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A User-Centered design and usability testing of a web-based medication reconciliation application integrated in an eHealth network

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ABSTRACT

Background: Medication discrepancies, which are a threat to patient safety, can be reduced by medication reconciliation (MedRec). MedRec is a complex process that can be supported by the use of information technology and patient engagement. Therefore, the SEAMPAT project aims to develop a MedRec IT platform based on two applications. The application for the professionals is called: the "MedRec app".
Objective: In the present study, we aimed to describe the development and usability testing of the MedRec app, reporting results of a three iterations user-centered usability evaluation.
Methods: We used a three phase iterative user-centered study spread over 16 months. At each phase, the usability evaluation included several methods (observations, questionnaires, and follow-up discussions with participants) to collect quantitative and qualitative data in order to improve the current prototype and evolve to the next prototype.
Results: In total, 48 healthcare professionals (25 general practitioners and 23 hospital clinicians) participated to the MedRec app evaluation. There were 14, 32 and 5 participants for phases 1, 2 and 3 respectively. At each phase, many design modifications were done to strengthen usability. Concerning usability, participants considered the prototypes as an acceptable interface with a median System Usability Score of 73 at phase 2 and 75 at phase 3. Participants emphasized the need for improvements concerning workflow integration, usefulness and interoperability.
Conclusion: The MedRec app was perceived as being useful, usable and satisfying. However, further improvements are required in several usability aspects. Our study demonstrates the importance of conducting usability assessments before investing time and resources in a large study evaluating the effect of an eMedRec approach on clinical outcomes. Our findings may also increase the chances of acceptability and sustained use over time by clinicians.

1. Introduction

Medication discrepancies are unexplained differences between medication lists at different transition points of care [1]. They are found in up to 88% of patients in outpatient clinics [2–4] and 71% of hospital admissions [5]. Eleven to 59% of discrepancies have a potential for harm [6]. Medication Reconciliation (MedRec) is a formal and collaborative process of obtaining and verifying a complete and accurate list of a patient's current medicines [7] to ensure that precise and comprehensive medication information is transmitted consistently across transitions of care. MedRec aims to resolve discrepancies and several leading organizations worldwide have promoted MedRec to improve patient safety [8–12]. However, successful MedRec interventions require important resources and integration in complex workflows with variation of multiple factors (leaders' endorsement, patient safety culture, health information technology systems, clinicians' education, expectations, etc.). Therefore, wide implementation of MedRec remains difficult [13,14] and user-centered design (UCD) approaches are

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particularly interesting as they enabled to integrate numerous of these factors.

Information technology (IT) has been presented as a promising approach to move MedRec forward. In a recent systematic review, we identified 11 IT tools supporting the entire MedRec process [14]. Studies showed positive results overall in terms of usability, satisfaction and adherence [15–26]. The use of IT for MedRec might also reduce time spent and clinicians' cognitive burden [27,28]. However, all tools were developed in North America in academic environments, and limited information was available on the context of development and implementation of the tool. Data on the effect of electronic MedRec (eMedRec) on quality and safety outcomes were lacking. In another recent systematic review [29], Mekonnen et al included studies reporting data related to the effectiveness of eMedRec. Interventions had to start in the hospital with the use of electronic but the whole MedRec process did not need to be electronic. Authors found that eMedRec was able to minimize the incidence of medications discrepancies. The ten included studies were performed in the US and Spain, and well-designed studies were lacking.

The present study took place in Wallonia (a French-speaking region in Belgium, of about 3,600,000 inhabitants). The Regional eHealth Network (ReHN), allows the exchange of eHealth documents between healthcare professionals (HCPs) caring for a particular patient. Currently, 91.9% of the hospitals, 73% of the general practitioners (GPs) and 35% of the inhabitants of Wallonia are connected to the ReHN [30–32].

Bearing this in mind, the SEAMPAT project, supported by the Walloon Region, aims to develop an eMedRec process to improve continuity of care. It is a multidisciplinary research project led by a research team of computer scientists (including usability experts), physicians, pharmacists, one sociologist and one lawyer. The SEAMPAT MedRec ICT platform, developed for ambulatory care as for inpatient care, is made of 2 applications: the "patient app" [33], designed specifically for patients, and the "MedRec app", designed for HCPs. These 2 applications are interconnected with the ReHN. The methodological approach to develop both applications followed recommendations of health IT experts [34–38]. Requirements for the low-fidelity prototypes were defined on the basis of needs analysis (through interviews and focus groups with end-users) and literature review [14,33]. In the present study, we specifically describe the testing of the MedRec app, reporting results of the three iterations.

