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Applying user-centered techniques to analyze and design a mobile application

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Abstract

Introduction: Techniques that help in understanding and designing user needs are increasingly being used in Software Engineering to improve the acceptance of applications. Among these techniques we can cite personas, scenarios and interaction models. Personas are fictitious representations of target users. Scenarios provide various types of information at different levels of abstraction. Interaction models help in design of an adequate user interaction with the system.

Case description: This paper presents a research that reports a set of practical activities applied by a software team using techniques in the analysis and design phases of a mobile application. In the analysis phase, we created personas and scenarios for the extraction of requirements. In the design phase, we created interaction models for describes the behavior between user and system during the interaction. We employed these interaction models to develop other artifacts, such as prototypes. In addition, we presented a technique developed by the analysis and design team for the inspection of interaction models. This technique reduced the spread of defects in the interaction models.

Discussion and evaluation: From the results of this research, we suggest: (i) employing personas and scenarios to understand the requirements; (ii) employing interaction models to understand the behavior between user and system; and (iii) using interaction models as basis to develop other artifacts.

Conclusions: Through the reporting of this set of practical activities, we hope to provide support for software engineers willing to adopt techniques that support the analysis and design of applications aiming at better quality of use for their users.

Keywords: Requirements specification, Communication model, Communication practices, Software engineering

1 Background

User involvement in the development process can provides satisfaction and acceptance of the software (Bano and Zowghi 2015). In this context, the software industry has applied appropriate techniques to provide a more positive user experience. Therefore, the users' satisfaction and the software acceptance may be related to the positive experiences.

Among the specific techniques for understanding the users' needs in the analysis phase, we can cite personas and scenarios. These techniques serve to identify the needs of different types of users (Castro et al. 2008). In the design phase, interaction models can describe the structure and behavior of the system during user interaction (Trætteberg 2008). According to Meixner et al. (2011), interaction models should include a high-level of abstraction about the interactive system to be developed. Interaction models can contribute to the quality improvement of the developed system, as they allow the detection of eventual problems in the user-system interaction (Lopes et al. 2015).

One of the methods that can assist the verification of artifacts developed during the software project is the software inspection. Software inspection has a rigorous and well-defined process (Fagan 1976; Taba and Siew 2012). Through an inspection in the analysis and design phases, it is possible to identify defects in the early phases of the development process to reduce costs and improve software quality (Qazi et al. 2016). Through such inspection, the propagation of defects in interaction models can be minimized, reducing the cost of correcting such defects in other artifacts, such as use case specifications and prototypes.

This paper presents a research conducted following the action research methodology (Wohlin and Aurum 2014). In this research, industry and academy worked together for the development of software, reporting the activities of an analysis and design team developing an application with user-centered techniques. The team applied techniques, such as personas and scenarios, for understanding the user and identifying requirements in the analysis step. In the design phase, the team used interaction models for user-system interaction and other artifacts. For the interaction modeling, we developed a technique which contributed to the reduction of defects in interaction models. This technique assists the inspection of interaction models and comparing the interaction modeling with the requirements. We did not find a technique with this purpose in the literature.

Our main contribution with this paper is to present the results obtained with the set of practical activities for the analysis and design of user-centered systems in Software Engineering and the technique for inspection of defects in interaction models. In addition to this section, this paper has the following sections: Section 2 describes the case description with: the description of the methodology we applied in this research, and the description of the theoretical basis of the techniques and notation used in the analysis and design phases. This section also presents some information on the mobile application and the activities of the analysis and design phases in this research. In addition, this section presents a technique that assists in the verification of interaction models. Section 3 presents a discussion of the results from this research and provides a set of practices that can be adopted by other software engineers in future projects. Finally, Section 4 presents the conclusions and future perspectives.

2 Case Description

This research was conducted using action research methodology, a methodology used when the researchers attempt to solve a real-world problem while simultaneously studying the experience of solving the problem (Wohlin and Aurum 2014). We used the structure from action research provided by Susman and Evered (1978), in five stages:

- Diagnosing

We observed the analysis and design team of a mobile application with user-centered techniques, such as personas, scenarios, interaction models, and others necessary artifacts. When creating the artifacts without having a model as basis, the design team had rework due to the lack of consistency between the artifacts (e. g. we analyzed whether the information in the prototypes was in agreement with the use case and the activity diagram).

- Action planning

We selected interaction models because they can be used as a basis for the development of other artifacts, such as prototypes (Bueno and Barbosa 2007; Marques et al. 2016). Interaction modeling provided the necessary understanding of the system interactions.

- Action taking

we used the interaction modeling as a basis for the development of other necessary artifacts, such as prototypes and UML (Unified Modeling Language) use cases. Based on the interaction modeling, the modifications for the consistency among the artifacts were finished in a simpler way.

- Evaluating

we identified that interaction models may contain defects which can impair the understanding of the practitioners that developed other artifacts. In this context, it is important to perform inspections in interaction models before they are used by other practitioners in the design of a mobile application.

- Specifying learning

Figure 1 presents a set of practical activities that we proposed during the analysis and design of a mobile application. We evaluated the set of practical activities presented in Fig. 1 and the results show that the proposal is feasible (as presented in the following section). We developed a technique called Inspecting MoLIC Interaction Diagrams (IMID) based on the defects that impaired the understanding of information from the interaction models. This technique proved to be feasible for the inspection and for reducing the propagation of software defects.

2.1 Background on the user-centered techniques to analyze and design an application

Requirements engineering has used different techniques for the requirements elicitation focusing on the user (Aoyama 2015), such as personas and scenario. Personas, originally presented by Alan Cooper (Cooper 1999), are fictitious, specific and concrete representations of target users. These are described like real people (i.e. they contain information such as names, ages, formations, skills, goals, and concerns) (Sima and Brouseb 2015). Scenarios describe sequences of interactions between systems and users (Carroll and Rosson 1992). They can be employed to illustrate how a user might

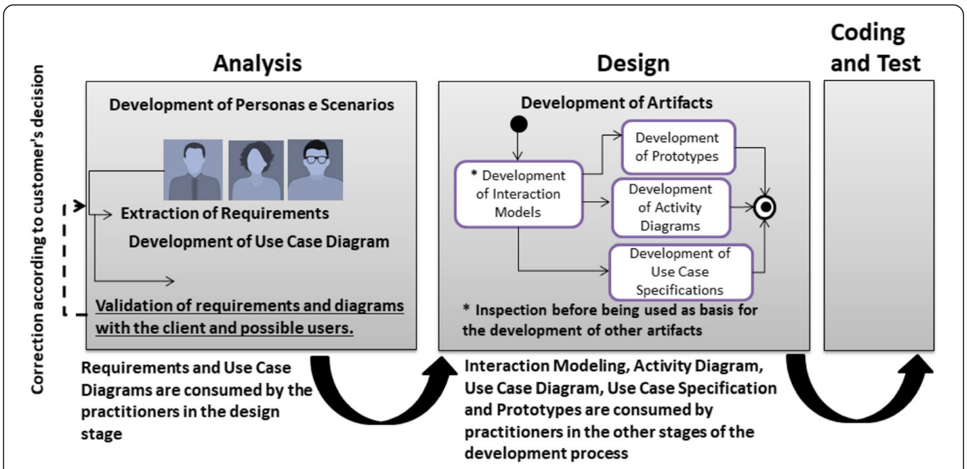

Correction according to customer's decision
Analysis
Development of Personas e Scenarios
Extraction of Requirements
Development of Use Case Diagram
Validation of requirements and diagrams with the client and possible users.
Requirements and Use Case Diagrams are consumed by the practitioners in the design stage
Design
Development of Artifacts
* Development of Interaction Models
Development of Prototypes
Development of Activity Diagrams
Development of Use Case Specifications
* Inspection before being used as basis for the development of other artifacts
Interaction Modeling, Activity Diagram, Use Case Diagram, Use Case Specification and Prototypes are consumed by practitioners in the other stages of the development process
Coding and Test

Fig. 1 Set of practical activities for the analysis and design of software that focuses on the user

accomplish particular tasks with the system. According to Benner et al. (1993), scenarios can supplement and support the activities that software engineers perform mentally on scenarios at the present time, such as uncovering system requirements and evaluating design alternatives. Scenarios can take many forms and provide various types of information at different levels of abstraction (Lombriser et al. 2016).

