
testObjective	Text	The objective/goal of the usability test.
userTask	Task or Text	Tasks to be performed by the user.
testQuestion	Text	A question presented to the user before/during/after the test.
successCriteria	Text	A successful design has been achieved when: 50% of users or 80% of users... etc.
testFinding	Text or URL	A finding extracted after performing the usability test. (e.g. "A number of users (specify the number) did/found..") – can be positive or negative finding.
recommendation	Text or URL	Recommendations to those findings can be issued, depending on the findings.
expectedAnswer	Text	An answer we expect to obtain to a certain question.
givenAnswer	Text	An answer that we obtained to a certain question.

With the inclusion of the *completionTime* property, we take into consideration that a user might complete a task in a shorter or greater amount of time than that estimated – *estimatedTime*. In case that the *completionTime* exceeds the *estimatedTime* then there is a problem with the task and/or the estimated completion time.

We must also take into account that a user might skip the current task, thus the *completionTime* would be **0**. For this reason, we added the *taskResult* property which provides a description the user thoughts on the task, how (s)he manages to complete it or why (s)he skipped or had trouble with the task. For example, a user might skip the task due to an unexpected error, inability to understand the task or due to a certain event that arises (e.g. the phone rings).

Although microdata is an easy way of annotating HTML document, it cannot express two aspects that RDFa supports: datatypes of literals and XML literals [19].

In the next section we will present the *PersonasOnto* ontology as an extension of the microdata schemas presented above.

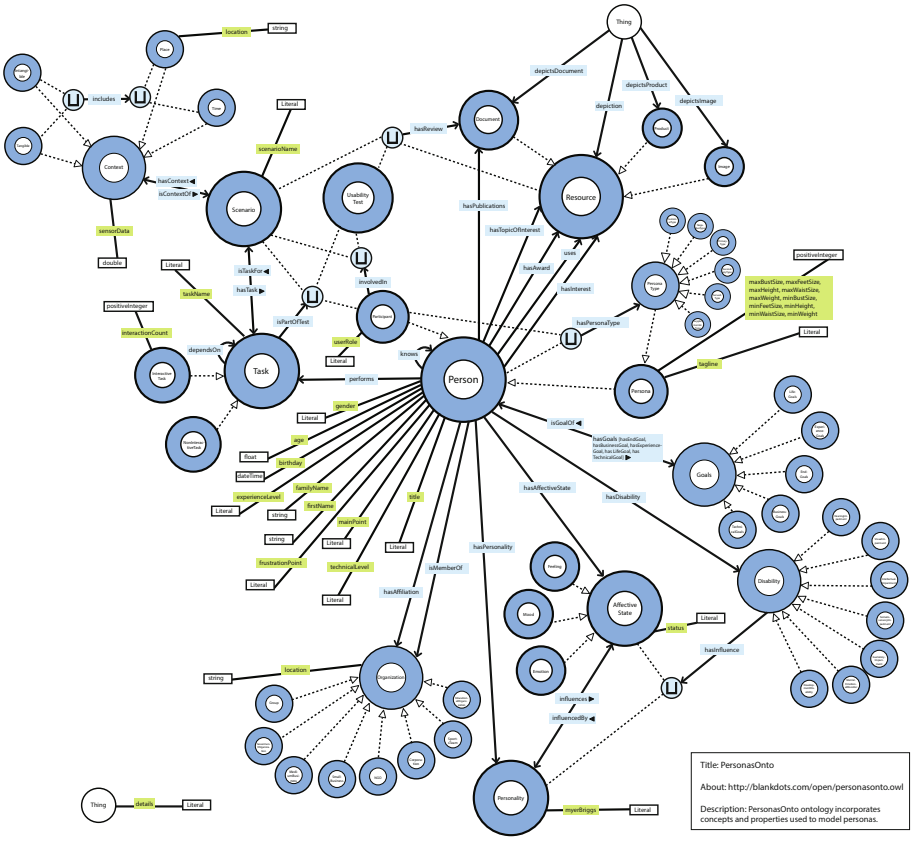

Fig. 1. Overview of the PersonasOnto ontology classes and properties using [20]

4 PersonasOnto Knowledge Engineering

As we previously mentioned, several widely used vocabularies like FOAF and `schema.org/Person` could be utilized, thus we applied such vocabularies to annotate information in our HTML template.

The *PersonasOnto*[13] ontology, provides a mean of annotating XHTML[14] and HTML documents with RDFa, but it can also be mapped in its RDF[15] representation to HTML5 microdata.

