Investigations and solutions for safer medication in healthcare

Iosif Kakalelis
Abstract

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Uppsala University Hospital aims to automate its drug management and distribution system in order to increase the speed and accuracy of the prescription process and reduce prescription errors. In order to achieve those goals, the hospital plans to introduce Closed-Loop-Medication (CLM). CLM enforces digitalization and automation of the entire drug management process. Studies show that CLM can reduce prescription errors. The Closed Loop Medication Management System is an electronic drug management process that automates drug management and disease management and documents all relevant patient history information. Drug prescription verification is one of the prerequisites in order to implement CLM.

The purpose of this thesis is to find solutions to support and improve the prescription verification routines at Uppsala University Hospital. The first part of the report consists of a literature review about CLM and its impact. The second and main part describes a solution that can facilitate the implementation of CLM at the hospital with focus on the prescription verification process. More specifically, I developed an interface prototype with the name VerifyPro. User-Centred Design (UCD) method was followed for the development of VerifyPro. UCD is an iterative design process in which designers focus on the users and their needs in each phase of the design process. Finally, user requirements for the new interface were gathered by performing interviews at the hospital.

Analysis on the responses from the interviews illustrated some problems on the hospital’s information system (COSMIC). On top of that the user needs became clear. Healthcare professionals need a support decision system that can supplement and facilitate their decision process. Last but not the least, they desire a customisable interface where users view only what they need to view about a patient.

VerifyPro was designed to work supplementary to COSMIC. Its goal is to improve the prescription verification process, improve the communication between the health professionals, and lastly to provide a better and customisable overview of patient data.
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1) Introduction

1.1 Background

Today, technology has been embraced by society in almost every field, and healthcare is no exception. New, innovative technologies are gradually being introduced in different health facilities around the globe with the mindset that modern technologies make healthcare more effective, less costly and better monitored.

Uppsala University Hospital intends to introduce Closed Loop Medication (Westermark, 2018) to its whole workflow. Pre-studies have already been carried out, and funds are allocated for this ambitious project. Closed Loop Medication Management System concerns almost everyone involved in healthcare. Most often, the end-users are nurses, who first check and then administer the prescribed medicine to patients. Other examples of people affected by this change are doctors who prescribe, pharmacists who control and verify the correct medicine doses but may also include storekeepers who inspect the availability of medical supplies. The following text describes the procedure of Closed-Loop Medication:

The selected medication is prescribed on a prescription order that is then verified. Verifying includes performing multiple cross-checks of the prescription order to real-time patient information, healthcare industry practices, and medication information to generate a verified prescription order. After transcribing, the appropriate dispensing method is determined for the prescription order and dispensed. The dispensed medication is administered after confirmation by the administering clinician of the right patient, right medication, right dosage, right route, and the right
time. The whole process of medication use described above is monitored continuously in real-time. The monitored information is communicated to the prescribing, transcribing, dispensing and administering parts of the system. (Henderson, D., Richard, L., Marklewicz, E., Tobin, C., 2003)

In other words, automation is part of the entire process, starting from the doctors who are prescribing medicine, pharmacists checking and verifying the prescribed medicine, nurses receiving medicine from vending machines, and finally the patient being given prescribed medication in a customized package for him. The reason for automating the process is ultimately to achieve improvement in the accuracy and speed of the medicine distribution chain (Westermark, 2018). Clearly, there is a need for the right medication, in the right place, at the right time, with the least possible effort and risk (Bhatti, 2019). Effectiveness could potentially be improved with closed-loop medication through a centralized, interconnected, and interoperable information system which embraces all the functionalities of the current solutions. This system should be closely aligned with the current routines and working habits of the staff. Implementing a closed-loop system involves many different specialists and knowledge from different fields including logistics (Westermark, 2018).

End-users are usually nurses or doctors, whose time ought always to be prioritized toward patients. Therefore, they should ideally be able to spend the minimum possible time learning and using a software for their daily tasks

1.2 The Current Situation in Uppsala

COSMIC is the name of the information system that Uppsala University Hospital uses. COSMIC is a complex EPJ (Electronic Patient Journal) which is responsible for the majority of the tasks that are involved in Uppsala University Hospital.

COSMIC incorporates a basic verification system. However, this system is observed to have some flaws. It is a very common case that it often generates warnings/alerts from trivial to severe when a doctor prescribes medicine. Those warnings are often perceived as very general or not informative. Sometimes, also, they are simply wrong (prescription of both long and short-acting opioid analgesics is an adequate procedure and should not generate a duplicate warning) (Westermark, 2018).

Given how the system behaves, users tend to regularly bypass and skip warnings. Many doctors and pharmacists would rather have the option to filter out and have only severe or important warnings. More severely, in other cases, the system may be tricked and skip an important warning, by prescribing medicine with a different name but the same chemical substance (Westermark, 2018).

However, problems are usually avoided by clinical pharmacists and nurses at the wards, who check the prescribed medicine for administered patients (Westermark, 2018)
1.3 Focus and Scope

The ‘closed-loop’ approach is of particular importance for quality management in clinics and hospitals seeking to integrate ICT in order to monitor and improve all stages of MMP (medication management process) continuously. The design focuses on achieving connection and reporting even up to the bed where the nurse prescribes the medication. In the healthcare setting, the Closed-Loop, therefore, focuses on the development of technologies that can enable comprehensive and timely information to be provided to the patient, physician and clinic at all drug delivery sites. The target is to significantly improve quality and prevent errors (Bowles, & Lu, 2015).

Before introducing Closed Loop Medication in Uppsala University Hospital, it is required by Swedish legislation to ensure verification and control over the prescribed medicine that it is intended to be distributed to patients via a dispensing machine. That means that a pharmacist must make a reasonableness assessment of the prescription of the incoming drug prior to dose dispensing.¹

In my research, I tried to find potential improvements to the prescription verification system that concerns health professionals in Uppsala hospital for it to be ready to be used within the closed-looped medication. It is expected that the hospital is going to keep using COSMIC for some years (At least until 2022, there is an agreement with the company that owns and manages COSMIC) (Westermark, 2018). However, it is desired for all the stakeholders involved to have a flexible, customizable system, non-binding to any specific EPJ (Electronic Patient Journal) (Westermark, 2018). The main research focus was on the user interface and user interaction parts (UI) for a new addition/solution to the system capable of improving the verification step in medical prescription. The question that arises is to what extent the system used in Uppsala University Hospital ensures a trustworthy and safe prescription verification step (something that is required in closed-loop medication) and solutions to make that happen.

More specifically, the main research questions needed to be answered before suggesting a new solution were:

1) What do people need in the new solution?

¹ Swedish regulation (LVFS 2010:9 3 kap 3§) states: Före dosdispensering ska en rimlighetsbedömning av förordnandet av ingående läkemedel göras av farmaceut. Bedömningen ska utgå från det underlag som finns tillgängligt på enheten för dosverksamhet. Av underlaget ska framgå om förordnandet utgörs av dosrecept eller av annan ordinationshandling
2) How a solution that can facilitate prescription verification in closed-loop medication could look and behave like?

It is worth to mention that the questions above focus mostly on the features of the new interface and not on the aesthetic design part (colour choices, text, etc.)

3) How could users interact with this solution?

4) What are the main problems that staff and patients face when using the existing interface?

2) Literature Review

2.1 Medication Errors and Adverse Drug Events

A medication error is any undesirable event, that may cause or lead to inappropriate medication use or harm to the patient while the medication is under the control of the healthcare professional, patient, or consumer. Such incidents may be related to professional practice, healthcare products, procedures and systems, including prescription, order communication, product labelling, packaging and nomenclature, distribution, management, training, monitoring and use (Bowles, & Lu, 2015).

Various e-medicine systems are available. They may be software for individual professionals in autonomous systems for specialties (e.g. oncology, intensive care), or hospital district-wide systems with or without a complete, fully electronic medical history. The data and reports available on electronic prescription systems allow drug use controls, including antimicrobial detection commands, drug recall, interactions and analysis of use. The software can integrate standard prescription protocols for specific conditions, for example, pain management, vaccinations and acute coronary syndromes. Electronic prescription also reduces the risk of dosing errors as it can prescribe frequent doses. Potential hazardous doses are minimized as software suggests to prescribers to use the most common doses. This, however, does not prevent errors, as the software is flexible in prescription (Robert & Whyte, 2018).

2.2.1 AI in Healthcare

In 2011, IBM estimated that the entire healthcare sector had about 161 billion GB of data and this volume nearly doubles every year. With significant amounts of data available, AI (Artificial Intelligence) is destined to become an opportunity to improve care and reduce unsustainable healthcare costs. (Fong, 2018).
Current technology and its algorithms support and complement healthcare professionals’ interaction with patients today. In the existing technology distribution platforms, the administrative and clinical functions of healthcare are not well coordinated and, in many cases, operate manually with some degree of success. With AI technology as an enabling technology, a single platform will be able to collect data from various databases and sense, understand, act and learn. It should then be able to play an important role in supporting health care initiatives on real-time prevention and treatment programs. As the requirements for healthcare evolution continue to increase significantly, the health care human resource will be positioned to respond with AI tools (Fong, 2018).

2.2.2 AI in Prescription

There are differences between health systems in different countries but, generally, one of the pharmacist’s responsibilities is to provide an independent review of prescriptions in advance to a patient’s treatment (Pharmacy 2018). This evaluation on whether a medicine is safe, accurate, and appropriate is also known as clinical reasoning and requires a high degree of both thinking and decision making (Pharmacy 2018). Furthermore, personal contact, observation and interaction with the patient along with reflection on his condition constitute an important part of the thinking process. Finally, clinical reasoning is aimed to provide the safest and best service to the patient. (Pharmacy 2018).

Solutions like Closed-Loop Medication dispensing systems are proven to improve efficiency and enhance patient-centred services since they have reduced drug distribution times and now nurses are able to devote more time with each patient instead of being occupied with other technical processes. However, whereas AI automates many technical processes, it is currently unwise to trust it with the verification process entirely, because the supply of medicine requires a high level of complex cognitive skills in order to determine the appropriation of a drug (Pharmacy 2018).