In the design phase, interaction models describe the communication between the user and the system, specifying when the user can perform specific tasks to achieve certain goals (Marques et al. 2016). One of the alternatives to support the development of interaction models is through MoLIC (Modeling Language for Interaction as Conversation) (Barbosa and Paula 2003). With the MoLIC models, all interaction paths can be represented, including alternative paths for the user to reach the same goal (Souza and Barbosa 2015). Thus, interaction models can support the software design with a focus on quality of use, since software engineers can design all interaction alternatives in the system.

Figure 2 presents an example of a MoLIC diagram, which represents an interaction model for a mobile educational game. Overall, the game helps teaching the software inspection. Software inspection of artifacts during development has shown to improve the quality of the system and reduce development costs in the Software Engineering (Travassos et al. 2001). Table 1 presents a description of the types of defects that can be found in software artifacts (De Mello et al. 2014).

We used the concepts presented in Table 1 for the design of the MoLIC diagram shown in Fig. 2. The game aims to teach the detection of types of defects that can be found in an artifact through a playful environment. Thus, students (users) may practice the concepts regarding inspection that were listed during their classes. The game can be used by professors that teach software inspection as a practical exercise. The MoLIC diagram has the following elements:

- Opening point

Indicates where the interaction can start, i.e., when the user select game. A filled black circle represents the Opening Point (the numbers in the blue circles) in the Fig. 2.

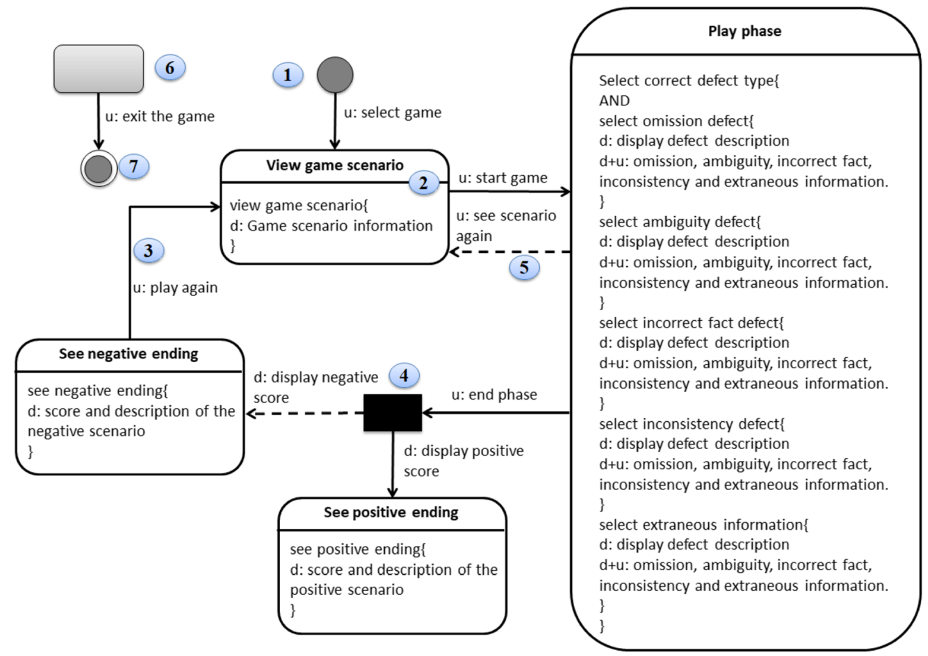

6
1
u: exit the game
u: select game
7
View game scenario
2
u: start game
view game scenario{
d: Game scenario information
}
u: see scenario again
3
5
u: play again
See negative ending
see negative ending{
d: score and description of the negative scenario
}
d: display negative score
4
u: end phase
d: display positive score
See positive ending
see positive ending{
d: score and description of the positive scenario
}
Play phase
Select correct defect type{
AND
select omission defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select ambiguity defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select incorrect fact defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select inconsistency defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select extraneous information{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
}

Fig. 2 A MoLIC diagrams example

- Scene

Represented in the Fig. 2 as a rounded rectangle. The scene shows the moment in the interaction where the user decides how the conversation should proceed. The top compartment contains the topic of the scene and represents the user's goal. The second compartment details the following elements:

- Signs

represent the information involved in the utterances issued by the user (i.e., user input) and by the designer's deputy (i.e., system output) during the dialogues. In Fig. 2, we have the following signs in the "Play phase" scene: "omission, ambiguity, incorrect fact, inconsistency, extraneous information".

- Dialogues

compose a conversation about a topic, and consist of utterances on signs. In Fig. 2, one example of dialogue is "select ambiguity defect" (in "Play phase" scene).

Table 1 Defects taxonomy for software artifacts

Types of Defects	Description of Defects
Omission	Omission of any information necessary in the artifact.
Ambiguity	Unclear definition of certain information in the artifact, which may lead to multiple interpretations.
Incorrect Fact	Misuse of the artifact elements.
Inconsistency	Conflicting information between the artifact and the information needed to solve the problem.
Extraneous Information	Unnecessary information included in the artifact (e.g., information that is not needed to solve the problem).

- Structures of dialogues

the dialogues can be composed of other dialogues according to some structure. In these cases, these structures can be represented by the reserved words SEQ, XOR, OR or AND. The SEQ structure represents the dialogues that must be exchanged in the specified sequence. The XOR structure represents mutually exclusive dialogues. The structure OR represents the choice of exchanging one or more dialogues. The structure AND represents the use of all dialogs, but not in a predefined sequence. In Fig. 2, the AND structure represents the use of all dialogs, such as "select omission defect" and "select ambiguity defect".

- Transition utterance

Represents turn-taking, or rather turn-giving, where either the user or the system gives the turn to the other, for instance, to change the topic of the conversation. It is represented by an arrow in the diagram, labeled with a user utterance indicator (u:) or designer utterance indicator (d:), e.g. "u: play again" in Fig. 2.

- System process

It is represented through a black box in the diagram. It represents the internal processing (of a user request) which needs to provide adequate feedback to the user when there are different outcomes possible, e.g. "See positive ending" and "See negative ending" in Fig. 2.

- Breakdown recovery utterance

is a type of utterance provided to help the user recover from a communication breakdown. It is represented by a dashed arrow in the diagram, e.g. "see scenario again" in Fig. 2.

- Ubiquitous access

represents an opportunity for the user to change the topic of the conversation from any other scene. It is represented through a gray rounded rectangle, e.g. "exit the game" in Fig. 2.

