Masters Thesis

Improving a Medication Error Alert System

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November 2009

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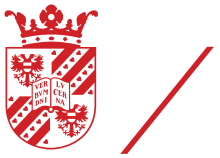

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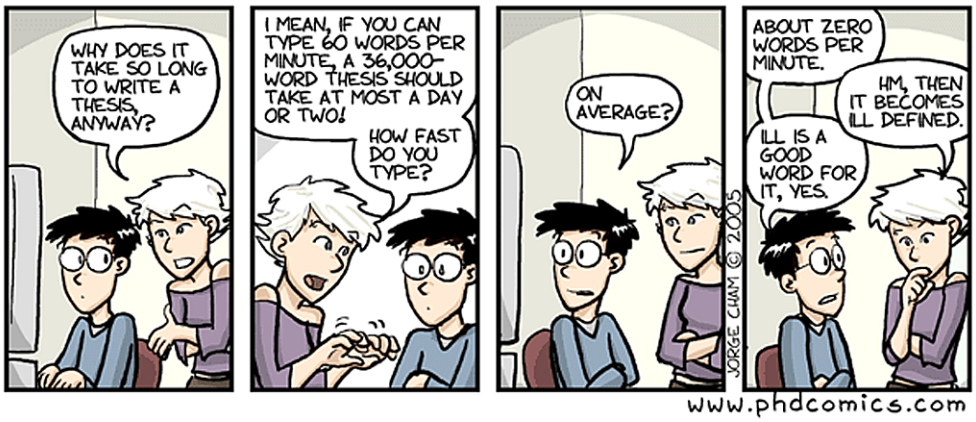
Abstract

Medication prescription errors and medication-related problems can cause an array of problems ranging from an increased work-load and cost in correcting errors to potential harm to patients. These adverse effects can be prevented by using a computerised physician order entry system combined with a prescription monitoring system as is currently done by the Department of Clinical Pharmacy in the University Medical Centre Groningen (UMCG). The purpose of a prescription monitoring system is to detect possible medication errors and generate alerts.

The current system in the UMCG does not perform as well and efficient as it possibly could. In an attempt to improve the alerts for medication errors and related problems the UMCG is now seeking to adopt a new system. This system will combine information from different systems (for e.g. patient data, lab results and prescriptions) in an attempt to provide only clinically relevant alerts.

A novel user interface prototype was developed to best suit the needs of the users of the new system. This user interface is based on current system use, user questionnaires and an expert analysis. The user interface underwent several iterations and was evaluated by future users. Users that participated in the final user-test were all positive about the interface and were also able to perform several tasks well. An interaction specification has been drafted based on the final prototype and the interface is currently being developed and will be deployed in the UMCG.



"Piled Higher and Deeper" by Jorge Cham

Acknowledgements

I would like to thank Fokie Cnossen for months of encouragement and valuable advice. Without the occasional smiley and motivational “sound-bites” this thesis might not have existed at all.

I would also like to thank Prashant Panday for providing invaluable information and support during this project. Furthermore I would also like to thank the Department of Clinical Pharmacy of the University Medical Centre Groningen and the pharmacists that were kind enough to donate their time this project.

Many thanks to my friends and Pieter who managed to keep me sane during this process. Thanks for your advice, listening, and simply being there.

Lastly I want to thank my family for always supporting me.

Contents

Chapter 1

Introduction

A physician prescribes a medication for a patient in a hospital, he scribbles the prescription on a prescription pad and drops it off at the nurses station. The prescription is brought to the hospital pharmacy where a pharmacist starts preparing the medication. The pharmacist is unsure about the medication name and contacts the prescriber. The prescriber informs the pharmacist about the correct medication name and the pharmacist continues to prepare the medication. The medication is delivered to the ward and a nurse administers the medication. After the medication is administered the patient gets a rash and becomes short of breath.

The patient had a known allergy to the prescribed medication.

Medication errors can occur in many stages during a patient's stay in a hospital. Errors can be made during prescription, preparation and administration. Medication errors cause problems ranging from increased work-load and cost to potential harm to patients.

It is thought that by using technology many of these errors can be prevented. A solution is the use of computerised physician order entry systems (CPOEs) where prescribers enter prescriptions using a computer. The prescriptions that are entered by computer can later also be checked for errors using clinical decision support system (CDSS). These aids provide additional safeguards in attempting to prevent errors occurring.

The University Medical Centre Groningen (UMCG) is currently using a CPOE combined with a CDSS. As technology is becoming more advanced the Department of Clinical Pharmacy is seeking to improve their medication safety systems: a new CDSS is being implemented. The new system will be able to combine information from several sources (patient data, lab results, and prescriptions) to provide medication error alerts. The expectation is that this will lead to alerts which are clinically relevant, and that the system should be able to find potential errors the old system could not.

First the interaction between system and user was analysed. This allows for better understanding of the users, which leads to better usability. Results were used to develop a prototype interface between the CDSS and the pharmacists. The new interface was based on the user's wishes as well as an expert analysis. This thesis describes the development of this prototype interface.

1.1 Structure of the Thesis

The thesis is divided into three main parts: the theoretical background, the current situation and the prototype. A short summary of the thesis is provided in Chapter 5.

The theoretical background describes errors in general, and medication errors specifically. Furthermore the effect of computerised aides on reducing errors is discussed.

Following the theoretical background the current situation in the UMCG is described in Chapter 3. This includes a description of the setting and the computerised aides currently in use to prevent medication errors. The future plans of the UMCG to improve medication error prevention are also described.

An analysis of the current situation was performed and is described in Section 3.5. This analysis includes both observation and description of the current system and an analysis of the performance of the system. The observation and description allows us to better understand the task and issues with the current system. The performance analysis is useful to determine whether the new system is indeed an improvement to the old system. The section concludes with a list of issues with the current system to consider during the development of the new user interface. Following the analysis, interviews were carried out with pharmacists. The interviews are used to determine further issues with the system as well as to gather ideas for the new interface.

A prototype was developed using the information gathered during the analysis of the current situation. A general description of this prototype, how it was built, and motivation behind design choices and can be found at the beginning of Chapter 4. After development the prototype was tested with users. This is a vital step to ensure that the interpretation of user wishes and desires gathered during the analysis and interview phase are correct. Section 4.4 describes how the prototype was tested using pharmacists and the results from this test.

Finally Chapter 5 summarises the entire process.

Chapter 2

Theoretical Background

> Mistakes are a fact of life. It is the response to the error that counts.
>
> Nikki Giovanni

The majority of errors in healthcare do not lead to injury as there are many safeguards to prevent errors from affecting the patient. Injuries as a result of errors are almost always a case of a series of people and systems failing. The example in the introduction shows that both the prescriber and the nurse neglected to check the patients chart for possible allergies. If either of them had checked the chart, the patient would not have been prescribed or administered this medication and adverse effects would have been prevented. Reason (2000) describes this concept in his model of accident causation called the "Swiss Cheese" model (see Figure 2.1). The model describes how different layers of safeguards are often in place to protect the patient from errors. But as no safety measure can be a hundred percent effective, it is possible that an "accident trajectory" occurs where all safety layers fail simultaneously and adverse effects for the patient result.

Reason (2000) divides the origins of errors into two categories: active failures and latent conditions.

Active failures are errors where people in direct contact with the patient commit unsafe acts. This includes knowingly deviating from protocol but also slips, lapses, fumbles and mistakes.

Latent conditions are features of the systems or protocols which are built into the system. They can be embedded in computer systems but also in procedures and guidelines. These features can cause error-provoking situations (confusing interface) when the system is used or even cause the system to be undependable (missing alarms).

2.1 Medication Errors and Adverse Drug Effects

An important type of error in health-care is the medication error. As this thesis deals with preventing medication errors it is important to understand what a med-

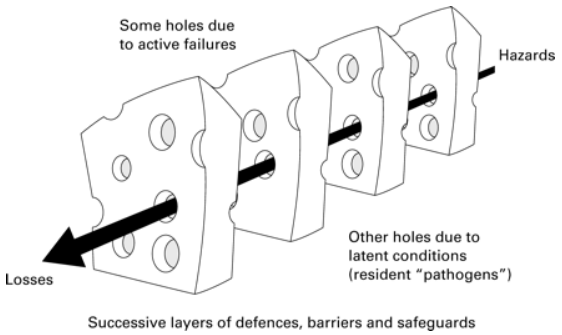


Figure 2.1: Reasons "Swiss Cheese" model of accident causation. Figure taken from Reason et al. (2001). The model describes how different layers of safeguards and protection prevent serious consequences from errors. But as no safety measure is a hundred percent effective, an "accident trajectory" can occur where all layers fail simultaneously and allow adverse effects.

ication error is and what the impact of such errors is. A medication error is defined by Aspden et al. (2006) as:

> "Any error in the medication-use process. Examples include wrong dosage prescribed, wrong dosage administered for a prescribed medication, or failure to give or take a medication."

Medication errors occur regularly in hospitals (Aspden et al., 2006). Determining the exact number of errors however is difficult. When researching numbers of errors both the setting and method of studies can cause results to vary greatly (Gandhi et al., 2000). In Aspden et al. (2006) a summary of several studies is used to give some insight in the prescription error rate in U.S. hospitals; the values obtained from this summary can be seen in Table 2.1. The results vary greatly, this is most likely due to different methods of recording errors (Aspden et al., 2006). The highest values all come from a study by Bates et al. (1995a) (from Aspden et al. (2006)). This study used very comprehensive methods: charts and medication orders were reviewed by an external reviewer; and staff were prompted about errors. The others studies reviewed by Aspden et al. (2006) used less comprehensive methods such as spontaneous reports from pharmacists after review of written errors or reporting by a clinical pharmacist actively involved in providing care (Aspden et al., 2006).

As explained above errors do not always affect patients: hospitals employ different levels of safeguards to prevent this. When a series of errors does combine to form a so-called "accident trajectory" this can lead to an adverse drug event (ADE). An ADE is defined by Aspden et al. (2006) as:

> "Any event where an injury occurs due to the use of medication. Examples include a wrong dosage leading to injury (e.g. rash, confusion, or loss of function) or an allergic reaction occurring in a patient not known to be allergic to a given medication."

Table 2.1: Error rates in hospitals from several studies. Table taken from Aspden et al. (2006).

Prescribing errors	**Per 1000 admissions** 12.3-1400 (5 studies) **Per 1000 orders** 0.61-53 (4 studies) **Per 100 opportunities for error** 1.5-9.9 (4 studies)

ADEs can result in injuries ranging from minor problems such as a rash or diarrhoea to serious problems, and even death (Bates et al., 1999). According to Bates et al. (1995a) (as cited in Bates et al. (1999)) 7% of medication errors cause ADEs.

The relationship between medication errors and ADEs can be seen in Figure 2.2. Not all medication errors lead to ADEs, when a medication error does cause an ADE, this ADE is categorised as preventable. Without the medication error the ADE would not have taken place, this assumes that all medication errors are in fact preventable. The remainder of ADEs cannot be prevented as the cause cannot not be anticipated. An example of this would be a reaction to medication due to a previously unknown medication allergy.

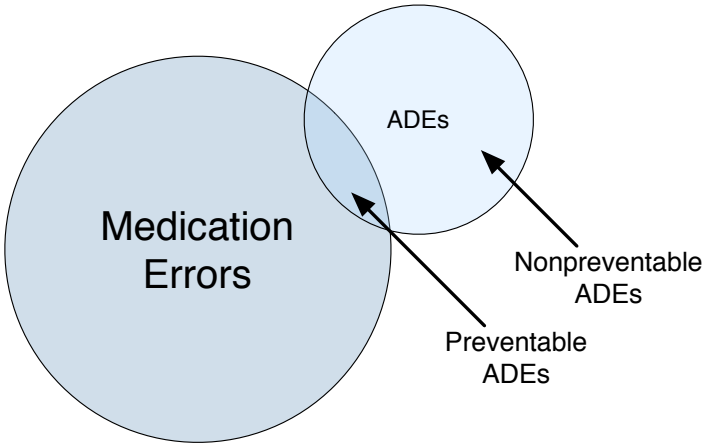


Figure 2.2: An overview of the relationship between medication errors, adverse drug events. Image taken from Gandhi et al. (2000).

There have been efforts to determine the percentages of preventable ADEs occurring in hospitals but similar to the reporting of medication errors results vary greatly. This variance is both due to study design, definitions used and differences between institutions (Aspden et al., 2006). Three major studies which are considered by Aspden et al. (2006) are summarised in Table 2.2. These studies show that 2.4-6.5 ADEs occur per 100 admissions and that between 27 and 50% of these ADEs were preventable.

Table 2.2: Results from three studies concerning preventable ADEs in hospitals. Table taken from Aspden et al. (2006).

Study	Preventable ADE Rate	Proportion of preventable ADEs	ADE Rate
Classen et al. (1997)	1.2 per 100 admissions	Circa 50% (2227)	2.4 per 100 admissions
Bates et al. (1995b)	1.8 per 100 admissions	28% (247)	6.5 per 100 admissions
	3.2 per 1000 patient-days		11.5 per 1000 patient-days
Jha et al. (1998)	5.7 per 1000 patient-days	27% (617)	21 per 1000 patient-days

A possible solution to some types of medication errors is assumed to be the use of computerised physician order entry systems (CPOEs) coupled with clinical decision support system (CDSS). Both systems, how they are used and what the measured effect is on medication errors and ADEs is will be elaborated on in the next sections.

2.2 Computerised Physician Order Entry Systems

With a CPOE prescriptions are entered via a computer instead of using written prescriptions. The initial goal of using CPOEs when they were introduced in the early seventies was to reduce cost. The cost of medications were to be reduced by offering prescribers a limited number of cheap prescription options (Aarts and Koppel, 2009).

It was however soon apparent that a CPOE can have many more advantages. A CPOE prevents legibility problems, prescriptions reach the pharmacy faster, and the system can be used to enforce entry for the required fields of information. Furthermore electronic prescriptions can be integrated with electronic patient records without additional work. Most importantly electronic prescriptions allow for analysis using computerised decision support systems (Koppel et al., 2005). Decision support systems can be used to find and signal possible errors in prescriptions.

The advantages offered by CPOE are valuable as research shows that paper-based prescriptions are associated with high error rates (Aspden et al., 2006; Kaushal and Bates, 2001). As many as 56% of medication errors occur in the prescription phase (Silveira et al., 2007). These errors include omission of doses, incorrect doses, incorrect frequency, and incorrect route of administration. CPOE systems can possibly reduce of prevent these types of errors.

The call to implement CPOE systems to reduce these errors is growing. Currently the implementation of such systems is still limited. Aarts and Koppel (2009) performed a survey of the implementation of CPOE in seven Western countries (United States, Germany, United Kingdom, France, the Netherlands, Switzerland

and Austria) and found that the highest adoption, in the United States and the Netherlands, is limited to 20% of hospitals. While the other countries are striving to implement CPOEs hospital-wide, only a few hospitals have done so.

While CPOE promise to prevent many types of error it is important to evaluate the effect of such a system.

Error Reduction

Silveira et al. (2007) and Bates et al. (1999) have researched the effects of employing a CPOE on the number of prescription errors and have concluded that the number of errors is reduced significantly after implementation of a CPOE.

Silveira et al. (2007) carried out a prospective study of two wards in a hospital. The number of prescription errors before and after the implementation of a CPOE were compared over the period of one month. The number of errors was reduced between 38.8% (for treatment duration errors) and 98.5% (for route of administration errors).

Bates et al. (1999) performed a prospective study over the course of four years. A baseline measurement was taken prior to the introduction of the CPOE and three measurements were taken in the following four years. Each of the measurements periods lasted seven to ten weeks. Between measurement periods the system was constantly being improved. Prescription errors fell 81% between the baseline and final measurement period. The rate of errors was reduced for all main types of errors (dose errors, frequency error, route errors substitution errors and allergies). Interestingly the number of ADEs did increase between the baseline period and period one, in period two and three the values fell below baseline level again. An examination of the errors did not provide evidence the additional errors were caused by the CPOE.

Error Introduction

While the use of CPOE can decrease medication errors there is also evidence that CPOE introduction can cause many new problems. Koppel et al. (2005) performed a quantitative and qualitative analysis of interaction with a CPOE and found 22 types of errors that possibly cause medication errors. As only one CPOE was evaluated it is not possible to claim all CPOEs suffer from these problems, but all CPOE could possibly face these issues.

The issues found can be divided in two groups: information errors, where the system provided incorrect information due to fragmentation of data and poorly integrated systems; and human-machine errors, where the interface of the system was inadequate and introduced problems.

Information Errors Of the 22 error types caused by the use of CPOE seven were information errors (Koppel et al., 2005).

For example prescribers assumed that the default dosage was the minimal effective dose or usual dose. This assumption was incorrect, as the default dose information was actually the smallest available unit in the pharmacy. As many of the prescribers used prescribed the default dose, prescribed dosages were often too low.

Another error this particular CPOE introduced was the delay of allergy information. Warnings regarding drug allergies were only given after the medication order was completed. Prescribers often ignored these warnings. Reasons prescribers ignored the warnings were, according to the prescribers: large number of prescriptions to be made, difficulties changing the medication, false allergy information, and the fact that the information was given after the order was completed.

Human-Machine Interaction Errors The remaining 14 errors found by Koppel et al. (2005) were human-machine interaction related issues.

A major human-machine error was that it was relatively easy to select the wrong patient as the interface was cluttered; information was close together and the fonts used were small. Furthermore, the patient's name was not always visible during the ordering process. 55% of the staff during the study reported difficulty in selecting the patient. Half of these people reported they experienced these problems several times a week.

Similarly the system also made it difficult to select the correct medication when viewing a patients medication information. The medication information was often spread out over many different pages (up to 20). 72% of staff reported that they were often unsure about medications and dosages due to the lack of overview.

2.3 Clinical Decision Support Systems

An important, or perhaps vital, addition to computerised physician order entry systems (CPOEs) is a clinical decision support system (CDSS).

Kawamoto et al. (2005) defines a CDSS as follows:

> "Any system designed to aid directly in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or recommendations that are then presented to clinicians for consideration."

CDSSs are systems can be used in several ways (Coiera, 2003). A common function of CDSSs is to act as prescription decision support system. CDSS that are used as prescription decision support systems can be used to detect a multitude of medication errors, examples are: drug-drug interactions; allergies; overdoses; route of administration errors; and duplicate medication orders. The combination of a CPOE and a prescription monitoring CDSS is thought to be a powerful. Besides the use of CPOEs to monitor prescriptions they are also used for other tasks.

For example CDSS can provide alerts and reminders based on patient data, a CDSS can monitor lab results and issue alerts and reminders when these values are nearing critical values. They are also used to provide diagnostic assistance, based on patient information and test-results a CDSS can aid in diagnosis. After a diagnosis has been made CDSS can also help with therapy critiquing and planning. Furthermore CDSS are used as an aid in information retrieval (e.g. automatic web search bots) and for image recognition and interpretation.

Performance of Clinical Decision Support System

The performance of systems can show what the success factors for CDSSs are. The three papers discussed below show us how effective CDSSs are, which types of CDSSs are most effective and what success factors are.

Kawamoto et al. (2005) reviewed 70 studies with the purpose of identifying features which are critical in CDSS for improving clinical practice. Clinical practise includes all treatments and procedures performed by physicians. Their inclusion criteria for studies were: "any randomised controlled trial evaluating the ability of a CDSS to improve important clinical practice in a real clinical setting; use of the system by clinicians directly involved in patient care; and assessment of improvements in clinical practice through patient outcomes or process measures". The studies included both electronic and non-electronic systems. Two reviewers independently reviewed studies to determine whether significant statistical and clinical improvement resulted from the use of a CDSS. They found that clinical practice improved significantly in 68% of the studies as a result of the use of a CDSS. Using several statistical techniques they found four features which significantly improved clinical practice. First, systems that provide decision support automatically are more effective than systems which need to be purposely consulted by physician. Second, to be effective decision support needs to be available at the place and time of decision making. Third, rather than discourage an action, the system should provide an alternative which can be of immediate use. Finally to be effective a computerised CDSS should be used to generate decision support rather than a non-computerised CDSS. From the 32 reviewed systems which contained all four features 30 (94%) significantly improved clinical practice.

Hunt et al. (1998) reviewed 68 studies to determine "the effects of computer-based CDSS on physician performance and patient outcomes". In order to be included a study had to describe the use of a computer-based CDSS systems in a clinical setting by clinicians, and the the effects of the CDSS had to be assessed. They found physician performance to increase in 66% of cases. Diagnostic decision support systems were least successful in improving physician performance (1 out of 5 studies) while preventative care systems were most successful (14 out of 19 studies). Patient outcomes were evaluated in 14 studies from these studies only six (43%) found benefits for the patient.

Garg et al. (2005) reviewed 100 studies with the purpose of determining the effect of a CDSS and which characteristics predict benefit. They included studies which compared practitioner performance and patient outcomes prior to and after introduction of a CDSS. 97 studies concerned practitioner performance: CDSS improved practitioner performance in 64% of studies. The most successful types of CDSSs in increasing practitioner performance were reminder systems (16 (76%) of 21) and drug dosing systems (19 (66%) of 29). Of the 52 studies that studied patient outcomes only 7 (13%) reported improved patient outcomes. The characteristic which was found most effective in eliciting positive effects from CDSSs was automatic support: systems where the user did not need to initialise the decision support. Perception of the effect of CDSSs on efficiency and cost is generally positive in literature but there is limited evidence available for this (Garg et al., 2005). Garg et al. (2005) concludes that the effect of CDSS on patient health is still unclear.

