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Application of triangulation approach in requirements engineering process: A study in analysis and design of the pediatrics epilepsy information system

Mohtaram Nematollahi [1] Marzieh Ahmadzadeh [2] Tayebeh Baniasadi [3] Fatemeh Sedigh Marvasti [4]

Anesthesiology and Clinical Care Research Center [1] , Shiraz Univeresity of Medical Sciences, Shiraz, Iran. Department of Computer Engineering & IT [2] , Shiraz University of Technology, Shiraz, Iran. Department of Medical Informatics [3] , Shiraz University of Medical Sciences, Shiraz, Iran. Department of Neurology [4] , Hormozgan University of Medical Sciences, Bandar Abbas, Iran.

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Original Article

Abstract

Introduction: Requirements Engineering process is a crucial phase in software development. In order to achieve a successful design of health information systems (HISs), applying the best methodologies is essential. Therefore, the aim of the present study was to design pediatrics Epilepsy Information System (EPIS) as well as the use of triangulation approach in elicitation and validation of epilepsy information system requirements in its engineering process.

Methods: This applied study was carried out in Bandar Abbas pediatric hospital. Triangulation approach based on three different analyses and validation methods in requirements engineering process was applied. To do the triangulation work, as well as designing a usable system, according to the most common User Centered Design (UCD) methods, we use three well-known methodological approaches in UCD: (a) Object-Oriented System Analysis (OOSA); (b) Hierarchical Task Analysis; and, (c) Prototyping. The results of each of these methods were analyzed by selected clinical staff, iterative cycle in models design also continued until lack of need for new changes. Then final results were presented in a general category in the form of triangulation matrix.

Results: 55 high-level requirements with minimum information items to store information of hospitalized epileptic patients obtained from multiple methods. The greatest requirements (84%) were identified or validated in the OOSA step, some requirements (13%) have been identified only in the design and evaluation of prototype.

Conclusion: Triangulation approach helped us in confirmation of findings, and finally enhance the credibility of the study. Health informatics specialists should try to use of multiple methods in the early phases of systems design that lead to a rich and comprehensive picture of HIS requirements.

Correspondence:
Tayebeh Baniasadi.
Department of Medical Informatics, School of Management and Medical Information Sciences, Shiraz University of Medical Sciences.
Shiraz, Iran
Tel:+98 9177611596
Email:
T_baniasadi@yahoo.com

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Introduction:

One of the most important applicable areas of information technology is health. Information and communication technology in healthcare includes a wide range of systems, applications, and services for a variety of users for diverse purposes (1).

There is a need to develop information systems for health care situations, to organize information, to enable an exchange of secure and reliable information among various health professionals, and to provide a platform for access to timely information by multiple people from multiple locations (2,3).

Although HISs are potentially advantageous, it sometimes fails to achieve the aims (4-6). There are several reasons for project failure. Many health information systems fail because of problems in planning or design stages (7). According to the survey conducted by Standish Group Study in 1995 the major source of failures resided on poor requirements. The main five factors leading to failure were the lack of user involvement, the incomplete requirements, the rapidly changing in the requirements, unrealistic expectations, and unclear objectives. These mentioned causes are related to the Requirements Engineering (RE) process which is a crucial phase in the software development (8).

Software requirements engineering is a disciplined, process-oriented and iterative approach to the definition, documentation, and maintenance of software requirements throughout the software development life cycle (9). In other words, RE is a systematic approach with defined roles for elicitation, organization, documentation, analysis, validation, and changes management of system requirements (10).

It is shown that human factors also have a prominent role in the success of health information systems (11-14). HISs are often developed disregarding the characteristics, preferences, needs, wishes, and expectations of the end users which may lead to dissatisfaction, difficulty for learning, abandonment of the system, and costly redesigning of the application (15-17). User-Centered Design (UCD) is a design approach in which the needs of users are considered at each stage of the design process (18) UCD methodology involves users throughout the design process and it uses iterative cycles in order to increase the ultimate usability (19). As it mentioned, the RE process has important ramifications for the overall success of the project. A numbers of consequences may arise due to wrong and incomplete requirements. So applying the best practices, processes, tools, technologies and methodologies for improving requirements engineering phase is way to reduce these problems (20). Using multi-method approach, widely called methodological triangulation, for elicitation and validation of requirements can improve analysis and design process, particular in requirements engineering phase. The triangulation approach combines methods and complements results to a comprehensive picture and provides confirmation of findings, increased validity and enhanced understanding of the phenomenon under study (21).