- Closing point

represents the end of the interaction. A filled black circle within a circle with no padding represents the Closing Point in the Fig. 2.

Interaction models can be used as a basis for the development of other artifacts, such as prototypes (Bueno and Barbosa 2007; Marques et al. 2016). In addition, software engineers can discuss the user-system interaction represented in the MoLIC diagram in order to collaborate on improving the represented information. Prototypes in the design phase are interface sketches that reflect customer needs with regards to more concrete aspects of presentation, from the point of view of requirements expressed in written language (Luna et al. 2010). The prototypes can be developed based on the interaction modeling to reflect the decisions of designers about the paths that the user can follow in the application. Figure 3 presents prototypes of a mobile application (the educational game) built based on the MoLIC diagram shown in Fig. 2. We will now describe the decisions for the

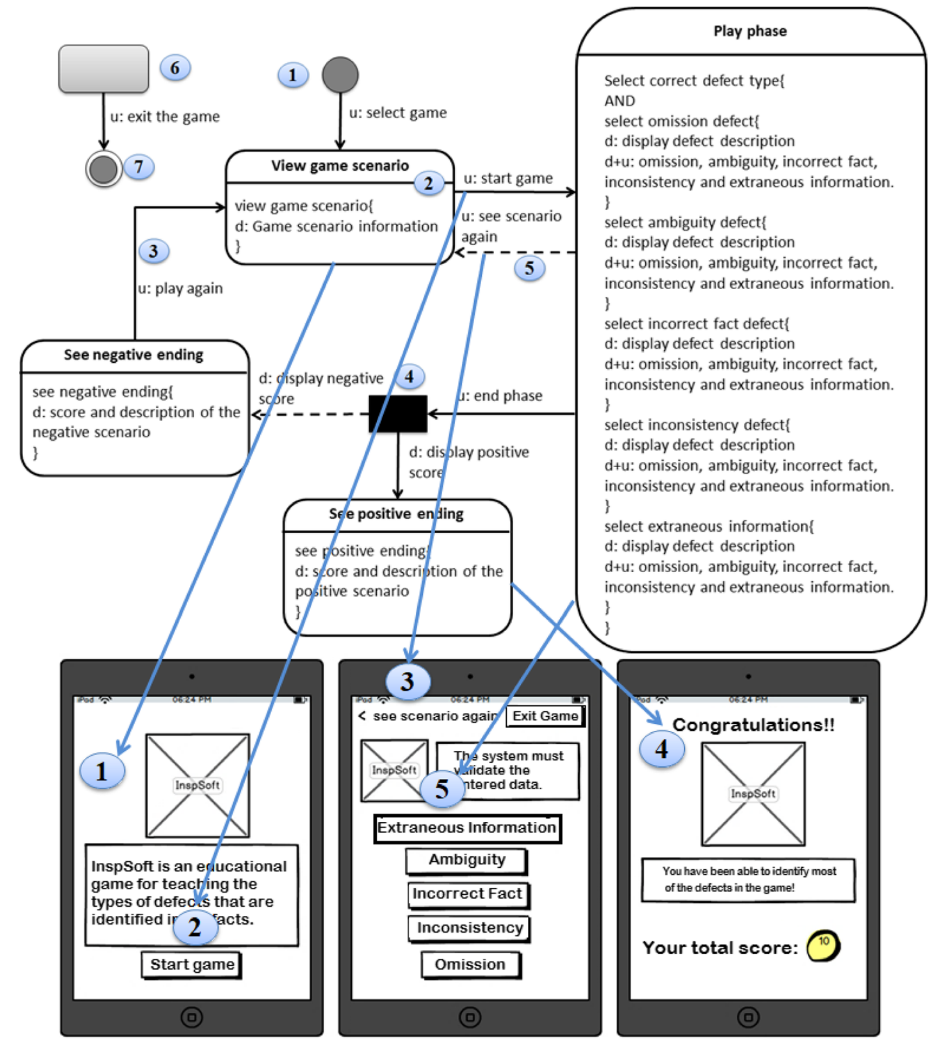

6
u: exit the game
7
1
u: select game
View game scenario
2
view game scenario{
d: Game scenario information
}
u: start game
u: see scenario again
5
3
u: play again
Play phase
Select correct defect type{
AND
select omission defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select ambiguity defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select incorrect fact defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select inconsistency defect{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
select extraneous information{
d: display defect description
d+u: omission, ambiguity, incorrect fact, inconsistency and extraneous information.
}
}
See negative ending
see negative ending{
d: score and description of the negative scenario
}
d: display negative score
4
u: end phase
d: display positive score
See positive ending
see positive ending{
d: score and description of the positive scenario
}
1
InspSoft
InspSoft is an educational game for teaching the types of defects that are identified in artifacts.
2
Start game
3
< see scenario again
Exit Game
InspSoft
The system must validate the entered data.
5
Extraneous Information
Ambiguity
Incorrect Fact
Inconsistency
Omission
4
Congratulations!!
InspSoft
You have been able to identify most of the defects in the game!
Your total score:
10

Fig. 3 Mapping the MoLIC diagram to the prototypes

mapping of the MoLIC diagram to the prototypes (numbers in orange circles in Fig. 3 correspond to the descriptions below):

1. The “View game scenario” scene has been mapped to the “initial game” screen.
2. The utterance transition “u: start game” was represented by the “START GAME” button.
3. The breakdown recovery utterance “u: see scenario again” was represented by the “See scenario again” link for the user to be directed to the “initial game” screen.
4. The transition utterance “d: display positive score” after the system processing was represented in the prototypes as user feedback, in the case of the final positive scenario of the game.
5. The “d + u: omission, ambiguity, incorrect fact, inconsistency, extraneous information” signs were mapped, respectively, to represent information and buttons in which the user can classify the defects.

2.2 Developed application and practices adopted for the development of artifacts in the analysis and design phases

The research presented in this phase refers to the work of the analysis and design team of an application called HCDP (Home Care Development Project). The motivation for the development of this application is the difficulty of family members trying to manage the routine activities of an elderly person. The HCDP application was developed to support a group of people, being family members and caregivers of the elderly, who took care of an elderly in a collaborative way. This application was part of a cooperation project among the Federal University of Amazonas, Pontifical Catholic University of Rio Grande do Sul and Samsung Research Brazil. Three distributed teams worked in the development of the HCDP application. The management team (Customer) defined all the functionalities to be developed and the artifacts that should be delivered. Another team performed the activities related to the application coding. The remaining team performed the activities related to the analysis and design of the application. The analysis and design team was composed of five software engineers and a project manager.

The authors of this paper were part of the analysis and design team of the HCDP application. In order to develop the HCDP application, we adopted the Scrum methodology (Scrum Alliance 2016). Scrum focus on collaborative teamwork and explicitly acknowledge the importance of self-organization and is the most often employed agile methodology (Hron and Obwegeser 2018). We adopted some practices from the Scrum methodology, such as: (i) the products are delivered in increments called "Sprints". The duration of each sprint was four weeks. Each sprint starts with a (ii) sprint planning meeting and a (iii) retrospective meeting may be scheduled to assess the team. We chose Scrum methodology because the management team requested the iterative and incremental development of the artifacts; and the team adopted transparency in the progress of activities.

We divided the analysis and design phases of the application into fixed duration Sprints of four weeks. The project lasted six months and was divided into six Sprints. Table 2 presents a summary of the activities carried out during the execution of the project.