2. Materials and methods

2.1. System and details

The MedRec app (using HTML5/Javascript technologies), usable on a desktop or laptop is accessible for every clinician through the ReHN. HCPs' authentication is done through secured log-in and password which are personal and mandatory. Data transfers occur through secure connections and data themselves are encrypted before their transfer [33]. The app can only be used for patients registered to the ReHN by a HCP taking care of the patient.

The MedRec app allows the HCP to compare three "medication lists" (Fig. 1): (1) the "reference" medication list (the most recent list edited by the GP – when the app is used by GPs, or by the hospital where the HCP is working – when the app is used by physician specialists (PS) or clinical pharmacists (ClinPharm)), (2) a compiled medication list presenting the most recent and complete information documented by other HCPs – this was done by an algorithm developed by the research team, that took into account various data such as date, ATC code, specialty code, identity of HCP, dosage,…), (3) the medication list documented by the patient, using the patient app. All information used is initially retrieved from the ReHN.

In order to relieve cognitive burden and support clinicians, we followed advices from Plaisant et al. [27,39], As examples: the MedRec app highlights differences and similarities of medications' name, dosage, etc. between the three lists; the app uses spatial grouping of medications and offers the possibility to modify medications' classification. The column with the patient's documented list uses the same color codes as for the patient app so that clinicians can easily show the main screen to the patient and start reconciliation discussion. Information such as reason for starting or stopping medication and prescribers' name are visible through tooltips. The HCP can stop, continue or modify each medication of the list. He can also add new medications. The aim is to publish the reconciled medication list on the ReHN.

2.2. Study design and sampling overview

We performed a three phase iterative user-centered study spread over 16 months, with low-, medium- and finally high-fidelity prototypes (Fig. 2).

At each phase, several methods (observations, questionnaires, and interviews/group discussions) were used to collect quantitative and qualitative data on usability. Results and more specifically areas of improvement were discussed within the research team. Modifications were decided and implemented in the next prototype.

Participants belonged to three groups of previously identified end-users of the MedRec app [14,33]: GP, PS and ClinPharm. GP were recruited from three local GP associations in Walloon Region and Brussels. PS and ClinPharm were recruited in a teaching hospital (CHU UCL Namur, Belgium). All participants were volunteers and contacted by email. They were selected in order to have a diverse sample in terms of age, gender, number of years of professional experience and information technology knowledge. We aimed to recruit 5 participants of each group for each iteration. The sample sizes are typical for usability studies and research has demonstrated that they are sufficiently large to elicit the vast majority of usability issues [40,41]. The protocol was approved by the Ethical committee of CHU UCL Namur (reference number B039201421687).

2.3. Phase 1: low-fidelity prototype

The aim of phase 1 was to evaluate the global structure and the visual design of the interface of the MedRec app. The low-fidelity prototype was a static mock-up designed on Powerpoint. Functional and non-functional requirements had been defined on the basis of needs analysis and literature review conducted by the research team [33,42].

After an introduction on the project and the session objectives, participants were shown the low-fidelity prototype. Interruptions to ask questions and make comments were allowed. Field notes of the discussion were taken by the main researcher (SM). At the end of the presentation, participants completed a close-ended questionnaire, developed on basis of literature [16,26,43] and advice from usability experts (Appendix I). Descriptive quantitative analysis was done using Excel. Qualitative data was analyzed using a conventional content analysis approach [44].

2.4. Phase 2: medium-fidelity prototype

The aim of phase 2 was to evaluate usability, to explore usefulness and acceptability. The medium-fidelity prototype was an interactive tool using a scenario with a mock patient. Using a computer, each participant accessed the web-based prototype and reconciled the patients' medication list.

Participants were invited to a session of one to two hours with colleagues from the same group. The sessions were organized as follows: (1) introduction about the project and the aim of testing; (2) presentation of the mock patient scenario; (3) interactive MedRec for the mock patient by each participant using the prototype; (4) discussion about usability, usefulness and acceptability of the tool; (5) filling the System Usability Scale (SUS) questionnaire (10 statements rated on a 5-