To do the triangulation work, as well as designing a usable system, according to the most common UCD methods across the articles (22,23), we use three well-known methodological approaches in user center design: (a) object-oriented system analysis (OOSA); (b) Hierarchical Task Analysis (HTA); and, (c) prototyping.

This study followed the design of health information systems focused on pediatrics epilepsy. This disease is a common neurologic disorder among children which is manifested during childhood and adolescence (24). About 10.5 million children are affected by epilepsy (25).

Epilepsy is a chronic and recurrent disease which requires long-term treatment, it also has direct and indirect costs for patients and society and affects the patients' individual and social life quality (26,27). To manage this disease, having knowledge about seizure type and epilepsy, EEG changes, and other factors in history and physical examination of the patients is essential (28). Therefore, having systems to record the patients' information (inpatient and outpatient) can be helpful in optimal management of patients' treatment. As a matter of fact, it will have potential benefits if the system is analyzed and designed successfully.

The aim of the present study was to use triangulation approach in elicitation and validation of epilepsy information system requirements in the requirements engineering process in order to improve this phase

Methods:

This applied study was carried out in Bandar Abbas pediatric hospital in 2013. Triangulation approach was used based on three different analyses and validation methods in the requirements

engineering process for the design and analysis of the epilepsy information system, which is divided into the following steps:

Identification and elicitation of epilepsy information system requirements & object-oriented system analysis (OOSA)

Interviews, ethnography, review of similar systems and analysis of documentation were utilized in order to identify and elicit the requirements of the system.

In the interview phase, 12 nurses, 3 neurologists, 4 pediatricians, 1 pediatric neurologist, 2 interns and 3 residents in pediatrics ward participated. Furthermore, hospital manager, 2 information technology personnel, and 2 health information management personnel were interviewed. Then use cases and scenarios as well as object classes were extracted for object-oriented system analysis. Enterprise Architect 9 software was used for drawing the diagrams.

Analysis of epilepsy information system requirements & using Hierarchical Task Analysis

We classified and found similar patterns in order to analyze the requirement of epilepsy information system for qualitative data. Also, task and subtask identification, classification, and sequence were analyzed using Hierarchical Task Analysis (HTA) method (29).

Hierarchical Task Analysis:

Task analysis approach to requirements specification is the process of understanding the user's task (30). It is a methodology that can be used to analyze a system function in terms of the human user's goals and sub-goals inherent in performing the task (31). A wide range of techniques exist for task analysis, Hierarchical Task Analysis (HTA), that first developed by Annett et al (29) and later revised by Shepherd (32), is one such technique. This is the original form of systematic task analysis that is well established (30).

It modeling approach was based on a detailed logical representation of task sequences. An HTA or a better term "Procedure hierarchy task analysis" involves taking a task and identifying its sub-goals (31) and involves describing a task as a hierarchy of tasks and subtasks, emphasizing the procedures that operators will carry out, using several specific forms of description. The results of an HTA are typically represented either graphically, as a sort of annotated tree diagram of the task structure (30).

Designing prototype of epilepsy information system

A prototype of the epilepsy information system was developed on the basis of the recommendation of the health care experts, users and experts in the field of information technology and medical informatics. Prototype information structure was based on classification and sequencing of data in paper format and according to sequencing of TA phase.

For fast and low cost design and simulation interface of epilepsy information system was selected low-fidelity prototype that for this purpose PowerPoint software was used.

In all of the above, obtained models was reviewed and analyzed by using qualitative and quantitative methods by selected clinical staff which including three doctors and three nurses and health IT expert who directly involved in activities. In some cases, modeling cycle up to two or three stages continued to final completion and lack of need for new changes.

