A Domain Ontology to Support Evidence-Based Practice and Context Usage on Crime Prevention[1]

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Abstract. *Evidence-Based Practice (EBP) represents a decision-making process centered on justifications of relevant information. Context is a kind of knowledge that supports the ability to define what is or is not relevant in a given situation. The decision-making context can have an impact on evidence-based decision-making, but the integration of evidence and context is still an open issue. Ontology is referred as the shared understanding about a domain. One of the main reasons for developing context models based on ontologies is the knowledge sharing that enables computational entities, such as agents and services to find actors' similar profiles in decision making environment. This paper presents the integration of evidence and context on decision making and proposes a domain ontology to support EBP and context usage on the crime prevention domain. A practical implementation serves to validate our work.*

1. Introduction

The Evidence-Based Practice (EBP) paradigm, usually employed in several areas such as Medicine, Crime Prevention, Education and Software Engineering, are systematic procedures that take into account a problem being faced by an actor (e.g. diabetes in children), his/her needs and preferences for decision, leading to a search for evidence and an application based on the best research evidence found (Sacket et al. 2001). The procedures represent an evidence-based decision-making process, centered on justifications of relevant information (Dobrow et al. 2004).

Context is a knowledge that supports the ability to define what is or is not relevant in a given situation (Vieira et al. 2010). The application of evidence to a

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particular patient, for example, detains important contextual information in the EBP procedures and includes comparative analysis between different contexts: that of the generation of evidence and that of the patient.

According to Dobrow et al. (2004) “the two fundamental components of an evidence-based decision are evidence and context. The decision-making context can have an impact on evidence-based decision-making”. There is significant research in the fields of EBP and context. However, the integration of evidence and context in computer models is still an open issue.

Ontology is referred as the shared understanding of some domains, which is often conceived as a set of entities, relations, functions, axioms and instances. One main reason for developing context models based on ontologies is knowledge sharing that enables computational entities, such as agents (human or software) to find similar profiles in decision making environment (Wang et al. 2004).

This paper aims at: (i) presenting the integration of evidence and context concepts preserving their characteristics of representation for domains that use EBP; and (ii) describing domain ontology to support the search and retrieval of evidence, regarding their contexts. This ontology is a start point to provide arguments for a semantic formulation about the characteristics of a problem, increasing the evidence-based solution, in the crime prevention domain. The motivation behind the ontology construction is due to the lack of ontologies adaptable to our purpose. Therefore, this paper also aims at providing artifacts to support system designers and provenance community experts.

The evidence retrieval increased with contextual information can also facilitate reapplying decision-making justifications when similar problems occur. The context usage also allows filtering out and sharing more useful information so the retrieved information can meet the decision maker needs. In this sense, context becomes a significant tool to optimize performance and reduce search results. Filtering mechanisms avoid more explicit user interactions with the application (Bunningen, 2004).

The remaining of the paper has the following organization. The key concepts regarding context and evidence are described in Section 2. Section 3 presents a meta-model that integrates evidence and context high level concepts. In Section 4, the domain ontology for the Crime Prevention domain, integrated with the meta-model concepts, is described. An implementation for a scenario of usage is presented in Section 5, which serves to validate our work. Related Works are described in Section 6. Finally, in Section 7 we present our conclusions and directions for further work.

2. Background

This section defines context and provides an overview of Evidence-Based Practice.

2.1. Context

There are several definitions about context. A classical definition is proposed by Dey and Abowd (2001) for whom context is “any information that characterizes the situation of an entity, where this entity is a person, place or object considered relevant in the

interaction between the user and an application. A context is typically the location, identity and status of people, groups and computational and physical objects". Context can also be seen as a set of conditions and relevant influences that make a situation unique and understandable (Brézillon 2007) or as a set of information items (e.g. concepts, rules and propositions) associated with an entity (Vieira et al. 2010).