All three studies found clinical practice and physician performance to improve in 64-66% of studies. CDSSs that were most effective were often preventative care,

Table 2.3: Bates et al. (2003b) ten commandments for effective clinical support systems

1: Speed: The system needs to respond quickly, people are not likely to wait for decision support alerts.
2: Anticipate needs and work in real-time: Information needs to be presented in such a way that no time and effort is lost in finding it. Information should be available as prescriptions are written or action is taken.
3: Fit into workflow: Support and amend the users workflow, do not attempt to change it.
4: Usability matters: It is important that the application is clear and easy to work with. Also the application should be designed to prevent errors.
5: Offer alternatives: Physicians are are unlikely to stop or change their actions if no alternative is offered.
6: Good defaults: If the systems default input values are good they are unlikely to be changed. This can for example be used to steer physicians in a certain direction when prescribing medication.
7: Keep it simple: Guidelines and explanations on screen should not be too lengthy (exceed the visible screen portion) as they are then likely to be ignored.
8: Only ask for information when necessary: by only asking for information when absolutely needed, you prevent physicians becoming reluctant to provide it.
9: Monitor impact and act accordingly: Monitor how your system is being used. When making changes always monitor outcomes and be prepared to adjust.
10: Manage and maintain the system: Constantly review results from the system, often interventions from the system will have unintended results. By reviewing results these can be corrected. A knowledge system is never finished while new knowledge is being found, keep updating the system.

reminder and drug dosing systems.

The two studies that also considered patient outcomes only found a small number of studies which discussed patient outcomes. From these studies the patient outcomes improvement rate was between 13-43%.

The features which were recognised as being most effective for CDSS performance were: automatic support (2x), immediate support, provide alternate action and use a computerised system.

Recommendations

Based on his extensive experience with CDSS (Bates et al., 1999; Bates and Gawande, 2003; Bates et al., 2003a) Bates et al. (2003b) compiled ten "commandments for effective clinical decision support". The commandments by Bates et al. (2003b) can be seen in Table 2.3. The main recommendation from the commandments is that

a CDSS should be swift, simple, and easy to use.

2.3.1 Conclusion

Safety is a high priority in healthcare. Errors can cause serious harm and are cause of increasing costs. As technology advances attempts are being made to reduce errors and effects of errors by using technology.

While there is evidence this technology is improving error rates, literature shows that a computer system is not always the solution. If a system is carelessly designed or introduced it may cause more problems than it solves.

In order to create an effective system it is important to be aware of possible points of failure, the intended user and usability practises. Including the user in the design process may ensure that that system will provide what the users require rather than what the software designer believes is important.

Chapter 3

Current Situation

> Know the user, and you are not the user.
>
> Arnie Lund

We first looked at the University Medical Centre Groningen (UMCG) and the Department of Clinical Pharmacy in general. Then the current medication safety systems running in the hospital, a computerised physician order entry system (CPOE) and a clinical decision support system (CDSS), are discussed. Finally the new system that is going to be introduced in the pharmacy is described.

Following the information about the general setting, the current system and work method is observed and analysed. Additionally the performance of the system was measured.

To conclude the overview of the current situation, users of the current system were interviewed. These interviews provide both insight in the strong and weak points of the system as a basis for the prototype.

3.1 Setting

The UMCG is an university teaching hospital in Groningen, the Netherlands. In addition to patient care the hospital is also extensively involved in research, education, and training. The UMCG is one of the largest hospitals in the Netherlands with 1339 beds, 494 233 consults and 34 411 clinical admissions in 2008 (UMCG, 2009). On average 1000 prescription mutations take place each day. These mutations include both changed and new prescriptions.

The Department of Clinical Pharmacy is involved in research as well as medication preparation and monitoring for the hospital and is staffed by 130 people. Circa 15 people are involved in monitoring the generated alert lists on a day to day basis. This group consists of hospital pharmacists and hospital pharmacy residents.

3.2 Computerised Physician Order Entry System

The UMCG is currently using Medicatie/EVS from iSoft[1] as their CPOE. CPOEs were discussed in detail in Section 2.2. Medicatie/EVS was taken in use in 2003 and is currently being used for approximately 85% of the prescriptions in the UMCG. The prescriptions from the intensive care units, oncology, haematology and neonatology wards are not entered using Medicatie/EVS.

3.3 The Clinical Decision Support System SESOP

Medicatie/EVS has a built-in CDSS which provides basic alerts to the prescriber when prescriptions are entered. The hospital has a second safety barrier: all prescriptions recorded using Medicatie/EVS are also checked by the hospitals CDSS known as SESOP. SESOP was developed by the UMCG and was taken in use in 2003 at the same time Medicatie/EVS was introduced.

SESOP uses the "G-standard" from the Royal Dutch Association for the Advancement of Pharmacy (KNMP[2]) to provide the pharmacists with alerts. The "G-standard" is a collection of safety information concerning "dosing, duplicate orders, drug-drug interactions, allergies and contraindications, pregnancy, renal function, and pharmacogenetics" (van der Sijs, 2009). The "G-standard" is based on outpatient medication use, meaning that dosage information and dangerous interactions are based on what is considered safe for patients at home. Medication interactions and overdoses are interpreted differently in the hospital. Dosages in hospital can be higher and possibly harmful medication combinations can be used since the patient is monitored constantly. These differences between hospital standards and the "G-standard" causes the SESOP system to produce a large number of alerts which are deemed clinically irrelevant by the pharmacists.

Each night SESOP checks all prescriptions that were entered since the previous check. Each morning the pharmacist will receive an overview of the alerts generated for the previous day. Please note that there is a lag time of nine and 33 hours between assessment and resolution of possible medication errors or problems.

SESOP generates alerts only once, during the first run after prescription. The alerts are stored internally for a period of time but are no longer reported. If a problem persists it will not be detected again. Ideally alerts would persist until they are marked as resolved or if they no longer occur due to altered medication prescription. The SESOP system only takes into account interactions and overdoses that are contained in the "G-standard". There is no possibility to check for other possible dangers from (prolonged) medication use.

The three lists that will be reviewed during this thesis are the interaction list, the overdose list, and route of administration list. Each of these lists will be described briefly now; a more specific description can be found in Chapter 3.5.

Interaction List The interaction list shows alerts concerning interactions between two medications. It is possible that the combination of two medications can cause dangerous or unwanted side-effects. There are different types of medication interactions: the effect of either or both of the medications can be nullified or reduced,

[1] http://www.isoft.nl
[2] http://www.knmp.nl/

the effect of the medication can be strengthened, or the effect of one medication can be disturbed by another.

The alerts are generated based on a list of known interactions which is provided as part of the G-standard.

Overdose List The overdose lists consists of alerts where the prescribed dosage exceeds the recommended dosage. The recommended dosages are taken from the G-standard.

Route of Administration List The route of administration list shows prescriptions which have a different route of administration than is defined as standard by the hospital pharmacy. This standard is the most effective and least potentially harmful for that particular medication. An incorrect route of administration can cause problems, for example clogging of arteries when an oral solution is administered intravenously.

3.4 Future Plans

An alternative to the SESOP system is currently being implemented by the UMCG. The Department of Clinical Pharmacy is shortly adopting a sophisticated decision support system named GASTON (de Clercq et al., 2001). Besides using the "G-standard" rules as a basis, GASTON can be expanded with knowledge rules (known as clinical rules) improving the quality of alerts. GASTON also has access to clinical patient information which allows for more complex rules.

The GASTON system is different from the SESOP system in that it runs continuously, giving the pharmacist the opportunity to act quickly. Another difference is the ability of the system to use knowledge rules in combination with patient data to determine if an alert should be given. For example if an alert is dependent on the degree of blood coagulation and this value is within normal range there is no need for the pharmacist to receive an alert. Finally another difference is its persistence; the system keeps monitoring patient medication even after initial prescription, preventing possible adverse events or errors occurring later on.

3.5 Analysis

In order to improve the interface of the medication alert system it is important to analyse the current SESOP system and how it is used. The analysis of SESOP has two goals: gain insight in the task that is being performed and determine what the users experience as positive and negative aspects of the current system.

When considering a new interface it is important to know how a task is currently performed. The interface should not necessarily be built to accommodate the current working method, as this method may be not be ideal, but an analysis of the task can clarify which features the interface should ideally have. The positive and negative characteristics of the old system can guide the design process.

To study the SESOP system we first observed and described the system. Later we also measured the performance of the SESOP system. When introducing a new

system it is important to have a baseline measure, this allows for objective comparison between the old system and the new system. The objective was to compare performance of SESOP to that of the new CPOE Gaston, as the implementation of the CPOE was delayed this comparison could not be made. For now this data is useful as it shows how well the present system operates.

This section will first describe the observation and description of the SESOP system which is followed by the performance measure and it will end with a discussion of the issues and results that will be taken into account during development of the new interface.

3.5.1 Observation and Description

The different types of SESOP alert lists and how they are used is described below. This initial description is based on observing a pharmacist during the task of reviewing the lists. During the observation the pharmacist also provided additional information about the method of using and the make-up of the lists. The results from this were also used to create three scenarios describing the method of reviewing and the circumstances this is done under. The scenarios can be found in Appendix C. The information gathered from the observation was expanded further by studying the actual lists.

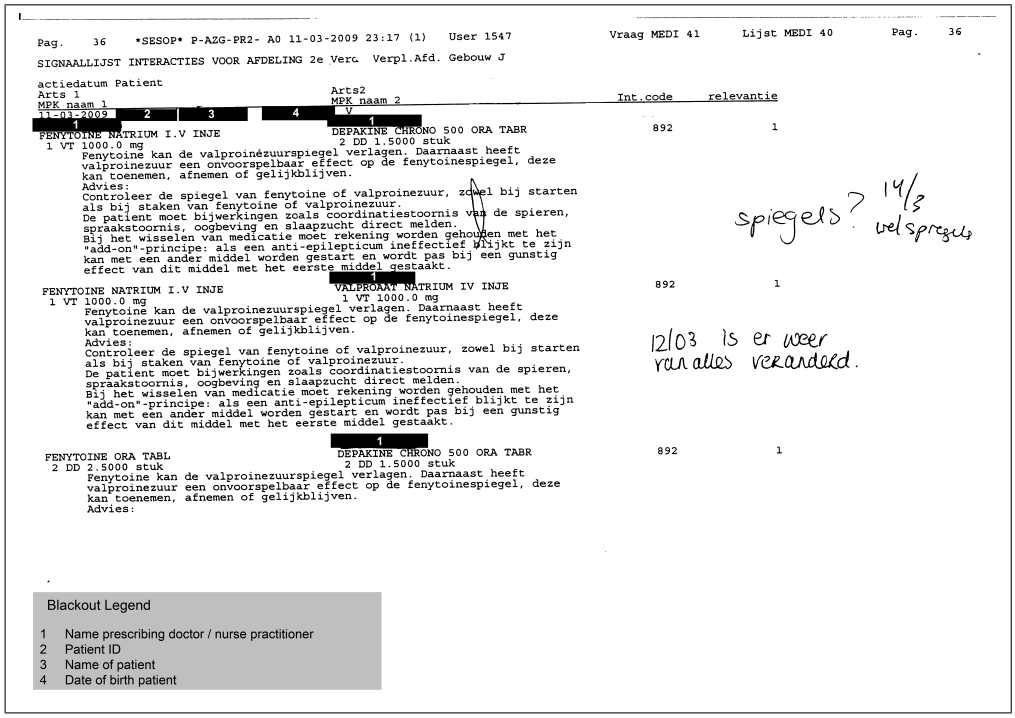
Interaction Alerts

The interactions lists is the list with the greatest amount of paper. There are 89 alerts on average (measured over one week, with $SD = 52$). Each page contains the interactions for one patient with a maximum of three per page. Each alert consists of the following information:

- Name of ward patient is admitted to
- Date the medication was prescribed
- Patient number: A unique 7 digit number. Using this number additional information can be retrieved from the patient information system
- Patient name
- Date of birth patient
- Prescribed medication
- Frequency of administration and dosage for each medication
- Name of prescribing doctor / nurse practitioner
- A description of the interaction that occurs. Following the description there is also an instruction on what should be checked and how/if staff and patients should be informed.
- Interaction code: A code which can be used to find more background information about the interaction in the Royal Dutch Association for the Advancement of Pharmacy (KNMP)[3] databank.

[3] http://www.knmp.nl/

- Relevance: A value that is always equal to one.



Pag. 36 *SESOP* P-AZG-PR2- A0 11-03-2009 23:17 (1) User 1547 Vraag MEDI 41 Lijst MEDI 40 Pag. 36

SIGNAALLIJST INTERACTIES VOOR AFDELING 2e Verc. Verpl.Afd. Gebouw J

actiedatum Patient | Arts2 | Int.code | relevantie
Arts 1 | MPK naam 2
MPK naam 1
11-03-2009 [2] [3] [4] V [1]

[1]
FENYTOINE NATRIUM I.V INJE — DEPAKINE CHRONO 500 ORA TABR — 892 — 1
1 VT 1000.0 mg — 2 DD 1.5000 stuk
Fenytoine kan de valproinézuurspiegel verlagen. Daarnaast heeft valproinezuur een onvoorspelbaar effect op de fenytoinespiegel, deze kan toenemen, afnemen of gelijkblijven.
Advies:
Controleer de spiegel van fenytoine of valproinezuur, zowel bij starten als bij staken van fenytoine of valproinezuur.
De patient moet bijwerkingen zoals coordinatiestoornis van de spieren, spraakstoornis, oogbeving en slaapzucht direct melden.
Bij het wisselen van medicatie moet rekening worden gehouden met het "add-on"-principe: als een anti-epilepticum ineffectief blijkt te zijn kan met een ander middel worden gestart en wordt pas bij een gunstig effect van dit middel met het eerste middel gestaakt.

spiegels? 14/3 wel spiegels

[1]
FENYTOINE NATRIUM I.V INJE — VALPROAAT NATRIUM IV INJE — 892 — 1
1 VT 1000.0 mg — 1 VT 1000.0 mg
Fenytoine kan de valproinezuurspiegel verlagen. Daarnaast heeft valproinezuur een onvoorspelbaar effect op de fenytoinespiegel, deze kan toenemen, afnemen of gelijkblijven.
Advies:
Controleer de spiegel van fenytoine of valproinezuur, zowel bij starten als bij staken van fenytoine of valproinezuur.
De patient moet bijwerkingen zoals coordinatiestoornis van de spieren, spraakstoornis, oogbeving en slaapzucht direct melden.
Bij het wisselen van medicatie moet rekening worden gehouden met het "add-on"-principe: als een anti-epilepticum ineffectief blijkt te zijn kan met een ander middel worden gestart en wordt pas bij een gunstig effect van dit middel met het eerste middel gestaakt.

12/03 is er weer van alles veranderd.

[1]
FENYTOINE ORA TABL — DEPAKINE CHRONO 500 ORA TABR — 892 — 1
2 DD 2.5000 stuk — 2 DD 1.5000 stuk
Fenytoine kan de valproinezuurspiegel verlagen. Daarnaast heeft valproinezuur een onvoorspelbaar effect op de fenytoinespiegel, deze kan toenemen, afnemen of gelijkblijven.
Advies:

Blackout Legend

1 Name prescribing doctor / nurse practitioner
2 Patient ID
3 Name of patient
4 Date of birth patient

Figure 3.1: An interaction alert list. A larger version of this list can be seen in Figure B.2 in Appendix B. This larger image is accompanied by an explanation of the markings.

An example of an interaction alert page can be seen in Figure 3.1. The use of space is generally effective, there is neither too much nor too little on the page. However the explanation and advice contain unnecessary line breaks. The relevance column has no significance (it is always equal to one)

The large number of pages is mainly due to the fact that alerts are fairly lengthy. Another factor in the amount of pages for the interaction alerts is that the system sometimes outputs jumbled alerts which can take up several pages (an example of this can be seen in Figure B.4). This is potentially dangerous as these alerts become difficult to read.

Whether an alert is cause for concern is often dependent on other factors. If a certain combination of medication requires an additional medication to combat the unwanted side-effects, the pharmacists has to manually check whether this medication has been prescribed. Another important factor is the ward the patient is on; if the interaction can cause heart failure and the patient is on the cardiology ward this is of less concern than when this person is on the maternity ward. For certain interactions it is important to monitor certain physiological values (e.g. the rate of blood coagulation), when these values fall outside of the acceptable range action needs to be taken.

Overdose Alerts

The overdose list ranged between 21 and 68 alerts per day over the course of one week.

On each page of the alert list overdose warnings for one patient are described with a maximum of three. Often there is only one alert per page, causing the overdose list contain quite a few pages. Each alert consists of the following information:

- Name of ward patient is admitted to
- Date the medication was prescribed
- Patient number: A unique 7 digit number. Using this number additional information can be retrieved from the patient information system
- Patient name
- Date of birth patient
- Prescribed medication
- Frequency of administration
- Dosage
- Maximum dosage per administration
- Maximum dosage per day
- Name of prescribing doctor / nurse practitioner

An example of an overdose alert list is Figure 3.2. The list is clearly laid out and as both the prescribed and recommended dosages are noted it easy to compare them.

Overdose alerts are generated based on the G-standard from the KNMP [4]. This information is based on dosages for an outpatient setting. The prescriptions in the hospital may differ from these dosage values. This is possible because of the clinical setting where patients are monitored continuously. The task of the pharmacist is to distinguish between alerts which are purposely above the maximum of the G-standard (but still within normal range for the hospital) and actual overdoses. This can partially be determined by looking at the department the patient is in, the doctor who has prescribed the drugs and checking patient medical records. If a dosage is too high, even in the clinical setting, the pharmacist will contact the physician by telephone informing them about the prescribed overdose.

Overdoses only appear on the list once, the night after they have been prescribed. This brings about two potential problems: firstly a serious error could take 24 hours to be discovered. This prescription can already have led to complications for the patient. Secondly if a pharmacist informs a doctor about a problem and the doctor does not act, the pharmacist will not be made aware of this again. There is not necessarily any feedback from the doctor and the system only checks prescriptions once.

[4] http://www.knmp.nl/

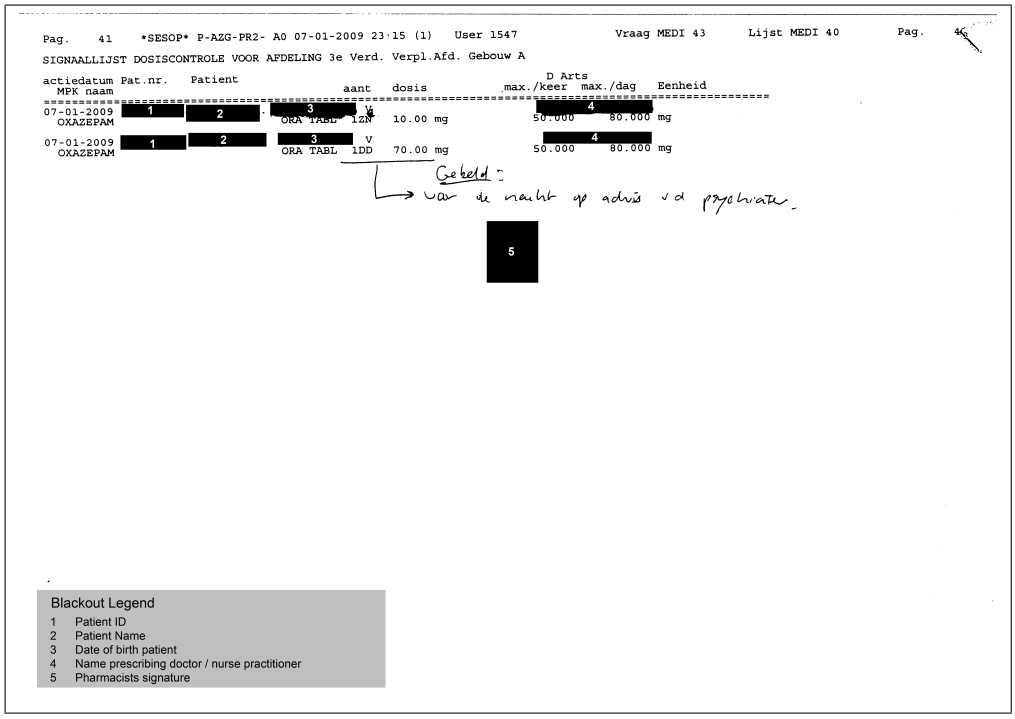


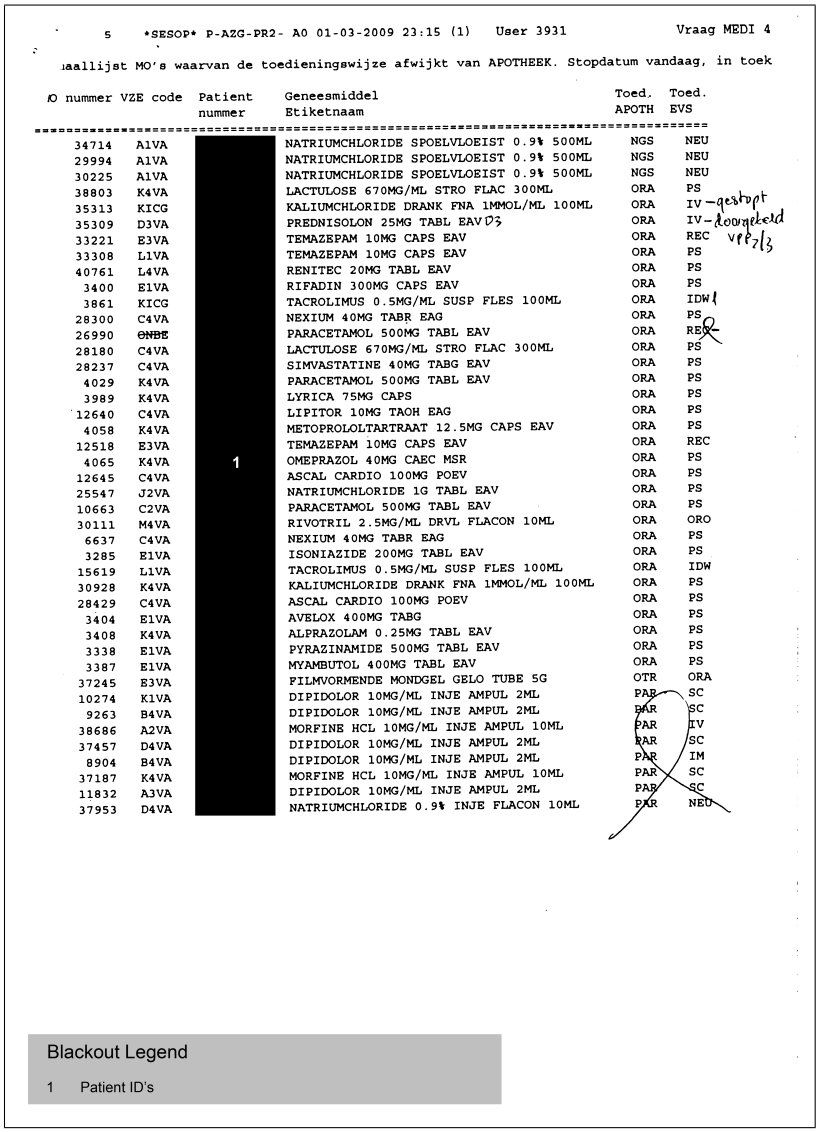
Figure 3.2: An overdose alert list. A larger version of this list can be seen in Figure B.6 in Appendix B. This larger image is accompanied by an explanation of the markings.