2.3 The Impact of Closed Loop Medication

According to a study which was conducted at a hospital in London, Closed-Loop Medication had noticeable effects (Franklin BD, O’Grady K, Donyai P, 2007). The most important gain was that prescription errors were reduced almost by half (47%) after its introduction. Furthermore, nursing time spent on checking drugs was decreased, something that allowed nurses to plan their time more efficiently. On the other hand, the need for intervention, in order to fix prescription errors, increased the time pharmacy staff and physicians needed to spend on medication. It is a challenge for the future to make medical software less time consuming, but regarding patient safety, the automation of the entire process is considered successful. The study was performed in a general surgery ward of 28 beds at a teaching hospital in London, with
an average stay of 7 days and 24 admissions per week. The drug rounds were scheduled four times a day. One nurse was in charge of medication duties for half of each ward. Each wing of the hospital had a standard pharmacy service, which included a daily visit by the pharmacist and a short visit on Saturdays. Before applying the interface, order medications had been prescribed on paper drug charts, and the medication was stored in two drug carts and storage cabinets (Franklin BD, O’Grady K, Donyai P, 2007).

Collecting data 3-6 months before and 6-12 months after the intervention and pre-intervention data on different outcomes, simultaneous measures had to be put in place to complete the data collection before application. Post-intervention data was collected in turn for each outcome measure. (Franklin BD, O’Grady K, Donyai P, 2007).

Sharing medical resources not only ensures better management but, in many cases, saves patients from harmful drug interactions. The rate at which new drugs are approved and marketed makes it impossible for clinicians to stay aware of all possible drug interactions. As the number of targeted drugs increases, the ability to accurately detect interactions decreases. Therefore, clinicians use the resources of digital technology to record and interpret related interactions. However, these resources are only reliable as long as the databases are accurate and complete. A 1996 study involving the Washington, DC, pharmacy community found that 32% of pharmacies were prescribing erythromycin and terfenadine without oral or written precautions, despite FDA letters warning of the life-threatening interaction (Barrons, 2004).

The evolution of disease management and the convergence of medicines, devices and digital health into different conditions now require pharmaceutical companies to adopt digital health as part of their DNA, and today almost every major pharmaceutical company has a digital strategy. The evolution varies greatly from company to company (Bhuller, 2018).

For the pharmacy, the interest in digital technologies that may have started as a marketing lever is now seen as increasingly important for business viability due to the need to improve the effectiveness of pharmaceutical supply chains (including pharmaceuticals) and to prove value and effectiveness to customers and providers. They are trying to enter the new era of value-based medicines and to promote medication adherence to better patient outcomes and to build patient centrality over a traditional provider-based approach. Examples of areas where pharmaceutical companies invest in digital solutions are targeted drug research, clinical trials and real-time evidence, the supply chain, digital marketing, and consumer-based services (Bhuller, 2018).

In Canada, some 1,600 adult patients suffer from some side effects of medication in hospitals across the country every day. The 2004 Canadian Side Effects Study reported more than 185,000 ADEs (Adverse Drug Effect) in Canadian hospitals, with nearly 40% of these being avoidable. In the decade after the study was published, a
follow-up report stated that there was only "limited evidence of substantial improvement". These estimates are worrying as medication errors can lead to adverse health effects for patients, including increased length of hospitalization, disability and death. Managing drug safety issues has become a top priority for many health care organizations in Canada. Errors can occur at any stage of the drug management process, from ordering to preparation and distribution, and finally, to the patient (Burkoski et al, 2019).

The closed-loop has focused on using technology to enhance connectivity and reporting from the point where the clinician prescribes the medication, to the station where the nurse or caregiver accords the medication. The closed-loop, therefore, focuses on developing technologies that can support integrated, timely patient information at all stages of the clinical medication management process, from physician to patient. The goal is to significantly improve quality and avoid mistakes. Closing the loop in the drug management process essentially means using different technologies for the following purposes:

• Prescription and ordering
  - Online prescription
  - Computerized Medical Order Entry Systems (CPOE)
  - Clinical Data Repository (CDR)
  - Drug information systems/databases
  - Ordering and IT systems for the pharmaceutical industry and the pharmaceutical industry

• Automation of drug administration
  - Bar code technologies
  - Nanotechnologies
  - Radio Frequency Identification (RFID)
  - Troubleshooting medicines in different care areas
  - Automating emergency department procedures
  - Automation of bedside care procedures
  - Automation of outpatient care procedures
  - Preventing medication errors when rejecting a patient
  - Automated Drug Dispensing Technologies

Online drug reporting and drug interactions control, cover all stages, including confirmation that medicines are provided at each stage of the process and in different cycles (episodes of care), by agreed specifications. Closing the loop cannot focus on just one single episode of care. Even with the multiple solutions and their often extensive features, attention is still focused on the clinical aspects of the drug management loop. These aspects do not necessarily support the non-clinical management of the supply chain, in terms of the value of the drug management chain. The clinical concept of a closed-loop system is quite different from that used in
supply chain management. If this setting is also included, the loop should include a value chain and should:

• Asses the full life cycle of a product, including its expected use after completion and waste management.

• Ensure that the value chain design has a forward and reverse logistics component related to the return of unused products, confirmation of actual usage patterns and disposal of used or waste related products (e.g. packaging);

• Ensures that replenishment and new orders are continuously linked to the end of the product as provided (e.g. expiration date) or the reverse loop in the closed-loop.

• Offers immediate re-use or replacement and quality review of product or service during the 'return loop' in a closed-loop supply chain (Bowles and Lu, 2015).

Figure. The Closed-Loop Supply Chain, (Bowles and Lu, 2015).

2.4 Healthcare Professionals’ Adoption of Closed-loop Medication Therapy Management

CLM is a means of reducing medication error associated with medication while recognizing the type of error that could be avoided. Using "traditional" methods, staff are not always aware that an error has occurred that may cause harm to the patient. Evidence suggests that medication errors can be minimized by using CLM by addressing the 'five rights' of drug administration (see Table 1) (Bhatti, 2019).
The value behind the introduction of CLM is to reduce the risks associated with medication and to improve the quality of care. It aims to support trust groups, including leading clinical doctors, nurses and pharmacists. The development of this tool would not have been possible without those who shared their learning (Bhatti, 2019).

CLEMM (Closed Loop Electronic Medication Management System), is an MMS that provides process control, and reduces risk at all stages of the process, especially from a pharmacist to a patient, as it confirms that the right drug arrives at the right patient at the right time. The essence of CLEMM is that it facilitates medical care and leads healthcare professionals to work together on all aspects of the drug management process to improve drug safety in areas where communication, such as packaging, review, management and administration has not been established. This feature completely closes the management loop. CLEMM is fully integrated into the drug chain, from drug packaging to administration and provides complete control and accountability over the process. Designed to allow full use of pharmacy services, CLEMM offers clinicians, pharmacists and care providers a convenient way of providing remote support and expert advice. Even when no provision is made for its installation, it utilizes existing infrastructure, and is easy to deploy once it has been specifically designed, for healthcare environments where staff and resources are limited (Bowles & Lu, 2015).

The above procedure, ideal as it may be, may not be feasible or even necessary in all cases, however (Lenderink, & Egberts, 2004). For example:

- In the emergency department, the timetable of actions is extremely limited, and circumstances are so pressing that there is no time to prescribe prescription

Table 1. The 'five rights' of drug administration, (Bhatti, 2019).

<table>
<thead>
<tr>
<th>Right Patient</th>
<th>Identifiable by scanning the barcode on a patient's wristband.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Medication</td>
<td>Identifiable by scanning a barcode on the medication package / label or by using an optical medication scanner. If the medication scanned does not match that which is prescribed, a warning appears.</td>
</tr>
<tr>
<td>Right Route</td>
<td>The electronic prescription can be cross referenced to ensure the right route is used for administration based on the profile of the scanned medication. The system provides a warning alert if the 'normal' route for the medication scanned does not match the prescription via the formulation.</td>
</tr>
<tr>
<td>Right Time</td>
<td>The user can ensure the medication is being administered at the right time by searching for a scheduled due time that falls within the permitted time window for documenting administrations. A warning alert is generated if the medication scanned falls outside the scheduled administration window.</td>
</tr>
<tr>
<td>Right Dose</td>
<td>The integrated medication scanning system compares the dose to be administered with the prescription; a warning appears if the doses do not match.</td>
</tr>
</tbody>
</table>
medications. In those times, the system should help the administrator (i.e. the health professional) at least provide and administer the ordered drug, following some basic checks, such as dose, known allergy and interaction with other medicines already taken by the patient. The physician should be able to authorize staff afterwards and, if necessary, continue the pharmacotherapy that has been started. These conditions also apply to surgeries and intensive care units.

- In psychiatric departments, some patients refuse to wear wristbands with their name and bar code. Alternative means should be devised in these cases.

- Regular medicines, such as infusion fluids (e.g. 5% saline or dextrose) or some ointments and creams may not be classified as dangerous and are therefore not considered candidates for the closed-loop system. Some treatment regimens are often modified, leading to increased workloads to ensure whereas any modification is introduced into the computerized physician order entry system. More often, protocols are designed to provide nurses with instructions or scenarios on when the dose can be varied. Some countries still do not support prescribing by a nurse or pharmacist. Registration of dosage modifications also requires registration of the underlying causes of change and is an important step in the drug management process.

- The administration of contrast media is another example of the use of drugs regulated in a similar manner, which means that even in this case, a single registration for the administration procedure is not sufficient.

- Another category of treatment that needs special attention is blood products. In order to ensure adequacy, some countries follow a set of legal instructions that require registration, not only of the product given to the patient, but also of the lot from which the product came from (Lenderink, & Egberts, 2004).

Adopting appropriate approaches can likely reduce the number of errors in drug delivery systems. One way is to inform the management about the problems the employees face, and to train them in the system, given that "the mistake is human"; In addition, the use of modern technology, such as line coding and scanning, can reduce the number of errors that occurred when importing drug use data into a computer system that eventually converts the distribution system into a closed-loop system. After acquiring knowledge and data from older and newer studies, one should try to introduce these new requirements as soon as possible, simply because many patients can be saved from serious injuries while in the hospital (Lenderink, & Egberts, 2004).