In the analysis phase (Sprint 1), the analysis and design team applied the personas and scenarios techniques to identify the needs of different types of users (Castro et al. 2008). Then, the personas were validated by the engineers through interviews with potential users. Based on the personas and scenarios, the requirements were identified and the use case diagram was developed, relating use cases to requirements. After that, the analysis and design team met with the management team and prioritized the development of the use cases in the later Sprints. In the design phase (Sprints 2, 3, 4 and 5), the artifacts requested by the management team were:

- **Interaction Models** - In the interaction modeling, the team developed the MoLIC diagrams to represent all interaction paths between the user and the system;
- **Use Case Specification** - In the use case specification, the team described the use cases considering the different execution flows;
- **Prototypes** - The prototypes necessary to represent the interface were also developed;

Table 2 Analysis and design activities performed on each sprint from the HCDP application

Sprint	Tasks Description
Sprint 1	Sprint Planning Meeting
	Personas Specification
	Scenarios Specification
	Extraction of Requirements from the Personas and Scenarios
	Development of Use-Case Diagrams
	Use Case Prioritization
	Retrospective Meeting between the Analysis and Design Team and Management Team on Lessons Learned
Sprint 2 Sprint 3 Sprint 4 Sprint 5	Sprint Planning Meeting
	Interaction Modeling for Use Cases: A (Sprint 2), B (Sprint 3), C (Sprint 4) and D (Sprint 5)
	Use Case Specifications: A (Sprint 2), B (Sprint 3), C (Sprint 4) and D (Sprint 4)
	Development of Prototypes for Use Cases: A (Sprint 2), B (Sprint 3), C (Sprint 4) and D (Sprint 5)
	Development of Activity Diagrams for Use Cases: A (Sprint 2), B (Sprint 3), C (Sprint 4) and D (Sprint 5)
	Retrospective Meeting between the Analysis and Design Team and the Management Team on Lessons Learned
Sprint 6	Sprint Planning Meeting
	Improvements in the Artifacts of the Previous Sprints
	Retrospective Meeting between the Analysis and Design Team and the Management Team on Lessons Learned

- **Activity Diagrams** – UML activity diagrams were developed to provide an overview of the system behavior through the sequence of actions in the activities (Czopik et al. 2014).

After the development of the artifacts, these were reviewed by different software engineers, i.e. the software engineer who created the artifact was not the same that carried out the review. This practice aimed to identify inconsistencies in the information represented in the artifacts. The analysis and design team was hoping to get insight into the analyzed and designed features from the HCDP application. As for Sprint 6, improvements were made in some of the artifacts from previous Sprints. At the end of each Sprint presented in Table 2, the analysis and design team held a retrospective meeting and discussed the lessons learned. At these meetings, the PABC-Pattern (Problem, Action, Benefit and Context – Pattern) approach was used to code lessons learned by the team (Rabelo et al. 2014). The purpose of the PABC-Pattern is the knowledge codification and sharing on the form of lessons learned. The main elements of the PABC-Pattern are:

- **Title** - description of the lesson's name;
- **Situation** - details of the situation in the project;
- **Cause of the Situation** - reason for the occurrence of the situation in the project;
- **Consequence of the Situation** - description of the consequences of the situation in the project;
- **Action -** details the solution to the situation, i.e. providing details of an activity that was applied to solve such a situation;
- **Benefit** - describes the effects that were caused by the action or situation in the project.

2.2.1 Activities of the analysis phase of the development process of the HCDP application

In Sprint 1, personas and scenarios were created with the purpose of understanding the different types of user of the application to be designed. The HCDP application should control the activities of an elderly person (e.g. go to the doctor, take medication, meals, and others). Therefore, the created personas represented family members and caregivers of the elderly. For the creation of personas, we used a template containing the following information: identification data, housing conditions, degree of experience with technologies, degree of responsibility, learning style, acceptance of change and the context of use of the application. After that, scenarios were developed with the details of the relationship between the personas and the mobile devices.

The scenarios show the relationship between the personas, which are related to the activity of notifying family members and caregivers about the elderly's appointments. To prepare the scenarios, we used a template composed of the following information: Context, goals, events and actions. From this scenario, the following requirements for the development of the application were identified: "*To notify that the activities of the elderly routine have been fulfilled*" - Requirement 1; "*To notify that the activities of the elderly routine have not been fulfilled*" - Requirement 2.

Based on these requirements, we developed the HCDP use case diagram. After performing these activities, the management team of the HCDP project and the analysis and design team prioritized together the development of use cases that would be developed in the other Sprints.

2.2.2 Activities of the design phase of the development process of the HCDP

Sprint 2 began the activities of the design phase. First, the analysis and design team selected one of the use cases according to the priority order defined in Sprint 1. After that, all the artifacts requested by the management team were developed. Different engineers were responsible for the development of interaction models, prototypes, use case specification and activity diagrams. The activities are described below.

A. Analysis of the development of artifacts in Sprint 2

In Sprint 2, the order for developing prototypes, MoLIC diagrams, specification of use cases and activity diagrams is presented in Fig. 4. We highlight that the development of the prototypes, MoLIC diagrams and use case specification was carried out in parallel, based only on the use case diagram, requirements and scenario.

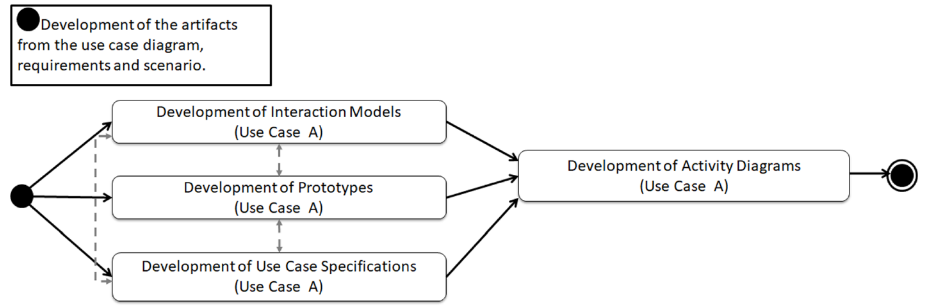

Development of the artifacts from the use case diagram, requirements and scenario.
Development of Interaction Models (Use Case A)
Development of Prototypes (Use Case A)
Development of Use Case Specifications (Use Case A)
Development of Activity Diagrams (Use Case A)

Fig. 4 Activities performed for the development of artifacts in Sprint 2

The use case diagram, requirements and scenario were discussed prior to the development of the prototypes, MoLIC diagrams and the use case specification. The project manager requested the development of these artifacts separately in order to assign different responsibilities to the software engineers and facilitate the process of developing the artifacts. Then, the engineers analyzed the consistency between created artifacts regarding the information with respect to the functionalities (dashed arrow in Fig. 4). The activity diagram was created, based on the three previously developed artifacts (prototypes, MoLIC diagrams and use case specification). At the end of Sprint 2, after the development of all artifacts, a retrospective meeting of the analysis and design team was held. The following are some of the lessons learned from Sprint 2.