Non-Standard Route of Administration Alerts

The non-standard route of administration consist on average of 313 alerts per day (measured over a period of one week, with $SD = 34$).

On each page of the list there is a date and time indicating when the list was generated. Each alert takes up a single row, with is a maximum of 43 alerts on each page. Each alert consists of the following information:

- MO number: The medication order number, which can be used to look up a prescription.
- VZE Code: A code representing the hospital ward where the patient is admitted (the cardiology ward, the maternity ward, etc.).
- Patient number: A unique 7 digit number. Using this number additional information can be retrieved from the patient information system.
- Medication name and strength.
- Recommended route of administration: The route of administration is noted as a shorthand code (e.g. ORA for oral administration).
- Route of administration as found in the Medicatie/EVS system. This route of administration is also noted as a shorthand code.



5 *SESOP* P-AZG-PR2- A0 01-03-2009 23:15 (1) User 3931 Vraag MEDI 4

...aallijst MO's waarvan de toedieningswijze afwijkt van APOTHEEK. Stopdatum vandaag, in toek

MO nummer	VZE code	Patient nummer	Geneesmiddel Etiketnaam	Toed. APOTH	Toed. EVS
34714	A1VA		NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
29994	A1VA		NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
30225	A1VA		NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
38803	K4VA		LACTULOSE 670MG/ML STRO FLAC 300ML	ORA	PS
35313	K1CG		KALIUMCHLORIDE DRANK FNA 1MMOL/ML 100ML	ORA	IV
35309	D3VA		PREDNISOLON 25MG TABL EAV	ORA	IV
33221	E3VA		TEMAZEPAM 10MG CAPS EAV	ORA	REC
33308	L1VA		TEMAZEPAM 10MG CAPS EAV	ORA	PS
40761	L4VA		RENITEC 20MG TABL EAV	ORA	PS
3400	E1VA		RIFADIN 300MG CAPS EAV	ORA	PS
3861	K1CG		TACROLIMUS 0.5MG/ML SUSP FLES 100ML	ORA	IDW
28300	C4VA		NEXIUM 40MG TABR EAG	ORA	PS
26990	~~ONBE~~		PARACETAMOL 500MG TABL EAV	ORA	REC
28180	C4VA		LACTULOSE 670MG/ML STRO FLAC 300ML	ORA	PS
28237	C4VA		SIMVASTATINE 40MG TABG EAV	ORA	PS
4029	K4VA		PARACETAMOL 500MG TABL EAV	ORA	PS
3989	K4VA		LYRICA 75MG CAPS	ORA	PS
12640	C4VA		LIPITOR 10MG TAOH EAG	ORA	PS
4058	K4VA		METOPROLOLTARTRAAT 12.5MG CAPS EAV	ORA	PS
12518	E3VA		TEMAZEPAM 10MG CAPS EAV	ORA	REC
4065	K4VA	1	OMEPRAZOL 40MG CAEC MSR	ORA	PS
12645	C4VA		ASCAL CARDIO 100MG POEV	ORA	PS
25547	J2VA		NATRIUMCHLORIDE 1G TABL EAV	ORA	PS
10663	C2VA		PARACETAMOL 500MG TABL EAV	ORA	PS
30111	M4VA		RIVOTRIL 2.5MG/ML DRVL FLACON 10ML	ORA	ORO
6637	C4VA		NEXIUM 40MG TABR EAG	ORA	PS
3285	E1VA		ISONIAZIDE 200MG TABL EAV	ORA	PS
15619	L1VA		TACROLIMUS 0.5MG/ML SUSP FLES 100ML	ORA	IDW
30928	K4VA		KALIUMCHLORIDE DRANK FNA 1MMOL/ML 100ML	ORA	PS
28429	C4VA		ASCAL CARDIO 100MG POEV	ORA	PS
3404	E1VA		AVELOX 400MG TABG	ORA	PS
3408	K4VA		ALPRAZOLAM 0.25MG TABL EAV	ORA	PS
3338	E1VA		PYRAZINAMIDE 500MG TABL EAV	ORA	PS
3387	E1VA		MYAMBUTOL 400MG TABL EAV	ORA	PS
37245	E3VA		FILMVORMENDE MONDGEL GELO TUBE 5G	OTR	ORA
10274	K1VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
9263	B4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
38686	A2VA		MORFINE HCL 10MG/ML INJE AMPUL 10ML	PAR	IV
37457	D4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
8904	B4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	IM
37187	K4VA		MORFINE HCL 10MG/ML INJE AMPUL 10ML	PAR	SC
11832	A3VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
37953	D4VA		NATRIUMCHLORIDE 0.9% INJE FLACON 10ML	PAR	NEU

Blackout Legend

1 Patient ID's

Figure 3.3: A non-standard route of administration alerts list. A larger version of this list can be seen in Figure B.1 in Appendix B. This larger image is accompanied by an explanation of the markings.

Figure 3.3 is an example of non-standard route of administration list. This example also gives insight in the method of recording actions. The pharmacist makes very short notes about the actions taken. This can range from a simple curl next to an alert (to indicate that this does not need action) to a short message like “called department” with the date. After a pharmacist has called or e-mailed the department there is usually no further action taken by the pharmacist.

If an incorrect route of administration is found the pharmacist will first look up the patient in the patient information system to check whether this medication is

still prescribed as it appears on the list. It is possible that the route of administration has already been changed or the prescription has been stopped. If the alert is still relevant the pharmacist will contact the physician. In most non life threatening cases this is done by e-mail. However if an incorrect method can lead to injury (for example a medication which should be administered orally but is prescribed intravenously) the pharmacist will contact them by telephone.

The list is ordered by the standard route of administration that should have been used. The list does not indicate when a prescription was written and the alert will keep appearing on the list as long as it is not changed in the system. This also means that if a medication is purposefully prescribed using a non-standard route of administration it will stay on the list until the prescription is finished.

The check between standard and used administration route is performed in a very basic way, they are only compared on string level. Medication which can be administered either intramuscularly (IM) or intravenously (IV) are recorded in the system as IMV. When these drugs are prescribed they are entered into the system as either IM or IV, since this is they way they actually will be administered. As the system only checks the route of administration on a string level all these medications are flagged as using a non-standard route of administration. This pollutes the list with many irrelevant alerts.

The persisting prescriptions combined with the fact that there is no start date visible on the list makes it quite inefficient to review this list. Additional to determining whether the route of administration is faulty the pharmacist also has to take into account whether an alert is old or new. This is often done by using the list from the previous day, or by checking the patient information system.

Archiving

After the lists are generated they are printed and kept by the pharmacy front office. The pharmacist who has the task of reviewing the lists picks them up from the front office. After reviewing them they are brought back to the front office where they are transferred to large folder; each type is filed in a different folder. There are multiple folders for each type of alert which are marked with numbers. Once the last folder is full the lists from that type are transferred into filing boxes. These filing boxes usually only contain one type of alert. On the outside of the box the start and end date as well as the type of list is written down. These filing boxes are initially kept inside several offices in the hospital pharmacy. After a certain amount of time these boxes are moved to a central filing facility where they are kept for a minimum of one year.

During the process of collecting the lists used for the initial performance measurement we found several issues with the current archiving system:

- There was one day of alerts which was not filed away correctly and could not be found.
- There were incomplete lists, often there were pages from a day missing.
- Sometimes the lists from different days are not in order, this makes it very hard to find all alerts for a given day
- At times loose pages would be found between alerts from a different day.

- Because of the lack of ordering it is very difficult to find a specific alert. Finding a single patient in the archives (before they are moved to the central archive!) can take several hours.

3.5.2 Performance

A small preliminary study was carried out to attempt to determine the performance of the SESOP system. This performance data can later be compared with the performance of the Gaston to determine whether the introduction of the new system is an improvement. The initial goal was to do this comparison as part of this research project but as the new system was not yet operational this was not possible.

This part of the study was carried out together with Marlous Wielema, a 5th year pharmacy student carrying out several small research projects in the hospital pharmacy. Most of the quantitative part was done together while the qualitative part was carried out by Marlous Wielema. The full report (Wielema, 2009) also includes the qualitative results while here only the quantitative results will be discussed.

Method

A retrospective quantitative and qualitative measurement was performed over the course of one week. All alerts generated by the SESOP system during this week were taken into account. They were reviewed using the printed and annotated lists from the pharmacy archives in combination with patient information from Poliplus, the electronic patient information system.

As part of the quantitative measurement the following data was recorded:

- Number of alerts (separate for each of the lists).
- Number of alerts for which the pharmacist contacts the clinic (alerts deemed clinically relevant by the hospital pharmacy).
- Number of times action is taken as a result of contact with pharmacist (alerts deemed clinically relevant by the clinic).

Whether a pharmacist had taken action on an alert was determined by markings on the pages (examples of these marks can be seen in Appendix B). For each of the alerts for which an action was taken by the pharmacy the patient prescription history was used to determine whether action had been taken in the clinic based on advice from the pharmacy. Therefore the number of alerts the clinic takes action on cannot be higher than the number of actions the pharmacy takes on. Correction of errors which were not signalled by the pharmacy cannot be detected in this set-up and are not included in this overview.

Additionally Marlous Wielema also performed an analysis based on the type of alert and the type of action taken. This qualitative evaluation was performed to determine when and which action was taken based on the current medication monitoring system.

Table 3.1: An overview of the number of alerts on the interaction lists per day, combined with the number and percentages of actions taken by the clinical pharmacy and clinic for these alerts. A summary of days has also been included.

		Pharmacy		Clinic		
Date	**Number of alerts**	**Number of actions**	**% of total**	**Number of actions**	**% from pharmacy**	**% of total**
26/02	30	5	16.7%	4	80.0%	13.3%
27/02	139	13	9.4%	3	23.1%	2.2%
28/02	32	3	9.4%	0	0.0%	0%
01/03	28	4	14.3%	3	25.0%	10.7%
02/03	89	10	8.9%	8	80.0%	9.0%
03/03	91	5	5.5%	4	80.0%	4.4%
04/03	130	14	10.7%	5	35.0%	3.8%
Totals	539	54	10.0%	27	50.0%	5.0%

Results

Below the results for each of the types of alerts will be displayed and discussed.

Interaction Alert Lists

Data Alerts generated between 26/02/09 and 04/03/09 were used for the analysis of the interaction lists. For 26/02, 01/03, 02/03 and 04/03 we could not locate all pages. As so many days had pages missing it was decided not to attempt to replace these dates. Since pages are numbered it was often possible to determine how many pages were missing, only on days where the final page was missing this was not possible. A total of 414 pages were retrieved for this period, a count of missing pages indicates that there will at least have been 480 pages of alerts during this period and possibly more.

Results Over the measured period of one week 539 overdose alerts were generated. There were 54 instances (10.0%) where the pharmacist took action based on the alert. From these actions at least 50% (27) where then acted upon by the clinic. The number of alerts varies from day to day, the highest number of alerts on one day was 130 on Friday 27/02 and the lowest was 28 on Sunday 01/03. A breakdown of alerts and actions per day can be seen in Table 3.1.

Overdose Alert Lists

Data The data used for the overdose alert lists was taken from the lists for 26/02/09 through 04/03/09. As the lists for 01/03/09 could not be found in the archive this date was substituted with the list from 08/03/09, also a Sunday. This was done as the number of alerts is connected to the day of the week, e.g. there are less prescriptions written on the week-end.

Table 3.2: An overview of the number of alerts on the overdose lists per day, combined with the number and percentages of actions taken by the clinical pharmacy and clinic for these alerts. A summary of the days has also been included.

		Pharmacy		Clinic		
Date	**Number of alerts**	**Number of actions**	**% of total**	**Number of actions**	**% from pharmacy**	**% of total**
26/02	53	0	0.0%	-	-	0.0%
27/02	62	0	0.0%	-	-	0.0%
28/02	25	0	0.0%	-	-	0.0%
02/03	55	1	1.8%	0	0.0%	0.0%
03/03	57	4	7.0%	1	25.0%	1.8%
04/03	68	7	10.3%	7	100.0%	10.3%
08/03	21	0	0.0%	-	-	0.0%
Totals	341	12	3.5%	8	66.7%	2.3%

Results Over the period of one week a total of 341 overdose alerts were generated by the system. The most alerts were generated on Wednesday 04/03 (68) and the fewest on Saturday 28/02 (25). For these 341 there were at least 12 which caused the pharmacists to undertake action, which amounts to 3.5% of the total. From the 12 alerts for which action was taken by the pharmacy, the clinic acted on 8, meaning that they acted on 66.7% of the pharmacy recognised alerts and on 2.3% of the total number of the alerts. An overview of the number of alerts and actions can be seen in Table 3.2. This table also includes the values for each day separately.

Route of Administration Alert Lists

Data For the analysis of the route of administration list, alerts generated between 26/02/09 and 04/03 were used. We were able to retrieve all the alerts for this time period.

Results A total of 2193 route of administration alerts were received by the pharmacy during the measured period. It should however be taken into account that, contrary to the overdose and interaction lists, these alerts persist and can be on the list for many days. As a result we do not know how many new alerts were generated (alerts both silently appear and disappear from this list) for the measured period. The same method which was used for counting actions has been used for this list as the pharmacist does need to review the entire list since there is no indication which alerts are new.

For these lists there was only a very small number of alerts for which the pharmacist took action, in total only eight (0.4%) over the period of one week. Based on these eight communicated alerts the clinic took action in five case, which is 62.5% of the pharmacy recognised alerts but only 0.2% of the total. A breakdown of alerts and actions per day can be seen in Table 3.3.

Table 3.3: An overview of the number of alerts on the route of administration lists per day, combined with the number and percentages of actions taken by the clinical pharmacy and clinic for these alerts. A summary of the days has also been included.

		Pharmacy		Clinic		
Date	**Number of alerts**	**Number of actions**	**% of total**	**Number of actions**	**% from pharmacy**	**% of total**
26/02	342	1	0.3%	1	100.0%	0.3%
27/02	320	0	0.0%	0	-	0.0%
28/02	344	0	0.0%	0	-	0.0%
01/03	258	0	0.0%	0	-	0.0%
02/03	272	4	1.5%	2	50.0%	0.7%
03/03	317	1	0.3%	1	100.0%	0.3%
04/03	340	2	0.6%	1	-	0.3%
Totals	2193	8	0.4%	5	62.5%	0.2%

Conclusion and Discussion

The results from the three results are all shown in Table 3.4 for easy comparison. When looking at the percentages it becomes clear that, as far as could be determined, only a very small percentage of alerts lead to an action. This indicates a very poor signal to noise ratio.

Table 3.4: An overview of the percentages of acted upon alerts for each of the lists.

		Pharmacy		Clinic		
List type	**# of alerts**	**# of actions**	**% of total**	**# of actions**	**% from pharmacy**	**% of total**
Overdose	341	12	3.5%	8	66.7%	2.3%
Interaction	539	54	10.0%	27	50.0%	5.0%
Route of Admin	2193	8	0.4%	5	62.5%	0.2%

The signal to noise ration is an important factor in the effectiveness of CDSS. This is also mentioned with the ninth and tenth commandment from Bates et al. (2003b) (see Table 2.3). When there is too much noise, i.e. clinically irrelevant alerts, the chance of a physician missing relevant alerts becomes ever greater. This effect is also known as alert-fatigue (van der Sijs, 2009). According to van der Sijs (2009) alerts are overridden between 49% and 96% of cases. adverse drug events (ADEs) as a result of an overridden alert were observed in 2.3 to 6% of cases (3 studies, van der Sijs (2009)).

It is not always the physician at fault when an alert is overridden. When the alert is clinically irrelevant the alert itself is actually a system failure. It is difficult to set boundaries for such alerts as you do not want too many alerts (possibly causing alert-fatigue) but by only providing alerts in extreme cases relevant alerts might not be generated (allowing incorrect medication orders to proceed unnoticed).

3.5.3 Issues to Consider

The initial analysis of the current medication safety systems in the UMCG shows there is room for improvement. Below an overview of the most important findings is shown.

- General
  - Information overload: the performance measurement shows that the number of clinically relevant alerts compared to the total number of alerts is very small, i.e. the signal to noise ratio is very poor. This creates the danger of low arousal which in turn is a can be cause of lower performance according to the Yerkes-Dodson Law (Sulsky and Smith, 2005). Another issue with a low-signal to noise ratio is the possibility of alert fatigue (van der Sijs, 2009).
  - Pharmacists often have to combine information from patient records (e.g. lab results) and the alerts. It would be more effective to use a computer to combine these two sources of information to determine whether an alert is relevant. By doing so the pharmacist will receive fewer alerts and they can focus on important tasks and avoid low job satisfaction. Performing menial tasks such a checking values from a system can lower job satisfaction (Rosson and Carroll, 2002).
  - A pharmacist has to copy numbers from the paper (patient numbers or interaction codes) to the computer to look up additional information. Mistakes can easily be made and the task is cumbersome.
  - The information on the list is often out-dated. Due to the delay between prescribing and reviewing alerts (between nine and thirty-three hours) many of the alerts have already been resolved when they are reviewed by the pharmacist.
- Environment
  - The task is not performed in isolation, interruptions occur.
    - It is important to be able to return to the task and easily find what you were working on.
    - Situation awareness might be lower right after an interruption, it should be easy to increase this again.
- Interaction Alerts
  - The misprints (Figure B.4) make it difficult to read these alerts. Also sometimes other alerts can be overlooked because of the clutter.
- Overdose Alerts
  - The G-standard information is not compatible with hospital standards for maximum dosages, generating many clinically irrelevant alerts. This overload of irrelevant information makes it more difficult to spot “real” alerts and it also may cause cause alert fatigue (van der Sijs, 2009).
- Route of Administration Alerts

  - The patient is only listed with their seven digit patient number on this list. There is no redundancy in the patients identity, making it harder to spot errors when looking up information.
  - As there is no useful ordering of the information and no start date is noted it is difficult to determine which alerts are new and require revision. This both costs a lot of time and new alerts can possibly be overlooked.

- Archiving / Information transference
  - There is no standard method or system in place to share information between pharmacists.
  - There is also no standard method of recording actions and decisions made based on alerts. This means it is nearly impossible to retrieve advice given (or not given) when needed.
  - The alerts are not saved digitally which makes it difficult to retrieve specific alerts, the only possible method of finding a specific patient is going through lists manually.
  - The alerts are not archived consistently (missing pages, pages not in the correct order, pages in the wrong archive box) which also makes it very difficult to retrieve specific alerts.

The initial observations and description have already made apparent a substantial number of drawbacks and flaws of the current system. However as an outsider and non-user of the system it is nearly impossible to fully grasp all the positive and negative aspects of a system, especially if this is merely done by observation.

