Medicine tray design and security for medication administration processes at hospital wards

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Abstract
Hospital ward nurses' everyday tasks, such as filling trays and dispensation of medicines to the patients, are stressful and meticulous. Errors at various steps of filling and dispensing medicines could lead to life-critical threats. These errors need to be identified and analysed so that they can be reduced and prevented to create a safer hospital ward. We propose a medication tracking application named *Smart Dosing*, and a tray design to support the tablet device running the application. The application is intended to integrate different information systems into a single application, as well as assist in medicine tray management. Keeping the sensitivity and criticality of information being carried by the tablet application in mind, a list of impending security threats was provided.

Author Keywords
e-health; Medicine tracking; Design; Healthcare; Security; Management; Medication error; Hospital.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g.,HCI)]: Miscellaneous; H.1.2 [User/Machine Systems]: Human factors; D.4.6 [Security and Protection]: Information flow controls; D.2.9 [Management]: Productivity

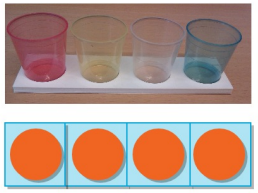

Figure 1: Horizontal cup holders developed with a 3D printing machine.

The need for smart medication tracking

According to Yle [6], hospital medical errors claim 700 to 1700 lives in Finland every year. Medication errors such as overdosing, under-dosing and giving wrong medicine, are the most common errors in hospitals .

Pilot studies by Díaz Rodríguez *et al.* [3] and Pirinen *et al.* [5] on problems faced by nurses in their daily activities suggest that a step-by-step tablet application can improve the medication management and increase the safety of patients at hospitals. A prototype of such an application was developed later by Khan *et al.* [4]. An analysis of the prototype from the security and usability perspectives led us to redesign both the application and the medicine tray. The design took into account the most common errors that were identified at various stages of filling the tray and dispensation of medicines [5]. The errors and how an IT application can overcome those errors are mentioned in Table 1.

Designing a medication management system

The smart medication management system includes a medicine tray, a tablet device running the application that is placed in the center of the tray, and cup holders surrounding the tablet as shown in Figure 2. The cup holders are a new feature in this design which overcomes the dysfunctions of the cups like spilling medicines when overfilled, and allows a controlled and sequential work flow. One cup holder carries medicines for a single patient. The colour of the cup represents the medication timing. For example, a red cup is for morning medicines, a yellow cup for afternoon medicines *etc.*, as illustrated in Figure 1.

The application has been designed to follow an order of actions similar to the existing process, so that the work flow feels familiar to the nurses when they are shifting to the new system. The application uses iconic elements for a better overview of the list of patients. These iconic elements carry the patients' location details to help the nurse navigate through the ward patient by patient as shown in Figure 2. On selecting a patient, the nurse views the list of medicines to be filled or dispensed to the patient. Images of the medicines, their packaging and notifications for controlled medicines are provided for the nurses to verify the right dosage of the right medicine to the right patient at the right time, as shown in Figure 3. The application also provides an option for searching equivalent medicines with the help of Pharmaca Fennica (electronic medication hand book with information about all medications) [1] and placing orders for out-of-stock medicines to make the work more synchronized and time-efficient. The ongoing work on designing the prototype and the source code is available online[1].

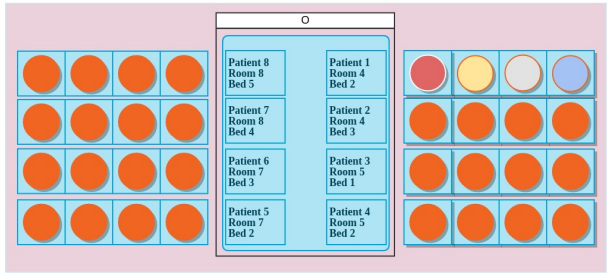

Figure 2: Tray design with the tablet device placed in the centre. The tablet view shows the list of patients. Cup holders with cups are on both sides of the tray.