An item is considered part of a context only if it is useful to support a problem solving. This item corresponds to a contextual element defined as "any data, information or knowledge that enables one to characterize an entity on a given domain" (Vieira et al. 2010). Contextual information regarding acquisition is: (i) given by the user, whether from persistent data sources or from profiles; (ii) obtained from a knowledge base; (iii) obtained by means of deriving mechanisms; or (iv) perceived from the environment (Henricksen and Indulska 2006). It is usually identified through the dimensions *why, who, what, where, when* and *how* (Brézillon 2007).

One step in the task execution or problem-solving process is known as *focus*. The contextual elements should have a relevant relationship to the focus of a human agent or software agent. In general, focus is what determines which contextual elements should be instantiated (Brézillon 2007).

2.2. Evidence-Based Practice

According to Thomas and Pring (2007), in general, information labeled as evidence is those whose collection has concerns about its validity, credibility and consistency with other facts or evidences. In relation to its credibility, evidences are categorized in ways:

1. Based on professional practice, as a clinical examination;
2. Generated by a process involving scientific procedures with a proven history in producing valid and reliable results, e.g a collect performed by biomedical;
3. Based from published research that corresponds to critical reviews of the area, such as randomized clinical trial.

"Evidence" in EBP, also called "research evidence", corresponds to the third category above and means a superior type of scientific research proof, such as generated through systematic review and meta-analysis in the highest level. These published researches are available in reliable data bases, usually found on sites over the Internet, carried out by independent research groups (Sackett et al. 2001). This is the concept of evidence applied in this paper.

To clarify further, a systematic review is a review that presents meticulous research and critical evaluations of primary studies (case study, cohort, case series, etc.), based on research evidence related to a specific *theme*. It contains analysis of *qualitative* results conducted in distinct locations and at different times. Meta-analysis is a systematic review of *qualitative and quantitative* characteristics (Friedland et al. 1998).

Evidence-Based Practice (EBP) involves complex decision-making, based on available research evidence and also on characteristics of the actor of the problem, his/her situations and preferences (Sackett et al. 2001).

In the medical area, EBP focus is to provide effective counseling to help patients with terminal or chronic illness to make decision in order to extend or increase the quality of their life (Friedland et al. 1998). What is objectively searched is "the

integration of best research evidence, clinical skill and patient's preferences, regarding individual risks and the benefits of proposed interventions" (Sackett et al. 2001).

In crime prevention, EBP involves the correlations practice that has been proven through scientific research, aimed at reducing the recidivism of offenders. EBP primarily considers the risk and need principle of the offender, besides the motivation, and treatment and responsibility principles (Warren 2007).

The EBP focus for education area is improving the quality of research and evaluation on education programs and practices, and hence, the information diffusion in the *educational research* field to be used by professionals and policies creators (Thomas and Pring 2004).

So, we generalize the EBP steps in the following way:

1. Transforming the need for information into a question that can be answered;
2. Identifying the best evidence to answer the question;
3. Critically analyzing the evidence to answer:
   - Is it valid (appropriate methodology and proximity to the truth)?
   - Is it relevant (size and significance of the observed effects)?
   - Can it help (applicable in professional practice)?
4. Integrating critical analysis with professional skills and the values and cultural aspects of the actor of the problem answering:
   - How much the evidence can help the actor in particular?
   - Is it adaptable to actor's goal and preferences?
   - How much safety can be expected?
5. Evaluating the efficiency and effectiveness of the results of each step for future improvement.

3. A Meta-model to Represent Evidence-Based Practice and Context Usage

The primary aim of a meta-model is to provide a set of building blocks and rules used to build models (Chomsky 1965). In this perspective we propose a class structure that represents information related to EBP procedures, while taking into consideration information about its decision-making context.

Thus, domain analysis was done in the crime prevention (particularly in juridical and social work), medical and educational environments, including: bibliographical research (Warren 2007; Satterfield et al. 2009; Sacket et al. 2001; Friendland et al. 1998; Thomas and Pring, 2004, etc.), specific legislation research, analysis of real cases collected and interviews with decision-makers from Pernambuco state court, Brazil.