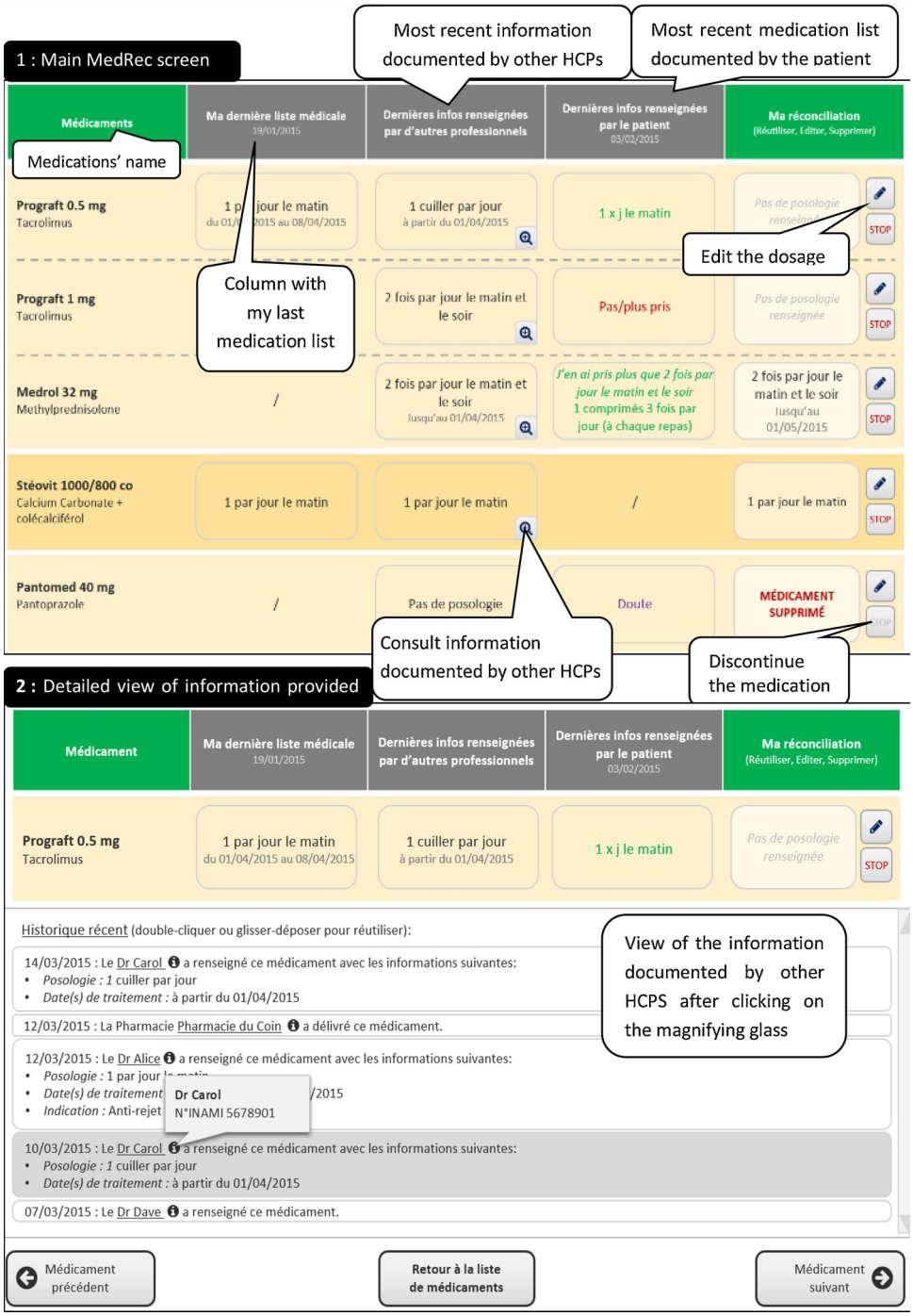

Fig. 1. Two screen shots of the static prototype (December 2015-January 2016).

point Likert-scale). The SUS was selected because it is successfully used in the medical domain [45–47], validated for a wide range of interface technologies, quick to complete, easy to interpret and can be applied to small sample sizes [48–52]. In reference to the qualification "good product" of Bangor's adjective rating scale, we considered a SUS score above 70 as acceptable [48,49,52].

During the MedRec session (part 3), observation notes were taken by at least 3 researchers (IT experts and clinicians, and in some cases a sociologist). The discussion (part 4) was organized following a guide (Appendix II) developed by the research team based on literature review [16,26,42,43,53], and pilot-tested with 3 external experts. Discussions were audio-recorded and transcribed. Subsequently, interview transcripts and observation notes were analyzed by two independent researchers (SM and DL) using a conventional content analysis approach to develop first themes [44,54]. Themes were matched with coding categories based on previously published coding schemes [55–57]. Discrepancies in the coding were resolved by discussion to achieve a consensus.