Validation of epilepsy information system requirements

In this study triangulation approach was used for validation of system requirements. For this purpose we used a combination of OOSA, HTA, and prototype in the triangulation matrix.

Triangulation approach:

triangulation refers to application of the combination of methodologies to investigate the same phenomenon or in the other words, to examine the same dimension of a research problem (33) also for validation of results, in order to confirm the results with data from other sources or methods (34). Triangulated techniques are helpful for cross-checking and overall, to provide confirmation and completeness findings of research (21).

Denzin (1970) extended the idea of triangulation beyond its conventional association with research methods and designs. He distinguished four types of triangulation: Data triangulation, Investigator triangulation, Theoretical triangulation, Methodological triangulation. Of the four methods, methodological triangulation represents the most common meaning of the term, as well as is a more

profound form of triangulation. According to the types of triangulation mentioned, we used data triangulation that refer to retrieve data from a number of different sources in a study and another approach used is methodological triangulation which is defined as the use of more than one method or technique for data gathering and analysis (21,35).

Results:

Based on the objectives of the research, results are as follows:

In this section, part of the three methods used in the triangulation matrix, which is one example of the high-level use-case diagram is depicted in Figure 1.

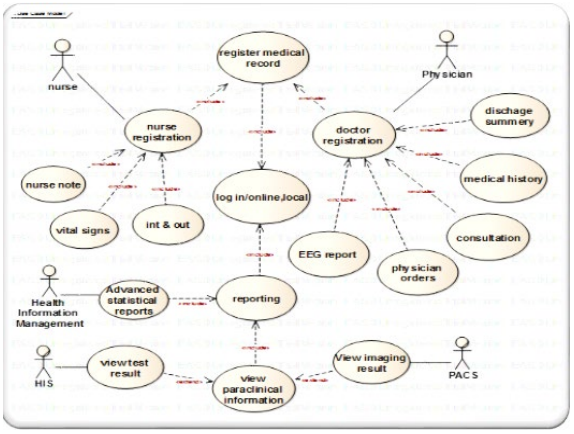

Figure 1. Part of high-level use-case diagram of EPIS

One example of the obtained HTA model about "register medical history" is illustrated in Figure 2. Then the appearance of one prototype interface screen is demonstrated in Figure 3.