Figure 1 below presents a meta-model that corresponds to integration of EBP with contextual information. We use the extension construct *stereotype* of the UML to select enumerated values. To facilitate its presentation in a systematic way, it became convenient to group classes in two integrated packages: *Context* and *Evidence*.

3.1. *Context* Package

The classes of the *context* package are based on Vieira et al. (2010). The *focus* is treated as an association of a *task* with an *agent*, which have a *role* in problem resolution. A

task "make a critical analysis of the best evidence found" for a “medical” agent in the role "evaluator", serve as example. *ContextualEntity* represents the entities of the application conceptual model and is characterized by at least one contextual element. A contextual element is a property that can be identified by a set of attributes and relationships associated with *ContextualEntity* (Vieira et al. 2010). *Accessibility* is an example of a contextual element for the *Document* class. The association between *Focus* and *ContextualElement* determines what is relevant for a focus.

Characteristics attributed to the type of context (dimension) and the method of acquiring contextual elements are considered in the framework. *Contextual sources* may be internal or external to the decision-making environment (e.g., the patient’s medical records, a document with evidence obtained from websites).

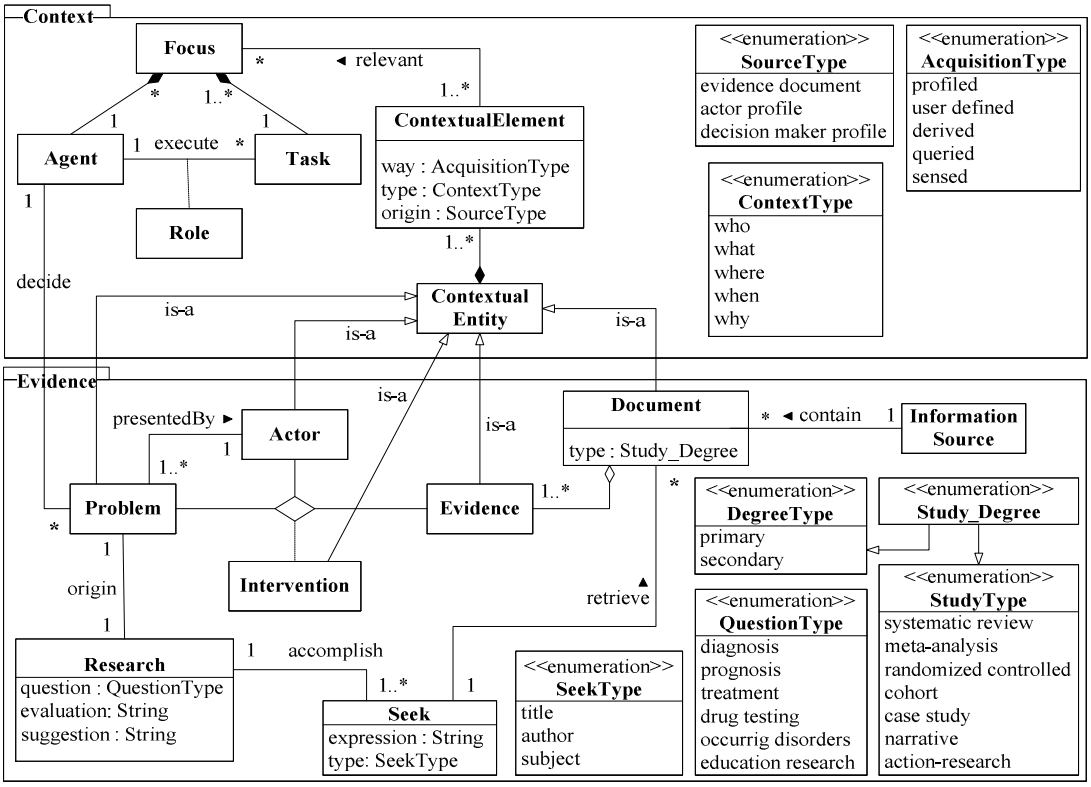

Figure 1. A meta-model integrating evidence with context

3.2. *Evidence* Package

The starting point is the observation of a problem presented by an actor to be decided by agent. Each problem is associated with an inquiry that is initiated by a formulated question (see step 1 of the EBP procedures), and completed with a self-evaluation of the research performance and suggestions for the future (see step 5 of the EBP procedures), whose information is instantiated in the *Research* class. Each domain in which EBP is applied has a list of different types of questions. For example: "diagnosis" and "prognosis" in the medical area, "drug testing" and "occurring disorders" in the area of crime prevention, and "educational research" in education.