2.5. Phase 3: high-fidelity prototype

The objective was similar to phase 2. The high-fidelity prototype was a functional prototype linked to real patient data through the ReHN. Given the timing constraints and the variety of EMR softwares used by participants, the MedRec app was not accessible through each software. Hence, the prototype was tested using a web-application link

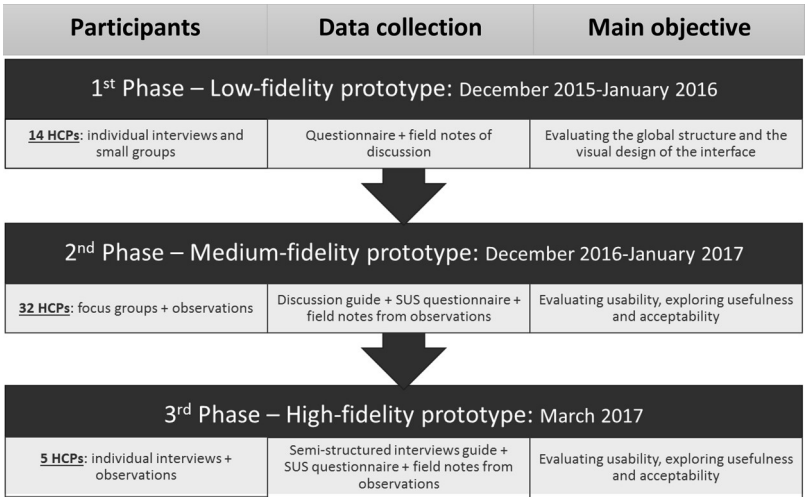

Fig. 2. Study Overview.

available from the ReHN.

Eligible participants had to be connected to the ReHN and had to have at least one patient having participated to the development of the patient app [33]. During an individual session in the presence of 2 to 3 researchers, each participant used the MedRec app to reconcile medications of one or two of their participating patients. Written consent was asked to these patients but for practical reasons, the patient was not present during this MedRec session. Therefore, it had been decided not to publish the reconciled list on the ReHN. Observation notes were taken by researchers during the MedRec session. Subsequently, a semi-structured interviewed was performed with each participant, using an interview guide derived from phase 2 and reviewed by usability experts (Appendix III). Interviews were audio-recorded. Finally, participants completed the SUS questionnaire. Observation notes and interview transcripts were analyzed using the themes developed during phase 2.

3. Results

3.1. Population descriptive statistics

In total, 48 clinicians participated in one of the three iterations of the MedRec app (Table 1 and Fig. 2). Three clinicians (2 PS and one ClinPharm) tested both the medium- and the high-fidelity prototype. Fifty-six percent of the participants had 10 or more years of professional experience.

Table 1
Sociodemographic characteristics of the participants (n = 48).

"Subgroup" (n)		
General Practitioners	25	52.1%
Physician Specialists (*6 anesthetists, 10 medical internists, 1 surgeon and 1 intensive care physician)*	18	37.5%
Clinical Pharmacists	5	10.4%
Gender (n)		
Female	25	52.1%
Male	23	47.9%
Number and types of participants at each phase of the study (n)		
Phase 1,	14	
General Practitioners	8 (57.1%)	
Physician Specialists	6 (42.9%)	
Phase 2	32	
General Practitioners	15 (48.3%)	
Physician Specialists	12 (34.5%)	
Clinical Pharmacists	5 (17.2%)	
Phase 3	5	
General Practitioners	2 (40%)	
Physician Specialists	2 (40%)	
Clinical Pharmacists	1 (20%)	

3.2. Low-fidelity prototype

Fig. 1 shows 2 screen shots of the low-fidelity prototype. All participants (n = 14), except one, were positive about the global structure and the visual design of the static MedRec app. Five participants, 4 GPs and 1 PS, (35.7%) commented on the background color. They thought alternating light and dark yellow was confusing, as they did not understand it stood for grouping medications per therapeutic class. Furthermore, they found it too different from the EMR design they were used to. Four of the 6 PS preferred to have the most recent medication list as reference, whoever did it, while GPs rather choose for the last medication list documented by a caring GP, even if less recent.

Participants thought it was easy to use drag-and-drop, double clicks, the "pencil" icon (to edit) or the "STOP" icon (to discontinue) but they wished to have a button allowing to confirm and validate the reconciled medication list. Physicians (6 GPs, 1 anesthetist, 1 cardiologist) appreciated the possibility to access "history details" for each medication (Fig. 1).