In order to fully understand how this system should function, the users of the system need to be consulted. Users are both involved in the analysis of the current system and determine what their wishes and demands for the new system are. The interviews that were held with the users will now be discussed.

3.6 Interviews

After analysing the current situation and work method, and measuring the performance the analysis of the current situation was extended with open interviews.

The purpose of the interview was to gather the following information:

- A limited amount of quantitative information about the users and use of the system (e.g. age, experience and which they used).
- General attitude towards the SESOP medication lists.
- Positive and negative properties of each of the lists (interaction, overdose, non standard route of administration).
- Attitude towards and experiences with each of the lists.
- Ideas regarding the archiving and follow-up of alerts.

- Initial feedback on a sample mock-up with the purpose of gathering ideas for the prototype.

The interview was structured in such a way that the interviews could be compared and that the interviewee would explicitly review each of the lists. Especially this last point is vital as the prototype will include each of the three types of errors (route of administration, overdose, interaction) and the requirements for each should be known.

3.6.1 Method

The interviews were conducted in Dutch, a translated version of the interview scheme can be found in appendix D.

The interviews started with a number of questions regarding the pharmacists age and experience (both as a pharmacist and with the SESOP system). This is interesting as we want the prototype to suit people from different background. By collecting this information we can how preference differ based on experience.

Following that the pharmacists were asked about their general experience with the system. This information is interesting as it might indicate how willing people are to adapt to a new system.

Then each of the lists were discussed separately. Pharmacists were asked the following questions:

- What do you like about this list and why?
- What don't you like about this list and why?
- Which information on the list can be removed?
- Which information is missing from the list and should be added?
- Other remarks

For each of the lists the pharmacist is also presented with a number of statements. The statements have to be rated on a 5-point Likert-scale, ranging from "strongly disagree" to "strongly agree". The statements are based on the USE Questionnaire (Lund, 1998b,a). The USE questionnaire was an attempt to create an universal usability evaluation tool. The list of propositions is used to gather data about the usefulness, satisfaction and ease of use of each of the SESOP lists. Using the same list of statements for each alert list allows for comparison between lists and between interviewees. The list of statements can be seen below. In this list the statements are subdivided by the three categories from the USE questionnaire. During the interview the statements were not in a specific order nor divided by category.

- Usefulness
  - The list contains all the information I expect it to contain.
  - The lay-out of the list is clear.
  - The information on the list is represented clearly.
  - I can always find all the information I need.

- Satisfaction
  - The list is pleasant to use.
  - I am satisfied with the list.
  - The lay-out of the list is pleasant.
- Ease of Use
  - It is easy to check the alerts.
  - I can check the alerts quickly.
  - The information on the list is easy to understand.

After discussing each of the lists pharmacists is asked for ideas regarding archiving of information. Which information would they like to record, how would they like to do this etc. It was necessary to explicitly ask the pharmacist about this as the initial analysis did not provide any information about this task.

Finally the pharmacists were presented with a simple mock-up (see Figure H.1). This was done to elicit ideas regarding a new interface.

3.6.2 Results

Interviews were held with a total of four pharmacists: two hospital pharmacists and two hospital pharmacist residents. The age was between 21 and 50 years and the experience as pharmacist ranged between 1-20+ years. The range in experience was intended to be large as the experience with the alert lists of novice users and/or pharmacists might differ from that of more experienced users and/or pharmacists.

The outcomes of the interviews will be discussed in the same order as they were conducted.

Quantitative

Three of the four pharmacists reported reviewing SESOP lists between “daily” and “weekly” indicating they have extensive experience reviewing the lists. The other pharmacist only used the lists rarely. Depending on the day of the week and combinations with other duties the pharmacists take 2-5 hours to review the lists generated for one day. This time includes interruptions which occur regularly to very often. Interruptions range from receiving e-mails and phone calls to people entering the room with questions. Reviewing of the lists is not a task which is performed in isolation, pharmacists are also on duty for different tasks.

Pharmacists were asked how often they used specific resources. The results can be seen in Table 3.5. Both Poliplus and the KNMP knowledge bank are used often, the UMCG Internet is more than regularly while the CBG website is only used less frequently. Pharmacists indicated they used the “Other” resources often; this results is however very difficult interpret as the question is not well-defined.

Table 3.5: An overview of the extent of use for several resources.

	Never	Sometimes	Regularly	Often	Very often
Poliplus / ZIS				**X**	**XXX**
KNMP Knowledge-bank		**X**		**X**	**XX**
CBG Website	**X**	**XX**	**X**		
UMCG Intranet			**XX**	**XX**	
Other (e.g. Micromedex, Farmocotherapeutisch Kompas, Kinderformularium.nl)				**XXXX**	

Open Questions

The open question section of the interview started with a very general question: "What is you opinion about the SESOP lists?". The interview was purposely started with a very general question, to avoid people fixating on minute details.

Pharmacists were generally not very positive about the SESOP lists and all pharmacists found the lists "not well arranged", "contain lots of unnecessary information" and "lost of necessary information is missing". Another often heard reply was that the list contains a large number of irrelevant alerts. These "irrelevant" alerts are relevant medication situations which pose a threat in home situation but are approved for hospitalised patients. Pharmacists reported that these "irrelevant alerts" make it more difficult to complete the task of checking the list and are very time consuming.

When asked whether they found the list pleasant to work with all pharmacists answered "no". This indicates that any improvement in the interface or working method would probably be accepted quite easily. None of the pharmacists found the lists easy to work with although some did report the lists are something "you can get used to".

Given the first set of open questions we can conclude that the general attitude towards the SESOP lists is poor. The users, both novice and experienced, have issues with the lists. To further to clarify the problems with the lists each of the pharmacists was asked specific questions regarding each type of the list. The discussion of each of the lists always started noting the positive points before moving on to the negative points. The results will now be discussed for each list.

Interaction Alert Lists

During the discussion of the interaction list a sample interaction list page (see Figure B.2) was given to the pharmacists as an aid in explaining their remarks and as a memory aid.

When discussing the interaction lists the pharmacists noted they liked how this list contained the basic information about the patient (e.g. name, number, ward), medication (e.g. name, dosage) and the prescribing doctor. They also found the information about the interaction informative (although a pharmacist did note that

after some time of performing the task the information becomes superfluous) and all found it useful that the interaction code was named. One pharmacist noted that it was easy to note down information when needed as there is sufficient space available. All pharmacists indicated that the aspects that were regarded as positive for this list should logically be part of the list and where therefore not very impressed.

When discussing the negative aspects of the lists the pharmacists were more outspoken. Many of the negative aspects they named concerned missing information. A short list of information found to be missing:

- Route of administration
- Contact information for physicians and wards
- Start and stop (if known) dates for medication
- Additional clinical information regarding the patient

Pharmacists also mentioned the "irrelevant alerts"; the frequent misprints (an example of such a misprint can be seen in Figure B.4); the fact that it is unknown if a medication order is new or is a dosage change or prolongation of an existing order; inconsistent coding of ward information; the "VAR" value for the dosage and no possibility to clearly record (for archive purposes) what was done with an alert.

To determine whether certain information on the list was unneeded pharmacists were asked which information could be removed. Here there were only a few items: "relevance" of an alert (all alerts actually have a relevance of 1); system information at the top of the page; and some suggested the explanation text of the alert could be made more suitable.

Finally all the pharmacists were asked to which degree they agreed with a number of statements. Table 3.6 shows the average response. The individual responses, where each pharmacist is decoded as a letter (A-D), can be found in Appendix E.

Pharmacists were generally not very positive regarding the interaction list. Only two statements, both regarding the ease of use, received any positive remarks. People were most negative concerning satisfaction with the list and they were are most negative about the statement "I can always find all the information I need.". By including all required information the satisfaction of users can most likely be improved.

Overdose Alert Lists

During the discussion of the overdose list a sample overdose list page (see Figure B.5) was given to the pharmacists as an aid in explaining their remarks and as a memory aid.

While discussing the positive aspects of overdose list some pharmacists noted that there weren't many positive aspects for this list. Pharmacists generally liked that all the patient information is present; you can at once oversee the alert; and they were positive about the maximum per administration and maximum per day information. It is interesting to note that they were later on also negative about

Table 3.6: An overview of the response to the statements concerning the interaction lists. The dots show the average value and the box shows the maximum and minimum value. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree.". The values are renamed from -2 to 2 to indicate the difference between positive and negative responses. The decoded results of individual pharmacists can be seen in E.1.

maximum per administration and day information as the values are also not adjusted to hospital standards.

Following the positive aspects the negative aspects of the list were discussed. Almost all pharmacists noted the "VAR" (meaning variable) value that is displayed for the dosage when a non-standard value, such as "when needed", is entered in the CPOE. The value "VAR" does not provide any useful information and the pharmacist will always have to look up additional information to determine what the reason for this variable dosage is. They would rather have this information visible in the alert. Also one of the pharmacists found the lay-out very "cluttered and squashed", making it difficult to find information.

In general there was no information which they found could be removed, although one person mentioned that the MO number could be removed.

The pharmacists indicated several items they felt that were missing from the list. An overview of these items:

- Contact information for the physician and wards.
- Clinical data (e.g. lab results).
- Additional explanation for the "VAR" dosage.
- Start and stop date of medication.

Pharmacists also rated the statements for this list. The result can be seen in Table 3.7. The average pharmacist responses is mostly around the neutral point,

however, the agreement between the pharmacists seems lower than with the interaction list. In general people seem to be reasonably satisfied with the overdose list but there is certainly room for improvement. Ideally people would be positive rather than neutral. One area which scores badly is once again the information provided: all pharmacists agree that there is information missing.

Table 3.7: An overview of the response to the statements concerning the overdose lists. The dots show the average value and the box shows the maximum and minimum value. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree.". The values are renamed from -2 to 2 to indicate the difference between positive and negative responses. The decoded results of individual pharmacists can be seen in E.2.

Route of Administration Alert Lists

During the discussion of the route of administration list a sample route of administration list page (see Figure B.1) was given to pharmacists as an aid in explaining their remarks and as a memory aid.

The positive point which was noted by all the pharmacists is that the list contains both the route of administration used in the CPOE and the route which is defined as the standard in the pharmacy. No further positive aspects were named for this rather sparse list.

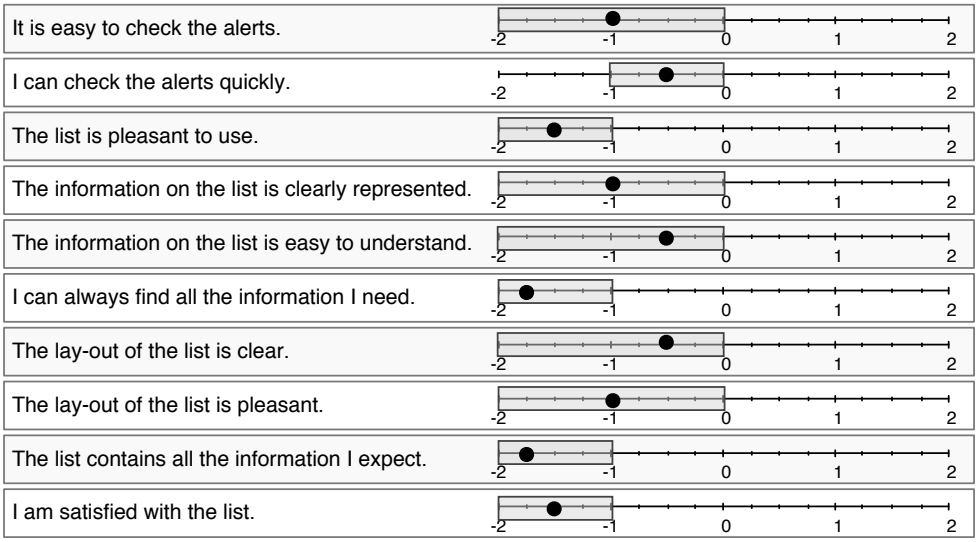
As negatives the most named thing was the omission of any patient-information besides the patient number. All pharmacists experienced this as bothersome. Pharmacists felt the same about the information about the prescribing physician, this information is completely absent. Another negative point was the occurrences of old alerts. Alerts from this list only disappear after the prescription ends, is changed, or stopped. As the list is sorted by pharmacy route of administration and alerts lack a start date, it is difficult to determine which alerts are new.

All pharmacists mentioned that they felt the MO-number could be removed from the list as well as the old alerts.

The pharmacists indicated that the were missing quite a bit of information. They would all like more patient information as well as the name of the prescribing physician. The start (and possibly stop) date medication order was also mentioned by everyone as missing. The additional notes for the route of administration were felt to be helpful in determining whether a problem would occur. Additionally it was mentioned that it is difficult (nearly impossible) to determine if an action has already been taken for a specific alert.

The pharmacists also rated the list with statements for this list. The result can be seen in Table 3.8. They are most negative about the route of administration list, there are no positive ratings and the agreement for the negative values is also high. While with the previous two lists the biggest problem seemed to be missing information the pharmacists indicate that with this list the lay-out and ease of use are also important negative factors. This suggests that the redesign needs to be to a larger extent than for the other two lists.

Table 3.8: An overview of the response to the statements concerning the route of administration lists. The dots show the average value and the box shows the maximum and minimum value. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree.". The values are renamed from -2 to 2 to indicate the difference between positive and negative responses. The decoded results of individual pharmacists can be seen in E.3.



Archiving

As the new application will also include an opportunity to record and archive pharmacist actions it is important to know which information the pharmacists feel they should be able to record. A list of common responses:

- The advice given.
- Reasoning behind the given advice.
- Extra information concerning the patient, including but not limited to relevant medical information.
- Name of person that handled the alert
- Date / Time when alert was handled.
- Has there been contact with a ward or doctor? How (e-mail versus telephone)? With whom? What was the outcome?

When discussing the more general question of archiving results and alerts pharmacists noted that they would also like feedback from physicians on the actions taken. They would like to be able to be able to look-up old actions taken by colleagues, preventing double work and allowing for more informed decisions.

3.6.3 Mock-Up

The mock-up section of the interview was used a springboard for brainstorming about the new application. By providing the pharmacists with a very simple mock-up on paper it was easier to talk about the new application. The mock-up was created using knowledge about the task and the relevant task information, it can be seen in Figure 3.4.

The general response to the mock-up was positive and the pharmacists all responded enthusiastically and had many ideas for the new application. As this part of the interview was very unstructured it is difficult to provide a summary, instead the ideas are compiled in a list. Many of these ideas were mentioned by more than one pharmacist.

- Search in the archive
- Search for a patient
- Structured method of handling alerts (standard information which needs to be filled out).
- Automatic recording of who handles an alert and when this is done.
- Register action taken in Poliplus automatically.
- E-mail or print an alert.
- Sort or group alerts by different types of information (ward, date etc.)
- See a patients history.
- Flag / mark alerts which require extra attention or a follow-up.
- Link an alert to an e-mail.
- Distinguish between new and altered medication orders.

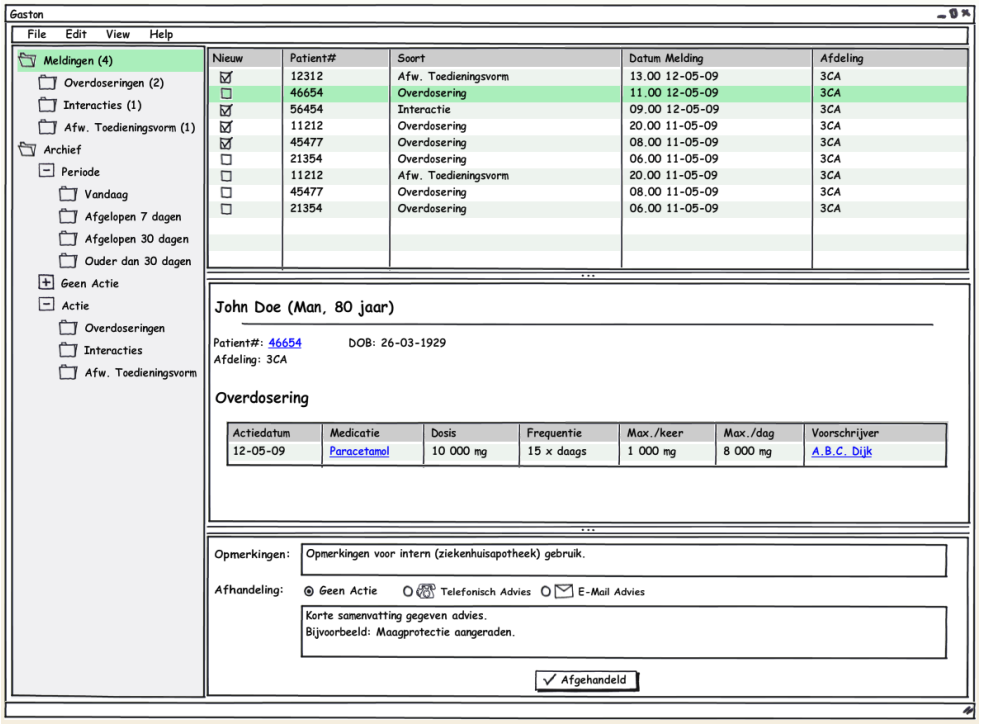


Figure 3.4: A simple initial mock-up for the interface of the Gaston application. By using a simple example it becomes easier to converse about an interface. A larger version can found in Appendix H.1.

- See start and stop date for medication.
- Have contact information for physicians and wards.
- Add remarks to a patient, which can always be seen.

3.6.4 Summary and Conclusion

Pharmacists are generally not satisfied with both the working method in general and the lists, especially the “route of administration” receives a lot of negative feedback. From the responses it is clear that pharmacists feel there is a gap between the information provided and information required to adequately deal with an alert. This discrepancy causes additional, often menial, work to a task that is already complex. The interview have been useful in gathering which information should be provided by a new interface to avoid the types of problems found with the current system.

Additionally the method of recording and transferring information between pharmacists and others was found to be inadequate. During the interview the pharmacists requirements for the archive / communication issue were gathered.

The interviews served as a useful tool in gathering information about the users and their interaction with the current system. The results from the interviews complement and extend the results from the preliminary analysis. It has become clear

where the major problems lie and what the most important demands for the new interface are. Using this information a prototype was developed in order to confirm these findings with the users again.

Chapter 4

Prototype Development and User Tests

> It is far better to adapt the technology to the user than to force the user to adapt to the technology.
>
> Larry Marine

Following the preliminary analysis and the interviews a prototype was developed. The prototype was developed for two reasons: perform user test to evaluate the new design, and be a basis for the final prototype which is to be used for development of the new interface.

4.1 Development

Balsamiq Mockups[1], a commercial application for creating software mock-ups, was used to create several initial low fidelity mock-ups. One of these mock-ups was used during the interviews and can be seen in Figure H.1. The choice to first create low fidelity mock-ups was made to avoid focussing on technical possibilities and instead focus on the layout and intended functionality of the prototype. Balsamiq mock-ups was used to create simple versions of most parts of the prototype which were later implemented in a more functional prototype.

The prototype that was used during the user test was implemented using web-technologies such as html, css, php and javascript and was created to run in a browser. A browser based prototype allowed for quick implementation. The prototype was developed without any intention of reusing it. It merely functioned as a testing platform and a sample for future developers.

The prototype uses the Yahoo! User Interface Library (YUI)[2] as a basis. YUI reduced implementation time as many features (e.g. sortable data-tables, adjustable lay-out elements and a tree-view) were already available and could easily be used.

[1] Balsamiq Studios LLC, http://www.balsamiq.com
[2] Yahoo! Inc., http://developer.yahoo.com/yui/2/

4.2 General Description

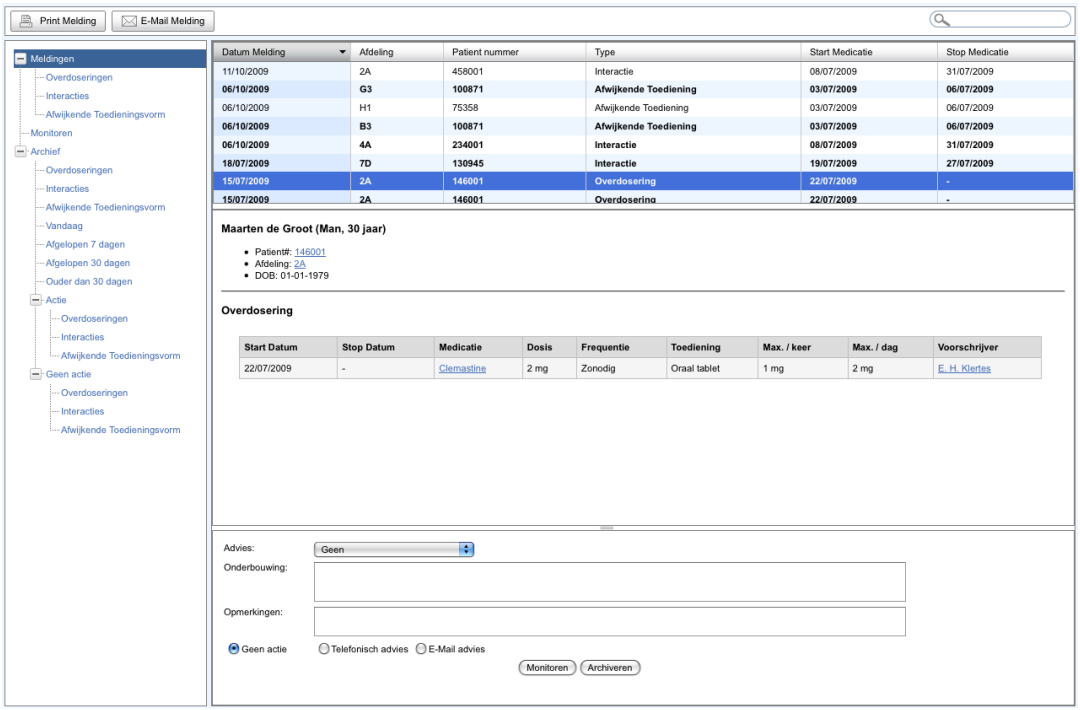


Figure 4.1: A screenshot of the prototype.