Table 3 presents an overview of the proposed ontology classes and subclasses and Figure 1[16] provides a graphical representation of the ontology classes and properties.

The *Person* class is the main one in the ontology, because it contains relevant characteristics such as age, gender, name, date of birth, concerning an individual but also

[13] Publicly available at: `http://blankdots.com/open/personasonto.owl`
[14] `http://www.w3.org/TR/xhtml1/`
[15] `http://www.w3.org/RDF/`
[16] `http://blankdots.com/open/data/personasonto_vowl.svg`

Table 3. PersonasOnto Ontology Classes

Class Name	Subclasses	Class Description
AffectiveState	Emotion, Feeling, Mood	The affective state of a person at a certain point.
Context	Intangible, Tangible, Place, Time	The Context in which a scenario takes place.
Disability	VisualImpairment, HearingImpairment, GustatoryImpairment, IntellectualImpairment, MentalEmotionalDisorder, SomoatosensoryImpairment, DevelopmentDisability	A person's disabilities mental and physical.
Goals	BusinessGoals, EndGoals, ExperienceGoals, LifeGoals, Technical Goals	The goals of a Persona.
Organization	Corporation, EducationalOrganization, GovermentOrganization, Group, MediumBusiness, NGO, SmallBusiness, SportsTeam	The type of Organization a Person belongs to.
Person	Participant, Persona	Basic information about a person and more precisely about a participant or a persona.
Personality	–	The MyersBriggs personality of a person.
Resource	Document, Image, Product	Type of resources available.
Scenario	–	A series of tasks the user performs in a certain context.
Task	InteractiveTask, NonInteractiveTask	Tasks performed by a Person in a Scenario. InteractiveTask could be certain action performed by a user, NonInteractiveTask could be a machine response to that action.
UsabilityTest	–	A usability test evaluates the usability of a certain Product in a Scenario.

is the super class of the *Persona* class. The*Persona* class could be regarded of being a separate identity of a person, although by definition has the same characteristics as the *Person* class. Also, as we previously mentioned, a persona represents a collection of preferences, goals, frustrations identifiable with a group of persons, and usually has a context associated.

Some of the classes like *AffectiveState*, *Personality*, *Disability*, *Organization* are used to describe several characteristics or a person like an emotion (e.g. anger), a disability (such as partial blindness), his/her personality (e.g. ESTJ – Extroversion, Sensing, Thinking, Judgment) and the organization (s)he works for, or (s)he is in.

Other classes like *Context*, *Scenario*, *Task*, *Goals*, *UsabilityTest* and subclasses *PersonaType* are connected with the *Persona* subclass. For example, a persona has a certain type (Primary, Secondary, etc.), has the characteristics of a (fictional) person, has

certain life or experience *Goals*, (s)he performs certain tasks in a scenario. The scenario is placed in a certain context and can be also used in a usability test.

Many of the classes, subclasses and properties are the same as in the *Persona* schema described in the previous subsection. On the other hand, classes like *UsabilityTest*, *Person*, *Scenario* and *Task* have certain properties which better define the relationship between them. Such a property is expressed below in Turtle[17] format.

```
###  personasOnto.owl#isPartOfTest
:isPartOfTest rdf:type owl:ObjectProperty ;
     rdfs:range :UsabilityTest ;
     rdfs:domain [ rdf:type owl:Class ;
           owl:unionOf ( :Person
                         :Scenario
                         :Task )].
```

The *Context* Class includes a tangible (physical world) or intangible (virtual world) environment, but also could specify spatial and temporal concepts. This inclusion is expressed below.

```
### personasOnto.owl##includes
:includes rdf:type owl:ObjectProperty ;
    rdfs:range [
      rdf:type owl:Class ;
           owl:unionOf ( :Place
                         :Time )] ;
     rdfs:domain [
       rdf:type owl:Class ;
            owl:unionOf ( :Intangible
                          :Tangible )].
```

In the next section, we will focus on presenting a use case.

5 Use Cases

In order to illustrate how our model could be used, we provided both HTML templates (in a small scale experiment) to several teams working on different projects in order to integrate them in their UCD process and fill it up with data. The first challenge the team faced was to gather data for the personas document. The second challenge was extracting the user characteristics in order to select participants for the usability test.

The third and last challenge was to collect data for the usability test by interviewing and observing the test participants. At the end of each test, they compiled the data into the HTML template provided.

To exemplify how the conceptual model was used to structure data collected from the UCD process, we selected one of the projects from a single team. The purpose of the project we chose was to develop an application for monitoring hospital patients.