Ten (71%, 5 GPs) preferred encoding medication posology in a structured way. Half of them asked for default values: frequency, duration, start date, end date. They stressed the need to highlight important information such as reason for starting or stopping a medication and medical specialty of the prescriber. Finally, they emphasized on improving the clarity of icons, minimizing the text to read and the number of clicks needed to accomplish a task. All participants wished to reduce time spent performing MedRec by using the app. Fig. 3 illustrates evolution from low- to medium-fidelity prototype.

3.3. Medium-fidelity prototype

Thirty-two professionals: tested the medium-fidelity prototype. The medium-fidelity prototype seemed relatively intuitive and participants gave it a median SUS Score (range: 55–92.5) of 73 (IQR = 65–79).

Qualitative feedback indicated an overall positive feeling about the MedRec app and also revealed a set of possible enhancements of the prototype. These were organized in seven categories: Visibility, Content, Understandability, Navigation, Workflow, Usefulness and Interoperability (Table 2). Improvements concerning workflow integration, usefulness and interoperability clearly appeared to be crucial to achieve users' acceptability. Fig. 4 illustrates evolution from medium- to high-fidelity prototype.

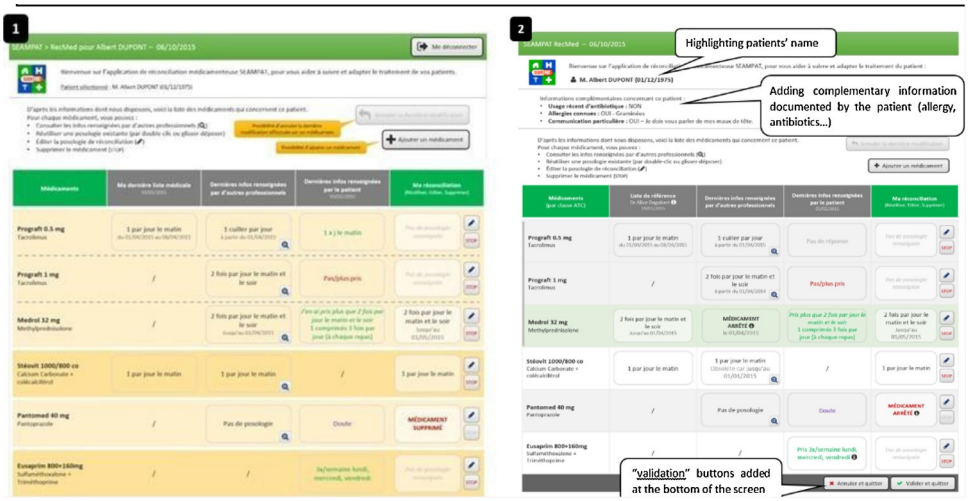

Fig. 3. Changes between the low-fidelity prototype (1) and the medium-fidelity prototype (2).
Main changes:
-background color: alternating white and light grey – green corresponding the "computer mouse localization",
-caption of the different columns were adapted. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.4. High-fidelity prototype

Five professionals tested the high-fidelity prototype. Median SUS score was 75 (IQR = 65–79). Qualitative data revealed that MedRec app clarifications and enhancements were appreciated by participants. Participants emphasized the importance of having as few clicks as possible. Participants testing the high-fidelity prototype in a real clinical setting expressed more concerns about usefulness, workflow integration and interoperability (Table 2). Main suggestions for further improvements are listed in Table 2.

4. Discussion

4.1. Main results

In this study, we conducted an iterative user-centered usability evaluation of a MedRec web-application for HCPs. Participants considered the medium- and high-fidelity prototype as acceptable interfaces (SUS score > 70). However, no significant change was observed in the SUS score (73 vs. 75). This is likely because the number of participants was too small, because not all usability issues of the medium prototype indicated by participants were implemented and because testing the high-fidelity prototype in a near real environment created an additional set of requirements [55,56], particularly concerning workflow integration and usefulness.

Because workflow integration as well as usefulness and interoperability are crucial to achieve user's acceptability [58,59], the high-fidelity prototype should undergo some essential improvements before being evaluated in a larger study. Results of the low- and medium-fidelity prototype testing enabled identification of different usability issues mainly related to four of the seven categories identified during the two last iterations: visibility (e.g. highlighting information), content (e.g. access to older historical data), understandability (e.g. alternating colors for grouping medications), and navigation (e.g. tooltips and tips on the right location at the appropriate moment). Most remaining issues related to these 4 categories and pointed by participants during phase 3 were modifications that were not implemented in the high-fidelity prototype. These issues should be addressed in priority. Finally, researchers should pay attention on the number of clicks needed to fulfil a specific action [25], as emphasized by participants.