In Sprint 2, there were 15 documents that reported the lessons learned that were coded using the PABC-Pattern approach, with a total of 7 documents related to the development of artifacts. The main three lessons learned that report problems in the development of the artifacts were selected. One of these lessons learned has the **Title: Rework by maintaining the artifact pattern**, which was generated by the following **Situation**: "*When developing the separate artifacts after the meeting, there is a lot of work in standardizing the use cases, prototypes, interaction modeling and activity diagram*". The analysis and design team defined the following **Action** strategy: "*A joint analysis where the main idea of the requirements will be defined before creating the artifacts through a formal document*". Thus, the team concluded that rework can be reduced with regards to inconsistencies between such artifacts.

The lesson learned that has the **Title: Dependence between activities can cause delays in the project**, occurred due to the following **Situation**: "*The improvement of the use case depended on the delivery of the prototypes. The delivery of the prototypes was delayed*". As a result, the following **Consequence of the Situation** was observed: "*Rework. Delay of the next activity that should be delivered to another participant*". Therefore, we can notice that there was a delay in the specification of use cases, since such an artifact should represent the same information in the prototypes and MoLIC diagrams.

The lesson learned that has the **Title: Lack of traceability between the prototypes and the use case**, occurred due to the following **Situation**: "*Lack of traceability or mapping to understand what is in the prototypes and what it represents in the use case*". The analysis and design team defined the following **Action** strategy: "*To verify which prototypes are represented in the use case and integrate the two artifacts*". Therefore, there was a lack of understanding of some software engineers regarding the understanding of the requirements for the development of different artifacts. As a result, there were inconsistencies about the information of the HCDP application among the developed artifacts based on the requirements, use case diagram and scenario.

We highlight that in Sprint 2 the MoLIC diagrams were not used as basis for the development of the other artifacts. Therefore, there was no artifact that represented the essential information in the user-system interaction for the development of the other artifacts. For this reason, there was rework of the analysis and design team with regards to the consistency of the artifacts. This rework was due to the team's lack of knowledge regarding the most appropriate order for the development of artifacts. To mitigate this problem, the team made a change in the order of development of the artifacts. This change is shown in the next subsection.

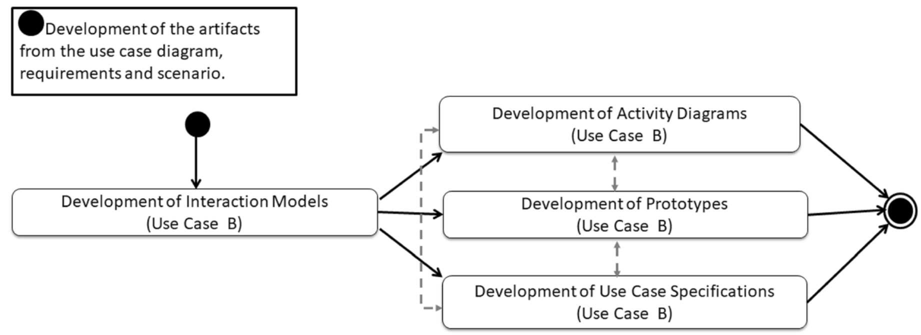

Development of the artifacts from the use case diagram, requirements and scenario.
Development of Interaction Models (Use Case B)
Development of Activity Diagrams (Use Case B)
Development of Prototypes (Use Case B)
Development of Use Case Specifications (Use Case B)

Fig. 5 Activities performed for the development of the artifacts in Sprint 3

B. Analysis of the development of artifacts in Sprint 3

In Sprint 3, the order of developing the MoLIC diagrams, prototypes, use case specification, and activity diagrams is presented in Fig. 5. This order of development is different with regards to the design activities in Sprint 2. The development of prototypes, activity diagrams and use case specifications was based on the MoLIC diagrams, requirements, use case diagrams and scenario. The project manager adopted this approach based on the lessons learned from Sprint 2 and the literature suggestions (Bueno and Barbosa 2007; Marques et al. 2016) on using the interaction modeling as a basis for the development of other artifacts. In similar way to Sprint 2, the engineers analyzed the consistency between these artifacts developed about their information (dashed arrow in Fig. 5).

In Sprint 3, the analysis and design team carried out a joint elaboration of the interaction modeling, that is, the software engineer responsible for the interaction modeling developed the MoLIC diagrams, while the other engineers discussed the interaction solutions. After doing this, the prototypes, activity diagram and case specification were developed, using the MoLIC diagrams as basis. At the end of Sprint 3, a retrospective meeting of the HCDP project was also held. Here, we present some of the lessons identified in Sprint 3.

Regarding the lessons learned from the Sprint team, there were 12 documents that report a coding of lessons learned, with a total of 4 documents related to the development of the artifacts. We selected the main three lessons learned on the use of MoLIC diagrams as the basis for the development of the other artifacts.

A lesson learned about the use of MoLIC in Sprint 3 has the **Title: Using MoLIC diagrams at the beginning**, which was caused by the following **Situation**: "*The use of the MoLIC diagrams at the beginning made it possible to think about the use case. Also, it enabled seeing that it is necessary to use the diagrams along with the interface*". This coded lesson learned was assigned to the following **Consequence of the Situation**: "*Based on the MoLIC diagrams, the team ended up gaining time and, at the end of the sprint, the modifications were finished in a simpler way*". However, the modifications in the prototypes made the analysis and design team think on modifications that must be made in the MoLIC diagram, since such models can be designed together (Lopes et al. 2015). Regarding the **Action** strategies, for this codification, there was no action planned to be defined, because the experience was considered positive.

Another selected lesson that has the **Title: Thinking about time consumption in the project activities**, which occurred as shown by the following **Situation**: "Benefits in activities that consumed design time and were not well understood by the participants". The analysis and design team defined the following Action strategy: "*Participants have to think that when there is no interface pattern, starting with the interaction modeling makes sense*". Therefore, the analysis and design team concluded that the use of initial interaction modeling is useful to understand the system's functionalities. Furthermore, in this project there was a better understanding of the functionalities from the MoLIC diagrams together with the prototypes.

Based on these lessons learned, we can identify the following positive aspects: (a) the use of MoLIC diagrams in the beginning to understand the functionalities and (b) their use as a basis for the development of other artifacts.

C. Analysis of the use of interaction models as basis for the development of other artifacts in Sprint 3

Besides the documents with the coded lessons learned, the document containing the review of the interaction model was analyzed in Sprint 3. Only the document with the interaction model review from the Sprint was chosen for this analysis because it was used by the software engineers as the basis for creating other artifacts. This document included the MoLIC diagrams and other information necessary to understand what problems may have occurred after defining the interaction model at the beginning of the sprint.

We carried out the review of the MoLIC diagrams based on the taxonomy presented by De Mello et al. (2014) in Table 1. The MoLIC diagrams review document identifies, for example, an inconsistency defect of the message displayed to the user. The defect could impact in development of the prototypes and the specification of use cases, since the information would be mapped inconsistently with the system requirements. In addition, we identified an omission defect of information about the description for details of the user. These defects could impact in development of the prototypes, since the information would not be mapped. The defects presented were found in the case study presented in the work by Lopes et al. (2015), based on the taxonomy presented by De Mello et al. (2014). Consequently, it is important to review the interaction models, because the defects may undermine the practitioners' understanding of the artifacts that were developed based on the MoLIC diagrams. This practice was performed in the interaction modeling document and in the other artifacts before being delivered to the analysis and design.

Although the review activity was performed on the MoLIC diagrams by another software engineer, we highlight that such review was not performed with a specific technique for reviewing MoLIC diagrams. Possibly, the use of a specific technique could have aided in identifying more defects prior to the development of the prototypes and use case specification. Thus, it was necessary to correct the MoLIC diagrams, specification of use cases and prototypes due to such defects.