The prototype's lay-out is similar to an e-mail application (such as Outlook[3] or Mail[4]). There is a tree on the left with different folders (or nodes), an overview of items at the top right and the content for a selected item below that (see Figure 4.1). The lay-out of an e-mail application was chosen as there are similarities between the task of reading e-mail and reviewing alerts. Both consist of discrete pieces of information with a number of unique identifiers which need to be dealt with. By using a well-known metaphor, all pharmacist use e-mail applications daily, a user quickly becomes familiar with the interface (Lewis and Rieman, 1993).

The application consists of three different views: the alert overview, the archive and monitor overview and a search view. The wireframes of these three views can be seen in Figures 4.2, 4.3, and 4.4. In the alert view you can view new alerts; in the monitor view you can view alerts which pharmacists have marked for further review / monitoring after an advice being given; and the archive view shows alerts which have been handled by the pharmacist and require no further action. Below the components (A-E) from wireframes are explained further. A full specification of the application can be found in Appendix I.

[3] Microsoft Corporation
[4] Apple Inc.

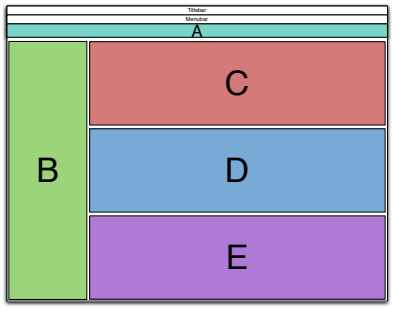


Figure 4.2: Simple wireframe for the main view of the application. A is the task-bar, B is the tree, C is the data table, D is the alert view, and E is the action view.

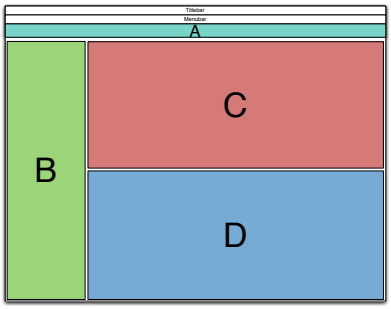


Figure 4.3: Simple wireframe for the archive and monitor view of the application. A is the task-bar, B is the tree, C is the data table, and D is the alert view.

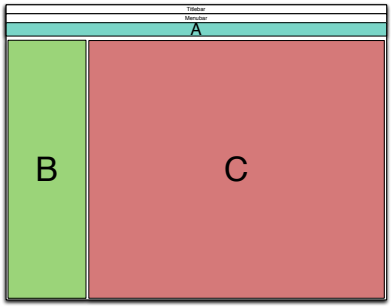


Figure 4.4: Simple wireframe for the search view of the application. A is the task-bar, B is the tree, and C is the data-table.

Task-bar - A All the views have the same task-bar. Dependent on the situation you will see different buttons, for example a re-open alert button only needs to be visible in the archive and monitor view, not in the alert view.

Tree - B All the views have the same tree (panel B) that can be used to navigate the application. The tree also indicates the current location in the application. An example of the tree can be seen in Figure I.5.

Data Table - C Panel C is a data table which shows the list of alerts for that view. When in the alert view the table contains un-handled alerts while when in the archive it shows archived alerts. An example of a data table can be seen in Figure I.6.

Alert View - D The alert view shows the content for an alert. This consists of patient information (the same for all types of alerts) and alert information which differs per type of alert. An example of the patient information can be seen in Figure I.9, while alert information for interaction, overdose and route of administration alerts can be seen in Figures I.10, I.11, and I.12 respectively.

Action View - E Only visible when looking at alerts while in the alert view. This section allows pharmacists to record the action they take, who they contacted and when possible the result of this contact. An example of the action view can be seen in Figure I.15.

4.3 Details of Implementation

The design of the application is partially based on Nielsen (1993) his heuristics. The heuristics that were used are: visibility of system status; consistency and standards; user control and freedom; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; and help users recognise, diagnose and recover from errors. Below is discussed how each these heuristics were implemented in the prototype.

- Visibility of system status: *The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.*
  - In the system the current location in the program is always shown through the highlighting in the tree, which indicates whether you are looking at a new or archived alert or a specific subset of alerts. Additionally the alert that is currently being viewed is also highlighted in the list view. The type of alert that is being viewed can also be inferred from the presence or absence of the "action field". By providing the information in multiple ways (redundancy) it becomes easier to determine the current state in the program.
- Consistency and standards: *Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.*
  - To promote consistency in reporting actions taken for an alert there is a drop-down box with standard actions for each type of alert. Furthermore the application will be built based on standard OS widgets, making users instantly familiar with the interface.
- User control and freedom: *Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.*
  - When reporting actions pharmacists use a drop-down box with options; however sometimes an action is not present in the list of default options. The application gives the user the freedom to specify a new action, not locking them in to the standard options. Alerts that have been archived can also be re-opened to add a new advice. The old advice is also kept for the records.
- Error prevention: *Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.*

  - For the recording of actions the name and e-mail field both autocomplete, both saving the user time and preventing errors. Contrary to the previous working method the pharmacist will nearly never have to manually enter data to look up information, there are automatic links to electronic patient dossiers and medication pages preventing any possible data entry errors. Additionally many of the manual checks which had to be performed by hand in the old system are now automated, also preventing possible human errors.

- Recognition rather than recall: *Minimise the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.*

  - For interaction alerts there is a short text available explaining the effect of the interaction and a short text indicating how this can be counteracted or prevented. These text are both easily accessible when viewing an alert. The pharmacist can jog their memory with this short reminder rather than having to recall this information.

- Flexibility and efficiency of use: *Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.*

  - Two instances where the flexibility and efficiency are very apparent in the prototype are the shortcuts and ability to customise. A user can, for instance, change the ordering and content of the data table. Each user can adjust these their needs and working method. The application will also be fully usable using just the keyboard. Frequent users can save a lot of time and effort by moving around the interface using the keyboard.

- Aesthetic and minimalist design: *Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.*

  - The application does not attempt to include all patient and medication information in the interface. This would lead to a cluttered screen where the most important component, the alert, can not clearly be displayed. The application does allow easy access to information using links which will open the relevant information in the applications designed to display that information.

- Help users recognise, diagnose, and recover from errors: *Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.*

  - The only place where user input takes place, the entering of an action for an alert, is designed to prevent errors. There are a number of fields which are required, preventing incomplete data entry, an alert cannot

be archived is the required information is not entered. When a user attempts to archive or monitor an alert which does not have all required fields filled out the system will notify the user which required fields are not yet filled out.

By implementing the prototype with Nielsen's heuristics in was attempted to create a prototype that is as user friendly and usable as possible. Merely using the heuristics when designing an interface is not a guarantee for a usable interface. It is important to always involve users.

4.4 User Test

As part of the user-centred design process the prototype was evaluated with users.

The pharmacists that participated in the interviews also took part in the user test. A total of four pharmacists participated in the user test, of those two were hospital pharmacists and two were hospital pharmacist residents. The age was between 21 and 50 years and the experience as pharmacist ranged between 1-20+ years. The range in experience was intended to be large as the experience with computer interfaces of novice users and/or pharmacists might differ from that of more experienced users and/or pharmacists.

4.4.1 Setting

The user tests were all performed in the University Medical Centre Groningen (UMCG) on the Department of Clinical Pharmacy. User tests were held in a conference room as to minimise interruptions. During the user test a laptop was used. The laptop was connected to an external 17 inch monitor (resolution 1280 x 1024px) and an external keyboard and mouse emulating a normal desk set-up. The prototype was running on a local web server and was displayed in the Safari 4 browser. The prototype was displayed full-screen and browser controls were not visible creating an application like experience. During the user test the screen, sound and video (showing the pharmacist) were recorded using Silverback[5]. The recorded information was used to summarise the results and record clicks in the interface.

4.4.2 Method

The user test consisted of five main parts:

1. Pharmacists were given an introductory letter explaining the set-up and purpose of the user test. This letter can be found in Appendix F.1.
2. The pharmacists were asked to explore the interface. They were allowed to ask questions during this exploration.
3. The pharmacists were asked to perform a number of small tasks. The purpose of these tasks was to determine how users would use the program and whether this was in accordance with the design. These tasks consisted of finding and entering information in the prototype. For example in one of

[5]Clearleft Ltd., http://silverbackapp.com/

the tasks they were asked to open an alert relating to ward G3 (task 3) and in another (task 2) they had to enter all the required information for an alert and archive it. An overview of the tasks can be found in Table 4.1. During the completion of these tasks pharmacists were asked to think aloud. This means that they constantly vocalised what they were doing, why they were doing something and whether the interaction met their expectations. The think aloud protocol was developed by Lewis (1982) and is used to gather information about what users are thinking when they interact with the system. Users often find it difficult to recall which problems they encounter with a system when questioned after using it (Lewis and Rieman, 1993). It is better to start collecting information while users are interacting with the system. During the completion of the tasks, the pharmacists were not allowed to ask any further questions. The following information was gathered: the time taken to complete the task; task success; number of clicks per task; and the route taken to complete the task.

4. A short demo of features they did not come across during exploration and task completion was given to the pharmacists. This was done to ensure they are aware of all aspects of the interface.

5. An interview was conducted concerning the different aspects of the interface. The purpose of this interview was gather information about the pharmacists felt should be added to or changed in the prototype to better suit their needs. Pharmacists were asked to give general feedback regarding the entire interface. During this interview the prototype was used to indicate problems they found. An overview of the questions asked can be found in Appendix F.3

Table 4.1: Tasks for the user test.

#	Task
1	Look at the newest interaction alert.
2	Give the advice “eat cookies” for the top alert (fill in the rest of the response with made up information) and archive the alert.
3	Open an alert from the G3 ward and print it.
4	What is the name of the patient in the oldest not yet handled alert?
5	Which patient (name) has more than one not handled alert?
6	What is the name of the patient with patient ID: 234001?
7	How old is the patient that has been prescribed Acenocoumarol?
8	How old is Lambert and was there an advice given based on the alert?
9	What is the patient ID associated with the newest alert in the archive where an advice was given?

4.4.3 Results

Exploration

During the initial exploration of the prototype pharmacists quickly found their way around the application and seemed at ease with the application. The questions during the exploration part were mainly to confirm their own ideas about parts of the interface.

Tasks

Following the exploration the pharmacists completed nine tasks. The following information was gathered: the time taken to complete the task; task success; number of clicks per task; and the route taken to complete the task.

Everyone was able to complete all of the tasks. Three of the subjects needed to be given a hint about the search field, the hint was given after a participant had been attempting to complete the task for at least 20s. None of the three that received a hint noticed the search field on the top right which made it nearly impossible to complete task seven (How old is the patient that was prescribed Acenocoumarol?) and eight (How old is Lambert and was there an advice given based on the alert?). This indicates that either the search field needs to be made more visually salient or be explicitly mentioned during the introduction of the system.

While the pharmacists were performing the tasks what they said out loud mostly seemed to indicate they were using the interface as it was designed. All made extensive use of the sorting and subset functions. The pharmacists all seemed well aware of the tasks that needed to be completed and were almost always able to directly choose a successful path towards the goal.

The only signs of confusion from the think-aloud results were regarding dates, search tasks when they were not aware of the search field, and that no time (but only a date) was provided with alerts. The dates of alerts were not all logical, some of the alerts actually had dates which were in the future. This caused confusion when they were asked to select the newest or oldest alert (Task 1 and 4, Table 4.1). In the prototype alerts only had a generation date, but not a time. This made tasks where order was important (Task 1 and 4, Table 4.1) confusing. By adding the time as well as the date alerts become more unique and you prevent sorting problems.

Performance Measures

Times The times are heavily influenced by the fact that the data was recorded while the pharmacists were also using the think-aloud protocol. Think-aloud can both make subjects slower and faster in completing their task, they can either go slower so they can explain all their steps or go very fast as they think all actions through before taking them and avoid wrong paths (Lewis and Rieman, 1993). To gather accurate quantitative data the tasks would have to be performed without thinking-aloud and perhaps with a larger group. It is however still interesting to look at the times and their spread. The gathered times can be seen in Figure 4.5 (the individual times, averages per subject and averages per task can be seen in Table G.1), the box plot shows us the median time (black line in the box), the first

and third quartile (beginning and end of the box) and the minimum and maximum time taken.

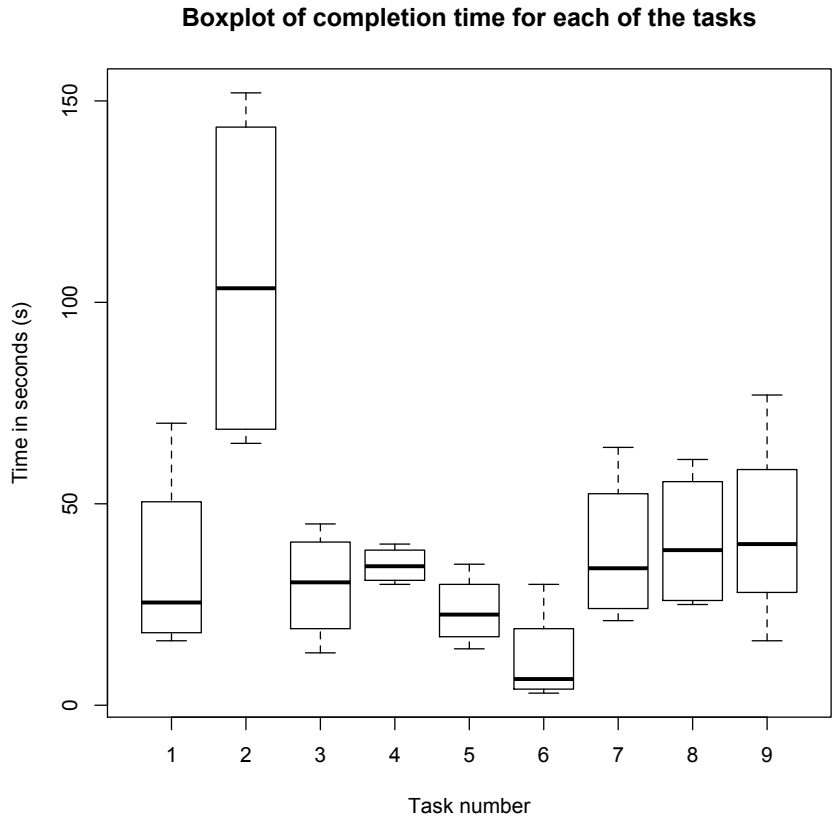


Figure 4.5: Box plot showing the times taken for each of the tasks. The individual times, averages per subject and averages per task can be seen in Table G.1.

Clicks The number of clicks is less influenced by the think-aloud task as is time. The number of clicks can vary for a number of reasons. There are several routes to the goal; people take a wrong approach; and people can click multiple times on the same object. A factor which can also cause slight differences is that each subject starts with a task at the point where they ended the previous task: as you can complete a task using different routes the starting point for a task is not always exactly the same for each of the subjects.

The number of clicks for each of the tasks is shown in a box plot in Figure 4.6 (the individual number of clicks, averages per subject and averages per task can be seen in Table G.2). The spread for the number of clicks is smaller than was the case for the times. All tasks, aside from task two, could be completed in between 2-4 clicks. The average for task 3-9 are all within this range.

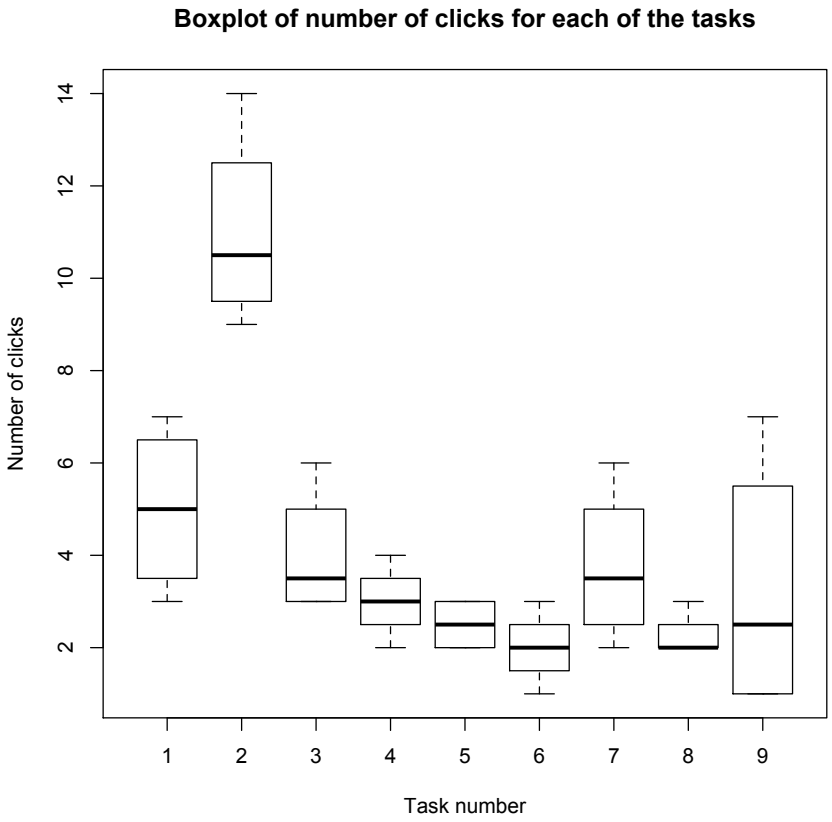


Figure 4.6: Box plot showing the number of clicks for each of the tasks. The individual number of clicks, averages per subject and averages per task can be seen in Table G.2.

There did not appear to be a correlation between time to complete a task and the number of clicks needed. Users that take longer to complete a task, don't specifically take incorrect routes, the extra time is most often due to lengthier explanations. There are a few occurrences where people use many more clicks than required, in these cases the pharmacists were often manually searching through alerts rather than use sorting or the search function.

Interview Results

At the end of the user test the pharmacists were interviewed about their experience with the prototype. During the interviews the pharmacists were able to indicate what they would like to change, what they are missing and what other things they feel could improve the interface.

During the interview each of the types of alerts, and all main parts of the interface (e.g. the patient information and the data table) were discussed. Pharmacists were asked if they would like to change anything, add any information, or had other remarks for each of the components. The results for each of the parts from

the interviews will now be discussed.

Alert Overview When the pharmacists were asked about the content and ordering of the alert overview (the data table) all had different ideas. Some felt the ward was one of the most important pieces of information while others felt this information could easily be left out from the overview. Pharmacists were in disagreement about the order of the columns. One pharmacist indicated that the information in the overview was not very relevant at all as you would have to look at each alert regardless. A list of items that were named as relevant was as following: degree of relevance; patient name; start date medication; stop date medication; prescribing physician and add the time to any dates.

Patient Information When the patient information section was discussed all pharmacist noted they felt "DOB" should be changed to "Geboortedatum" (Dutch word for Date of Birth). Some pharmacists indicated they would also like to see known contra-indications and allergies for the patient and lab results. It was noted by two pharmacist that it was easy enough to access the complete patient information and that this short overview would be sufficient.

Interaction Alerts With regard to interaction information three of the pharmacists indicated that all relevant information was present. The other pharmacist indicated they would like to be able to view the medication history for that specific medication (to determine whether the alert is caused by a change or a new medication order). One pharmacist indicated it would be useful to be able to see the physicians notes. Physicians can add additional information to a prescription, these notes often contain relevant information about the prescription or administration. It was noted that they would like the newest prescription to be on top in the table of prescriptions. Another pharmacist said they would like the "Effect" text to always be visible.

Overdose Alerts With regard to overdose alerts, one of the pharmacists mentioned they would like to be able to see medication history, the medication remark / notes field, and which of the values exceeds recommendations (through a visual indication). Further one pharmacist brainstormed about naming conventions for medication names; these will follow hospital conventions in the actual program.

Route of Administration Alert One pharmacist felt information was missing from the route of administration alerts; they would like to be able to see the remark / notes field.

Review After discussing all the different types of alerts the review section; the section where a pharmacist can record their actions for an alert. Two of the pharmacist mentioned that they would like the options in the advice drop down box to be dependent on the type of alerts: standard advice for an overdose alert is different form advice for an interaction alert.