### 2.5 The Leuven Example - Development and Implementation of “Check of Medication Appropriateness”

Inappropriate prescribing has shown to be a risk for adverse drug events which can lead to patient’s hospitalization. Studies have shown that those unnecessary
admissions can be prevented if inappropriate prescribing be reduced. (Quintens et al., 2019)

In the University Hospital of Leuven, in Belgium, different strategies to reduce prescription errors were available like bedside, embedded clinical pharmacists responsible for medication reconciliation and review. However, due to healthcare budget limitations, the former option could be limited only to high-risk patients. Moreover, the hospital’s information system already included a basic computerized physician order entry with a clinical decision support system (CPOE/CDSS). Given the limitations of their basic CDSS and the lack of ubiquitous embedded clinical pharmacist availability, new measures were necessary in order to increase the quality of medication surveillance and monitoring. Therefore, a new back-office clinical service was developed with the name “Check of Medication Appropriateness” (CMA). The service comprises a set of advanced clinical rule alerts aiming exclusively to clinical pharmacists at the hospital. Thereafter, pharmacists’ actions are sent to physicians in case of medication inappropriateness. CMA’s objective is to validate patients’ prescription by combining structure data available at the hospital’s information system, along with using standard algorithms, also known as clinical rules. Furthermore, CMA uses the same safety alert system for DDIs (drug-drug interactions) as the existing basic CDSS uses. DDIs are based on a national database and are categorised in three groups: very severe, severe and other minor DDIs.

Setting up the CMA involves three phases:

1) Development of the clinical rules
   
The clinical rules were defined based on literature and national and international guidelines. Afterwards, all the rules were reviewed by a multidisciplinary team consisting of clinical pharmacist and other medical staff and then approved by the hospital’s board. The rules were classified into five types (overrules of alerts for very severe DDIs generated by the CDSS, drugs with a restricted indication or dosing, medication potentially leading to biochemical changes, potential sequential therapy, others).

2) Development of the CMA
   
The CMA system is based on a Microsoft Access database and alerts are invoked by a set of triggers (clinical rule alert criteria). The algorithms that trigger those alerts are based on if-then conditions. CMA takes as input screening of the available patient data in the electronic medical record and prescriptions that are included in the CPOE. Screening of the data takes place daily at 12 pm and generates the respective alerts if any violation of the clinical rules is observed. For every clinical rule, a user-friendly decision support flowchart is drawn and shown to the clinical pharmacists while they validate prescriptions. When an alert requires an action, clinical pharmacists leave an electronic note for the treating physician in the patient’s medical
record. Additionally, in serious cases, the physician is also contracted by phone. There are predefined electronic note messages for every clinical rule.

Table 1  Pharmacotherapeutic categories and subcategories used to define the clinical rules

<table>
<thead>
<tr>
<th>Category (and subcategories)</th>
<th>Example of a clinical rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Overuse of alerts for very severe DDI's generated by the CDSS</td>
<td>Reduced effect of valproic acid by carbapenems leading to an increased risk of convulsions</td>
</tr>
<tr>
<td>2 Drugs with a restricted indication or dosing</td>
<td>Patient with high dose mesopenem</td>
</tr>
<tr>
<td>3 Medication use potentially leading to biochemical changes</td>
<td>Patient with a GFR &lt; 30 ml/min and treated with metformin</td>
</tr>
<tr>
<td>* Drug use in renal insufficiency</td>
<td>Patient with a GFR &gt; 500476 ms and treated with aspirin</td>
</tr>
<tr>
<td>* Drug use associated with QTc interval prolongation</td>
<td>Patient with a K &gt; 75 mmol/L and treated with an ACE inhibitor</td>
</tr>
<tr>
<td>* Drug use associated with hyperkalemia</td>
<td>Patient with a K &lt; 3.5 mmol/L and treated with furosemide without potassium supplementation</td>
</tr>
<tr>
<td>* Drug use associated with hypokalemia</td>
<td>Patient with a superacute INR (INR &gt; 4) and treated with VKA</td>
</tr>
<tr>
<td>* Drug use associated with bone marrow suppression</td>
<td>Patient with an absolute neutrophil count &lt; 1.5*10³/L and treated with clodronate</td>
</tr>
<tr>
<td>4 Potential sequential therapy for bio-equivalent drugs</td>
<td>Potential sequential therapy for levofloxacin</td>
</tr>
<tr>
<td>5 Others</td>
<td>Patient treated with non-crushable drugs administered through enteral feeding tube</td>
</tr>
</tbody>
</table>

*DDI drug-drug interaction, CDSS clinical decision support system, INR International normalized ratio, COC coumarine clearance, ACE angiotensin converting enzyme, VKA vitamin K antagonist

Figure. Clinical Rules (Quintens et al., 2019)

(3) Validation of the CMA

Fictive patients and behind the scene tests on hospitalized patients were used as a sample in order to evaluate and test CMA with quantitative and statistical methods

(Quintens et al., 2019)

Study results showed that CMA is an important addition to the existing basic CDSS, which runs and audits only during the prescription phase without taking into consideration patient-relevant laboratory results and bedside services. CMA added value to the support of medication surveillance since it enables automated screening of multiple data sources. However, CMA has still room for improvements because irrelevant clinical alerts still appear sometimes (Quintens et al., 2019).

3) Methods

User-Centred Design (UCD) principles were followed throughout the entire design process. UCD is a general term for design methods with focus on designing for and
involving the users throughout the entire development of computerized systems. (Abras, C., Maloney-Krichmar, D., & Preece, J., 2004).

3.1 Field Studies at Uppsala University Hospital

Before looking into any solutions for the given problem, getting familiar with the environment that surrounds it is a prerequisite for a researcher. In this case, the environment was the Uppsala University Hospital. The first step was carrying out an observational field study at the hospital. A field study involves the evaluator observing the users as they carry out regular or routine activities in the natural context of use. (Duignan, J., 2016) This gave me the opportunity to get the first-hand contact with the software that is currently used. The visit took place at a physiotherapist’s office during an examination with a patient and helped me form a clearer image of how she interacted with COSMIC in order to write the diagnosis for the patient and then book a follow-up meeting. Another experience with COSMIC was a tutorial shown by a doctor on how prescriptions take place and what kind of warnings may appear if something goes wrong. These visits were an invaluable source of information that helped me understanding existing opportunities and limitations. Feedback gathered from the field study along with hands-on experience with COSMIC contributed to creating, even from this early research stage, many design ideas and suggestions. Thereby, a method in the quest to find answers in the second research question (How could users interact with a new solution for prescription verification?) was using personas and scenarios. The personas and scenarios created comprise an early research stage that was carried out before getting feedback from the interviews. Therefore, the design ideas presented on the scenario descriptions differ from the final suggestions (See appendix 1)

3.2 Interview with a Head Pharmacist

The first interview was conducted with a head pharmacist at the hospital without recording its content. No particular theory was followed, and the interview had the form of a predominantly unstructured interview. Among the topics that were discussed were the advantages and flaws of the current system, opportunities and limitations, and desired improvements to the prescription workflow. Furthermore, the personas and scenarios were presented, and the discussion that followed up led to interesting ideas. (Read more in Appendix 2, interview 2 section)

3.3 Interview with Clinical Pharmacists

This interview was the main inspiration for the suggested interface.

The method that was chosen to analyse the contents of the interview was Thematic Analysis. The interviewees were two clinical pharmacists, working in a medical ward in Uppsala. Their responses gave a clearer understanding of how medical prescription
works at the hospital and who is responsible for verifying those prescriptions. In comparison to previous interviews, this was semi-structured and recorded.

Thematic analysis is a method for pattern analysis, identification, and reporting within a dataset. This method is popular because it allows describing data which is rich in detail (Braun, V., Clarke, V., 2006). In this case, in order to analyse the data, I followed a procedure introduced by Braun and Clarke (2006).

The first step involves the researcher to read the data as many times as required until she becomes familiar with it. Afterwards, the researcher starts generating codes within the data. This is accomplished by coding interesting features. For example, after she writes down the first draft of notes, she can create bullet points for the parts which she considers important. Thereafter, she begins searching themes in the dataset. An efficient practice for identifying themes and patterns is using graphical representations also known as thematic map diagrams for the coded features used in the previous step. Finally, after reviewing the potential themes, the researcher creates a final report about her findings (Braun, V., Clarke, V., 2006).

The interview was conducted in a semi-structured form (Duignan, J., 2016), (Clifford, N., Cope, M., Gillespie, T., French, S., 2016), (Drever, E., 1995) since it is a model that provides both structure and flexibility to the interview process. In this work, I prepared a general interview structure, by defining topics and preparing in advance a list of, mostly, open-ended questions. During the interview, issues that arise from a response may often lead to new questions. Finally, I recorded the interview and stored it for future analysis, since writing down people’s thoughts while conducting an interview at the same time may be distracting and result in poor quality notes (Cohen, D., & Crabtree, B., 2006.).

**Prescription Process Diagram**

The key points from the interview with the clinical pharmacists were transferred to a diagram which includes all the workflow processes involved in prescription. The diagram works as an unofficial map on how users currently interact with the current system. The process diagram facilitates the analysis of the interview data (facts, opinions, limitations) and aims to provide insight and answers primary to the following research question:

- *How could users interact with a new solution for prescription verification?*

**Legend of the Diagram**

- **Entities**: Actors (users involved), systems or important parts that participate in the workflow are symbolized with rectangles in the diagram.
- **Attributes**: Characteristics and traits of an entity. They are symbolized with round-shapes in the diagram. An attribute can have sub-attributes.
- **Relations**: Interactions between two entities. They are symbolized in the diagram with diamond shapes.
**Notes:** Comments or further description of an entity, attribute or relation. They are symbolized with curly bracket shapes in the diagram.

**Sets:** A set that includes the sum of all possible attributes is symbolized with a circle in the diagram.

The diagram was designed by using LucidChart tool². The full schema can be found in the appendix section. Below follows the description of the workflow. No specific format or pattern for the diagrams was followed. However, the diagram shapes are borrowed from Relation Diagram theory (ER) (Tillmann G., 2017).

### Pharmaceutical Prescription Workflow

The following processes concern an orthopaedic clinical ward, but similar procedures are also followed in other wards.

Who is responsible for prescriptions?

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² [www.lucidchart.com](http://www.lucidchart.com)
Pharmacists at a medical ward work as a team in close collaboration with the doctors. One of their main tasks is to fill the gap between the patient and the physician by ensuring a flawless, punctual and correct medicine flow, starting when a physician prescribes a drug and ending when the target patient successfully receives it.

What clinical pharmacists do

![Diagram]

Figure. Clinical Pharmacist Workflow in Uppsala University Hospital

When a patient arrives at the hospital to be operated, clinical pharmacists ask him about any medication that he is currently taking. Moreover, they check for his overall health overview by searching through his medical records in COSMIC. When finally, the patient leaves the hospital and has to take medicine at home, clinical pharmacists are still accountable for a correct drug admission.