2.3 A technique for inspecting MoLIC interaction diagrams

An inspection helps identifying defects during the development process (Taba and Siew 2012). The main purpose of an inspection is to identify defects in software development to reduce costs and improve software quality (Qazi et al. 2016). The importance of conducting inspections during the development process is broadly cited in the literature (Aurum et al. 2002; Misra et al. 2014). Regarding the MoLIC diagrams, these diagrams should be also verified regarding their consistency and completeness to reduce the number of defects and to prevent them from propagating defects to derived artifacts. As suggested by Lopes et al. (2015), MoLIC diagrams may contain defects, which can impair the understanding of the practitioners.

We developed a technique for Inspecting MoLIC Interaction Diagrams (IMID) based on the different types of defects found in the MoLIC diagram for the HCDP application from Sprint 3, such as Omission, Ambiguity, and others (De Mello et al. 2014). Table 3 presents the IMID technique. The verification items assess both the consistency of the MoLIC diagrams with the requirements and their completeness. The IMID technique was developed because we did not find a technique in the literature for the inspection of MoLIC diagrams with regards to the requirements. We believe that these verification items can be instantiated for other interaction modeling notations, as long as the elements have the same purpose in the interaction modeling. We applied this technique in Sprints 4 and 5, as follows: After the software engineer responsible for the interaction modeling finished the diagram, the reviewer responsible for the verification of the interaction model used the IMID technique with the aid of a defects reporting form.

We analyzed the use of the IMID technique for the inspection of MoLIC diagrams in the Sprint 4 and 5. In the Sprint 4, the MoLIC diagrams contained a total of 5 defects; and, in the Sprint 5, the MoLIC diagrams contained a total of 6 defects. Figure 6 presents examples of some of the identified defects found with the technique by the reviewer of interaction modeling. In this sense, we present: the identifier of the defect (e.g. “Verification item 1”), the verification item description of the IMID and the type of identified defect. The number of defects, the inspection time and the indicators of effectiveness and efficiency of each subject (software engineer responsible for the verification of the interaction model used the IMID technique) are described in Table 4 (for Sprint 4 and 5). The indicators of effectiveness and efficiency that were adopted, this is often used in studies investigating inspection techniques, such as inspection techniques for models (Fernandez et al. 2012). The effectiveness was calculated using the number of defects found by the subjects divided by the total number of defects from the oracle. The efficiency was calculated on the number of defects found divided by the time of inspection of each subject. We refer to the subjects using the letter S#, where # is a number that uniquely identifies each software engineer.

Analyzing the effectiveness indicator, we can see that each single subject was able to identify more than 40% of the defects. This is a good result in terms of effectiveness when compared to the indicators achieved by other inspection techniques (Valentim et al. 2015) and, as such, it indicates the feasibility of IMID. However, it is still necessary to perform a controlled experiment to compare the effectiveness of IMID with other techniques for identifying defects in interaction models. Regarding efficiency, the subjects found between 2 and 5.71 defects per hour. However, the number of defects is directly dependent on the inspected models, is not suitable to compare the results of efficiency from this study with the results of other techniques. As an overall result, these identified defects were not propagated

Table 3 Technique for Inspecting MoLIC Interaction Diagrams (IMID)

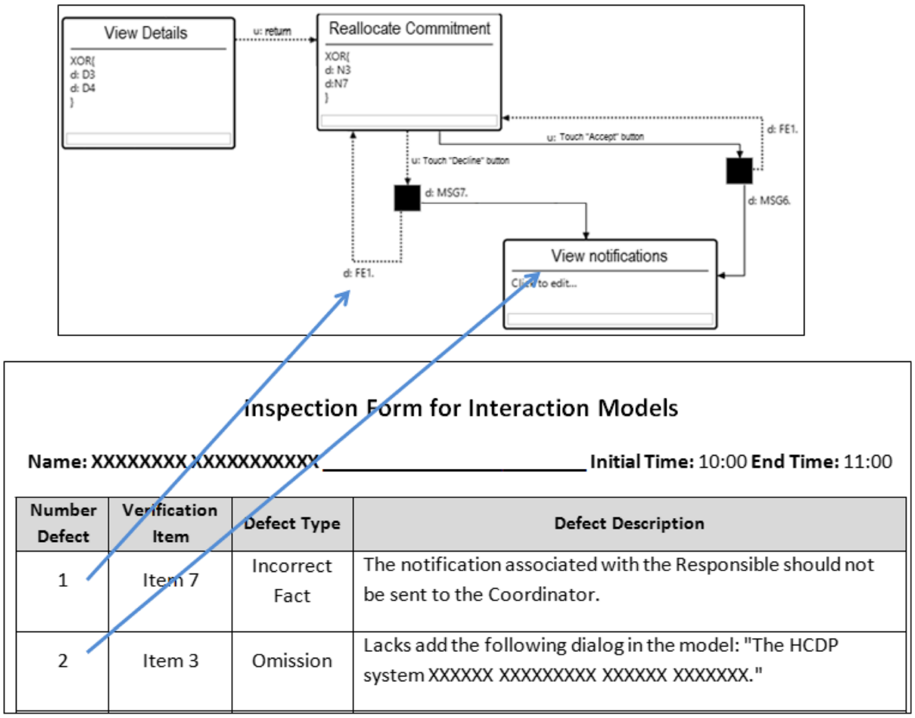
E#	Verification Items for the MoLIC Element vs Software Requirements
Opening point Closing point	Verification item 1: Was the element used in the model to represent the start/end of the interaction? If not, report it as an Omission defect. *Generated problem: This defect may impair understanding the beginning/ending of the interaction by the team members.* Verification item 2: If the previous item occurs, does the element represent the beginning / end of the interaction according to the requirements? If not, report it as an Inconsistency defect. *Generated problem: This defect may impair the consistency of requirements with the appropriate start/end of the user interaction in the system* (e.g. *incorrect sequence of interaction scenes with regards to what was described in the requirements*).
Scene, Signs, Dialogues and Structures of dialogues	Verification item 3: Are all requirements represented in the interaction model? If not, report it as an Omission defect. *Generated problem: This defect may hinder the development of a necessary requirement* (e.g. *the software engineer did not capture all of the goals that the user could have, considering the requirements used as basis*). Verification item 4: Are there inconsistent requirements in the interaction model? If so, report it as an Inconsistency type defect. *Generated problem: This defect may make the software inconsistent with the requirements* (e.g. *in a sequence of dialogues that should be structured with XOR, the AND structure was used*). Verification item 5: Is there information in the interaction model that is not in the context of the requirements? If so, report it as an Extraneous Information defect. *Generated problem: This defect may make the software present irrelevant information* (e.g. *scenes that were not described in the requirements can be represented in the prototypes*). Verification item 6: Is it possible to understand all the information about the requirements in the interaction model in a clear way? If so, report it as an Ambiguity defect. *Generated problem: This defect may cause the insertion of other defects in the developed artifacts, since each team member may have a different interpretation* (e.g. *description of similar scenes provided multiple interpretations about the user goals.*) Verification item 7: Have all requirements been correctly represented in the interaction model? If not, report it as an Incorrect Fact defect. *Generated problem: This defect may hinder the development of correct requirement* (e.g. *the sign issuers can be attributed to the user or to the designer's deputy in an incorrect manner with what was described in the requirements - confusion between “d:” and “u:”*).
Transition Utterance and Breakdown recovery utterance	Verification item 8: Are there any omissions on interactions required for the software features? If so, report it as an Omission defect. *Generated problem: This defect may impair the user interaction with the system* (e.g. *lack of transitional utterance when switching from one scene to another, impairing the interaction sequence*). Verification item 9: Is the content of the interactions between the features consistent with the requirements? If not, report it as an Inconsistency defect. *Generated problem: This defect may make the user interaction inconsistent from the requirements point of view* (e.g. *the content “u: play again” regarding the scene that is outside the context of the interaction in the game, such as the “see positive ending” scene*). Verification item 10: Is the content of the interactions between the functionalities in the context of the requirements? If not, report it as an Extraneous Information defect. *Generated problem: This defect can also impair the user interaction from the point of view of the requirements* (e.g. *the content “u: search hotel” is outside the context of the game*). Verification item 11: Does the content of the interactions between the features provide multiple interpretations? If so, report it as an Ambiguity defect. *Generated problem: This defect may provide for the insertion of other defects in the developed artifacts, since each team member may have a different interpretation* (e.g. *the use of two user transition utterances for the same goal, which provided multiple interpretations about the user transition*). Verification item 12: Have all interactions been correctly represented in the interaction model? If not, report it as an Incorrect Fact defect. *Generated problem: This defect may hinder the development of correct interactions* (e.g. *in the breakdown recovery utterance, solid lines can be used, instead of the dashed lines).*