Security requirements for Smart Dosing application and tray design

Both the medicine tray and the tablet application play a key role in tracking medicine administration and prevent-

[1] Smart Dosing: https://github.com/NataliaDiaz/SmartDosing

Common errors while filling and dispensing medicines	
Reasons/context	**Solutions**
The medicine names in the printed medicine charts are written according to trade names and not pharmacological names	Integration with Pharmaca Fennica [1] systems for having both options
Information on medicine charts is illegible and it is difficult to track the progress because of the limited space available in the tray slot	Electronic extensible charts
In the absence of the prescribed medicines, searching for equivalent medicines is time-consuming and sometimes confusing due to the large number of available substitutes	In-application query system integration with Pharmaca Fennica [1] system
Disconnection between the medicine software and the printed medicine chart	Ubiquitous and real-time information update via a tablet application
Difficulty in identifying and verifying the medicines while filling the tray	Integration with Pharmaca Fennica system enabling pill and package pictorial information
Dealing with unfamiliar medicines (new drugs, seldom used drugs, new packages *etc.*)	Integration with Pharmaca Fennica system enabling pictorial information
Difficulty in keeping up with patients' changing treatment and patients' location	Ubiquitous and real-time information update via a tablet application, enabling better communication
Improper or no reminders for limited-access medicines	Notification for controlled drugs

Table 1: Common errors while filling & dispensing medicines [5]

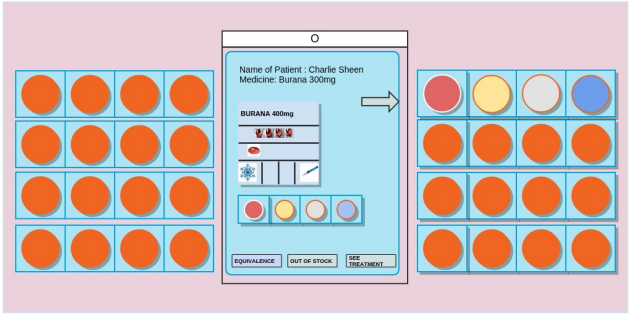

Figure 3: Patient details view with an image of the medicine prescribed and notifications for refrigerated or controlled drugs.

ing medication errors. In order to design such a life-critical system, it is necessary to do a security analysis of both the tray design and the software application.

While developing the tablet software application, there is a requirement for the authentication, verification and identification of the nurses. Since Smart Dosing is intended to integrate different information systems, it is also required that the application verifies the identity of the services it uses. Identification and verification of patients is equally important in order to ensure right medication to right patient. It is suggested that the application uses QR-code reader to read from the patient's wrist strap to identify them.

The patient medical data being the most critical asset in this application, there is a need for data integrity protection while at rest or in transit. The application must encrypt patient data with a strong encryption algorithm to prevent easy access to patient data. This adds to the requirement of choosing a device with sufficient processing power.

Smart Dosing uses touchscreen icons as data communication interface, thus potentially increasing integrity vulnerability of the system [2]. It is also required to log security incidents and access to information on the application so that errors or mistakes made, if any, can be tracked back to. The log of the generated data must be securely stored locally or transferred securely to the server.

The application must avoid interaction with unsafe applications if present in the same device or in the same network. It is recommended that the application installs VPN to provide direct and encrypted tunneling of data among the application and its server while minimising traffic.

Information sharing between the Smart Dosing application and untrusted applications on the same tablet device is capable of disclosing sensitive information. This raises a need for monitoring inter-process channels and applying safeguards to prevent such disclosures.

In terms of tray design, wrong orientation of the tablet device could cause a risk of misalignment between the cup holders and the iconic elements. This would result in giving wrong medicines to wrong patients. It is therefore recommended that the tablet should be allowed to fit onto the tray only in a specific direction. Once a tablet device is detached from the tray, there is the risk of not knowing which tray it belongs to. Along with a password for the application, a near field communication tag on the tray along with the nurse's personal tag would overcome this problem. The use of handheld devices in a busy environment like a hospital and the recurring use of the application can easily drain the battery of the tablet device. The application should be able to restore its interrupted state when the tablet is put in sleep mode to conserve power utilisation. This action would help with *Denial of Service*.

Future work includes prioritising security requirements and implementing them in the *Smart Dosing* application in the next iterations of the software development.

Acknowledgements

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