The pharmaceutical prescription verification on their behalf involves control on whether:

- A prescription is recent, still actual and up to date
- The doses of the drugs are correct
- The actual drugs are correct and suitable for the patient both before and after the surgery.
- An order that has been delivered is correct. (i.e. pharmacists check drugs that have arrived if they comply with the prescription)
There is a series of further actions clinical pharmacists may perform to prescriptions. Their aim is to find errors in prescriptions or update them after changes. More specifically, they are able to recommend or request prescription orders. A patient’s health conditions may suddenly change and either improve or deteriorate. Therefore, a prescription cannot always remain stable and often needs to be modified or even removed. It is essential for patients to have 24/7 health status monitoring. Clinical pharmacists may need to change active prescriptions when required, but in order for the new prescription to be valid, they must first notify the doctor. Certain actions where they are involved to are:

- Prepare a prescription for sign in. Doctors and surgeons at a medical ward have a heavy overload. Therefore, it is not uncommon for pharmacists to prepare a prescription on the hospital’s EPJ (COSMIC)
- Change intake time for a drug’s dose
- Spread out a drug’s intake throughout the day (i.e. A prescribed dose of antibiotics can be divided and administered into three intakes during the day).
- Fix errors in prescriptions. Sometimes mistakes happen during prescription typing (i.e. The doctor may accidentally type two zeros instead of one for a dose)
- Remove medication that a patient stopped taking from the system (COSMIC)
- Update patients who have left the ward for prescription changes.

It is noteworthy that according to the interviewees, the nursing staff is also involved in the processes mentioned below. Not only nurses are the ones that administer the drugs but also have the most direct, first-line contact and communication with the patients. Thus, it is not unexpected that they have the latest information about a patient’s health status. Therefore, they also check medical orders and have a say on whether a prescription should be revised or not. (i.e. A patient’s fever is increased during the night, and the ward’s nurse requests the doctor to approve an increase in the painkiller dose). In other words, nurses are authorized to actively omit doses or administer different drugs at their own discretion if a list of criteria is met.
What doctors, pharmacists, and nurses check during pharmaceutical verification

Figure. Prescription Verification in Uppsala University Hospital

Prescription verification currently happens with COSMIC. All users involved, usually check a set of parameters in order to decide if a prescription is safe or effective for a patient. Those parameters vary from case to case but usually are:

- Lab Results Diagnosis (i.e. results from a patient’s blood analysis)
- Kidney function
- If a dose is within the limits. (All medicine include documentation that specifies the maximum allowed intake dose. However specific patient’s health condition may requisite to readjust a drug’s dose limit)
- Pulse rate
- Blood Pressure
- Saturation
- Allergies
- Breastfeeding
- Weight
- Other Patient Characteristics

Other important factors users check is:

- Medicine interactions (When a patient takes more than one drugs, it is important to check what effects and complications to the patient’s health has a medicine when combined with other medicine)
- Duplications between drugs (When a doctor prescribes two drugs with the same substance)
COSMIC automatically checks for the latter two factors. For some cases it is effective and for some other inefficient

What kind of warnings are currently triggered?

![Diagram of prescription warnings]

Figure. Prescription Warnings in Uppsala University Hospital

Currently, COSMIC triggers the entire set of available warnings during the prescription stage. A certain amount of them may reveal important information about a patient’s health conditions and, therefore, they should draw the required attention. On the other hand, other warnings which often appear may either not be clinically relevant or for some users not informative at all. During the prescription process, doctors receive a massive amount of warnings where it is hard to distinguish a serious warning from an extraneous one. Because of this complexity, doctors often seek to skip the entire warning system, by closing all the warnings that appear without reading them first. Therefore, important information can be easily lost. Moreover, preferences vary between different professionals, so the same warning can be not equally important for every doctor. Consequently, this unfiltered sequence of information usually does not lead to the expected results that a warning system aims to serve, which is to support physicians in the decision-making process and to prevent severe faults from occurring.
Figure. Advantages and Disadvantages of COSMIC

1) Where COSMIC succeeds and fails

According to the Clinical Pharmacists, COSMIC works pretty efficiently in identifying issues in medical duplications. (But without being entirely fault-intolerant)
However, except for the problematic warning system, there are also many complaints about the complexity of the interface. Regarding tasks, users need a significant number of clicks and intermediate interface access before they complete their task. Additionally, performing tasks sometimes takes a considerable amount of time. Last but not least, the interviewees also claim that there is a lack of instruction on how to perform specific tasks.

3.4 Presentation to Pharmacists and Medical Staff at the Hospital

The final step of the entire process involved presenting the final suggested interface in front of pharmacists, and pharmaceutical students at the hospital. The reception was positive, and the feedback from the presentation led to some design modifications. Some of the feedback included.

- They liked especially the networking ideas (messenger inside the app)
Some design modifications were requested in the layout and patient information section appearance order

(Material and notes from the interviews are located in Appendix 2)

4) Results

4.1 Desired Features in the New Interface

What do people need in the new solution?

All the people interviewed asserted that new application which automates the prescription verification step would reduce significantly medical time at the ward both for the patients and the health staff. However, they have their doubts and concerns about the feasibility of a fully automated decision support system due to limitations that exist. It is hard to impossible to replace the decision process with an automated predictive system (based on rules verification) because there are too many different patients’ cases and needs between different medical wards. Even if a system like the one described in the scenarios above existed, it would not be capable of being 100% accurate and fault-free for the following reasons:

Limitations

- There is an enormous number of cases and combinations between medical rules. Therefore, users manually access what they want to check about a patient in COSMIC
- The legal framework about the responsibility in an automated prescription process is still unclear
- It happens that doctors and nurses sometimes miss info or make mistakes when typing the patients’ data. It would not be easy for a system to identify such errors
- Technology cannot help against missing data (which is not an uncommon phenomenon for a patient)

However, even a partial solution could facilitate pharmacists’ job. A good looking and safe overview interface for each patient would be embraced. An interface with the following characteristics:
Desired Features

- A patient overview interface with touchscreen capabilities and the ability to customize what the users view depending on the occasion or their preferences
- It is essential to include checks for patient parameters (pregnancy, allergies, etc.), lab parameters (kidney values, liver values, etc.) and clinical parameters” (blood pressure, weight, etc.)
- Information about a diagnosis
- A customized page for every patient based on his health needs
- Ability to display only the important warnings for each patient. Again, the interface needs to be customizable when it comes to which warnings to show
- Show a pain scale option. Caretakers at the ward need to record in the system patients’ pain in a scale from one to ten (1-10) every hour
- COSMIC includes everything regarding a patient’s data. Users usually prefer using something more specialized
- Show observation date for each patient’s measurement (i.e. blood analysis test). It is important for health staff to be able to assess if a patient’s indicator result is still trustworthy and up to date. Unfortunately, currently (2018) there are many old data inside COSMIC
- A platform that improves communications between all the stakeholders involved in medicine prescription.

What is the weakness of the system? The main weakness of the system is the warning system. Not only is very complicated, with some of the warnings which often appear may either not be clinically relevant or for some users not informative at all, but also sometimes a massive amount of warnings appears, where is hard to distinguish a serious warning from an extraneous one. Another weakness of the system is the amount of time the staff needs to perform a certain task. Users need a significant number of clicks and intermediate interface access before they complete their task

How can the system design meet the needs and the goals of the staff and patients?

The need of the system which automates the prescription verification step and would reduce significantly medical time at the ward both for the patients and the health staff was evident from the interviews. The communication between the users should be improved, and the system should be designed to display only the important warnings for each user. The information about the diagnosis should also be displayed, so the patients could also have access to the data.

What are the main problems that staff, and patients face when using the interface? One of their main concerns of the stuff is to fill the gap between the patient and the physician by ensuring a flawless, punctual and correct medicine flow, starting when a physician prescribes a drug and ending when the target patient successfully receives
it. This means that the users need to be able to supplement the decision process with an automated predictive system (based on rules verification) because there are too many different patients’ cases and needs between different medical wards.

4.2 A Suggested Interface for the Verification Step

The proposed interface was developed by taking into consideration feedback both from the interviews and the literature review. The interface should:

- Support a wide range of screen sizes and touch screens, to help the search of individual cases
- Be able to identify the typing mistakes or the missing information
- Support a 24/7 verification system
- Display the important warnings for each professional

Several desired features that mentioned above would also allow easier and detailed access, making the system facilitate medical professional’s work.

Based on answers and findings on what users need I designed a prototype of an interface.

The name of the interface is VerifyPro, and the idea behind it is a fully customizable patient overview dashboard page which supports communication between medical staff. It works as a submodule of an EHR (Electronic Health Record) were end-users have the option to display only the patient records that they need.

A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance. (Stephen P., 2004)

The interface was built, making use of bootstrap’s Grid Layout system. It is an effective way to arrange the layout and align content based on rows and columns. Bootstrap is a popular open-source toolkit for developing with HTML, CSS and JavaScript. It provides a rich front-end component library which allows users to build apps or prototype ideas.

4.2.1 Interface Usage Description

How a solution that can facilitate prescription verification in closed-loop medication could look and behave like?

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3 https://getbootstrap.com/docs/4.1/layout/grid/
It is worth to mention that the first question focuses mostly on the features of the new interface and not on the aesthetic design part (colour choices, text, etc.)

How could users interact with this solution?

The suggested steps when a user accesses the interface are the following

1) **Initiation of the app and script running:**
   A login page appears, and the user needs to be successfully authorized in order to proceed to the next screen.

2) **Ward’s Patient Page**
   A list with the entire set of the patients currently admitted at the user’s medical ward appears. Patients are classified in descending order based on their *emergency rate*. (Read also assumption 9).
   
   - **Emergency Rate** is a fictitious scale from 1-10, indicating how severe is each patient’s health condition. It has the potential to help doctors and other medical staff prioritize which patient to look after first. Development of a real algorithm is out of this thesis’ scope. However, readers can assume that emergency rate works like a *black box*[^1]. A

[^1]: https://en.wikipedia.org/wiki/Black_box
magic box that receives a series of factors as input and returns a number from 1-10 as output, without an explanation of the calculations that take place internally. These affecting factors for a patient could be:

I. **Auto-generated warnings** reflecting a patient’s special conditions. Age, pregnancy or kidney dysfunction, for example, can be reasons for a patient to appear higher on the list. Those warnings are triggered when a set of rules is being violated. Rulesets may be created by the entire hospital, the ward or a doctor’s needs. VerifyPro envisions high flexibility in rule creation. Users ought to be able to only see what they truly need. An example of an auto-generated warning could be a reminder when lab data is too old.