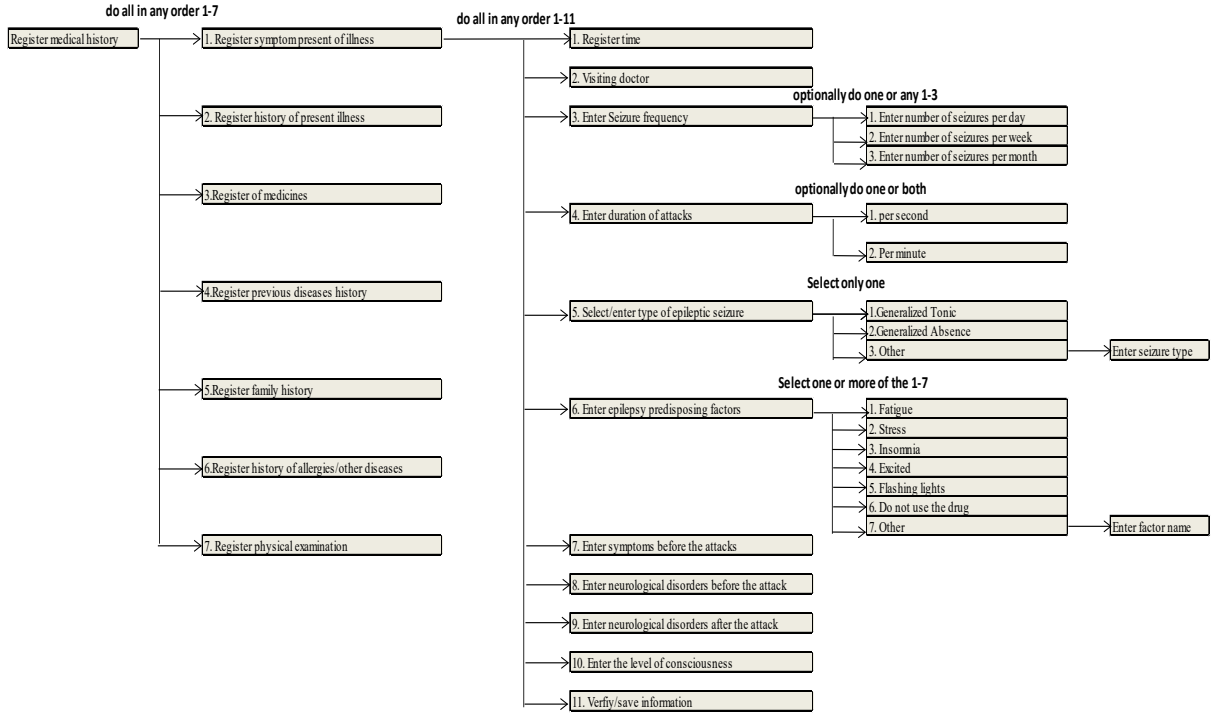

Figure 2. Part of HTA for "Register medical history: symptom present of illness" functionality

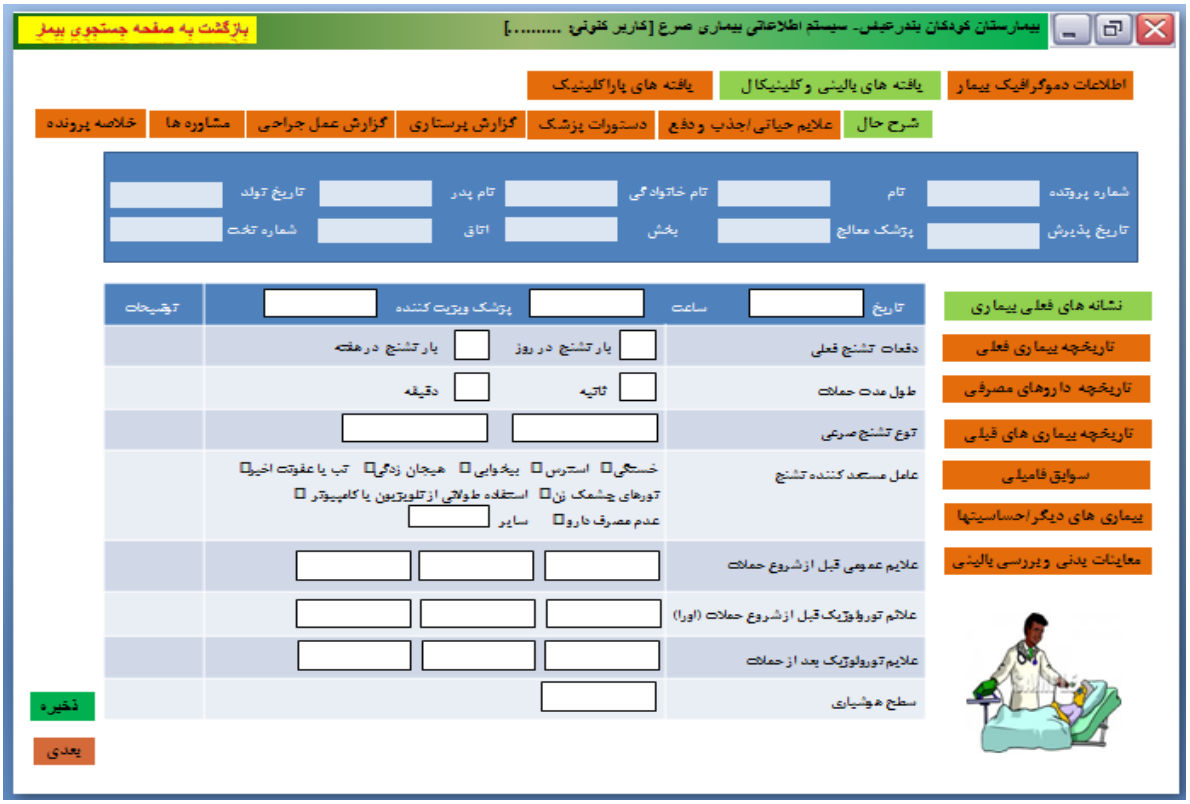

Figure 3. One screen of the final prototype of EPIS

Table 1. New and confirmed requirements related to human and non-human actors based on three methods