Supplementary functionalities to improve usefulness and design modifications related to workflow integration and interoperability, essential for sustained used over time, should be deepened when the MedRec app is implemented.

4.2. Comparison with prior work

Several research teams previously developed MedRec tools for either HCPs [14–22,27,60,61], or patients [23,53,62–68], and some of these tools were used in laboratory or were disconnected from the IT ecosystem [27,39,60,69,70]. Our MedRec app shared several similarities to existing tools, but differed in the way that it was integrated in the eHealth Network and used electronic information from multiples sources including the medication list as documented by the patient. Most usability issues identified in the present study (e.g. using medication names similar to the one of the usual software [27], having access to pharmacy deliveries [61,71] and prescribers' contact information [24,26], etc.) were considered as essential for successful implementation in these previous studies. However, some issues (e.g. managing complex posologies, embedded video tutorials, etc.) have not been reported previously.

4.3. Strengths

We used a UCD with a purposive and diverse sample that can be considered as a valuable design as it ensures that the final product is desirable and suitable for whom it was created [58]. Even though our samples were small, we had rich and meaningful discussions. Secondly, being a team composed of members with different knowledge and skills was ideal to prepare and observe testing of the different prototypes [38] as understanding and translation of results into requirements [58,59,72]. Besides, working in close collaboration with the ReHN gave us the possibility to work with real data, coming from multiple sources–unlikely most eMedRec tools [5,23,53,62,66,73] – and in a real clinical setting to test the high-fidelity prototype. It guaranteed the compatibility of the MedRec app with the standards used by the ReHN (message format, data exchange mechanism, security…) and will greatly facilitate integration into the Belgian eHealth landscape and interoperability with EMRs. Both factors are known to be highly fundamental to translate the tool interface into a practicable and usable user-interface [58,59] and to reach acceptability of the tool, optimal users' compliance and sustained use over time [26,55,74].

4.4. Implications for research

Future evaluation of the usability of the MedRec app should be performed on a larger sample of participants and evaluate, in addition to the SUS score, the three aspects of usability as defined by the ISO 9241-11 [75]. First, effectiveness could be evaluated by measuring discrepancies, for example by using safety probes as published recently [76] and the HCPs' cognitive burden [77]. The potential risk of

Table 2
Coding categories with corresponding themes and examples after testing the medium- and high-fidelity prototype.