During the evidence research, several searches can be performed to retrieve documents. For the *Seek* class, the expression and the type of search must be present.

InformationSource represents database sources that hold documents with research evidences, such as Cochrane Library, Campbell Library or Springer International Publisher, and the evidences were generated by independent research groups of specific areas (e.g. Cochrane Collaboration for medical area and Campbell Collaboration for areas of education and crime prevention).

Each document presents a type of study that can be in all domains (e.g. systematic review, case study) or in specific domain (cohort - in the medical area; action-research - in education). Systematic review and meta-analysis are studies of second degree; the remains are of first degree (Friedland et al. 2001).

After finding evidences, the agent (decision maker) will choose the one that seems the most appropriate (step 2 of EBP), which is instantiated in the *Evidence* class.

The result of the critical analysis – the validity, relevance and applicability of the best evidence (step 3 of EBP) – corresponds to contextual information. Relevance is a contextual element in *Document*, while applicability (practical utility) is in *Evidence*. Thus, *Document* and *Evidence* are specializations of *ContextualEntity*.

The *Intervention* class is the result of an association among the *Problem*, *Actor* and *Evidence* classes. It contains a description of a decision made (intervening solution) where information about associated classes have been considered including preferences, values and cultural aspects (conduct, behaviour, for example) of the actor with the problem presented (step 4 of EBP). A preference is a contextual element and hence *Actor* is a specialization of *ContextualEntity*. Problem aspects, such as the circumstances about a juridical fact for the criminal area, generally, are contextual elements used to diagnose the problem. So, the *Problem* class is a *ContextualEntity* too.

Summarizing, some elements that characterize a meta-model are shown through some examples. The *Agent* class corresponds, respectively, to the *Doctor, Judge* and *Professor* classes for the medical, juridical and educational areas. *Evidence* and *Seek*, for example, are general classes for any domains. The classes *ClinicalProblem*, in the medical domain, and *JuridicalFact*, in the juridical domain, represent the *Problem* class of the meta-model.

4. A Domain Ontology for the Crime Prevention

This section describes the main steps in the construction of ontology for representing EBP considering contextual information in the crime prevention domain. The ontology is constructed using the Web Ontology Language (OWL). To edit the ontology and axioms we used the Protégé (http://protege.stanford.edu).

4.1. Ontology Concepts

Figures 2 and 3 show a set of subclass/superclass of the main concepts defined in the crime prevention ontology. The concepts were constructed based on a survey of the concepts related found in the technical and scientific literature (Warren 2007; Gomes 2008; Moreira 2007; Saliba 2009). In this section, we present the specific concepts for the crime prevention domain, since the high level concepts concerning context and evidence were described in the meta-model (Section 3).

The ontology comprises two main classes: *ContextualEntity* and *ConventionalEntity*. *ContextualEntity* contains the subclasses that detain at least a contextual element (or contextual property), which supports the description of scenarios found in environmental decision making. According to the meta-model, described in Section 3, *ContextualEntity* has six main subclasses: *Agent*, *Actor*, *Problem*, *Document*, *Evidence* and *Intervention*. For the crime prevention domain, we defined the subclasses illustrated in Figure 2 and summarized the main contextual properties in Table 1.