Actors		METHOD		
		OOSA	HTA	Prototyping
		New	New/confirmed	New/confirmed
Human actors	Nurse	10	2/3	3/12
	Physician	29	0/21	4/29
	Health Information Management	2	0/1	0/2
Non-human actors	HIS/PACS	5	NA	0/5
Total		**46**	**2/25**	**7/48**

The results are presented list of high-level requirements in analysis and design the clinical information system in pediatrics epilepsy care. Each of the high-level requirements has subsets. But in the following triangulation matrix only general categories is examined.

High-level requirements identified

Table 1 presents new and confirmed requirements related to human and non-human actors based on three methods, also Table 2.1 and Table 2.2 presents a list of 55 high-level requirements with necessary data element for any main register that obtained from multiple methods (OOSA, HTA, and Prototyping) which were grouped by human and non-human actors; 46 requirements (84%) were identified or validated in the OOSA step, 2 new cases (3%) were identified in the HTA step, and 7 other new cases (13%) were identified in the Prototyping step.

According to the triangulation matrix presented in Table 1, different actors were identified; physician, nurse and health information managers represent the human actors (in this study, patients were not considered as an actor), and HIS and PACS, represent non-human actors, i.e. other existing ISs that will be integrated with EPIS.

Table 2.1. Triangulation matrix with final list of high-level requirements of the EPIS based on three different analyses and validation methods (related to human actors)

Actors	Requirements Identified	Method		
		OOSA	HTA	Protoyping
Physician	P1: **View medical history**	*	NA	+
	P2: **Register symptom present of illness** (Seizure frequency, duration of attacks, type of epileptic seizure, epilepsy predisposing factors, symptoms before the attacks, neurological disorders before and after the attack, the level of consciousness)	*	+	+
	P3: **Register history of present illness** (Age at first epileptic seizure, the first date of seizure, Last seizures, etiology of epilepsy, status epilepticus history, history of febrile convulsions, history of hospital admissions due to seizure, Last admission because of seizures, frequency of hospital admissions due to seizure)	*	+	+
	P4: **Register history of prenatal and newborns evaluation** **-History of prenatal:** (maternal high-risk pregnancy history (cause), problems during pregnancy, maternal gestational age, type of delivery, maternal age at birth, several pregnancy) **- Newborns evaluation:** (Apgar score, neonatal problems, history of neonatal admission, cause of neonatal hospitalization, child motor development, speech development of children, mental development of children, vaccination) - Other assessment: (history of head trauma, hospitalization due to other than seizures and surgery)	*	+	+
	P5: **Register another assessment of the patient's history**	*	+	+
	P6: **Register drugs history:** - Current anticonvulsants drugs: (medication name, start date, dosage, frequency of drug use, blood levels AED, side effects, drug sensitivity) - Anticonvulsant drug used previously: (drug name, expiry date, history of sudden withdrawal) (the names of other drugs)	*	+	+
	P7: **Register family history & cultural and economic factors** (Family history of convulsions, family history of epilepsy, family history of premature deaths, history of stillbirth the mother, addicted parents, other family medical history, parent family relationship, parent education, occupation of parents, family income level)	*	+	+
	P8: **Register physical examination /clinical assessment:** (type of organs, result of the examination, height, weight, BMI, head circumference)	*	+	+
	P9: **Register history of allergies** (type of materials / medicines, kind of sensitivity)	*	+	+
	P10 : **Register history of other diseases** (disease name, onset date, illness duration, treatment condition)	*	+	+
	P11,P12: **Register/view Physicians' Order** - Non-drug orders (visit date and time, early diagnosis, the patient's condition, treatment progress, specific instructions for nursing care, requests [testing / imaging, consulting, etc.], type of diet, type of the patient activity)	*/*	+/NA	+/+
	P13: **Register medication orders:** (number of medication units, dose, drug usage, intervals of use, date / time of onset and cessation of drug)	*	+	+
	P14,P15: **Register/view consultation** (applicant physician , date and time of the request, consultant, specialty of consulting physician, consultation type, consultation subject, consultant medical observation, consultant diagnosis, consultant recommendations)	*/*	+/NA	+/+
	P16: **View record summaries**	*	NA	+
	P17: **View admission and discharge Summary data**	-	-	*
	P18: **Register diagnosis & ICD cods**	*	+	+
	P19: **Register summary of surgical procedures**	*	+	+
	P20 : **Register summary of treatment**	*	+	+
	P21: **Register summary of death information**	*	+	+
	P22: **Register summary of imaging and EEG results**	*	+	+
	P23 : **Register summary of tests results and other Para clinical findings**	*	+	+
	P24: **Register supplementary information in record summaries**	*	+	+
	P25: **View operation report**	-	-	*
	P26: **View nurse note**	*	NA	+
	P27: **View vital signs**	*	NA	+
	P28: **View output &Intake(Fluid Balance)**	*	NA	+
	P29, P30: **Register/view EEG report** (Date /time EEG, No. EEG, requesting doctor, the technician name, current antiepileptic drugs, Medications before the EEG, Last seizure, type of seizure, the patient's condition during EEG, skull defects or craniotomy (place), the seizure status during the EEG, activation changes, hyperventilation changes, photostimolation changes, test result, final diagnosis, doctor report)	*/*	+/NA	+/+
	P31: **View test result**	-	NA	*
	P32: **View imaging result**	-	NA	*
	P33: **Edit clinical documentation**	*	+	+