II. **Custom Warnings** that users create for a patient. For example, a doctor, being more aware of a patient’s condition, can draw increased attention by creating a warning with a high severity grade (>7 usually)

The script below shows how the rule system is imagined to function:

```java
// = comment //
if (login()==True){
    Array[] patient_list = Array [] // A list of the current patients at the ward
    Array [] all_rules = Array[] // A set of rules created by the ward or the hospital's administration
    Array[] unwanted_rules = Array[] // A set of the rules that the user does not desire to include
    Array[] special_rules = Array[] // A set of custom rules created for specific conditions
    // 0<= unwanted_rules <= all_rules !! // A user can choose to include all the rules
    rules = (all_rules - unwanted_rules) + special_rules
    ward_patient_list_page (patient_list, rules)
}
else {
}
```
ward_patient_list_page (patient_list, rules) {
    foreach(partient in patient_list) {

        patient_rules = Array[] //Unique rules for the specific patient

        rule = 1 rule in rules
        prule = 1 rule in patient_rules

        if(any rule = a prule) {
            overwrite(rule,prule) // If any patient specialized rule is similar to a general rule, the first has precedence over the latter
        }

        total_patient_rules = Array[] = rules + patient_rules // The total set of rules for each patient,

        assess_emergency_scale (patient, total_patient_rules ) // Check every patient against the ruleset and assign a degree of emergency ranging from 0 -10

        sort(patient_list) //Sort patients in descending order according to their emergency rate (1-10)

        load_main_page(patient_list) //Display the list of patients at the ward
    }
}

3) Patient Personal Page

This page corresponds to the overview page for every patient. There, users cannot only monitor the patient’s data they need, but also check and create warnings, messages, and notifications regarding the patient. The core functionalities of the interface are located here, and the page consists of the following features:
Menu Features

A user is located on patient Oscar page, where she/he can:

- Search in Cosmic’s database for another patient and change the patientDisplay page
- Open and inspect notifications and warnings concerning patient Oscar Jacobson
- Use a link to open the patient’s page in Cosmic
- Check Oscar’s pain scale from 1-10
- Import more parameters from Cosmic
- Read messages sent by other users regarding Oscar
- Create a new notification/message/warning regarding Oscar.

Components

The core functionalities of the interface lie on its components. A component has the following traits:

- Components can be dynamically resized. A user may click or touch (I.e. tablet) within the component’s limits and modify its current width and size.
- Components can change the location on the screen. For example, by default, the notifications component is located above the prescription's component. This order is possible to be modified.
- Components can be maximized on screen. In that case, the other components appear as tabs. Respectively components can also be minimized
- A component can be locked against changes in its position and size
– A user can search for entries inside a component. Search and result filter rules are also allowed.

Each component includes a controller menu above its content part, where a user can perform resize, position, and search-related actions. This area is by default hidden, but a user can display it in order to perform actions in the component. The image below shows how the component controller menu looks.

The Prescription List is one of the core components, where the verification actually takes place. It shows all the prescribed medicine for the current patient and includes information fields along with a series of actions that users can perform.

**Currently available fields:**

1. **ATC**: It is an international system that the Swedish Medicine Product Agency (Läkemedelsverket) uses for medicine classification. The classification is based on the main substance of each drug. The field contains the ATC code for the drug, and it is clickable. When a user presses into it, he/she is redirected to the agency’s page that contains documentation and

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information about this specific drug type. (Example image regarding Paracetamol follows below)

II. Substance Name: The field contains the name of the prescribed substance. It is also clickable and redirects the user to a page containing instructions and recommendations about using the prescribed drug. (example: https://www.internetmedicin.se/page.aspx?id=938 , source: Swedish Health Agency 1177)

III. Product Name: The field contains the name of the prescribed drug. It is possible different products to contain exactly the same substance.

IV. Dosage: A field containing info about the frequency of drug intake (i.e. 2 pills X 4 times per day). It is recommended that the dosage description to follow a standard predetermined format in order for its processing to be easier by the algorithms
and scripts. If there is a warning related to the dosage, the field appearance changes reflecting the warning’s color. A severe warning, for example, will make the field red.

V. Risk Severity: It contains a value from 1-10 corresponding the patient’s risk rate if he/she intakes the medicine. This field's value and color are being automatically set by the verification scripts or manually by a user who reviews the prescription (see also emergency rate section above)

VI. Date: It contains information about the date that the drug was prescribed. Old prescriptions may trigger warnings which change the color of the field respectively.

Currently available actions:

Actions trigger warnings-notifications, messages or modifications on an active prescription. There are five actions a user can perform. She/he can request a modification on a prescription, comment about it, create a warning or approve the prescription by pressing the ‘Mark as read’ button. All the actions except for the approval require a message to the prescriber (preselected) or a user who may be relevant with the prescription.

The available actions can be easier explained by using a simple example.

Dr Albert J. has prescribed paracetamol to the patient named Oscar Jacobson. Sofia is a pharmacist who is responsible for validating prescriptions for Oscar. She finds paracetamol in the prescription list and deems that an increase to the dosage is required. So, she first updates the dosage field on the prescription list, then she writes a message about the reason for this action and finally presses the ‘Request Change’ button. Dr Albert when he logins to Oscar’s page can access Sofia’s message.
Notifications

Auto Generated Warnings: warnings generated by the scripts when the interface boots up and thus their severity rate is calculated automatically (see description above). Depending on the severity rate, they can have three colors. Red for the most severe warning, yellow for warnings that require attention, and finally blue for the less important ones.

Custom Warnings: They have exactly the same style with the automatic warnings, but custom warnings are created by authorized users such as doctors, pharmacists or nurses. Those warnings are visibly by the rest of authorized users for this particular patient.

Notifications: A user can create notifications or notes about anything that concerns the current patient. Moreover, other authorized users are able to access and read his/her notifications.

When a user presses the ‘Mark as Read’ button, the corresponding warning/notification disappears. Furthermore, there are filters for the warning display. A user is able to either view only the warnings having a specific color. He/she can also choose to see only warnings with severity rate bigger than a given one [See Assumption 11]
Patient Info Data

It includes the parameters imported from cosmic. The data categorization into Patient Data, Lab Data and parameters is based on the feedback collected during the interviews. Again, a user can perform actions similar to the prescription ones. (Remove the data, request recalculation if the data is old or comment on it) Furthermore, there can be warnings related to patient data.

Note: Warnings in the patient’ data received mixed reactions during the final presentation to the pharmacists at Uppsala Academic Hospital, because there were many concerns that this feature can lead to an overflow of obvious warnings. Therefore, the necessity of this approach is debatable. However, according to the interviews, a desired feature was that the system could warn users about old data and thereby, the suggested implementation makes that possible.

Diagnosis List
An important component showing information about the diagnosis of the patient. The ICD 6 code [*] field is clickable and redirects the user to a page containing instructions, information and guidelines regarding a diagnosis. Finally, there is also a link that displays, when clicked, the prescription items (medicine) related to the diagnosis. The description field describes the patient’s case and explains the reason behind the diagnosis. When a user clicks on the info area, two events are triggered. First patient notes tagged with the specific ICD code appear on the Notification/Warning area.

\[1\] ICD-10 is the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD), a medical classification list by the World Health Organization (WHO). It contains codes for diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases
Secondly, an information area appears that contains a list with the date when the diagnosis was created, the person that created the diagnosis, and a link that leads to the prescriptions regarding the diagnosis.

[*] ICD-10 is the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD), a medical classification list by the World Health Organization (WHO). It contains codes for diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases.

5. Discussion and Conclusion

5.1 Discussion
As with other medical transformation programs, inserting data into the closed-loop system requires careful planning and a broad commitment to clinical leadership to ensure success. In the hospital staff studied, there is already increased experience in

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8 https://en.wikipedia.org/wiki/Medical_classification
applying technology to support drug management with the recognition of positive benefits. Medical staff must get used to working with other professionals as well as patients and make use of the available resources. Around the world, healthcare providers are faced with the challenge of providing effective drug management in advanced supply chains that cover different scientific disciplines, service providers and even geographical locations. So, it is important to have a system that does not increase the complexity of service provision. The ability to provide access to medicines and quality healthcare services, it is now the main purpose of designing the relevant systems. Previous solutions have required a significant investment in infrastructure, management, training and education to improve the integration of electronic information with prescription drug management to the patient. Ongoing efforts to close the loop in drug management also have a single flaw: the loop does not include or provide a system-wide view of each drug management episode.

The responses from the interviews shed light both on the current limitations and the desired additions in the system and provided concrete opinions and answers regarding the research question *What do people need in the new solution?* Which in its turn in connection with the identified limitations gave insight and ideas about the research question *How could a solution that can facilitate prescription verification in closed-loop medication look and behave like?* Moreover, it is important to highlight that only one design iteration cycle took place in the User Centre Design due to time limitations on the project.

Finally, there are many similarities in the cases between Leuven University Hospital and Uppsala University Hospital. Both hospitals use information systems (COSMIC in Uppsala) that include clinical decision support systems in prescription. Leuven has developed an adequate system for decision making rules in prescription that Uppsala can take ideas from. Furthermore, the Leuven case is an important example that can provide with answers in the research question about *what do people need in the new solution?* A system that can supplement and facilitate their decision process.

What seems to be lacking in the Dutch hospital is an interface to present the results of the rules since they use only diagrams for decision making. But a similar rule system could be used along with *VerifyPro*. Both the Leuven example and the suggested design ideas from this report may hopefully facilitate Uppsala University Hospital to eventually introduce Closed-Loop-Medication

**Assumptions – How the Interface Should Work:**

1. The interface supports a wide range of screen sizes. A typical example of its usage are personal computers, tablets, and smartphones
2. The interface supports touchscreens
3. **The interface does not aim to replace decision making but only facilitate users’ tasks**
4. The interface consists of components. The proposed architecture allows expanding the list of the available ones.

5. If there is an overflow between components the screen automatically auto-adjusts to display all the components optimally.