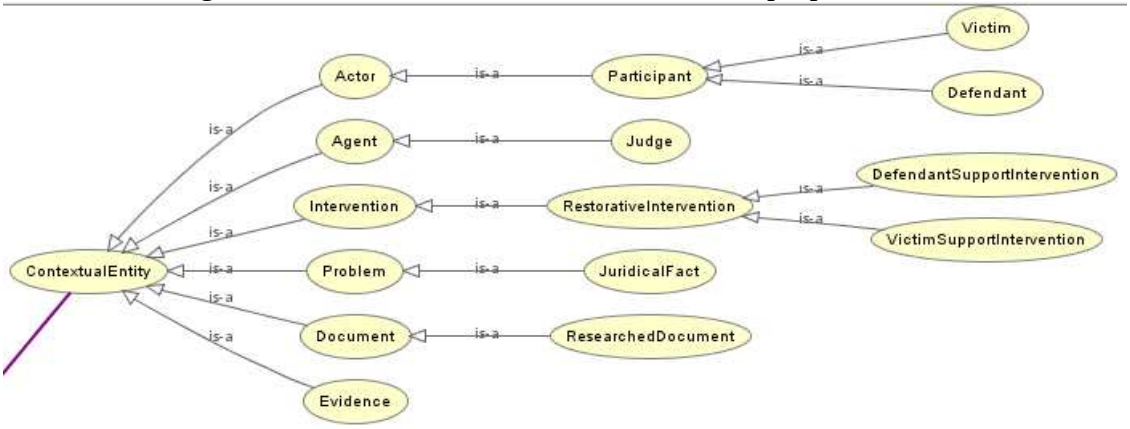

Figure 2. Subclasses of *ContextualEntity* for the crime prevention domain

Table 1. Descriptions of the main contextual properties - crime prevention domain

Subclass	**Contextual Properties**	**Description**
Judge	*hasExpertAffinity*	identifies a relation of expertise from the Judge profile on a given subject matter (e.g. crimes against children). It helps to identify mutual affinities among judges optimizing performance and reducing search results
Participant	*hasAbilities*	represents the defendant's or victim's skills, and is used to find mutual affinities with intervention programs (e.g. revenue). Reduce search results
Defendant	*hasPotentialRisk*	comes from juridical and psychosocial evaluations (profile). Behavior data, conduct, fact description and given sentences, especially for recurrent cases, are bases to characterize an offender's degree of risk.
JuridicalFact	*hasCircumstances*	describes the information about time and geographic aspects for the occurred fact. Information about number of people involved and their attitudes are desirable too. It is relevant and determinant to understand the juridical fact
Researched Document	*hasValidity*	indicates whether the document should be selected based on its quality and the methodological rigor associated with the question asked by the decision maker (judges, in this case)
	hasRelevance	indicates whether the set of results (outcomes) in the document, often presented in statistical form, is consistent and significant
Evidence	*hasApplicability*	indicates whether the evidence presented in the document is credible in the context of other knowledge, or whether it has practical utility in general
Restorative Intervention	*hasAdaptability*	indicates the degree of coherence in the application of evidence for the conducted behavior, needs and preferences of the defendant (or victim)
	hasSafety	denotes the percentage of safety that the judge have to apply the specific evidence to a particular participant (defendant or victim)
	hasExpectation	refers to the percentage of support expected from the use of evidence in relation to the participant (defendant or victim)

ConventionalEntity contains all the specific subclasses of the domain, which does not have a direct influence of context. They are *JuridicalResearch*, *Seek* and *JuridicalEvidenceProvider* as shown in Figure 3. For the *JuridicalResearch* subclass, the property *historic* should include general comments and the number of documents that were accepted and rejected, besides of the properties presented in Figure 1. In the

Seek subclass, properties about the researched document validity time must be considered. They are specific to instantiate the start and the end of the document validity found. The *JuridicalEvidenceProvider* subclass contains the follow properties: *name*, that mean the name of the Internet site accessed, and *homepage*, that detain the URL address.

Besides the enumerations presented in Figure 1, for the crime prevention domain, we add a subclass *BasicProgram* with the following values instantiated: *citizen*, *revenue*, *education*, *psychosocial*, *psychiatric* and *shelter*. This subclass serves to support the conventional intervention (no evidence-based) that exists in the courts. All subclass with enumerations are children of the *TypeClass* class.