Table 2.1. Triangulation matrix with final list of high-level requirements of the EPIS based on three different analyses and validation methods (related to human actors)

Actors	Requirements Identified	Methods		
		OOSA	HTA	Protoyping
Nurse	N1,N2: **Register/View vital signs** (date, time, blood pressure, temperature, pulse, respiration)	*/*	+/NA	+/+
	N3,N4: **Register/View output &Intake**-Fluid Balance: (date, time, type, value)	*/*	+/NA	+/+
	N5,N6: **Register/View nurses note:** (Dates and times Report, patient status, medical practices based on prescriptions, and other medical procedures, nursing care)	*/*	+/NA	+/+
	N7: **View medical history**	*	NA	+
	N8: **View physicians' order**	*	NA	+
	N9: **Verify drug order**	-	*	+
	N10: **View consultation note**	*	NA	+
	N11: **View operation report**	-	-	*
	N12: **View laboratory report**	-	NA	*
	N13: **View record summary**	*	NA	+
	N14.N15 **View/ Change demographic information**	-/-	*/NA	*/+
Health Information Management	M1: **Reporting of application**	*	+	+
	M2: **View Electronic Patient Records**	*	NA	+
Subtotal of new requirments identified		41	2	7

Table 2.2. Triangulation matrix with final list of high-level requirements of the EPIS based on three different analyses and validation methods (related to non-human actors)

Actors	Requirements Identified	Method		
		OOSA	HTA	Protoyping
HIS	H1: Register demographic information	*	NA	+
	H2: Register admission and discharge summary	*	NA	+
	H3: Register the results of laboratory tests	*	NA	+
	H4: Register operation(surgery) report	*	NA	+
PACS	PA1: Register imaging(MRI/CT)	*	NA	+
Subtotal of new requirments identified		**5**	**0**	**0**

*: identify; +:confirm; - : nothing; NA: no-applicable;
N: Nurse; P: Physician; M: Health Information Management; H: HIS;PA: PACS

Some data such as vital signs could be registered by a nurse (N1:N15). Also the physician registers and views a lot of specific information related to the patient and details about their treatment (p1:p33). The HIS and PACS represent non-human actors and they register some data (PA1; H1:H4).

Conclusion:

In this study, we illustrated the use of triangulation matrix in order to specify the requirements document of an information system for managing the clinical information in epilepsy care. Identifying information needs of the target population has led to the identification of a variety of data elements and structures within the epilepsy information system. Was tried the special requirements of electronic health records system in children, as the study of Spooner (36) also considered requirements in design of epilepsy and EEG information system by Finnerup (37) be included in the program.