Archive Finally the pharmacists were asked about the archive section of the prototype. People were generally satisfied with the content and lay-out of this section. When asked about the content and ordering of the data table the results differed again per pharmacist (as they did for the data table for alerts). Additional columns that were named were: pharmacist that handled the alert: patient name and medication name. Pharmacists were positive about the "advice" being one of the columns in the prototype.

4.4.4 Changes

Based on the user test it was determined that several things should be changed. These changes were not implemented in the prototype but included in the user and interface specification (Appendix I). A list of changes following the user test:

- As there was no agreement on which columns should be visible in the data tables, users can now choose their own order and content in the data table. This goes with the philosophy of allowing the user to finish the design A number of additional categories such as patient name and prescribing physician can now be chosen.
- The tree shows whether there are unread alerts in a category. This is both shown by the number behind the category (between brackets) and making it bold.
- The items from the action drop down box are dependent on the type of alert shown. This should keep the list more concise.
- The notes field for medication was added to the table in the alert displays.
- DOB was changed to "Date of birth".
- As the history of a patient is of interest to the pharmacist threading of patient alerts is made possible. Alerts for one patient will be grouped together (including old alerts) to allow easy access to this information.

4.4.5 Conclusion

A nearly functional prototype was developed. This prototype was developed using information gathered from the analysis of the current situation and principles from usability engineering. This resulted in a simple and minimalist interface which is similar to an e-mail application.

The prototype was tested with users during a user test where the users explored the interface, completed a number of tasks and could provide feedback. The prototype was received positively by the pharmacist and all were able to complete the tasks. Feedback from the users suggests that the interface design is likely to be accepted and appreciated by the users.

Chapter 5

Conclusion

The purpose of this thesis was to determine whether the usability of a medication safety system could be improved by providing a new method of interaction. The prototype that was developed to research this question was received with great enthusiasm. Also, the pharmacists are all able to quickly and easily use the program to perform their tasks. The prototype is currently being implemented and will be taken in use by the UMCG Clinical Pharmacy Department.

5.1 Summary

An interface was developed for the new medication safety system in the UMCG. This was done in several steps.

Literature regarding medication safety was reviewed, the review showed the impact errors can have in healthcare. Errors can lead both to higher cost and even possible harm to patients. The effectiveness of computerised measures to combat errors in healthcare was reviewed. While computerised physician order entry systems (CPOEs) and clinical decision support systems (CDSSs) can be beneficial it is important to keep in mind that such systems can also introduce error. An important error-introducing factor in systems is poor design and implementation. It is therefore vital to ensure a system is well designed for the task and the work flow of its intended users.

The development of the new interaction method started with an analysis of the existing system. This analysis considered both performance and general usability of the system. The performance measure showed that only a small portion of alerts were acted upon. Another performance measures after the implementation of the new system should is needed to truly determine performance. A number of issues were found with the current SESOP system. While some, for example manually checking information, were mostly cumbersome others, others could possibly cause harm. An example of such an issue is the delay between prescription and the review of alerts. Delays can be very long and possible problems can already have occurred.

Following the initial analysis of the current system, interviews were held with pharmacists. This was important as the user was to be involved in the entire design process. The interviews were used to gather information about how the cur-

rent system is used, record opinions about system, determine which aspects were considered positive and negative, and gather ideas for the new system. The interviews showed that the pharmacists were not satisfied with the current system. A number of the issues found during the initial analysis were also confirmed by the pharmacists during the interviews. These mainly concerned missing information and lack of archiving or transfer of information.

Using the information gathered during the analysis and the interviews, combined with a knowledge of usability principles a prototype was developed. The prototype was based on an e-mail client and each alert was represented as a message. The prototype was developed using web-technologies, allowing for a nearly fully functional prototype to be developed quickly.

As part of the user centred design process the prototype was also tested by pharmacists. The pharmacists were allowed to explore the application. After initial exploration they were asked to perform a number of tasks. All pharmacists were able to complete the tasks and used the prototype as was expected. Furthermore the pharmacists were very enthusiastic about the prototype and were looking forward to final implementation. The new interface will likely be easily accepted by the pharmacists.

5.2 Future Work

To ensure that the developed prototype is indeed as usable as it is currently perceived it is important to conduct more testing once the system has been in use. Often new problems arise once a system is taken in use. Ideally a final user test would be performed to uncover problems and improve these immediately.

Furthermore it is important to evaluate the quantitative performance of the Gaston system. By comparing the performance of Gaston once it is operational with the baseline measure performed in this thesis it becomes clear whether Gaston had indeed improved performance and to what degree. Such a performance measure might also uncover new problems that are introduced by Gaston.

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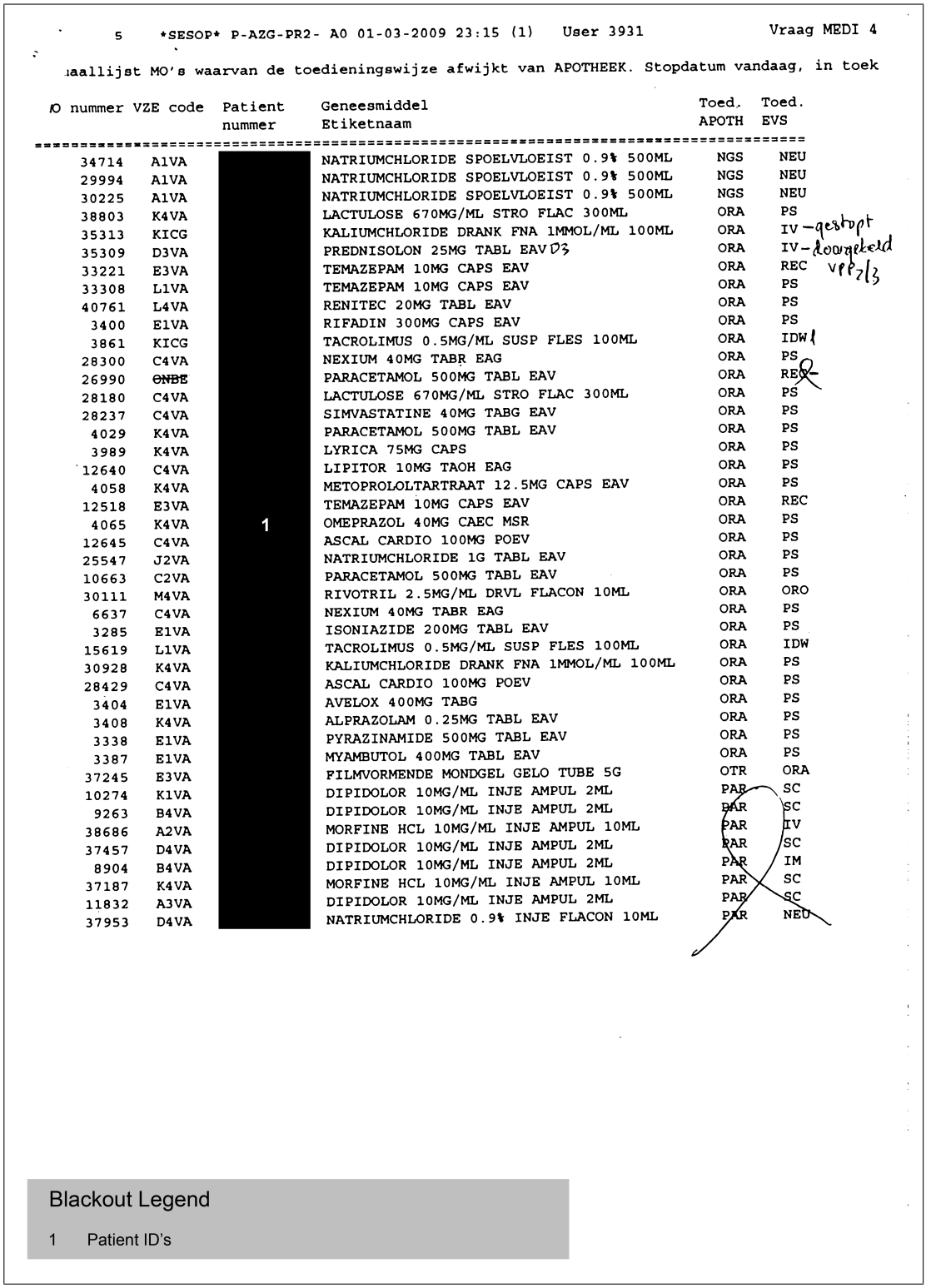
Appendix A

Acronyms

ADE	adverse drug event
CPOE	computerised physician order entry system
CDSS	clinical decision support system
KNMP	Royal Dutch Association for the Advancement of Pharmacy
UMCG	University Medical Centre Groningen
YUI	Yahoo! User Interface Library

Appendix B

SESOP List Examples



5 *SESOP* P-AZG-PR2- A0 01-03-2009 23:15 (1) User 3931 Vraag MEDI 4

aallijst MO's waarvan de toedieningswijze afwijkt van APOTHEEK. Stopdatum vandaag, in toek

O nummer	VZE code	Patient nummer	Geneesmiddel Etiketnaam	Toed. APOTH	Toed. EVS
34714	A1VA	[redacted]	NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
29994	A1VA		NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
30225	A1VA		NATRIUMCHLORIDE SPOELVLOEIST 0.9% 500ML	NGS	NEU
38803	K4VA		LACTULOSE 670MG/ML STRO FLAC 300ML	ORA	PS
35313	KICG		KALIUMCHLORIDE DRANK FNA 1MMOL/ML 100ML	ORA	IV – gestopt
35309	D3VA		PREDNISOLON 25MG TABL EAV D3	ORA	IV – doorgekeerd
33221	E3VA		TEMAZEPAM 10MG CAPS EAV	ORA	REC vpp 2/3
33308	L1VA		TEMAZEPAM 10MG CAPS EAV	ORA	PS
40761	L4VA		RENITEC 20MG TABL EAV	ORA	PS
3400	E1VA		RIFADIN 300MG CAPS EAV	ORA	PS
3861	KICG		TACROLIMUS 0.5MG/ML SUSP FLES 100ML	ORA	IDW
28300	C4VA		NEXIUM 40MG TABR EAG	ORA	PS
26990	~~ONBE~~		PARACETAMOL 500MG TABL EAV	ORA	RE
28180	C4VA		LACTULOSE 670MG/ML STRO FLAC 300ML	ORA	PS
28237	C4VA		SIMVASTATINE 40MG TABG EAV	ORA	PS
4029	K4VA		PARACETAMOL 500MG TABL EAV	ORA	PS
3989	K4VA		LYRICA 75MG CAPS	ORA	PS
12640	C4VA		LIPITOR 10MG TAOH EAG	ORA	PS
4058	K4VA		METOPROLOLTARTRAAT 12.5MG CAPS EAV	ORA	PS
12518	E3VA		TEMAZEPAM 10MG CAPS EAV	ORA	REC
4065	K4VA	1	OMEPRAZOL 40MG CAEC MSR	ORA	PS
12645	C4VA		ASCAL CARDIO 100MG POEV	ORA	PS
25547	J2VA		NATRIUMCHLORIDE 1G TABL EAV	ORA	PS
10663	C2VA		PARACETAMOL 500MG TABL EAV	ORA	PS
30111	M4VA		RIVOTRIL 2.5MG/ML DRVL FLACON 10ML	ORA	ORO
6637	C4VA		NEXIUM 40MG TABR EAG	ORA	PS
3285	E1VA		ISONIAZIDE 200MG TABL EAV	ORA	PS
15619	L1VA		TACROLIMUS 0.5MG/ML SUSP FLES 100ML	ORA	IDW
30928	K4VA		KALIUMCHLORIDE DRANK FNA 1MMOL/ML 100ML	ORA	PS
28429	C4VA		ASCAL CARDIO 100MG POEV	ORA	PS
3404	E1VA		AVELOX 400MG TABG	ORA	PS
3408	K4VA		ALPRAZOLAM 0.25MG TABL EAV	ORA	PS
3338	E1VA		PYRAZINAMIDE 500MG TABL EAV	ORA	PS
3387	E1VA		MYAMBUTOL 400MG TABL EAV	ORA	PS
37245	E3VA		FILMVORMENDE MONDGEL GELO TUBE 5G	OTR	ORA
10274	K1VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
9263	B4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
38686	A2VA		MORFINE HCL 10MG/ML INJE AMPUL 10ML	PAR	IV
37457	D4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
8904	B4VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	IM
37187	K4VA		MORFINE HCL 10MG/ML INJE AMPUL 10ML	PAR	SC
11832	A3VA		DIPIDOLOR 10MG/ML INJE AMPUL 2ML	PAR	SC
37953	D4VA		NATRIUMCHLORIDE 0.9% INJE FLACON 10ML	PAR	NEU

Blackout Legend

1 Patient ID's

Figure B.1: A Non-Standard Route of Administration alerts list. On this list there are several markings made the pharmacist. On line 5 a medication has been prescribed which should be administered orally but which was marked as intravenously. The pharmacist has checked the system and found that this prescription was already stopped. This is written down on the list for future reference. On line 6 there is another marking from the pharmacist. The pharmacist checked the system and found this error to still be current and then contacted the ward by telephone to alert them. This is also noted on the list: "called vpp 2/3". Finally there is curl marking that the entire list has been checked and looked at by the pharmacist.

Figure B.2: An interaction alert list. On this list there are two markings made by the pharmacist. Next to the first alert the pharmacist has written: “levels?”. Meaning that because of the the interaction certain levels have to be checked. After looking up this patient, it is noted that there were levels recorded. A curl is added to indicate this has been dealt with. Next to the second alert there is a somewhat more ambiguous note saying: “12/03 (date) all kinds of things have changed”. From this note it is not possible to draw any conclusions about the alert.

Pag. 1 *SESOP* P-AZG-PR2- A0 15-03-2009 23:09 (1) User 1547 Vraag MEDI 41 Lijst MEDI 40 Pag. 1

SIGNAALLIJST INTERACTIES VOOR AFDELING 1e Verd. Coron.Care Gebouw C

actiedatum Patient
Arts 1 Arts2
MPK_naam 1 MPK_naam 2 Int.code relevantie
15-03-2009 M
1 S.S.P. 1 S.S.P.
TAMSULOSINE HYDROCHLORIDE ORA CAPR METOPROLOL SUCCINAAT ORA TABR 78 1
1 DD 0.4000 mg 1 DD 1.0000 stuk
Bij de eerste dosis van een alfablokker kan acute hypotensie optreden;
bij
toevoeging aan een betablokker of calciumantagonist kan dit effect
worden
versterkt. Het betreft hierbij doorgaans oudere mannen bij wie een
plotse
daling van de bloeddruk grote gevolgen kan hebben.
Advies:
- Alfablokker in gewoon preparaat: vertel de patient de alfablokker bij
voorkeur 's avonds en zittend (op de bedrand) in te nemen, en niet
plotseling op te staan.
- Alfablokker in preparaat met gereguleerde afgifte: vertel de patient
dat

CIPROFLOXACINE (ALS HYDROCHLORI ORA TAOH ACENOCOUMAROL ORA TABL 566 1
2 DD 500.00 mg VAR! mg
Antibiotica versterken indirect het effect van cumarines. Hierdoor
neemt de stollingstijd toe. Het versterkte effect van cumarines is
waarschijnlijk het gevolg van een verhoogde afbraak van
stollingsfactoren gedurende de koortsperiode.
Advies:
Instrueer de patient contact op te nemen met de trombosedienst.

AMIODARON HYDROCHLORIDE ORA TABL ACENOCOUMAROL ORA TABL 531 1
1 DD 200.00 mg VAR! mg
Het effect van de cumarine kan toenemen door amiodaron of propafenon.
Hierdoor neemt de stollingstijd toe.
Advies:
Instrueer de patient bij dosiswijziging of staken van amiodaron of
propafenon contact op te nemen met de trombosedienst.

INR 3.1

16/3

5

Blackout Legend

1 Name prescribing doctor / nurse practitioner
2 Patient ID
3 Name of patient
4 Date of birth patient
5 Pharmacists Signature

Figure B.3: An interaction alert list. On this page there are three markings. There is a curl on the first alert to indicate this is OK. There is not further indication how this was determined. Next to the second alert there is a note: "INR 3.1". The explanation explains that blood clotting problems can occur and the pharmacist has therefore checked if the INR level is in the normal range and noted the value. On the bottom right there is a signature and date written by the pharmacist indicating that he is checking this list on the given date. These signatures only appear on the first page of each interaction alert list.

Figure B.4: An interaction alert list. This page is an example of a problem existing in the current system. Sometimes alerts are printed incorrectly, this makes the alert very difficult to read.

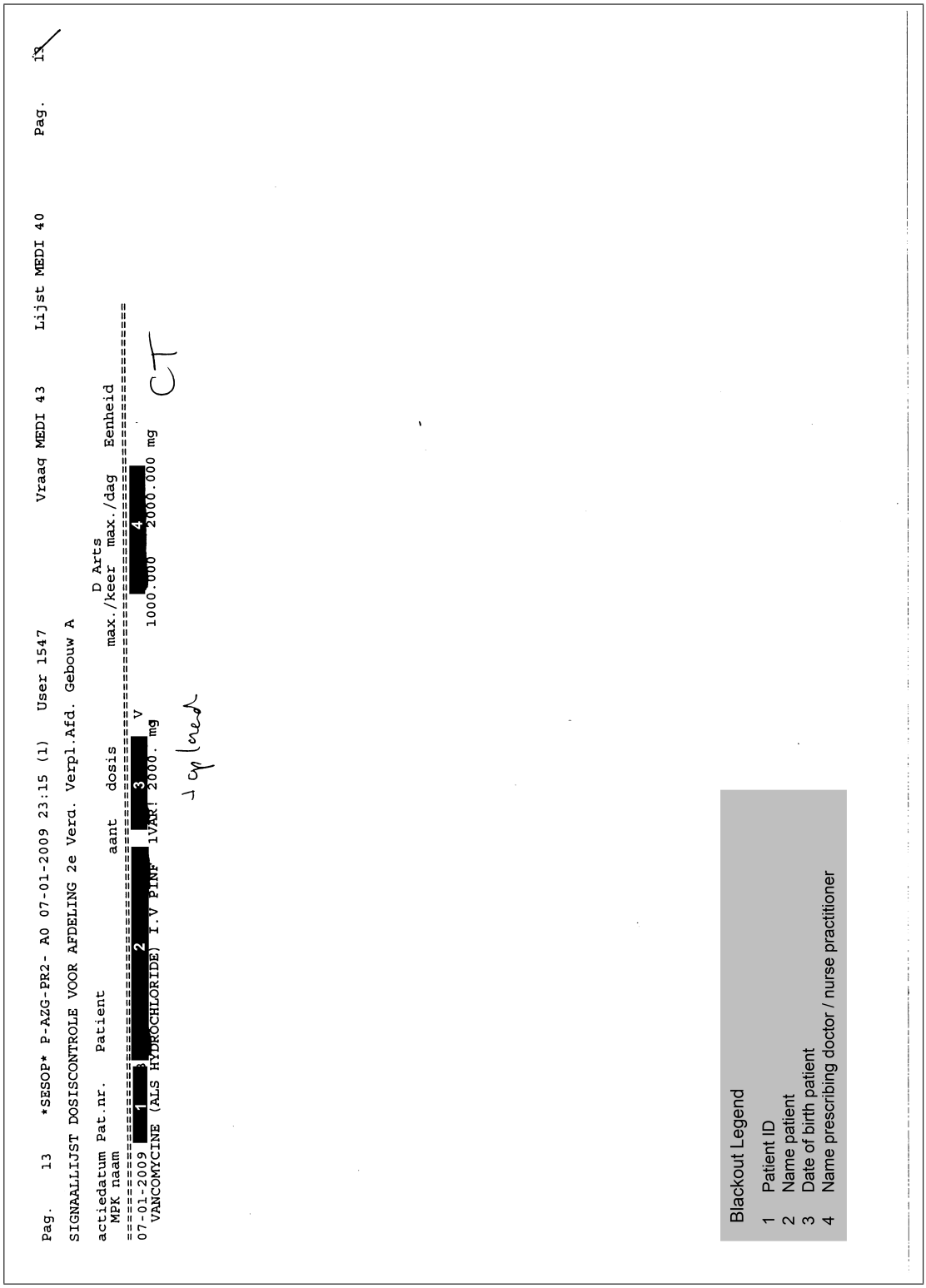


Figure B.5: An overdose alert list. This page only contains a single alert, each page will only contain alerts regarding one patient. The pharmacist has noted “increasing” beneath and “CT” next to the alert. The pharmacist has found out that this prescription is in preparation of a CT and the dosage (which is reported to be variable on the printed list) is increasing.