Figure 3. Subclasses of *ConventionalEntity* for the crime prevention domain

The figures and table of this subsection were not fully developed in this article due to the limits of space.

4.2. Inference Rule

Some inference rules have been built and others are in development. In the following section addresses the applicability of some of them. For the sake of space we will not describe the properties of all classes in this paper. We will mention briefly the characteristics of some of them.

Intervention program rule for victims: When the participant is an offender, he has access to any program described in the basic ontology. However, when the participant is a victim, potential routes are: citizenship, psychosocial and psychiatric;

Rule to retrieve evidence-based solutions centered on the judge's specialty: from the expertise of a judge, logged in the system, the research solution space can be reduced based on: (i) his/her expertise, (ii) two specialties, or (iii) all experts;

Rule to find documents with evidence based in query keyword: the query terms must be confronted with the words found in researched documents; programs must order the most similar to facilitate the choice of the decision maker and a ranking as presented.

5. Application to the Crime Prevention Scenario

We present an example adapted from a real case involving an alternative penalty - a model for infractions that are of minor and moderately offensive potential (e.g., contravention, illegal weapon possession). It deals with a new modality, face-to-face restorative justice, in which a victim that suffered violence of an alcoholic offender receives support. A prototype, developed in *Java* language, interacts with a XML Database generated by Protégé ontology editor. The original data, approximately one

hundred cases, were extracted from conventional Court's Database. Figure 4 presents data for searching by evidence in the local database.

The High or Moderate Intervention Complexity is due to offender and victim need of treatment. The Judge's expertise in the new case is "drug crimes". We applied similarity cosine formula used in *Information Retrieval* for keyword similarity search between query and document with evidence.

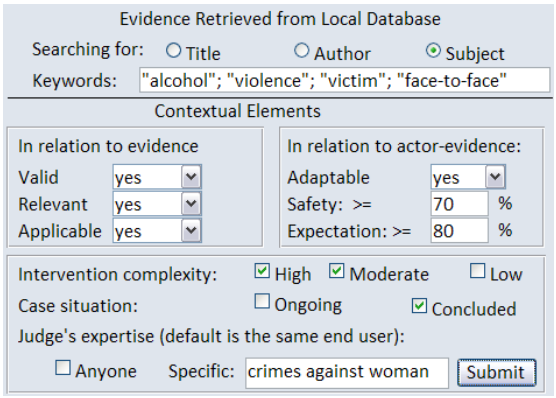

Figure 4. Data for searching evidence from local database

In the first retrieval, we do not use contextual elements and the results with several cases are present in Figure 5a. Using contextual information parameters as filter fewer cases were selected (see Figure 5b). This filtering was carried out as follows: (i) based on the desired expertise ("drug crimes" and "crimes against women") only the documents 1, 3, 4 and 5 were selected initially; (ii) document 4 was rejected by the safety indicator = 60.0 (so less than 70 % desired); and (iii) document 5 was not accepted by expectation indicator = 70.0 (so less than 80 % desired).

	title character varying(200)	keywords character varying(200)	study character	source charact	sa nu	ex nu	expertise character varyir	con cha	situ- chai
1	Drunk and dangerous: a randomized controlled trial of alcohol	alcohol, brief interventions, violence, random	randomized	Spriger V	75	90	drug crimes	high	concl
2	Reducing violence through victim identification care and suppo	violence, crime victims rehabilitation, health p	narrative	World He	0.0	0.0	homicide		ongo
3	Assessing the effectiveness of interventions designed to supp	victims of crime, systematic review, violence,	systematic r	Campbell	80	85	crimes against wom	mod	concl
4	Change in behaviour of alcohol consumption: what is the moti	alcoholism, motivation, gastroenterology, out	case study	National .	60	50	drug crimes	mod	concl
5	Effects of Drug Substitution Programs on Offending among Dr	drug substitution, drug-addicts, alcohol depe	systematic r	Campbell	70	85	drug crimes	low	concl
6	Police crackdowns on illegal gun carrying: a systematic review	Campbell Collaboration, crackdowns, violence	systematic r	Spriger V	80	85	homicide	high	concl
7	Cognitive-Behavioural Interventions for Children Who Have Be	child sexual abuse, victim, cognitive-behaviou	systematic r	Campbell	85	80	crimes against child	mod	concl
8	School-Based Education Programmes for the Prevention of Ch	child sexual abuse, victim, school-based educ	systematic r	Campbell	70	80	crimes against child	low	concl