Category	Definition	Themes	Examples
Visibility	Ability to quickly recognize key messages and instructions provided by the MedRec app	Visibility improves when clarifying titles and names	Column titles are long, confusing and lack clarity **(medium-fidelity prototype)**. Medication names should be similar to the one of my software. **(high-fidelity prototype)**
		Visibility improves when instructions and information are appropriately located and highlighted	Button to add medication seems on the right place but the icon used was not clear enough and many clinicians did not understand why it stood for **(medium-fidelity prototype)**. Stopped medication should be easier to identify and the reason for stopping a medication should be visible directly on the main screen **(medium-fidelity prototype).** Molecule name, date of initiation of prescription and first prescriber should easily visible somewhere **(high-fidelity prototype)**.
Content	Medical accuracy or appropriateness of the MedRec app (patient information, documentation)	Content improves when available information allows optimization of MedRec	Physicians "contact information" should be accessible (specialty, phone number) to easily reach prescriber for explanation about one medication **(medium- and high-fidelity prototype)**. Having access to pharmacy deliveries is essential **(medium- and high-fidelity prototype)**.
		Content improves when available information helps supporting actions beyond MedRec: for example appropriate prescribing	It could be an added value to have access to older historical data up to several years. For example to remember which medications have already been tested for a patients' epilepsy **(medium- and high-fidelity prototype)**. Manage complex posologies (such as regimen) should be possible **(medium- and high-fidelity prototype)**.
Understand-ability	Ability to quickly comprehend meaning of text, instructions and the purpose of the MedRec app	Using common medical terminology and the standard icons, and providing clear instructions improves understandability	Vocabulary such as "alternating stop" was not understandable by majority of clinicians **(medium-fidelity prototype)**. The trash icon, to cancel an action was mixed up with the "STOP" icon, to discontinue medication. **(medium-fidelity prototype)** To facilitate posology editing, there is a real need to prioritize information… it is important to highlight which information is mandatory and which is nice to have **(medium- and high-fidelity prototype)**.
Navigation	Ability to move easily through the CDS tool	Tooltips and tips should appear on the right location at the appropriate moment to ameliorate navigation	The text explaining how to reconcile medication and why each icon stands for should be visible only on demand **(medium-fidelity prototype)**. Therapeutic intent and condition for taking a medication could be additional information visible with a tooltip on the main screen **(medium-fidelity prototype)**. Little video tutorials could be accessible in order to help users to operate efficiently the MedRec App. **(medium- and high-fidelity prototype)**
Workflow	Ability of the MedRec app to fit into the natural order of events in a patient encounter	To prevent workflow disturbance, the MedRec app should be accessible at any moment on various devices and provide additional functionalities	The MedRec app user interface should be adapted to be usable on smartphone and tablets **(medium- fidelity prototype).** Access should be possible 7 days a week, 24 hours a day **(high-fidelity prototype).** We should being able to print the medication list in a "patient-friendly" format so patients could receive a resume of the reconciliation process **(medium- and high-fidelity prototype)**. The MedRec app should be totally integrated with other existing systems such as CPOE, CDSS (prescribing error and drug-interaction detection system, e.g. drug-drug interaction detection, drug-disease interaction detection) and the EMR **(medium- and high-fidelity prototype)**.
Usefulness	Ability of the app of Improving MedRec speed, decreasing cognitive burden and/or improving accuracy of MedRec	Implementing supplementary functionalities are essential to improve usefulness and so acceptability	To save time, it would be great to be able to reconcile several medication together **(high-fidelity prototype)** The reconciled medication list should automatically replace the medication previous list in our software and on the ReHN to avoid errors and double work **(high-fidelity prototype).**
Inter-operability	Ability of the MedRec app to easily share information with other medical softwares	Structured data is fundamental for interoperability and information sharing	Editing posology should be by default in a structured way so data exchange would be facilitated in the future **(medium-fidelity prototype).** Interoperability and information sharing are a key for usefulness and utility **(high-fidelity prototype).**

Abbreviations: CDSS: Clinical Decision Support System; CPOE : computerized Physician Order Entry; EMR : electronic medical record; ReHN: Regional eHealth Network.

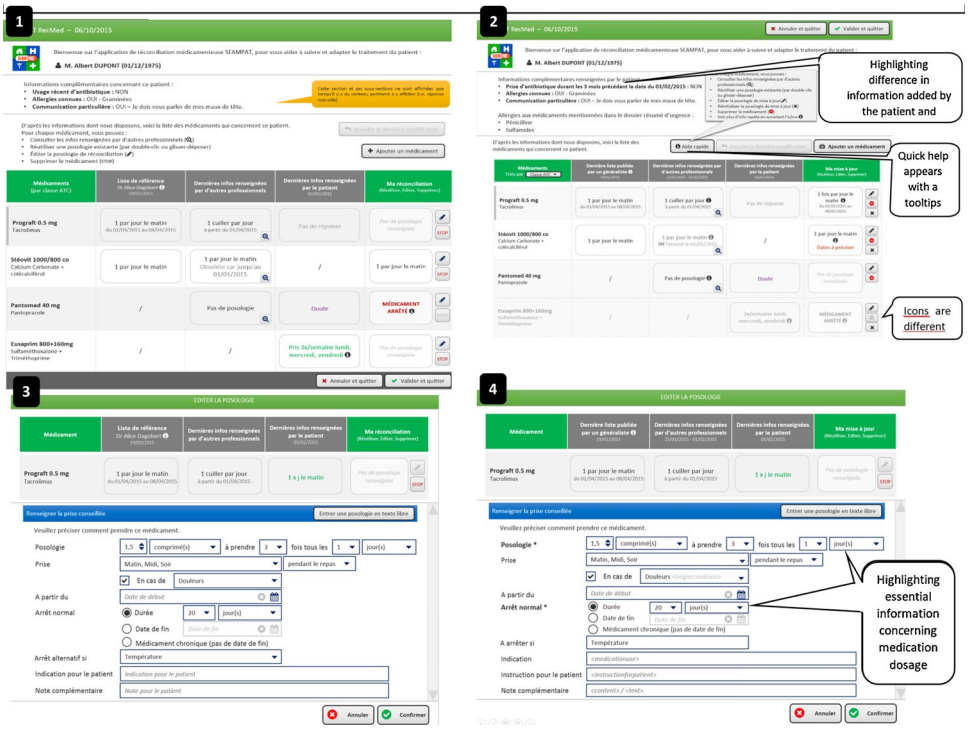

Fig. 4. Changes between the medium-fidelity prototype (screen shots 1 and 3) and the high-fidelity prototype (screen shots 2 and 4).