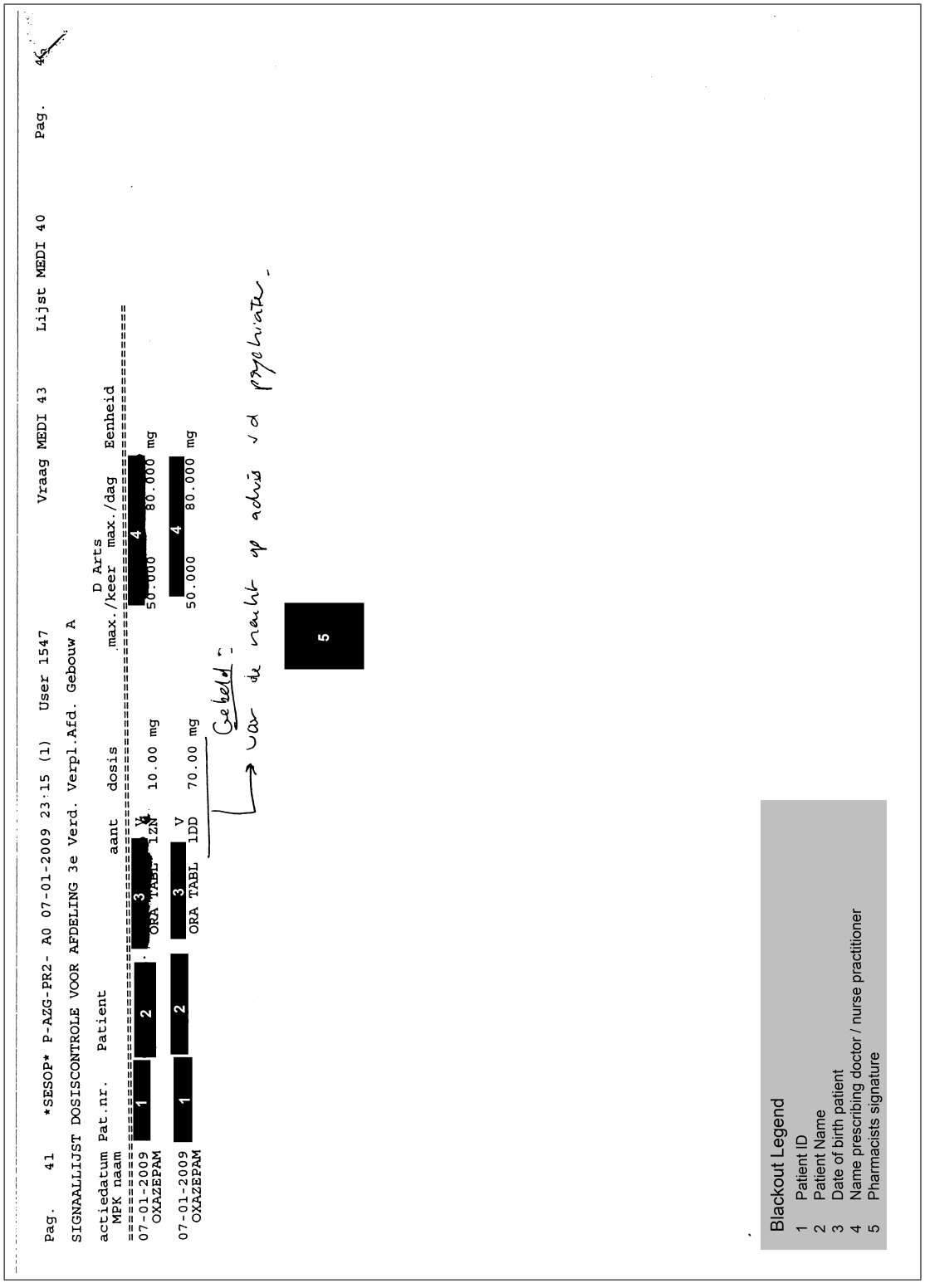


Figure B.6: An overdose alert list. This page contains two overdose alerts. The pharmacist has called the prescribing physician to find out the reason behind the second high dose. Apparently this was prescribed during the night on advice of a psychiatrist. The pharmacist documents this information by writing it on the page. This page is also signed by the pharmacist.

Appendix C

SESOP List Scenarios

Below are three scenarios describing the manner in which interaction with the SESOP lists takes places. In each scenario is described how a (clinical) pharmacist reviews the list. This includes both the interaction with the list itself as well as influences from the environment. Images of all these lists can be found in Appendix B.

C.1 Route of Administration List Scenario

Theo is a pharmacist in the hospital pharmacy. Today he is assigned to check the SESOP lists which were generated last night based on the prescriptions of the previous day. Besides checking the SESOP lists Theo is also on-call for the clinical trials.

He starts by picking up the all the SESOP lists around 10 o'clock in the morning from the pharmacy front office desk. He puts the stack of circa 100 pages on his desk. He starts by checking other alerts lists. After having done this he moves on to checking the "non-standard route of administration" list. Today this list consists of 8 pages.

The first part of the list can be checked quickly since the system does not always efficiently evaluate the route of administration. He quickly looks through the IMV alerts for any alerts that are not recorded as IV of IM. After this Theo gets yesterday's list from the front office desk to be able to compare for new alerts.

Theo finds an alert which could prove problematic. He opens up the digital patient-record (the patient information system) application and types in the seven digit patient number. He then opens up the medication prescription tab to check if the prescription has been changed since the SESOP list was generated. It turns out the doctor already changed the prescription and the problem has already been solved. Theo scribbles "changed" next to the alert.

As Theo continues checking the list for possible problems Rita walks in. There is a problem with a prescription that is being prepared in the pharmacy. Theo discussed the problem with her and in the end walks to the pharmacy to try and resolve the problem. After the problem is resolved Theo goes back to the SESOP list. In between checking the list he also keeps an eye on his e-mail to make sure he does not miss any urgent e-mails.

When Theo finds another potential problem he checks the patient information system again to determine whether this problem is still current. When he finds it is, he decides to contact the doctor. Since the problem is not life threatening he decides to contact the doctor via e-mail. He uses the doctors name from the electronic patient dossier and types in his last name in his e-mail program. The program then offers suggestion of address to auto-complete with, Theo chooses the correct address.

While writing his e-mail Theo receives a phone call from a clinical trial with a question regarding a specific prescription. Theo checks this prescription in the patient information system and informs the lab about what needs to be done.

After his interruption Theo resumes writing his e-mail. He informs the doctor about the incorrect route of administration which was discovered. In his e-mail he refers to the patient using their 7 digit patient code. After writing the e-mail Theo also writes on the list that he has contacted the doctor by e-mail by adding "e-mailed" next to the alert.

In this manner Theo checks the entire list.

C.2 Overdose List Scenario

After checking the route of administration list Theo turns his attention to the overdose list. For each alert he looks at the prescribed dosage and frequency and the maximum values for this certain medication.

Theo comes across a high dosage for a certain heart medication. He then checks which ward the patient is on, this appears to be the cardiology ward and the prescribing doctor is also a cardiologist. As the medication is not yet in the region which is considered dangerous in the hospital Theo takes no further action.

Next Theo encounters another high dosage for a certain medication and the frequency is also noted as variable (which in itself causes the medication to occur on the overdose list). After checking the patient information in the patient information system Theo discovers that the prescription was given in preparation of a CT scan. He noted on the alert page that this was due to a CT scan by adding "CT" next to the alert.

When Theo is checking another patients medical records one of the assistants walks in with a question. Theo goes with her to solve the problem. After coming back he also sends a quick e-mail to one of his colleges about a drug trial. Then Theo looks at his screen and sees lab information for a patient on his screen. He checks the list again and determines that the levels of this patients are OK and no action needs to be taken at the moment.

As Theo checks the final page of the overdose alert list he encounters an unusually high dosage. When checking the patient information in the patient information system he does not find any indication why such a high dose should be prescribed. He decides to contact the department to ask about this prescription. It turns out that the prescription was written on advise of a psychiatrist for the night. As this psychiatrist is aware of the high dosage and feels it is safe the prescription remains as it is.

C.3 Interaction List Scenario

After finishing the other two lists Theo start on the interaction alert list. After several alerts he comes across an alert which increases the chance of internal bleeding, especially in the stomach. Theo knows that in this case stomach protection is needed. He checks in the the patient information system system whether there is already a prescription for stomach protection. This does not appear to be the case, Theo writes an e-mail to the physician alerting him that this should be done as soon as possible.

During checking another alert Theo accesses the Royal Dutch Association for the Advancement of Pharmacy (KNMP) online knowledge bank to find some extra information about a certain medication. After he is sure the problem does not need an action he moves on checking the alerts.

When Theo finds an alert where to medication can cause decreased blood-clotting. In such a case it is important to monitor the patients INR level and make sure this is within normal range. Theo jots down “INR” next to the alert and looks up the patient. It appears that levels have been tested and the INR level is within normal range. Theo writes down the value on the alert page for future reference. After this he moves on to the next alert.

He checks some more levels but does not find any other alerts which require action. He puts his signature on the front of the list to indicate he has reviewed the entire list. After this the list is returned to the pharmacy front office desk.

Appendix D

Interview Scheme

The interview scheme used for the initial interviews. The goal of these interviews was to make clear how people are using the SESOP system to review alerts and what their wishes and demands for a new interface are. The interview consists of three main itemise: demographics, quantitative information and open questions.

Demographic

- Age:
  - 21-30 / 31-40 / 41-50 / 51-60 / 61+
- Function:
  - Pharmacist / Pharmacist in training / Hospital Pharmacist
- Number of years working as a pharmacist:
  - 0 / 1-5 / 6-10 / 11-15 / 16-20 / 20+
- Number of years working as a pharmacist in the UMCG:
  - 0 / 1-5 / 6-10 / 11-15 / 16-20 / 20+

Quantitative

- How often do you use the SESOP lists?
  - Daily / Weekly / Monthly / Rarely / Never
- How long does it take on average to check all alerts for one day? (including interruptions)
  - 0-1 hour / 1-2 hours / 2-3 hours / 3-4 hours / 4+ hours
- How often are you generally interrupted (telephone, e-mail, etc.) when checking the alerts?

  - Never / Sometimes / Regularly / Often / Very often

- Which external sources do you use when checking the alerts?

	Never	Sometimes	Regularly	Often	Very often
Poliplus / ZIS					
KNMP Knowledgebank					
CBG Website					
UMCG Intranet					
Other (e.g. Micromedex, Farmocotherapeutisch Kompas, Kinderformularium.nl)					

Open Questions

- What is your opinion about the SESOP list?
- Do you find the lists pleasant to work with?
- Do you find the lists easy to work with?

Lists

For each type of lists (overdose, interaction and non-standard route of administration) the questions below will be asked.

- What do you like about this list and why?
- What don't you like about this list and why?
- Which information on the list can be removed?
- Which information is missing from the list and should be added?
- Other remarks

Table D.1: Indicate to which degree you agree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree.

Archiving

- Which information would you like to be able to record when reviewing and archiving an alert?
- Is there anything you would change in the manner in which an alert is resolved (feedback physicians)

Table D.1: Indicate to which degree you agree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree

	1	2	3	4	5
It is easy to check the alerts.					
I can check the alerts quickly.					
The list is pleasant to use.					
The information on the list is clearly represented.					
The information on the list is easy to understand.					
I can always find all the information I need.					
The lay-out of the list is clear.					
The lay-out of the list is pleasant.					
The list contains all the information I expect.					
I am satisfied with the list.					

Prototype

- What do you think off the prototype (Figure H.1)?
- Do you have any thoughts / ideas etc. about the new interface?

Appendix E

Interview Results

	1	2	3	4	5
It is easy to check the alerts.	**C**	**B**	**D**	**A**	
I can check the alerts quickly.		**BCD**	**A**		
The list is pleasant to use.		**ABCD**			
The information on the list is clearly represented.		**A**	**BCD**		
The information on the list is easy to understand.			**BCD**	**A**	
I can always find all the information I need.	**B**	**ACD**			
The lay-out of the list is clear.		**C**	**ABD**		
The lay-out of the list is pleasant.		**ABC**	**D**		
The list contains all the information I expect.	**B**	**AC**	**D**		
I am satisfied with the list.	**C**	**ABD**			

Table E.1: An overview of the response to the statements concerning the interaction lists. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree."

	1	2	3	4	5
It is easy to check the alerts.			**CD**	**B**	**A**
I can check the alerts quickly.		**CD**	**B**	**A**	
The list is pleasant to use.		**CD**		**AB**	
The information on the list is clearly represented.	**C**		**D**	**AB**	
The information on the list is easy to understand.		**C**	**D**	**AB**	
I can always find all the information I need.		**ABD**	**C**		
The lay-out of the list is clear.		**C**	**D**	**AB**	
The lay-out of the list is pleasant.		**CD**	**A**	**B**	
The list contains all the information I expect.	**BC**	**AD**			
I am satisfied with the list.		**C**	**AD**	**B**	

Table E.2: An overview of the response to the statements concerning the overdose lists. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree."

	1	2	3	4	5
It is easy to check the alerts.	**B**	**AC**	**D**		
I can check the alerts quickly.		**AD**	**BC**		
The list is pleasant to use.	**AB**	**CD**			
The information on the list is clearly represented.	**AB**		**CD**		
The information on the list is easy to understand.	**B**		**ACD**		
I can always find all the information I need.	**ABC**	**D**			
The lay-out of the list is clear.	**A**		**BCD**		
The lay-out of the list is pleasant.	**A**	**CD**	**B**		
The list contains all the information I expect.	**ABC**	**D**			
I am satisfied with the list.	**AB**	**CD**			

Table E.3: An overview of the response to the statements concerning the route of administration lists. Above the table it said: "Indicate to which degree with the following statements (1-5): 1 stands for strongly disagree and 5 for strongly agree."

Appendix F

User Test Scheme

All the materials below were presented to users in Dutch, they have been translated for this thesis. The user test consisted of 4 main parts: the introduction letter, discovering the interface, a number of tasks during which they would TALK-ALOUD, a short demo and a short interview. Below will be the letter, the tasks and the questions asked during the interview.

F.1 Introduction Letter

Welcome

Thank you for taking part in this user test.

Today we will look at the prototype I have developed. It is important for me to know how you are using the system (and whether the design needs to be adapted to your working method), if there are problems with the interface or if there are things that bother you. All feedback (positive and negative) is very welcome, together we can make sure the final application will satisfy your needs and demands.

The prototype is not a fully functional version of the application and you can at times receive alerts about what should have happened for a specific action. It is also possible that there are small errors in the prototype which are not intended but have not yet been removed.

Set-Up

I will now give you a short overview of the set-up of this user test. If after reading this letter things are unclear please ask.

1. Read this introductory letter (circa 5 minutes).
2. Independently discover the interface by using it and trying this out. At this time you are allowed to ask questions.
3. Performing a number of small tasks. During these tasks you are asked to perform certain actions of find information in the program (circa 10 minutes). During these tasks I would like to ask you to constantly talk out loud. This should be things like:

- What are you doing
- Why are you doing something
- What do you expect to happen when you do something
- What do you like and what don't you like

This is known as the THINK ALOUD protocol. This will hopefully make it clear to me if there and where there are problems in the interface.

During these tasks you cannot perform "badly", we are testing the interface not your performance.

During this task I will not answer any questions. By not answering questions it should become clear whether the interface is intuitive enough to instantly use. After the tasks I can answer any questions you might have.

4. A short DEMO about features in the interface you might have missed.
5. A short interview about the different aspects of the interface. We will discuss the strong and weak points, information you are missing or whether there is too much information.

F.2 Tasks

1. Look at the newest interaction alert.
2. Give the advice "eat cookies" for the top alert (fill in the rest of the response with made up information) and archive the alert.
3. Open an alert from the G3 ward and print it.
4. What is the name of the patient in the oldest not yet handled alert?
5. Which patient (name) has more than one not handled alert?
6. What is the name of the patient with patient ID: 234001?
7. How old is the patient that has been prescribed Acenocoumarol?
8. How old is Lambert and was there an advice given based on the alert?
9. What is the patient ID associated with the newest alert in the archive where an advice was given?

F.3 Interview

Alerts

- Is there other of more information you would like to see in the alert overview (other columns)? NOTE: Space available is limited.
- Would you like to change the order of the columns?
  - If so, how?

Patient Information

- What do you think about the patient information overview?
- Do you feel there information missing?
  - if so, which information?

Interaction

- Are you missing information for the overview of this type of alert?
  - If so, which?
- Is there information which you would like to be shown in a different format?

Overdose

- Are you missing information for the overview of this type of alert?
  - If so, which?
- Is there information which you would like to be shown in a different format?

Route of Administration

- Are you missing information for the overview of this type of alert?
  - If so, which?
- Is there information which you would like to be shown in a different format?

Review alert

- Is there more or other information you would like to be able to note?
- Are there fields which are unneeded?
- What do you feel about the difference between “Archive” and “Monitor”?
  - Would you like to give this another name, and so which name?

Archive

- Is there other of more information you would like to see in the alert overview (other columns)? NOTE: Space available is limited.
- Would you like to change the order of the columns?
  - If so, how?
- How do you feel about the information shown in the information table about how the alert was handled?
- Would you like more / different subdivisions of the information under the archive portion of the tree?

Appendix G

User Test Results

Table G.1: Times to complete the tasks for each of the pharmacists, showing the average, median and standard deviation per task as well as per subject.

	Subjects						
Task	1	2	3	4	Average	Median	SD
1	16	20	70	31	34.25	25.5	24.66
2	152	72	135	65	106	103.5	43.95
3	45	13	25	36	29.75	30.5	13.84
4	37	32	40	30	34.75	34.5	4.57
5	25	14	35	20	23.5	22.5	8.89
6	30	3	5	8	11.5	6.5	12.50
7	64	41	21	27	38.25	34	19.10
8	50	61	27	25	40.75	38.5	17.63
9	40	16	77	40	43.25	40	25.18
Average	51.00	30.22	48.33	31.33			
Median	40	20	35	30			
SD	40.41	23.50	39.80	15.67			

Table G.2: Clicks to complete the tasks for each of the pharmacists, showing the average, median and standard deviation per task as well as per subject.

	Subjects						
Task	1	2	3	4	Average	Median	SD
1	6	3	7	4	5	5	1,83
2	10	9	14	11	11	10,5	2,16
3	3	3	4	6	4	3,5	1,41
4	3	3	4	2	3	3	0,82
5	3	2	3	2	2,5	2,5	0,58
6	3	2	1	2	2	2	0,82
7	3	6	2	4	3,75	3,5	1,71
8	2	3	2	2	2,25	2	0,50
9	1	1	7	4	3,25	2,5	2,87
Average	3,78	3,56	4,89	4,11			
Median	3	3	4	4			
SD	2,68	2,46	4,01	2,93			

Appendix H

Mock-ups

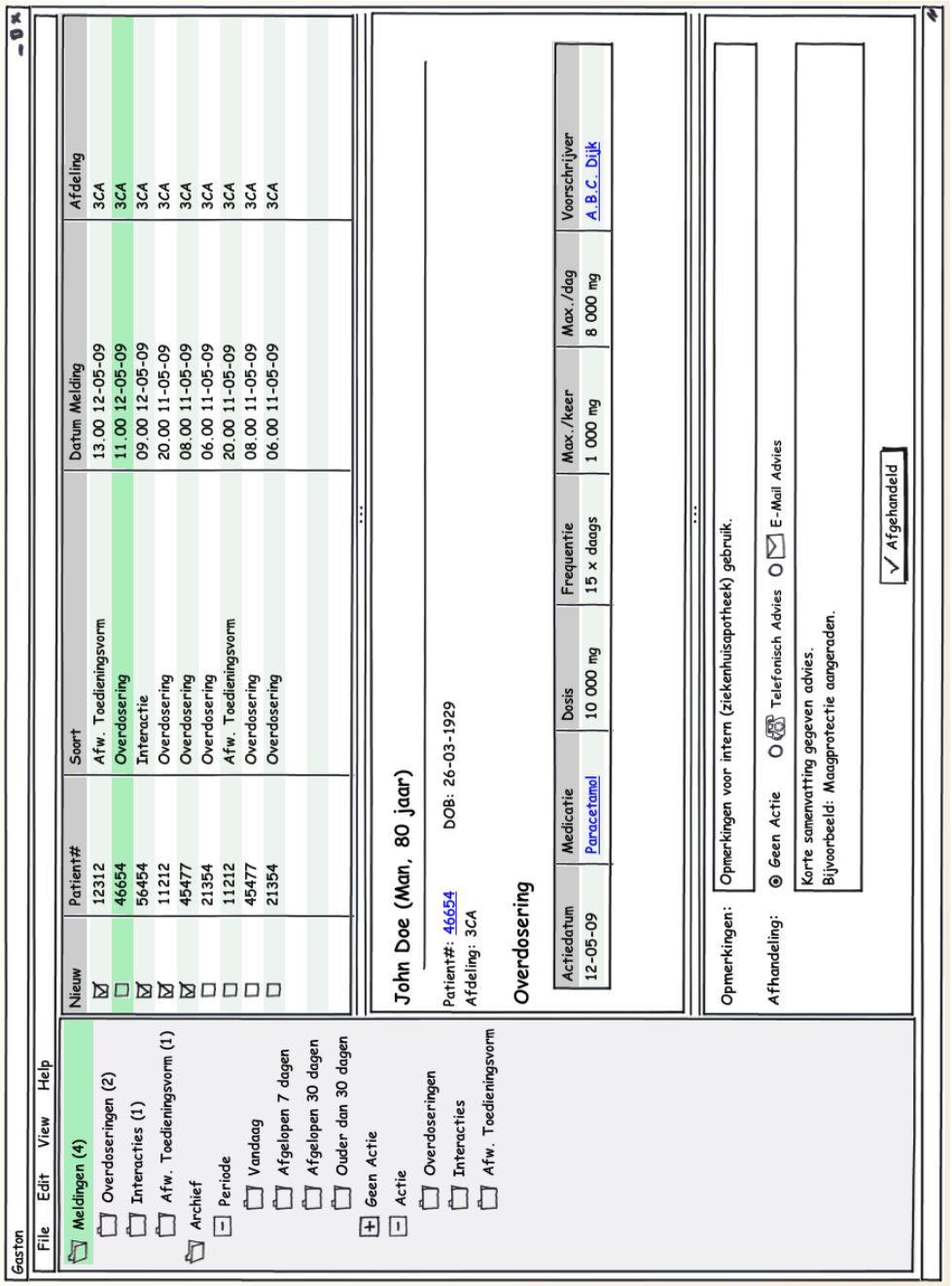


Figure H.1: A simple initial mock-up for the interface of the Gaston application. This incomplete (and completely static) mock-up was used to gather ideas about the wishes and demands for a new interface. By using a simple example it becomes easier to converse about an interface.