We have confirmed the system requirement using 3 different techniques, by considering methods of User-Centered Design to improve the understanding of user and task requirements which led to more complete results.

The greatest requirements were identified in the OOSA phase (namely, in determining the use cases, writing scenarios and extracting program classes). Use cases organized functional requirements in ways meaningful to users and they designed to help ensure that the behavior of the system is what the users require. In fact, Use cases are high –level descriptions of system processes (38).

We analyzed the functional requirements for the main task of the system done by human actors and then draw the HTA chart. HTA diagrams, all task and subtask detail are provided. In HTA, such as calculating body mass index for children, length of stay for patients, Frequency of hospitalization, which is calculated automatically by the system, not shown. Although two new requirements (3% of

requirements) were identified by the use of HTA, it was a good way to obtain detailed information about the system, and supports the interface design by providing essential plans to users' activities in order to help design a computer system that will effectively support users in doing the task (39) as well as, HTA models are useful in designing complex human-computer systems (40).

Another part of our work was to design a prototype. It is representation of all or part of a product or system, although limited in some way (41), can be used in health systems as simple tool to increase the users' involvement and determine the high level specifications and user interface of the system. Some of the needs (13%) have been identified only in the design and evaluation of prototype.

Teixeira study also extracted from 48 high-level requirements, 38 (79 percent) in the OOSA step, 2 (4%) in the HTA stage, and 8 (17%) were identified in the prototype stage (23). Our results with Teixeira results in percentage term identifying needs at different stages had a match.

In this paper, the results of some parts of the study were validated by those from other parts in the requirement triangulation matrix, which is presented in Table 1 and Table 2.

In triangulation matrix presented, for example, requirements P2-P10 were identified in the first step and were confirmed in the second and third steps. According to the study of Teixeira et al., it might be indicated as core requirements (23).

Requirements such as N10 and P26-28 were identified in the first step; they were not considered in the second step (since we applied the TA method only to insertion tasks performed by human actors) and were confirmed in the third step. Thus, they might also be the core requirements according to Teixeira study. The requirement P25, p31, and p32 were discovered only in the third step. This type of requirements are denominated "emergent requirements" which emerge with the users' understanding of the system development during the design process (10).

Also, in this approach one method presents the results which have not been found with the other method. In the other words, the use of multiple measures, observers, theories, methods, may also uncover some unique variance which otherwise may have been neglected by single methods, single-observer, single-theory studies (21,42). Actually, the core premise of triangulation as a design strategy is that all methods have inherent biases and limitations (43). The results showed that the use of several methods instead of using of only one method for synthesis and strengthen findings during analysis and design of the pediatrics epilepsy information system aided in reducing biased and limited results.

The results of a survey conducted by Teixeira et al. indicated that with this methodological approach, in addition to elicitation and validation of the system requirements, helps to reduce weaknesses of individual methods and elicitation easier of emergent requirements as well as identify the critical needs. On the whole, it has been a good solution for requirements engineering process in the design of web information system for hemophilia patients (23).

In general, purpose of strategy triangulation is to produce different result arising from the different methodological approaches that can be related to each other (44), also more for studies that are needed on a combination of qualitative and quantitative methods, have been considered (45).

In sum, the designing and implementation of HIS is more sensitive and should be done more carefully (1). Accordingly, benefit from multiple perspectives and viewpoints on various aspects would be helpful.

This approach helped us in confirmation of findings, also to get more complete data and finally enhance the credibility of the study. Moreover, the requirements triangulation matrix plays an important role in extract the essential requirements and prioritize them.

Despite limitations of this work such as time-consuming and poor participation of clinical staff in gathering requirements, we recommend applying this method for other systems by health informatics specialists in other to obtain all the required information from various sources in the early phases of system design that leading to a rich and comprehensive picture of the real requirements of the system under study at lower costs, since solving a lot of problems after designing and implementation of HIS is associated with spending more time and cost.

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