6. Components have pre-set default location and size settings on screen.

7. It is adjustable the screen percentage that a component occupies when maximized.

8. The control menu appears only in the prescription component for demonstrational purposes. It is assumed that it is hidden for the rest of interfaces. Design of the hide/show button has not been designed yet.

9. Due to time limitations, the patient list page, unfortunately, has not been created. **However, it has a similar style to the Patient List component.**

10. An additional field should be created in the prescription list which indicates until when the patient needs to intake the prescribed medicine.

11. When a prescription has been modified or triggered a warning, the prescriber (usually a doctor) receives a mail or SMS prompting to check the respective message, warning or notification on the patient’s page.

12. The reason for a diagnosis needs to be filled by a physician. Lorem ipsum was used instead for demonstration purposes.

Whoever writes a note and includes the symbol @ with the ICD code, the note becomes searchable with search criteria the ICD code or diagnosis name in the **Warnings/Notifications** area (This feature is not included in the demo interface)

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**5.2 Conclusion**

It is true that there is already a long list of available software, and the creation of an additional one may cause increased complexity. So, it would be reasonable to question the purpose of a new interface’s existence. The answer is, however, that it would be helpful for the medical staff to reduce complexity in their daily tasks. **COSMIC** is a large-scale information system which carries out, successfully in most cases, the majority of the hospital’s processes, including almost all data regarding patients. However, users usually need only a small subset of the entire information set. Quick access to the info needed is capable of facilitating the completion of their tasks.

The proposed solution offers a customizable experience, fitted to each user’s needs (i.e. a midwife may need to check different data than an orthopaedic doctor.) and thereby may contribute to the reduction of complexity since it allows users to check and only follow what they need to.
VerifyPro comes with a module installed on COSMIC, from which users can import the data that they desire. This module adds an import option, for every record of patient data, like patient parameters, lab data, or prescriptions. That functionality allows a doctor, for example, to collect all the parameters she/he needs and display them in a user-friendly and neat interface.

Verify Pro is not only a prototype since its interface has been developed with accessible and editable code, which means that its contents can be modified, improved and expanded in the future by giving ideas for real projects. However, yet it includes a limited amount of interactivity, it is only the skeleton of the end program since there is no data included nor interaction between the components have been incorporated. Finally, due to the project’s time limitations, the interface could not have been a complete solution. Nevertheless, it has the potential, hopefully, to provide useful ideas to future developers as well as illuminating the path on how the digitalization of the verification process can effectively become a reality, based on user’s needs.

Appendix 1: Personas and Scenarios

Based on the User-Centred Design, personas and scenarios were used the purpose of this approach is to clarify how the proposed interface is going to be used and by whom. User-Centred design provides high coverage in interactions between users and the interface, in a language easy to understand. Personas are non-existing characters, which represents the average needs of a broader group of users. In our case, this group consists of pharmacists. Facts about a persona’s habits and routines come out of research for this specific group. Therefore, personas are rather a representational example of the interface’s end-users. Scenarios are interaction examples between a persona and the interface. A scenario is an early design paradigm, reflecting how users cover their goals, desires, and needs by using the interface (Gudjonsdottir, 2010).

Persona 1: Oscar Ericson, 40 years old, Pharmacist

Oscar is a clinical pharmacist at the orthopaedical ward of Uppsala university hospital. Every day Oscar receives a vast amount of prescriptions for the ward’s patients that need to be signed. A part of his duties is also to check a patient’s medical record and deem if a prescription is safe for the latter’s health. Workload at the ward is extremely heavy. Oscar has the best intentions to verify all the prescribed medicine, but due to shortage of time, sometimes he simply trusts the doctor’s decision. He tries to prioritize severe cases first. Oscar wishes to have a decision support tool for every prescription.

Persona 2: Marina Nilsson, 63 years old, Nurse
Marina, a colleague of Oscar, is a nurse at the hospital of Uppsala. Every day she deals with a vast number of patients that need to be treated. An experienced nurse with many years of experience treats every patient in a unique way with care, based on his personal traits and needs. She is responsible for administering the prescribed medicine to them. Before that, she always double-checks if the medicine and doses are correct and safe for each patient. Marina finds it difficult to learn and use new technologies. She has many complaints about the high complexity level of COSMIC.

Persona 3: Chris Gordon, 32 years old, surgeon

Chris is the new surgeon at the emergency ward of Uppsala university hospital. Chris likes technological solutions but finds COSMIC slightly obsolete and time-consuming. Before each operation, Chris needs to check the active prescription for every patient. Therefore, a tool, displaying medical prescription for patients ready to be operated but also for those who have been recently operated, would facilitate his workflow.

Persona 4: Sofia Carlsberg, 50 years old, pharmacist and head of the orthopaedic ward

Sofia is the dean of the orthopaedic ward. Among her tasks is to guarantee for the ward’s flawless and seamless function. She is also aiming for the most affordable purchase of medical supplies. Occasionally, Sofia checks prescriptions against some criteria for the patient’s safety or simply financial reasons. A decision support tool would alleviate her already heavy workload considerably.

Persona 5: Carl Ellsberg, 78 years old patient

Carl was suddenly hit by a heart attack. It is urgent that he have an operation the soonest possible.

Scenario 1: Uppsala University Hospital has developed a solution for medical verification. Oscar’s desire has finally been fulfilled. Oscar opens the interface and logs in with his credential. There is a checkbox with the name “Run scripts and view all severe warnings”. Next to it, there is another warning that Oscar ignores it. In the main page, there is a calendar-styled prescription overview page. There are many view options. The default selection for him is the Prescription Verification view. For every entry on the list, there is a link to the patient’s page on COSMIC. Oscar selects by clicking the first entry. It is a paracetamol prescription. There is a button next to the list with the name Verify Selected. Below of the button, there is a preselected radio button with the name Against all rules. Next, there is another option with the
name Against custom rules. Oscar ignores the second option and presses the button. After a couple of seconds, A red window appears with the message that there is a complication with this prescription. A red flag appears next to the prescription entry. Oscar then immediately reports the incident. Sofia receives a message. She investigates the incident, and it turns out that the red flag is a result of the patient’s wrong data in the system. Therefore, she changes the flag’s colour into green and the prescription proceeds into the vending process. Finally, Oscar selects all the remaining prescriptions and presses the same button. Again, after a while, an info window appears, showing that all the prescriptions have been successfully sent to the vending machines. Green flags appear next to the entries. There are already many preinstalled rules on the program, but this list can be increased, either by experienced users like Oscar or by the IT team. At the same day Oscar, before leaving work he tries to use the interface again in order to add some new rules. Suddenly he realizes that he does not have access rights. Then he calls his boss Sofia and asks her to authorize him. Next day his request is accepted, and he begins the new day by opening the interface and accessing the rule tab again. The rule creation form opens. There is a selection field with the name “Rule Type” (More details in the database section below). He types the rule parameters and then saves the rule. A pop-up window appears with a success message. Sofia receives a status update pop-up at her interface about the new rule. From now on, there is a new rule in the database. Furthermore, a script which checks prescriptions against the available rules runs every 24 hours.

Marina has had a busy day since patients are hospitalized at the ward. She is aware of the new software, but initially, she remains sceptical due to previous bad experiences. However, she decides to give it a try. Surprisingly, this new tool helps. She logs in with her credentials and then accesses the main interface. Another preselected view is available for her, named Prescription Overview. There again, a calendar appears with prescriptions allocated to different time slots. Next to each prescription, there is either a green, yellow or red flag. The flags are clickable, and they contain notes. There is only one yellow warning for a patient’s prescription. Marina checks the description of the warning and decides that it is not something important. Therefore, after retrieving the patient’s medication from the vending machine, she administers the medicine to him.

A new day starts for Chris. Before the surgeries, he has to inspect the medical status and prescriptions for the corresponding patients. A well-designed solution can make this task easier. Chris open the software and enters his login credential. Then he accesses the main interface, which is similar to Marina’s Prescription Overview. However, now the interface is quite different. There are two areas on screen. On the left the Pending Surgery list on the right the Completed Surgery list. On each area there is a table. On the first column there are patient names and surgery information.

On the second column appear the prescriptions for the selected patient. Each prescription can be checked against the rules as mentioned above. Chris finds Carl’s
name first on the pending surgery list. He clicks on it, and then his active prescription list appears on the second column. Five out of his six prescriptions have been checked against the rule and hence are highlighted with light green background. The sixth has not been checked yet. Chris selects it and follows the same procedure as Oscar. The result is a yellow flag. Chris reads the warning, and he must decide if he should allow the medicine to be administered to Karl or not. Luckily, the interface seems to work for him. Below the list areas, there is a panel showing coloured tiles with warnings (green, red or yellow) for the selected patient in descending order. Underneath this area, there is a checkbox allowing to show the severe warnings only. Chris clicks the box and in order to filter out less significant warnings for Karl. Then he realizes that now red tile appears for him. Therefore, he decides to approve the prescription and sends the medicine to the vending machine. A few hours later, Karl’s operation finishes successfully.

To sum up, all those cases mentioned above are basic examples of how the interface could be used by more than one cases of users. In the sections below, I present how this interface could work and look like.

Appendix 2: Interview Process

Interview 1: Field study at a physiotherapist during a patient visit, followed up by an interview (Some parts are connected to another course – not everything relevant)

Interviewers: Iosif Kakalelis, Arvid Granroth

Questions about Cosmic

1. **What are the main problems in your healthcare center?**
   Often the digital workflow breaks, and some processes are being carried out analogically. That slows down considerably the whole procedure. There are still many processes that need to be digitized. A major part missing comes from vital parameter indicators in patients. A mobile device that records those parameters, like blood pressure, for example, would save a huge amount of valuable time to nurses. Until now nurses note those measurements in paper and then they type them in a computer terminal (That takes 15 minutes, it can be reduced to 6 minutes).

2. **What possibilities and limitations exist for the development of the patient record?**
   We need to take into consideration that all processes are very slow and take a long time to be implemented. Cosmic cannot easily take in data. There is a huge problem with taking input. The system is very old.

3. **What new initiatives have been planned for Cosmic?**
   A mobile app for Electronic visit has been developed. It is similar to Kry and Doctor24 but is only available for the Uppsala region and only for follow-up conversations. First contact communication is not possible because there is a fear that it will create more work for the already heavy workload that the doctors have.

4. **How flexible is Cosmic for changes/improvements? Does the hospital have access to**
the source code?
It takes so long for changes. There is also a lack of resources. The hospital has no access to the source code. But recently Cambio has introduced open services API which facilitates changes. There is a big pressure from competitors to Cambio for improvements, but procedures take long.

