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Addressing the Complexity of Mobile App Design in Hospital Setting with a Tailored Software Development Life Cycle Model

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Abstract. Recent studies on workflow processes in hospital settings have shown that, since the introduction of EHRs, care-providers spend an increasing amount of their time on documentation rather than on bedside patient care. In order to improve the bedside work process and facilitate bedside documentation, we are developing an evidence-based mobile app for healthcare providers. In this paper, we present a tailored software development life cycle model that we created and validated during the design and development of this smartphone application.

Keywords. mHealth, Software Design

1. Introduction

With the advent of electronic medical records and documentation requirements, studies on workplace efficiency and patient care underline the need to improve the work processes [1]. Completing medical charts, such as for progress notes or for clinical assessments and vitals, takes a considerable amount of time, time that is taken from direct patient care [2]. Furthermore, jotting down results on bits of paper at the bedside, then transcribing these results into the medical chart can be a source of errors [3]. Mobile smartphone applications can offer solutions to some of the issues, by simplifying the documentation process, and providing timely information for patient care [4].

Developing a mobile app in a healthcare environment imposes numerous challenges linked to specific constraints from the medical domain [5] and therefore should follow evidence-based design principles. We define evidence-based design as an approach to design driven by evidences, particularly at the requirement and evaluation phase. We contrast this approach with expert-driven design or participatory design, which is mainly driven by user needs. This is particularly important in the medical domain, where the developed tools need to fulfill safety constraints and confidentiality issues.

When defining the requirements, the optimal functionalities of an app should be identified through an assessment of user needs, as well as an integration of evidences from the literature. Multiple stakeholders should be involved in the discussions. It is

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particularly important to collect the needs at an institutional level as well as to integrate the complexities linked to the variations in needs from the different departments. Patient care, and thus bedside needs, can vary widely, even within two departments of an institution. End users, such as nurses and nurse assistants from the wards need to be included to assess the specific needs in a department. Ergonomics is also one of the factors that should be taken into consideration. For instance, a recent study showed that the good design of data entry interface affects significantly the accuracy of data entry of vital signs [6]. Therefore, prior findings in usability should inform the design choices, to improve the perceived ease of use and help to maximize the acceptance of information technology by care-providers [7]. The medical domain also sets constraints for the evaluation phase, where the continuous 24/7 patient care in hospital setting limit the testing of new tools.

Some of the existing development life cycle (SDLC) models provide strategies to deal with moving specifications. However, most of them are more focused to orchestrate the work of a team of developers rather than dealing with complex identification of the requirements as well as the specific constraints linked to the evaluation [8–10]. The later are the real challenges linked to mobile applications development in healthcare.

The purpose of this article is to present a version our tailored SDLC, that takes into consideration the constraints of mobile app in a healthcare environment, and integrates both development and evaluation frameworks.

2. Methods

We performed a literature review of existing life cycle models, searching for models adapted to healthcare users in a hospital setting. We created an initial model based on a SDLC agile model, then added findings from various others models with different levels of granularity. We adapted the phases according to our needs, constraints and resources. We used the evidence from prior studies and our own data to drive the specification process. Different types of evaluation, adapted to the project advancement were chosen to address the specificities of the healthcare environment. Furthermore, following our evidence based design we selected assessment methods to formally validate the efficiency of the app, rather than solely relying on user satisfaction. The new model takes into account the specificity of developing a mobile application for health care providers in hospital setting.

We present our final model, which was iteratively adapted with the feedback received and validated while developing an app for nursing staff in internal medicine and surgical wards.

3. Results

Guided by the building blocks of SDLC, we defined 4 main phases in our development process: the definition of the requirements, the implementation, the evaluation and the deployment.

3.1. The requirements phase

Independently of the chosen development life cycle, the initial task in the process is to define the requirements. We began the project with a brainstorming session aiming to collect ideas about improving the bedside work process of care-providers and to facilitate documentation. We recruited a group of 24 care-providers (physicians, nurses and nursing assistants) from the two largest departments of our university hospital, general internal medicine and surgery (e.g. general surgery and orthopedics) to share their needs. Ideas were collected using a mind map for a subsequent feasibility analysis. After attributing priorities the various ideas, the project leaders assessed the feasibility in terms of institutional priorities and availability of the data sources. As a result of this analysis, we decided to pursue the development of a mobile application to manage the daily nursing interventions and to record simple patient information about the bedside.

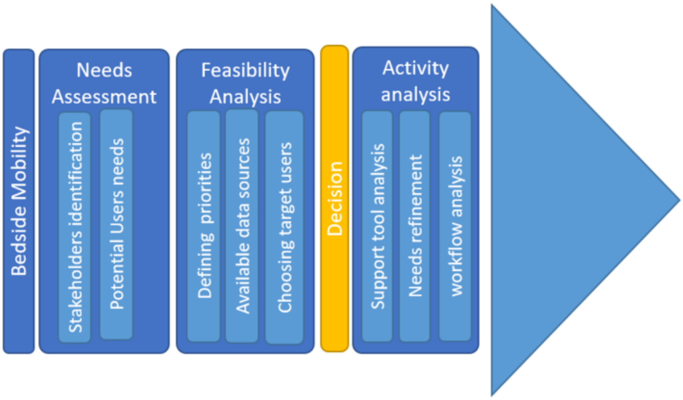

Figure 1. Detailed requirement identification process

After determining the scope of the application, we needed to define the requirements with a deeper granularity, identifying the functionalities desired in the tool. This more detailed roadmap was constructed based on observations of nursing activity, creation of persona and identification of important use cases.