Table 3 Technique for Inspecting MoLIC Interaction Diagrams (IMID) *(Continued)*

E#	Verification Items for the MoLIC Element vs Software Requirements
System process	Verification item 13: Was the element required for the interpretation of an applied user action? If not, report it as an Omission defect. *Generated problem*: *This defect can impair proper user interaction in the system after a certain action* (*e.g. an interpretation for the game results regarding the positive ending or negative ending*).
Ubiquitous access	Verification item 14: Can the features associated with this element be accessed at any time in the user-system interaction? If not, report it as an Inconsistency defect. *Generated problem: This defect may make the user interaction inconsistent from the requirements point of view* (*e.g. there is not opportunity for the user to change the topic of the conversation from any other scene for the game exit. Therefore the ubiquitous access element should not be related to closing point element).*

to artifacts that were developed based on the MoLIC diagram, thereby reducing analysis and design rework.

After Sprints 4 and 5, we conducted an interviewed with two software engineers (subjects) who used IMID during the design phase. We asked the following question was for software engineers: *Please report your perceptions about the IMID technique*? Regarding the positive aspects of the technique, the software engineers quoted the following: "*I believe that the items guided me well to find defects in the diagram*" (S1) and "*I consider that this technique helps finding defects in the diagram before creating other artifacts*" (S2). However, S1 also reported a negative aspect of the technique: "*I had trouble in remembering the difference between the*



Inspection Form for Interaction Models

Name: XXXXXXXX XXXXXXXXXX ________________________ **Initial Time:** 10:00 **End Time:** 11:00

Number Defect	Verification Item	Defect Type	Defect Description
1	Item 7	Incorrect Fact	The notification associated with the Responsible should not be sent to the Coordinator.
2	Item 3	Omission	Lacks add the following dialog in the model: "The HCDP system XXXXXX XXXXXXXXX XXXXXX XXXXXXX."

Fig. 6 Example of the inspection results from a software engineer responsible for verifying the interaction modeling

Table 4 Results per Subjects

Sprint	Subjects	Number Defects	Time Hours	Effectiveness (%)	Efficiency
Sprint 1	S1	2	0,83	40%	2
	S2	3	1	60%	3,61
Spint 2	S1	4	0,7	66%	5,71
	S2	3	0,6	50%	5

types of defects" (S1). Concerning the opinion from S1, we identified the difficulty of understanding the types of defects described in the technique. To solve this problem, we describe the definition of each type of defect (as defined in Table 1) so practitioners can understand the classification of defects that the technique helps to identify. The final version of the technique can be accessed elsewhere (Lopes et al. 2017).

Through the use of the IMID technique in Sprints 4 and 5, we noticed that the technique achieved the goal of detecting defects in interaction models. With this technique, the interaction models are improved so that defects cannot propagate from the defects found within the model, as observed in the design phase of Sprint 3. Therefore, this technique can help practitioners, since it was useful for the inspection of MoLIC diagrams.

3 Discussion and evaluation

We adopted some practices from the Scrum methodology (Scrum Alliance 2016) for development of artifacts produced in the analysis and design phases of a mobile application called HCDP. These practices refer to the products delivered in Sprints, sprint planning meeting and retrospective meeting. The use of the Scrum methodology, with its emphasis in incremental development and constant monitoring, provided the team the opportunity to improve the order of developing artifacts in the design phase, as also increased the team collaboration on all Sprints.

We analyzed the use of interaction modeling in Sprints 2 and 3 and the development of other artifacts (from the artifacts and lessons learned that were discussed at the retrospective meeting). From this analysis, we developed the set of practical activities presented in Fig. 1 for analyzing and designing a mobile application. Regarding this set of activities, practitioners should acquire knowledge about personas, scenarios and interaction modeling. Scenarios and personas are developed with textual descriptions, and there are some personas techniques that help introduce personas to development teams with little training time (Ferreira et al. 2016). For instance, Ferreira et al. (2016) reported the use of PATHY Personas technique after a one-hour training, and Ferreira et al. (2017) described a forty minutes training to enable participants using a personas technique. Regarding interaction modeling, the development team needs training on a specific modeling language, such as MoLIC (Barbosa and Paula 2003). There are many Computer undergraduate courses that include interaction modeling as a topic in a Human-Computer interaction class (Lopes et al. 2015), therefore some developers might already know how to use these modeling languages. The duration of a specific training about interaction modeling varies between four to six hours (Marques et al. 2016).

Although there is a learning curve, such activities provide a better support for the development of user-centered applications. In addition, the adoption of these activities provides better team communication regarding users and their needs during the whole design process; and helps teams on decision-making about efficient design (Mashapa et al. 2013; Marques et al. 2017).

The set of practical activities was used in Sprints 3, 4 and 5; and caused the reduction of rework in Sprints 3, 4 and 5 when compared with the rework from Sprint 2. We applied a Focus Groups (FG) (De França et al. 2015) to evaluate the perceptions from the analysis and design team perceptions about the set of practical activities presented in Fig. 1. FG is a qualitative technique for collecting data by organizing group interviews to discuss a certain object of study. It determines how a researcher has to choose moderators, questions and participants. All software engineers participated in the FG, including the software engineers who used IMID to inspect the MoLIC diagrams (S1 and S2). The software engineer responsible for the interaction modeling and manager of the design team were the moderator in the FG. We also refer to the software engineers using the S# for identifies each software engineer. The following question was asked to the software engineers to them answer: *Please report your perceptions about the set of practical activities used in the HCDP*. In the FG discussion, the team reported in the FG board that:

> "*I found it great to have the interaction model for developing prototypes. I mapped the information in the prototypes from the diagram, which improved my performance in this activity*" (S3).

> "*I believe that the definition of these activities helped each team member carry out his/her tasks and improved our communication. The team was already aware of what they would do; and we found fewer errors in evaluating the consistency of the developed artifacts*" (S4).