technology-induced errors introduced by the MedRec app should also be evaluated [13,71,78]. Second, efficiency could be studied by the number of clicks, scrolls and the time needed to reconcile medication [39]. Finally, to assess satisfaction and to increase chances of successful adoption, the MedRec app should be used in routine in a real clinical setting for a few weeks so that usability issues related to workflow integration and interoperability can be deepened as well as user experience of different HCPs' subgroups [35].

In a later stage, an experimental study measuring the effect of the app on patient outcomes (e.g. reduction of adverse event, emergency visits) and users' performance [58,79] will be needed and may reveal improvement concerning patient safety.

4.5. Limitations

Our study has several limitations. Firstly, although a UCD with a purposive and diverse sample can be considered as a valuable design, we recruited volunteers, who maybe more interested in the tool and more experienced in health informatics. Therefore comments may have been more positive or more negative than if participants were randomly selected [56]. Moreover, during testing researcher(s) were present, which could have an impact on behavior and reported observation as a results of being observed (Hawthorne effect) [56,61]. Secondly, in phase 1, field notes were recorded by the primary researcher which could also have introduced some biases.

Thirdly, in phase 3, due to time-constraints, a limited number of HCPs reconciled the medication list in absence of a participating patient. However, many suggestions and comments emerged from discussion and identified usability issues confirmed the importance of addressing some design modifications before conducting a larger study. Finally, the MedRec app in phase 3 was not accessible via the local EMR. However, given the compatibility of our tool with the standards used by the ReHN, such integration will be facilitated, though it should still be realized on a case-by-case basis.

5. Conclusion

Using a UCD approach with three iterations led to the development of a functional MedRec app. The MedRec app was perceived as being useful, usable and satisfying. Combining questionnaires, observations and interviews also enabled a more in-depth understanding of priority issues such as integration of the MedRec app with other existing systems (CPOE, CDSS). Several remaining issues (e.g. having access to pharmacy delivery data) were still present in the high-fidelity prototype and will have to be addressed in future developments.

Our study describes the importance of conducting usability assessments before investing time and resources in a large study evaluating the effect of an eMedRec approach quality and safety of healthcare outcomes. Our findings will also hopefully increase chances of successful implementation, acceptability and sustained use over time by clinicians.

Authors contribution

Sophie Marien designed the study, acquired the data, analyzed and interpreted the data, and wrote the manuscript.

Anne Spinewine (AS) assisted in study design and in the analysis and interpretation of the data, revised the manuscript for important intellectual content, and approved the final version.

Ravi Ramdoyal (RR) and Valery Ramon (VR) developed the different prototypes, assisted in study design and in the analysis and interpretation of the data, revised the manuscript for important intellectual content, and approved the final version.

Delphine Legrand assisted in the analysis and interpretation of the data, revised the manuscript for important intellectual content, and approved the final version.

Jimmy Nsenga and Gustavo Ospina, developed the different prototypes with RR and VR, modified prototype when encountered important usability issues during assessments, revised the manuscript for important intellectual content, and approved the final version.

Conflicts of interest

This work was supported by the Région Wallonne WBHealth program Grant1318069 (principal investigator: AS). The funding source had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Summary points

What was known already before the study

- Discrepancies are a treat to patient safety. Discrepancies are numerous and happen inside hospitals as well as in ambulatory care.
- Medication Reconciliation (MedRec) – the process of that aim to resolve discrepancies – is a worldwide patient safety goal. Many organizations are struggling to implement effective processes.
- Information and communication technology tools have been developed to optimize the MedRec process. But
- To our knowledge, none possesses all the functionalities recommended in the literature [14,42].
- Most were developed and evaluated in North America where patient safety culture and healthcare system and environment are different from Europe.

What this study added to our knowledge

- This study confirms the importance of conducting usability assessments before investing time and resources in a large study evaluating the clinical impact of an eMedRec approach on patient safety goals.
- We underlined the need of testing prototypes in a real clinical setting, as evaluations in a real clinical environment created an additional set of requirements.
- Our findings will also hopefully increase chances of successful implementation, acceptability and sustained use over time by HCPs: interoperability and workflow integration are key factors to reach a successful adoption of the tool.

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