	title character varying(200)	keywords character varying(200)	study character	source charact	sa nu	ex nu	expertise character varyir	con cha	situ- chai
1	Drunk and dangerous: a randomized controlled trial of alcohol	alcohol, brief interventions, violence, random	randomized	Spriger V	75	90	drug crimes	high	concl
2	Assessing the effectiveness of interventions designed to supp	victims of crime, systematic review, violence,	systematic r	Campbell	80	85	crimes against wom	mod	concl

Figure 5. Retrieved documents with evidence: a) without using context (upper), (b) using contextual element (lower)

The presented cases are not sufficient to give support to the solution (they do not treat face-a-face meeting). So, the judge should search for documents with evidences. The research began with the question containing the problem and actor (woman with a psychological problem who was assaulted), intervention (face-to-face sessions), comparison of interventions (face-to-face sessions and conventional processes) and outcome (beneficial effects). The sources Campbell Collaboration and Springer Verlag were chosen and their respective home-pages were obtained. Figure 6 show data for second search regarding documents published between 2005 and 2010.

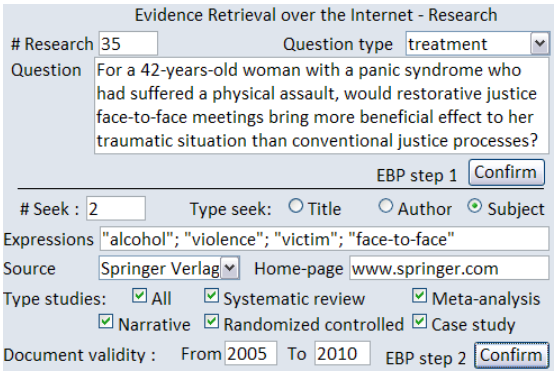

Figure 6. Data for searching evidence in Springer Verlag's database

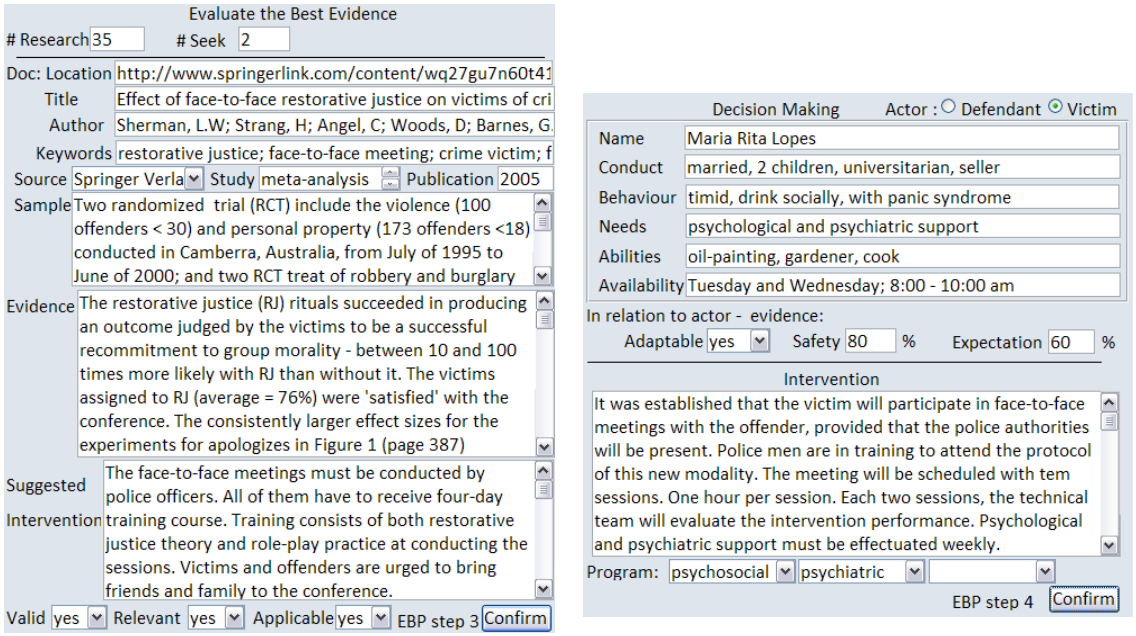

Figure 7. a) Evaluate the best evidence; e b) Decision-making g evidence in Springer Verlag's database

Figure 7a shows a meta-analysis study (taken from Springer Verlag) that was selected by the judge as presenting the best evidence on face-to-face meetings between victims and offenders. The study sample is derived from two randomized controlled trials: one conducted with offenders who committed crimes against private property involving violence in Canberra, Australia, and the other, crimes of burglary with victims in London, England. The sample context was analyzed and contrasted with the new problem. The evidence drawn from this showed objectively that 76% of victims were satisfied with the results obtained from the face-to-face meeting with offenders. This study led to a successful implementation of a training course for police officers, in which the concepts of restorative justice and practice sessions in face-to-face meeting between offenders and victims were applied. The document and the evidence were evaluated in terms of validity, relevance and applicability, and the information was extracted manually and recorded in a local database.

The decision making is presented in Figure 7b. Data of the victim were informed and they are compatible with the best evidence founded. The victim agrees to participate

in face-to-face meetings with the offender, provided that in previously established time and with the presence of authorities. Victim support programs, with respect to psychosocial and psychiatric treatment, must be offered in this particular intervention. The process concludes with documentation of the research performance made by judge.