> "*The dependency between activities can cause rework, as in Sprint 2. With the set of activities, we did not have this problem. In addition, we do not become idle*" (S2).

> "The *interaction modeling meetings provided a better understanding of the artifacts to the team members*" (S1).

members in the FG, it was possible to obtain indications about the benefits of using the set of practical activities proposed in this research. However, if the MoLIC diagrams have defects, this will prejudice the understanding of the involved practitioners. These defects can cause rework in both the MoLIC diagrams and the artifacts developed based on the diagrams. For this reason, we suggest that the developed interaction models are inspected before being used as basis for the development of other artifacts.

Through this research, we observed the experience of this analysis and design team when applying user-centered techniques, we suggested personas and scenarios for the understanding of requirements; and we carried out interaction modeling at the beginning of the design phase in order to develop other software artifacts, such as the specification of use cases, prototypes, and activity diagrams. Through the use of interaction models it is possible to design and detect possible problems in the user-system interaction during the design phase of the system. Thus, it is possible to develop user-centered software.

In addition, we highlight the importance of carrying out meetings on the lessons learned for the team's understanding of the project's analysis and design activities. Regarding the lessons learned from Sprint 2, there was a rework of the design team with regards to the consistency of the artifacts developed. This was due to the lack of an artifact that represented the essential information in the user-system interaction for the development of the other artifacts. Based on the lessons learned from Sprint 2 and the literature suggestions (Bueno and Barbosa 2007; Marques et al. 2016), the design team adopted the interaction modeling as a basis for the development of other artifacts. The use of interaction modeling provided the necessary understanding of the system interactions and the modifications for the consistency among the artifacts were finished in a simpler way. These lessons learned can help software engineers understanding our proposal of a set of practical activities. Thus, it is possible to improve the execution of activities when analyzing and designing applications.

3.1 Related work

Regarding the practice with the user-centered techniques used in the HCDP, we did not find any other works on how software engineers used these techniques together in the initial stages of the development process. In general, studies assess the techniques individually for specific contexts.

Choma et al. (2016) used Personas to facilitate the communication between the UX and Scrum teams due to differences in vocabulary. Furthermore, personas are recognized by UX practitioners as a good practice to keep the software development focus on the users' needs. In their development process, they created user stories based on the created personas. In our work, we created scenarios and use cases based on the created personas.

Regarding the interaction modeling with MoLIC, Silva et al. (2006) proposed the Extreme Designing methodology for interaction design through the use of prototypes and MoLIC diagrams. The methodology aims to unify the vision represented by the prototypes. In our work, in addition to analyzing the use of interaction models and prototypes, we verified that it is possible to use it for UML diagrams. Sangiorgi and Barbosa (2009) developed the MoLIC Designer tool to support the creation of MoLIC diagrams, avoiding the insertion of syntax defects. We used the MoLIC Designer tool in our research. However, we identified the need to inspect defects that affect the relationship between the MoLIC diagrams and the application domain. As a result, we have developed the IMID technique, which allows the inspection of different types of defects between the MoLIC diagrams and the application requirements.

3.2 Threats to validity and limitations

During the analysis, we tried to mitigate the "researcher bias" about the interpretation of the software engineers' perceptions. Therefore, to address the threats to valid interpretation of the results, the questions regarding the set of practical activities and IMID were formulated to encourage the interviewees to express his/her own opinion. In addition, we discuss the validity threats according to the classification provided by Wohlin et al. (2000). We analyzed the following threats that may affect the validity of the results from this experience report, which are:

- Internal validity

The expectation of the software engineer responsible for the MoLIC diagrams regarding the benefits of carrying out interaction modeling: This may have influenced the designer responsible for building the MoLIC diagrams to obtain positive results in the design phase. However, we emphasize that none of the team's designers had any relationship with the authorship of the MoLIC diagrams. In addition, the lessons learned were codified by a team member who had not participated in the development of the MoLIC diagrams. Therefore, the results of the lessons learned address only the team's conclusion for each Sprint.

- External validity

MoLIC diagrams as a basis artifact for the development of other artifacts for a mobile application: It is not possible to state that the same benefits can be generalized to different types of applications, such as web or desktop. It is important to understand the use of diagrams for different types of applications. However, the focus on this research is to increase the understanding of the user-centered techniques in the software development.

- Conclusion validity

Small sample: Regarding the analysis and design team, these results were obtained from a single team. Therefore, the results are not generalizable, but are considered valid for the project context.

4 Conclusions

This paper described a research about the analysis and design team with user-centered techniques, such as personas, scenarios and interaction modeling. In this research, industry and academy worked together for the development of a mobile application. On the analysis phase, the personas and scenarios provided the understanding of the users of the HCDP application and the extraction of its requirements. In the design phase, the interaction modeling provided the team with the necessary understanding of the system interaction alternatives for the users. Therefore, we used the interaction modeling as a basis for the development of other required artifacts of the application. Based on our research, we suggest this set of practical activities for the analysis and design of user-centered systems in Software Engineering. This set of practical activities can help the software engineers regarding the quality in use of applications and the development of other artifacts.

Regarding interaction modeling, we highlight its use at the beginning of the design. During Sprint 2 there was a lot of rework in the correction of the inconsistencies among the artifacts developed based on the requirements, use case diagram and scenario. The rework in Sprint 2 was mitigated through a discussion of the interaction model when designed by the Sprint 3 team, which was later used as basis for the development of the other artifacts in the other sprints. In addition, we suggest inspecting the interaction models before using them as the basis for the development of other artifacts. To do so, we developed a technique for Inspecting MoLIC Interaction Diagrams (IMID) based on the defects that impaired the understanding of the information from the MoLIC diagrams. This technique has proven to be feasible for the inspection of the HCDP diagrams and may help to reduce the propagation of software defects.

Our main contribution with this paper is to present the results obtained with the set of practical activities for the analysis and design of user-centered systems and the IMID technique for inspection of defects in interaction models. We expect that the set of practical activities and the IMID technique become widely adopted by software engineers for understanding the user in the software development. Although there is a small learning curve for practitioners that have no knowledge of personas, scenarios and interaction modeling, the benefits of the set of practical activities provide the development of user-centered applications and a better team communication. With this understanding, it is possible to develop software focused on the quality in use and with greater acceptance of the users.

In future applications, it is important to understand the artifacts of the design phase that may contain redundancies in the representation of information to understand the artifacts necessary for the development of high quality software. However, we stress that all of the elaborated artifacts in the design phase of the HCDP application were requested by the management team. In addition, it is also important to understand other technologies that are used for a better understanding of the software, based on the identified requirements.

Abbreviations

HCDP: Home Care Development Project; IMID: Inspecting MoLIC Interaction Diagrams; MoLIC: Modeling Language for Interaction as Conversation; UML: Unified Modeling Language

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Availability of data and materials

We do not provide data because the HCDP application deals with confidential information.

Authors' contributions

Authors participate in drafting the paper and study case execution. We following describe the name of the authors who contributed in this research: *Study Case Execution* - AL, NV, BM, RZ and TC. *Data Collection* - AL, NV and BM. *Data Analysis and Interpretation* - AL, NV, BM, RZ and TC. *Drafting of manuscript* - AL, NV, BM, RZ and TC. *Critical review of the case study and paper* - RZ - Project manager of the Management team (Samsung Research Brazil) and TC - Project manager of the Analysis and Design team (Federal University of Amazonas). All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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