3.2. The implementation phase

Our coding process is guided by the principles of the Agile philosophy, which promote adaptive methods and iterative testing. We progressively integrated the functionalities identified as relevant for the application, with recurrent feedback from the team leaders. A working group of variable geometry regularly validated the existing version of the application and conveyed their wishes of evolutions. These evolutions were discussed and validated by the working group and put on the development agenda. After formalizing the evolutions through mockups or sequence diagrams these evolutions were incorporated to the tool and a new cycle could start again.

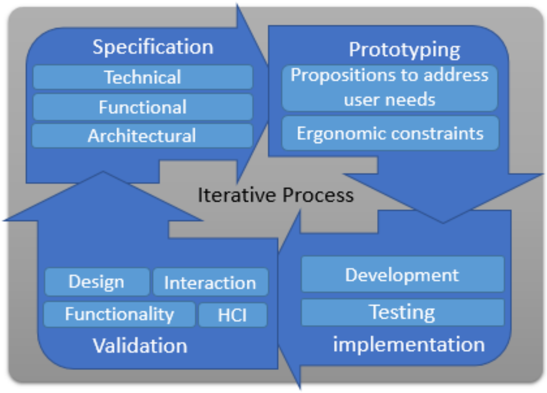

Figure 2. Agile development cycle

3.3. The evaluation phase

Due to the constraints associated to the deployment of mobile application in a healthcare environment, we have planned four evaluation stages with increasing level of ecology in order to test different aspects of the tool without being limited by unnecessary deployment concerns. After each stage of evaluation, new cycles of implementation begin again to correct the issues identified. If the weaknesses have been properly tackled, we expect these cycles to get shorter and shorter. However, this approach cannot entirely prevent new problems from appearing later in the process. These late problems induce significant changes in the application even after several successful evaluations.

The first stage of the evaluation is a purely functional evaluation to verify that all the functionalities required from the tool are properly implemented. This first stage of tests can be easily done by confronting the tool with a list of predefined tasks to see if all the required manipulations are possible and that all the processes are executed in an adequate way.

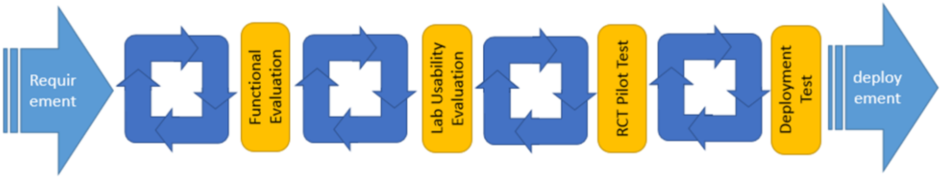

Figure 3. Overall life cycle process with the different evaluation stages

The second evaluation stage targets the usability of the tool. Tests are organized in an evaluation lab to put users in realistic but controlled situations. At this stage, participants are recorded while performing predefined tasks in a realistic scenario. Probes are installed in the software in order to record every manipulation. The analyses of the collected data and debrief of participants helps identify various usability problems, such as data entry errors, inconsistencies in the workflow as well as care-providers concerns.

The third stage of evaluation is closely linked to the need of an evidence-based validation of the tool. After fulfilling all the usability requirements, the app is pilot tested in a real-life context to assess its global efficiency. Moreover, this stage also helps ensure that the subsequent modifications in the care-providers' workflow do not threaten patient safety or confidentiality. We have undertaken a randomized controlled trial comparing the use of the application in a medical and a surgical ward with two wards with standard care. Although the ecological validity increases at this stage, we still have a limited integration with the existing clinical information system (CIS).

The fourth stage of evaluation is the final stage prior to the full integration of the application with the existing CIS. All the communications between the tool and the CIS therefore must be validated; security and proper identification must be ensured, and larger scale tests must be performed in different environments.

4. Discussion

Although our initial design process was inspired from an existing SDLC model, we quickly realized that the specificities of our working environment obliged us to adapt our approach, especially for the requirement and evaluation phases. At the validation stage, the complexity of real-condition testing and the need for an evidence-based app clearly convinced us to split our evaluation in several stages of increasing ecological validity.

Several challenges made us realize that identifying the requirements was harder than expected. Despite the participants' enthusiasm for the project, generating creative solutions was a new experience. Also, end users often tended to be resistant to change, and had a conservative vision of novelty. They preferred solutions that they considered compatible with their existing tools and needed convincing to adopt a tool that they perceived as disruptive. Moreover, it was difficult to obtain patient-containing data to build credible use cases due to confidentiality issues.

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