5. How long does Cosmic change take? Is an improvement affordable?
10 months from production to implementation and 2 years to roll out a new version

6. What is the degree of interconnection between different software in healthcare?
There are standard protocols, that look like XML, for communicating. Those include web services and Zebra service (Report Service inside Cosmic). The way to structure information is very strict and specific.

7. Do you think long queues in the healthcare center are also caused by shortcomings in digitization or problems with systems like Cosmic?
Digitalization improves drastically this issue. For example, self-service terminals helped a lot, and now employees can start working with more important stuff than serving patients at the Cashiers.

9. Why is it difficult for health professionals to use all functionalities of Cosmic?
The system is very complex, and even though there is a training available, it is hard to have complete oversight of all of the different subsystems that are a part of Cosmic. This is partially a problem with the user interface and partially a problem with the sheer complexity of the system itself. It is also a problem that some of the users have a negative perception of the system already and are unwilling to learn. There is some training in place in the form of courses, both general and about specific parts of Cosmic.

10. What do people think about Cosmic? Are there any complaints?
At first, people get horrified because of the complexity, but in the long run, they become quite satisfied. There are complaints that Cosmic can be very slow, sometimes taking several minutes to open a patient journal.

11. How could staff get better exercise at Cosmic?
There is an E-Learning tutorial through videos. Employees need a general course for Cosmic. There are also specific courses that are available about specific Cosmic features.

12. Would it be a good solution to break down all different processes into individual software?
• Smaller modules
• Easier for use
No, because Cosmic covers very complex processes and is really difficult and time-consuming to move to another platform. That would also require a lot of additional resources and time to train staff. The entire workflow is heavily dependent on Cosmic. Despite the flows, Cosmic works. Moreover, there are binding contracts between the hospital and Cambio.

13. Is Cosmic’s database available for use by other software? / Can you develop a new solution based on Cosmic’s database?
It is possible to develop Apps with the help of Cosmic.
Interview 2: Informal discussion-interview with the lead pharmacist at Uppsala hospital

Discussion interesting points:

- Cosmic helps reviewing overview of medicine
- Cosmic does not prevent prescription
- Nurses participate actively in prescription. Therefore, they should get a warning after an issue in prescription
- Läkemedelsverket (Swedish pharmaceutical agency) is responsible for generic medicine (medicine with the same substance)
- Traceability in prescriptions is desirable
- Vending machine signals (in closed-loop-meditation) must be sent through Cosmic
- Prescription desired features: Substance name, product name, strength, dosage (Alvedon, paracetamol, 500 mg, 2X4 for 10 days)
- Recommended doses are not included in Cosmic
- Need for risk and toxic drugs prevention

Interview 3: The main interview, semi-structured and more formally formatted with two clinical pharmacists

1. What is a pharmacist’s workflow in a medical ward?

Pharmacists work in close collaboration with the doctors. They feel a gap between the patient and the doctor and they check the whole picture of a patient.

a) They are responsible for:
   - Back Pain patients’ surgeries
   - Implant operations
b) They compare what prescription patients take at home with COSMIC.
   - If a prescription is updated
   - if the doses are correct
   - if pre-surgery drugs are correct
c) Meet patient before an arranged surgery. They ask about medication they take.
d) They try to fix errors in orders or update them.
   They can:
   - Change orders,
   - Move the time for the dose
   - Spread out antibiotics
   - Remove medication that the patient stopped taking
e. They prepare a prescription for the doctor to sign (If the doctor does not have time)
f. They are responsible to update patients that leave the hospital for prescription changes
What they usually check in COSMIC for each patient

- Lab work diagnosis
- Kidney function
- Check if the doses are okay
- Pulse
- Blood pressure
- Saturation.

1. Does cosmic allow real time monitoring of those indications?

NO:
- For parameter like blood pressures, the doctor decides when to take measurement. Not in real time. It is up to what the doctor orders. (Usually morning and evening)

YES:
- Check for interactions
- Patient’s general overview.

Many patients live in nursery homes. The take medication through a system called pascal.

Who prescribes the medicine?
- The doctors are responsible for prescriptions. In Sweden pharmacists are not allowed to prescribe medicine.

Does the verification apply to all of patients?
- No, many patients arrive and many leave at the same day. There is no time to look everyone. They check at the patient’s charts.
- Interaction database in theory exists but there are different needs for different wards and different patients

What Cosmic warnings include?

Interactions between:
- Drugs recommended to take for young women with pregnancy (breastfeeding)
- Duplicate orders
- Many doctors do not read the warnings Cosmic displays all kinds of warnings.
  - some of them are not clinically relevant
  - others are very important
- Doctors do not always read all the warnings. They simply click the boxes and skip them. Because:
  - An overload of warnings is being displayed to them
  - It is hard to process them and distinguish what is important and what is not

important information is lost because of that. Doctors just want to get away with all the warnings

What improvements do you suggest?
- Include check for kidney function, blood pressure. They know orthopedic patients but don’t know about problems that concern other health problem. Therefore, it is hard to make a quick verification.
- Nurses take an assessment of the patients. The control also lies there (verification)
- Doctor at the specific ward responsible for what the patients are given today.
- A safe automatic system would reduce medication at the ward. That would save time for the personnel and the patients
  **BUT:**
  - It is a challenge to make an efficient validation system
  - Who has the responsibility for the verification (Unclear)

Do you think that an automated system would be able to guarantee for all the prescriptions?
  - They think that it would impossible a system to check against all the parameters. They are not much time to think what to give.

How often the verification should be applied
  - Hard to say, maybe every time an order goes to the machine

Would you like the system to be customizable?
  - Many users don’t care about all kind of info. It should be customized.

Are you satisfied with Cosmic?
  - It helps with duplication warnings.
  - But:
    - sends too much warnings.
  
Verification should take place in Cosmic

Would a decision support system would help?
  - Maybe

Does Cosmic have a good interface?
  - NO:
    - Not instructive
    - Complex
    - A lot of clicks
    - Takes 4 minutes to log on

What parameters to import from COSMIC?
  - Electrolytes
  - Potassium level
  - Others mentioned above
  - Age
  - Drugs not recommended

Would you have time to add rules on the system?
  - Yes, they would like to monitor a specific parameter individually providing data is imported from cosmic.
  - **But:**
● It is a doctor’s responsibility. A pharmacist cannot interact with a warning. They do not know about all parameters; they don’t have the full picture. They need to be in close interaction with the doctors.
● The doctors should create the warnings.
● Law in Sweden at pharmacies regulates the pharmaceutical control. However, in the hospital the situation is different. It is important to be cleared out who is going to have the legal responsibility to verify.

Would you fully trust a system?
● They would never blindly trust an automated system
● The want to have the full overview
● In Sweden pharmacists don’t have clinical experience

What would make your work easier?
● Painkillers scale option
   ● Patients need to record their pain from 1 – 10 every hour. But nurses don’t do that.
● A touch screen for each patient which shows overview
● They don’t have a recent date for each measurement
   ● Some measurements are old
   ● Check if the measure is old or new. Date of each measurement is important
● Check if the record of the measurement is correct

Limitations
● It is impossible to create a good review of a patient even with a good overview interface
● Users search what they want to look anyway since there are too many patient cases
● It is very hard to replace the decision process
● Doctors and nurses miss info or make mistakes when recording patient’s data.
● We need computers to do our job because we don’t do our job right. But technology doesn’t help with missing data.

Thoughts about a notification app
● Pharmacists create warning notifications
● Messaging option to the doctor would help.
BUT:
● The doctor is not going to be happy. Doctors are usually busy and it would be annoying for them

At a pharmacy:
● They check a dose by searching documentation of the medicine.
● They don’t know anything about the patient.

Appendix 3: VerifyPro Code
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8">
<meta name="viewport" content="width=device-width, initial-scale=1">
<link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/4.7.0/css/font-awesome.min.css" type="text/css">
<link rel="stylesheet" href="https://static.pingendo.com/bootstrap/bootstrap-4.1.3.css">
<link rel="stylesheet" href="https://maxcdn.bootstrapcdn.com/bootstrap/4.1.3/css/bootstrap.min.css">
<script src="https://ajax.googleapis.com/ajax/libs/jquery/3.3.1/jquery.min.js"></script>
<style>
.row {
  display: flex;
}
.row > div {
  flex: 2;
  background: lightgrey;
  border: 1px solid grey;
}
.scrollNotification {
  overflow-x:scroll;
  overflow-y: hidden;
}
.mist{
  background-color: #90AFC5;
}
.stone{
  background-color: #336B87;
}
.shadow{
  background-color: #2A3132;
}
.autumn{
  background-color: #763626;
}
.prescription{
  overflow-y:scroll;
}
.infoGrey{
background-color: #dcdcdc;
}

table tr td {
  padding: 20px;
  background: transparent !important;
}

#warning {
  class: bg-danger;
}

</style>
<script>
  $(function () {
    $('[data-toggle="popover"]').popover()
  })
</script>
</head>

<body>
<div class="py-5 p-3" style=""
  <div class="container"
    <div class="row"
      <div class="col ">
        <nav class="navbar navbar-expand-md navbar-dark stone "
          <button class="navbar-toggler navbar-toggler-right border-0" type="button" data-toggle="collapse" data-target="#navbar18"
            <span class="navbar-toggler-icon"></span>
          
          <div class="collapse navbar-collapse collapse navbar-collapse" id="navbar18">
            <a class="navbar-brand d-none d-md-block" href="#"
              <i class="fa d-inline fa-lg fa-circle"></i>
            
            </a>
          <a class="nav-link" href="#">Help</a>
          <a class="nav-link" href="#">About</a>
        </ul>
      </div>
    </div>
  </div>
</div>

53
Oscar Jacobson

Personnummer: 199301012xxxx

Age: 33

Pain Scale: 6/10

Show patient's page on COSMIC

Import Parameters

New Warning

New Notification

New Notifications

Warnings

Important Warnings

Show:

All

Danger
Warning

Notifications

Advanced Filters:

<form class="form-inline md-form mr-auto mb-4">
  <input class="form-control mr-sm-2" type="text" placeholder="Minimum Severity" aria-label="Search">
  <button class="btn btn-outline-info btn-rounded btn-sm my-0" type="submit">Show</button>
</form>