This example shows that the presented application has potential to be leveraged to support a more appropriate evaluation of the ontology.

6. Related Works

In this section we present some related work on the themes *evidence, context, ontology,* and integration of this themes.

In Stolba et al. (2009) is showed how Data Warehouse facilitating Evidence-Based Medicine can be applied for reliable and secure processing of huge amounts of medical data. The authors present a data model for building a federated Data Warehouse considering adopted international standards for the exchange of healthcare data. Nakaya e Shimuzu (2006) present the Knowledge representation architecture based on Evidence based Logical Atomism (KELA) that consider the anatomic hierarchic structure from genome to human. Knowledge atoms of molecular and disease findings are modeled as entities and relationships - describes species, birthplace, and existing place in an ontological view.

Vieira et al. (2010) presents a domain-independent context meta-model, which guides context modelling in different applications. The meta-model offers integrated support for modeling structural and behavioral aspects involved in context management and usage. Contextual graph and UML were used. Sheng and Benatallah (2005) Introduce the ContextUML meta-model developed to support the modeling of context-aware Web Services. It separates modeling context (types, sources, etc.) from modeling context-awareness (objects and Mechanisms) becoming restrict to the Web Services category of Context-Sensitive Systems.

The related works above regard individually evidence or context. The combination of research evidence with context was not developed computationally. Besides, none of them has the perspectives of integration and extension for several domains, and none of these present a vision of combining ontological proposal.

7. Conclusions and Future Work

This article proposes the integration of context with evidence represented in a meta-model to facilitate the development of applications centered in EBP considering context for several domains. The class structure of the meta-model was the base for build domain ontology oriented to crime prevention. Contextual information related to the EBP of the criminal area were represented and instantiated. With a practical implementation we showed how contextual EBP can be used to support Judge's decision making and was verified that using contextual information makes the retrieve more effective.

Future researches encompass (i) the building of: task ontology for the criminal area; a high-level ontology for the areas that use EBP such as Medicine and Education; and a semi-automatic Evidence-Oriented Information Extractor (EOIE); and (ii) the

incorporation of the classical case structure (problem, solution and result) and Case-Based Reasoning technique for decision making support.

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