[17] http://www.w3.org/TR/turtle/

The data from the usability testing document for this project is presented below. We made used of Microdata to RDF Distiller[18] tool, in order to extract data from the template – expressed as RDF triples in the Turtle format.

```
[ a schema:UsabilityTest;
## general information regarding the test ##
    schema:productTested "Product"@en-us;
    schema:componentTested "Searching a patient
           and viewing his personal details"@en-us;
    schema:personaTested [ a schema:Persona;
       schema:personaType "Primary"@en-us ];
    schema:context [ a schema:Context;
       schema:location " University of Medicine
       "@en-us ];
    schema:testDuration "P5M"^^xsd:duration;
    schema:testObjective [ a rdf:Bag;
        rdf:_1 "Assess the overall effectiveness
           of the PaMI application for medical staff
           performing the search for a patient;"@en-us,
        rdf:_2 "Evaluate the time it takes users to
           find a patient through the search interface;
        "@en-us,
        rdf:_3 "Have an evidence of the users that
            needed the Online Help in order to do this
            task and ask them if it was helpful;"@en-us,
        rdf:_4 "Test if the terminology and the
            labels makes the application understandable;
        "@en-us ];

## details of some of participants in the test ##

    schema:participant [ a schema:Person;
       schema:gender "Male"@en-us;
       schema:name "User 1"@en-us ];
    schema:participant [ a schema:Person;
       schema:gender "Female"@en-us;
       schema:name "User 2"@en-us ];

## test report ##

    schema:successCriteria [ a rdf:Bag;
       rdf:_1 "50% of users did not used the Online
          Help in order to perform the task"@en-us,
       rdf:_2 "80% of users succeded in performing
          the task in a short time"@en-us ];
    schema:testFinding [ a rdf:Bag;
       rdf:_1 "Finding 1: 2/4 users found it very
          easy to perform the task."@en-us,
```

[18] http://www.w3.org/2012/pyMicrodata/

```
        rdf:_2 "Finding 2: 2/4 users used the Online
            Help in order to perform the task."@en-us,
        rdf:_3 "Finding 3: All the users found the
           application understandable."@en-us ];
     schema:testQuestion "Question 1: How easy was
           it for you to authenticate into the
           application?"@en-us,
     schema:givenAnswer "The interface of the
           application is simple and effective"@en-us;

## a list of given tasks and estimated
   completion time ##

     schema:userTask
        [ a schema:Task;
            schema:description "Searching a patient
                   in application "@en-us;
            schema:estimatedTime "P2M"^^xsd:duration ],
        [ a schema:Task;
            schema:description "Tap on View patients
                   button and then start typing the
                   patient name "@en-us;
            schema:estimatedTime "P30S"^^xsd:duration ],
        [ a schema:Task;
            schema:description "Authenticate into the
                   application "@en-us;
            schema:estimatedTime "P30S"^^xsd:duration ],

## results of the tasks performed by the users in the
   usability test ##

        [ a schema:Task;
            schema:completionTime "P3M"^^xsd:duration;
            schema:description "Searching a patient in
                   application "@en-us;
            schema:taskPerformer [ a schema:Person;
               schema:name "User 1"@en-us ] ],
        [ a schema:Task;
            schema:completionTime "P2M"^^xsd:duration;
            schema:description "Searching a patient in
                   application "@en-us;
            schema:taskPerformer [ a schema:Person;
               schema:name "User 2"@en-us ] ] ]
```

Although the conceptual model described in previous sections provides a guide for structuring and extract meaningful information from the templates, the challenge of linking information can only be solved by developing a software system.

Such a system would incorporates a knowledge base a TBox component [21] based on the *PersonasOnto* and the ABox populated with data extracted from the personas and usability testing documents. Furthermore, this system will aim to automatically to

match persons to a personas document and recommend them for the usability test as a participant.

6 Conclusions and Future Work

In this paper we presented the *PersonasOnto* ontology along with the Persona and Usability Testing schemas. Both of them incorporate concepts and properties used to model the corresponding User-Centered Design methods. These vocabularies form a basis for structuring, extracting and linking information between the personas and usability testing methods.

We also explored the advantages of providing machine-readable HTML5 templates (personas and usability testing) which can be annotated information using microdata or RDFa. We illustrated the applicability of the conceptual model by integrated the machine-readable templates in the user-centered design process.

We plan to develop a system that that automatically validates and generates of personas and usability test based on existing social network user profiles, but also linking the collected information with other data for.

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