<div class="row scrollNotification">
  <div class="col-md-4">
    <div id="trial" class="card text-white bg-primary mb-3">
      <div class="card-header bg-danger contenteditable="true">Automatic Warning</div>
      <div class="card-body bg-danger h-25">
        <h5 class="card-title contenteditable="true">High Level of Dose</h5>
        <p class="card-text">Generated by @auto_rules. Severity Level: 8/10
High level of paracetamol prescribed. Maximum recommended level < 2200 mg<br> Date created: 12/10/18"</p>
        <button type="button" class="btn btn-success">Mark as Read</button>
      </div>
    </div>
  </div>
  <div class="col-md-4">
    <div class="card text-white bg-secondary mb-3">
      <div class="card-header bg-warning">Automatic Warning</div>
      <div class="card-body bg-warning h-25">
        <h5 class="card-title">Lab Data Too Old</h5>
        <p class="card-text">Generated by @auto_rules Severity level: 4/10
Lab Data: Potassium<br> Date created: 12/10/15"</p>
      </div>
    </div>
  </div>
</div>
<button type="button" class="btn btn-success">Mark as Read</button>

<div class="col-md-4">
  <div class="card text-white bg-primary mb-3">
    <div class="card-header">Notification</div>
    <div class="card-body h-25">
      <h5 class="card-title">Message from Doctor</h5>
      <p class="card-text">
        Generated by @Albert J. Concerns: @J13.9 @Pneumonia Take blood pressure test three times per day Date created: 12/10/18
      </p>
      <button type="button" class="btn btn-success">Mark as Read</button>
    </div>
  </div>
</div>

<div class="row">
  <div class="col-md-12 w-75 h-50">
    <h4 class="text-center mist">Prescription List</h4>
    <ul class="nav pi-draggable">
      <li class="nav-item active">
        <a href="#" class="nav-link active" contenteditable="true">Maximise</a>
      </li>
      <li class="nav-item">
        <a href="#" class="nav-link active" contenteditable="true">Lock</a>
      </li>
      <li class="nav-item">
        <a href="#" class="nav-link active" contenteditable="true">Restore</a>
      </li>
      <li class="nav-item dropdown">
        <a class="nav-link dropdown-toggle" data-toggle="dropdown" href="#" role="button" aria-haspopup="true" aria-expanded="false">Filter</a>
        <div class="dropdown-menu">
          <a href="#" class="dropdown-item">All Prescriptions</a>
          <a href="#" class="dropdown-item">Prescriptions With Warnings</a>
        </div>
      </li>
    </ul>
  </div>
</div>
<a class="dropdown-item" href="#" >Out-of-Date Prescriptions</a>  
<a class="dropdown-item" href="#">+ Create Filter</a>

<form class="form-inline mr-auto">
  <input class="form-control mr-sm-2" type="text" placeholder="Search" aria-label="Search">
  <button class="btn btn-outline-success btn-rounded btn-sm my-0" type="submit">Search</button>
</form>

<div class="row pi-draggable" draggable="true">
  <div class="col-md-12">
    <a class="btn shadow rounded p-1 mr-2 btn-success" href="#" contenteditable="true">Verify</a>
    <a class="btn shadow rounded btn-secondary" href="#" >Edit Rules</a>
  </div>
</div>

<table class="table table-bordered table-responsive prescription infoGrey" style="">
  <thead class="thead-dark">
    <tr>
      <th>ATC</th>
      <th>Substance Name</th>
      <th contenteditable="true">Product Name</th>
      <th>Strength</th>
      <th>Dosage</th>
      <th style="">Risk Severity</th>
      <th>Date</th>
      <th>Actions</th>
      <th>Info</th>
    </tr>
  </thead>
  <tbody>
    <tr>
      <td><a href="https://lakemedelsverket.se/LMFLakemedelsinformation/?nplid=20120627000017&type=product">N02BE01</a></td>
      <td><a href="https://www.internetmedicin.se/page.aspx?id=938">Paracetamol</a></td>
    </tr>
  </tbody>
</table>
| Alvedon | 2500 mg | 2x4/Day | 8 | 30/11/18 |

**Important Warning**: Request Change

**Warning**: Comment

**Notification**: Mark as read

---

@Albert J.
<div class="example-popover").popover({
  container: 'body'
});
}
})
$('#link').click(function (evt){
  $("#pneumoniaPre").focus();
  evt.preventDefault();
});
</script>
<button type="button" class="btn btn-secondary" data-html="true" data-container="body" data-toggle="popover" data-placement="bottom" data-content="Prescribed by <a href=''>@Albert J</a>. <br> <a href=''>Show Diagnosis </a> <br> Date created: 12/10/18" data-toggle="popover" data-placement="bottom" data-content="Prescribed by @Albert J. <br> <a href=''>Show Diagnosis </a> <br> Date created: 12/10/18">
  Info
</button>
</td>
</tr>
<tr>
 <th><a href="https://lakemedelsverket.se/LMFLakemedelsinformation/?nplid=20120627000017&type=product">A07EA06</a></th>
 <td><a href="https://www.internetmedicin.se/page.aspx?id=938">Budesonid</a></td>
 <td>Budesonid Orifarm</td>
 <td>300 mg</td>
 <td>1x1/Day</td>
 <td contenteditable="true">1</td>
 <td>30/11/18</td>
 <td class="warning">
   <div class="btn-toolbar mb-3" role="toolbar" aria-label="Toolbar with button groups">
     <div class="btn-group mr-2" role="group" aria-label="First group">
       <button type="button" class="btn btn-primary">Request Change</button>
       <button type="button" class="btn btn-info">Comment</button>
     </div>
   </div>
 </td>
</tr>
Mark as read

Create

@Albert J.

<script>
$(function () {
  $('.example-popover').popover({
    container: 'body'
  })
})
</script>
Prescribed by @Albert J. Show Diagnosis Date created: 12/10/18
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Actions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Actions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Actions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>75 kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Toolbar with button groups**

- **Request Recalculation**
- **Comment**
- **Remove**

**Created by @Albert J.**

**Date added:** 21/12/18
<table>
<thead>
<tr>
<th>Height</th>
<th>1.85 m</th>
</tr>
</thead>
</table>

Allergies:
- Lactose
- Gluten

65
Age: 33
<button type="button" class="btn btn-secondary" data-container="body" data-toggle="popover" data-placement="right" data-content="Created by @Albert J. Date added: 21/12/18" data-container="body" data-toggle="popover" data-placement="right" data-content="Created by @Albert J. Date added: 21/12/18">Info</button>

</td>
</tr>
<tr>
<th scope="row">Pregnant</th>
<td>No</td>
<td>
<div class="btn-toolbar mb-3" role="toolbar" aria-label="Toolbar with button groups">
<div class="btn-group mr-2" role="group" aria-label="First group">
<button type="button" class="btn btn-info">Edit</button>
</div>
</div>
</td>
</tr>
</tbody>
</table>
</div>

<div id="pLab" class="tab-pane fade">
$(function () {
  $('\'.example-popover').popover({
    container: 'body'
  })
})
</div>
<button type="button" class="btn btn-secondary" data-container="body" data-toggle="popover" data-placement="right" data-content="Created by @Albert J. Date added: 21/12/18">Info</button>
</td>
</tr>
</tbody>
</table>
</div>
<div id="pLab" class="tab-pane fade">
</div>
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Actions</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>1400 mg</td>
<td>![Request Recalculation](button type=&quot;button&quot; class=&quot;btn btn-primary&quot;)</td>
<td>![Comment](button type=&quot;button&quot; class=&quot;btn btn-success&quot;)</td>
</tr>
</tbody>
</table>

```javascript
$(function () {
    $('.example-popover').popover({
        container: 'body'
    })
})
```
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Value</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>2200 mg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Auto-generated warning: High level of sodium. Maximum recommended level < 2200 mg. Date created: 12/10/18
| Magnesium | 380 mg |

**Generated warning:** Calculation is too old

Date created: 12/10/15
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Actions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Pressure</td>
<td>83</td>
<td>&lt;button type=&quot;button&quot; class=&quot;btn btn-primary&quot;&gt;Request Recalculation&lt;/button&gt;</td>
<td>&lt;button type=&quot;button&quot; class=&quot;btn btn-secondary&quot;&gt;Comment&lt;/button&gt;</td>
</tr>
</tbody>
</table>

```javascript
$(function () {
  $('.example-popover').popover({
    container: 'body'
  })
})
```

Date added: 21/12/18
<h4 class="text-center text-muted mist" id="diagnosis">Diagnosis List</h4>
<form class="form-inline">
<div class="input-group w-50" id="inlineFormInputGroup" placeholder="Search">
    <input type="text" class="form-control" name="search" value="%">
    <div class="input-group-append"><button class="btn btn-primary" type="button"><i class="fa fa-search"></i></button></div>
</form>
<table class="table table-striped table-dark">
    <thead>
        <tr>
            <th scope="col">ICD Code</th>
            <th scope="col">Name</th>
            <th scope="col">Reason</th>
            <th scope="col">Info</th>
        </tr>
    </thead>
    <tbody>
        <tr>
            <td>Pneumonia</td>
            <td></td>
            <td></td>
        </tr>
    </tbody>
</table>
"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua"

</p>
</td>
<td>
<script>
$(function () {
  $('.example-popover').popover({
    container: 'body'
  })
});
</script>
<button type="button" class="btn btn-secondary" data-toggle="popover" data-placement="bottom" data-content="<div>Prescribed by
<a href=''>@Albert J</a>. Show Prescription</div>" data-container="body" data-html="true" data-toggle="popover" data-placement="bottom" data-content="Show Prescription" data-container="body" data-html="true">
  Info
</button>
</td>
</tr>
<tr scope="row">
  <th scope="row"><a href=''>J45.9</a></th>
  <td>Asthma</td>
  <td>
    <div class="btn-toolbar mb-3" role="toolbar" aria-label="Toolbar with button groups">
      <div class="btn-group mr-2" role="group" aria-label="First group">
        <button type="button" class="btn btn-info">Show</button>
      </div>
    </div>
  </td>
</tr>

</table>

<script>
$(function () {
  $('.example-popover').popover({
    container: 'body'
  })
});
</script>
Bibliography


Clifford, N., Cope, M., Gillespie, T., French, S., 2016. Key Methods in Geography. SAGE.


Westermark, A. (09 2018). Discussion with my project supervisor. (I. Kakalelis, Interviewer)