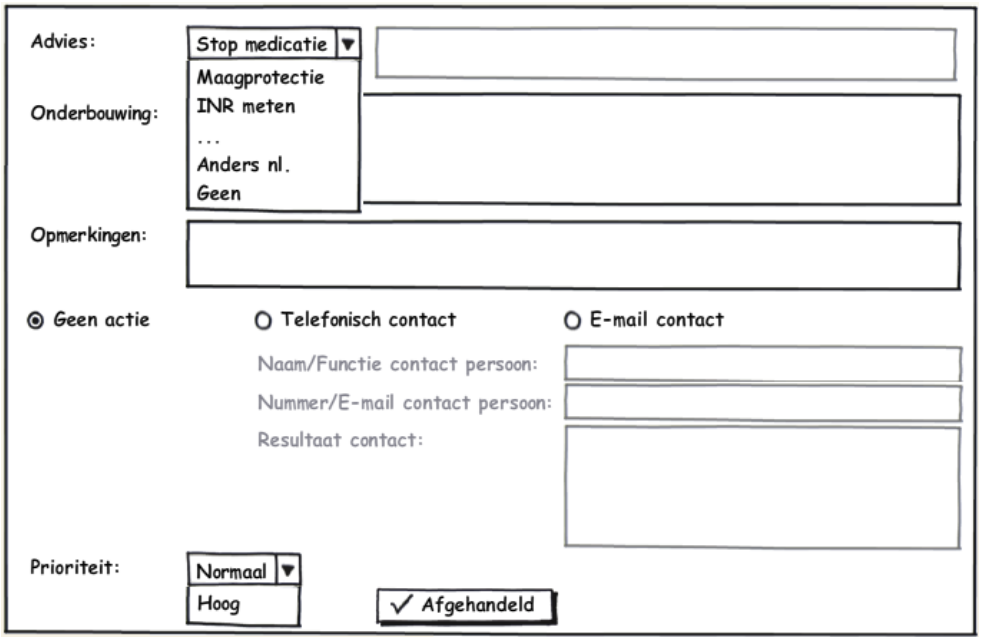


Figure H.2: An example of a simple mock-up of the action panel. The mock-up is very similar to the actual implementation in the prototype (which can be seen in Figure I.15).

Appendix I

User Interface and Interaction Specification

I.1 Notes

- The information in the text is the proper specification, meaning that when the text and what is seen in the screenshots and prototype differ: the text is always correct. The changes from a later stadium are not reflected in the prototype and are only described in the text.
- A working version of the prototype (not fully functional and with some bugs) can be found here: http://kdoes.nl/sites/gaston. The prototype was developed for Safari (Mac OS X) but can also be viewed in Firefox and Chrome. It does not function correctly in IE6 (other versions are untested).
- All the images have been placed at the end of the document.

I.2 General

The application can be used to :

- View Alerts
- Record actions taken by a (hospital) pharmacist for an alert
- Archive or monitor alerts after taking action
- View archived or monitored alerts; showing both the alert and the action taken.

The intended users of the application are hospital pharmacists. By logging in to the application at the start of a session the identity of the user can automatically be added to alerts when actions are taken.

The alerts which are shown and handled are generated by the Gaston application. Gaston uses the Colbert link to extract information from the Hospital Information System. Possibly other databases with information need to be composed

(e.g. mapping between medication and a link to that specific medication on the KNMP site).

I.2.1 Look and Feel

The prototype has a very clean look and feel. The actual implementation should strive to have a similar clean look. Where possible light colours should be used.

Wherever possible standard OS widgets and conventions should be used in the implementation, allowing users to be instantly familiar with what they see. Another advantage is that the application will look good regardless of the display settings or OS version used by the user.

For the sizing and spacing of the controls and elements please take into account Microsoft recommendations:
http://msdn.microsoft.com/en-us/library/aa511279.aspx#sizingspacing.

I.2.2 Authentication

Preferably the authentication when logging on to the hospital network is automatically used. The main purpose of this is to be able to record which pharmacists handles alerts. If automatic network authentication is not usable, the user starts the application and logs on separately.

I.3 Lay-Out

The application has a total of four different views: main view, archive view, monitor view and search view. The archive and monitor view are actually identical in build-up and differ solely in information displayed. Some elements are repeated between views and will have the same letter in the wireframes.

- Wireframe main view (Figure I.1): The main view is used to view alerts which have not yet been dealt with. This view also allows the user to record which action was taken for an alert and either archive or monitor the alert.
- Wireframe archive/monitor view (Figure I.2): The archive/monitor view is used to view alerts which have been archived or marked as “monitor”, this view includes the action taken by the user. It is also possible to reopen an alert placing it back in the main view.
- Wireframe search view: Figure I.3: The search view is used to view a list of results from a search. The search results will remain in the table (Panel C) when an alert is clicked. After clicking on one of the found alerts, the layout will then either be similar to the main or archive/monitor view depending on the type of alert which is clicked.
- Screenshot prototype main view: Figure I.4.

Now each of the panels will be discussed, both the way the information is laid out and how the application functions will be described.

I.3.1 Panels

Below each of the panels from the wireframes will be discusses in more detail.

Panel Sizes

- Width
  - Panel A: width is 100%.
  - Panel B: width is 20%.
  - Panels C, D, E: width is 80%.
  - The width of panel B can be resized using a "grab bar". When B is resized the width of C - E is resized as well to come to 100%.
- Height
  - Panel A: height is approximately 40 pixels.
  - Panel B: height is $100\% - 40$ pixels.
  - Panels C, D, E: height is initially equally distributed $((100\% - 40)/3)$ between the tree panels.
  - Panels C and D: when panel E is not present (archive view), the height is initially equally distributed between C and D.
  - The height of panels C and E can be changed using a "grab bar".
    - When C is resized, the size of D changes to accommodate this.
    - When E is resized, the size of D changes to accommodate this.
    - When a user wishes to resize D either the grab bar from panel C or E can be used.
  - If the content of the panel extends beyond the visible area; add a scrollbar.
- Persistency
  - Resizing of panels should be retained between sessions. E.g. if a user changed the width of panel B to 50% it should also be 50% when restarting the application.
  - Resizing of panel B is visible in all views and should be retained between sessions.
  - Resizing panels C-E (for e.g. panel C which is in all views) are not persistent between views and can be changed independently and should be retained between sessions. E.g. panel C may be 50% in the archive view while being 10% in the alert view.

I.4 Panel A - Toolbar

The toolbar will generally be the same for all the different views. All the buttons it contains will be a combination of a simple icon and text. The text can either be placed below or besides the icon.

Examples of icons / functions that could be added here:

- Print alert button: Create a print-friendly version of an alert.
- E-mail alert button: Create an e-mail friendly version of an alert and (?) automatically paste this in an e-mail.
- Re-open alert: When an alert from the Archive is re-opened, the alert should be returned to the alert overview. In the alert information field the archive information (how it was handled, see Figure I.14)is still present, if an alert has a new action taken a second field of archive information should be added. This should only be available for archived and monitored alerts.
- Archive alert: When there is no further need to monitor a "monitor" alert this allows it to be removed from the monitor section and added to the archive section. This should only be available for monitored alerts.
- Links to resources which are used by pharmacists. Examples: KNMP databank,

Search Field At the far right of the toolbar there is a search field, which is indicated by the use of a magnifying glass. The search field is a "Regular search" as specified here: http://msdn.microsoft.com/en-us/library/aa511489.aspx. Searches are performed on all the fields which are named under the Panel C section.

I.5 Panel B - Tree

Panel B contains a tree which can be used to navigate between groups of alerts. A screenshot from the tree as it was implemented in the prototype is in Figure I.5. The tree can be used to switch between the different views of the application: alert view, monitor view, archive view. In the prototype the tree can also be used to view different subsets of alerts. Subsets that were shown in the prototype were:

- Alert view
  - Overdose alerts
  - Interaction alerts
  - Route of Administration alerts
- Monitor & Archive view
  - Overdose alerts
  - Interaction alerts
  - Route of Administration alerts
  - Today's alerts
  - Last 7 days
  - Last 30 days
  - Older then 30 days
  - Action [alerts where an action has been taken]
  - No Action [Alerts where no action was taken]

Filters Users should also be able to create their own folders in the tree based on filters. A user could for example create a folder which contain all alerts which involve a specific medication or patients in a specific age-range. Alerts are not moved to this folder, but merely be displayed below this folder as well. A user can only see their own custom filtered alerts.

Behaviour and Properties The behaviour and some of the important features of the tree are described below:

- The tree is the same for all views and does not change.
- The tree always indicates the current location by highlighting it in the tree.
- The collapsed and extended nodes persist between sessions. E.g. if "Archive" is collapsed, it will stay collapsed until explicitly extended by the user.
- Nodes in the tree are bold when there are unviewed alerts contained in that node.
- The number of unviewed alerts is also indicated between "()" after the node name.
- The monitor node is always bold whenever there are alerts being monitored regardless if they are marked as unviewed or not.

I.6 Panel C - Data-table

A screenshot from the data-table as it was implemented in the prototype can be seen in Figure I.6.

- General
  - **Fixed headers:** The column headers should be fixed to the top of the frame / panel.
  - **Scrollable:** If the table with records exceeds the current height of the panel a scrollbar should appear on the right.
- Columns
  - **Sortable columns:** All columns are sortable. An arrow and colour change indicates by which column is currently sorted.
  - **Direction of sort:** The arrow indicates in which direction data is sorted; Down: descending Up: ascending.
  - **Visibility:** Which columns are visible can be determined by the user. Visibility can differ per layout.
    - The user can change this by right clicking on the header bar. A context menu with the possible fields is shown, the fields which are checked are visible.

∗ A list of possible fields. Fields followed by **[*]** are only available in the "Archive", "Monitor" and "Search" views. Fields followed by **[@]** are only available in the "Search" view.

Item	**Formatting**	**Example**
Date and time alert created	hours:minutes day/month/year (24h clock)	*16:45 15/12/2009*
Patient number	xx.xx.xxx	*12.34.567*
Patient name	Initials Last name	*J. Smit*
Patient age		*36 year*
Ward	Standard abbreviation	*A2*
Type of alert	Interaction/Overdose/Route	
Medication 1 name	Label Name (according to hospital specifications)	
Start medication 1	hours:minutes day/month/year (24h clock)	*16:45 15/12/2009*
Stop medication 1	day/month/year	*26/08/2009*
Prescriber 1	Last name, Initials	*Cuik, A. B.*
Medication 2 name	Label Name (according to hospital specifications)	
Start medication 2	hours:minutes day/month/year (24h clock)	*16:45 15/12/2009*
Stop medication 2	day/month/year	*26/08/2009*
Prescriber 2	Last name, Initials	*Cuik, A. B.*
[*] Advice		*Stop medication*
[*] Date Archived / Monitored	hours:minutes day/month/year (24h clock)	*16:45 15/12/2009*
[*] Pharmacist	Last name, Initials	*Cuik, A. B.*
[@] Status	New/Archived/Monitored	

  - **Order:** The order of columns can be changed by the user by dragging them. Order can differ per layout.
  - **Save:** Both the order and visibility of the columns for all of the layouts (main, archive, search) should be saved between sessions.

- Rows
  - **Unviewed records:** when a record is unviewed the text is bold otherwise it is not.
  - **Highlighting when selected:** when a line is selected it will be highlighted.
  - **Highlighting on hover:** when hovering over a record the line will highlight.
  - **Alternate row colours:** colour alternates between each record.

Threading Per Patient There should be an option to thread alerts per patient. Meaning that old alerts (which have already been archived) will be shown when that patient has a new alert. An example of threaded messages (in an e-mail program) is shown in Figure I.7.

I.7 Panel D - Alert View

Panel D is the view in which the actual alerts can be viewed. This panel is divided up into two regions when in normal mode: the patient view and the alert view. This can be seen in Figure I.8. When an alert from the archive / monitor section is displayed, it is divided in three parts. This can be seen in Figure I.13. The patient view is always the same while the alert view is dependent on the type of alert shown.

The layout and content of the patient view can be seen in Figure I.9. The patient information is displayed compactly but in a way that is easy to read. The age / date of birth of information is displayed twice, once as a date and once as an age.

The look and feel of the alert view is consistent between different types of alerts. A simple table with a header with a dark grey background and bold text, followed by one or more rows which are light grey with normal text. Links are indicated by both a different colour (in the prototype blue is used) and underlined text. Additionally the cursor should also change to a hand with one finger pointing out to indicate it is hovering over a link. Links do not change colour when clicked.

In this prototype three types of alerts are specified: interaction alert, overdose alerts and non-standard route of administration alerts. Each of the layouts and specifications for each of the types of alerts can be found in Figure I.10 for interaction alerts, Figure I.11 for overdose alerts, and Figure I.12 for route of administration alerts.

When an alert from the archive or monitor section is watched an “archive” section is added to panel D (as is shown in Figure I.13). In Figure I.14 an example of the “archive” portion is shown as well as a schematic with detailed information on the content.

I.8 Panel E - Action view

Panel E is only visible when an alert is not yet handled by a user or if an alert is reopened. The purpose of this panel is to record information and the action taken for each alert; it is there for archive purposes.

In Figure I.15 there is a screenshot of the action view combined with an overview of all the fields and how they work. This figure shows all the fields, also the ones that might be hidden during normal use. Which fields are hidden is indicated in the figure.

Required Some of the fields are required when recording an alert, they are denoted with a star in Figure I.15. A list of the required fields:

- Advice
- Different (only when “Other” is selected for Advice)

- Actions
- Name contact (only when an action other than “no action” is selected)
- Number / e-mail contact (only when an action other than “no action” is selected)

An example of the drop-down box as described in the advice field in Figure I.15 can be seen in Figure I.16. The contents of the drop-down field will be determined by the hospital pharmacy. The contents will be dependent on the type of alert which is currently being viewed.

An example of the autocomplete can be seen in Figure I.17.

I.9 Shortcuts

For advanced users, shortcuts should be implemented in the application. Where possible standard Windows shortcuts are used. The list of shortcuts is shown in Table I.1.

Table I.1: An overview of shortcuts in the application.

Shortcut	**Function**
Ctrl+P	Print a printer friendly version of the currently selected alert
Ctrl+M	Create a new e-mail in the default e-mail client with an e-mail friendly version of the currently selected alert
Ctrl+E	Focus on the search field
Ctrl+Tab	Switch between different views (Alert view / Monitor view / Archive view)
Ctrl+(number)	Go to different views (Alert view = 1, Monitor view = 2, Archive view = 3)
Home	Select top alert
End	Select bottom alert
Up/Down arrow keys	Move through the alerts list.
Tab	Cycle through search and input fields and buttons. Do not cycle through static components (e.g. text paragraphs).

These shortcuts should be both indicated in the menu structure (where applicable) and be explained in a help file.

I.10 Figures

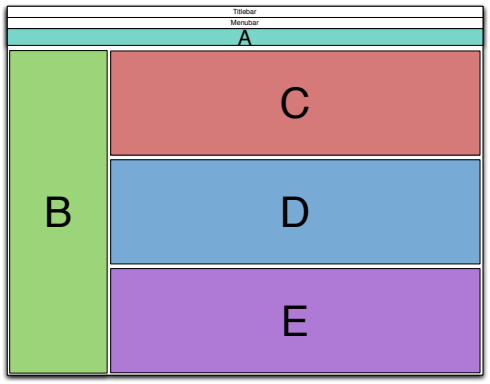


Figure I.1: Simple wireframe for the main view of the application.

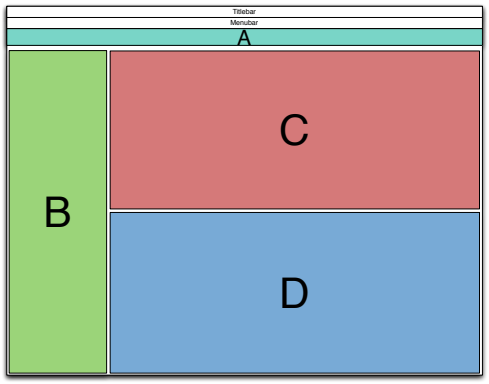


Figure I.2: Simple wireframe for the archive and monitor view of the application.

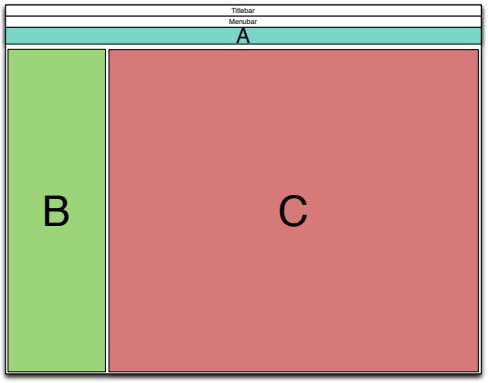


Figure I.3: Simple wireframe for the search view of the application.

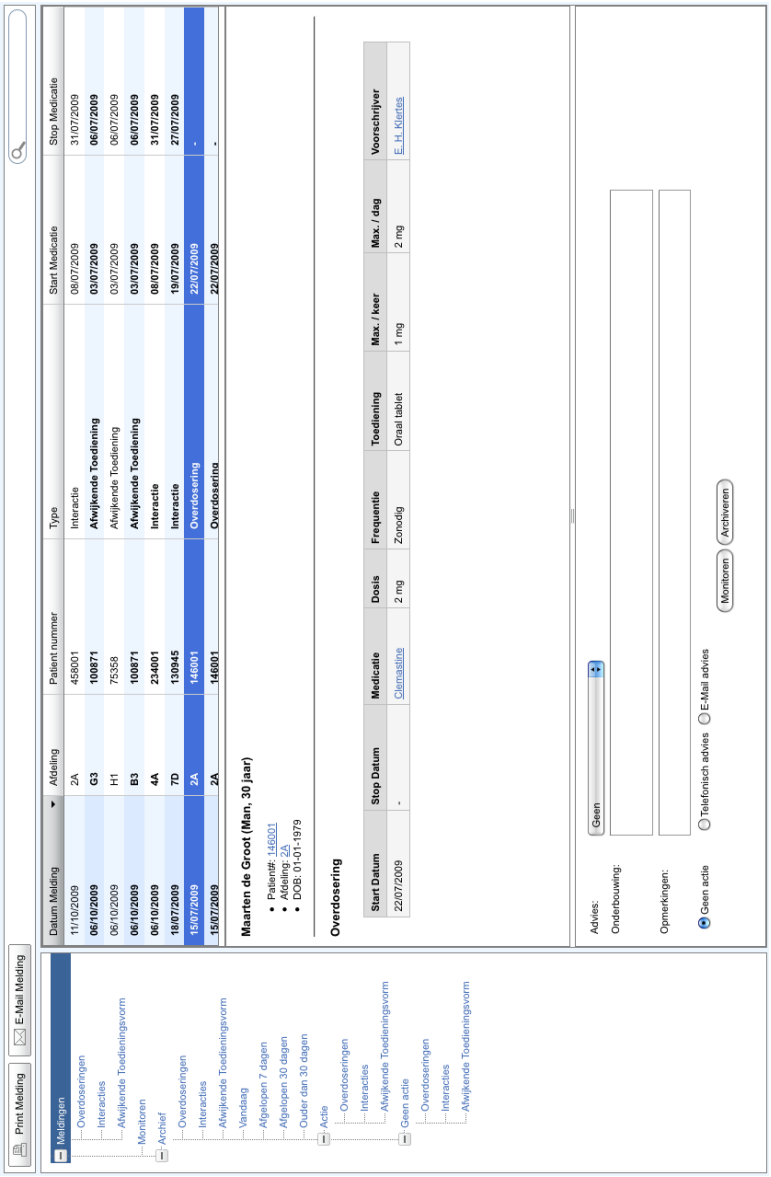


Figure I.4: A sample screenshot of the main view. Not all mentioned features may be implemented in the prototype version which is shown here.

Figure I.5: A sample screenshot of the tree. Not all mentioned features may be implemented in the prototype version which is shown here.

Datum Melding	Afdeling	Patient nummer	Type	Start Medicatie	Stop Medicatie
11/10/2009	2A	458001	Interactie	08/07/2009	31/07/2009
06/10/2009	**G3**	**100871**	**Afwijkende Toediening**	**03/07/2009**	**06/07/2009**
06/10/2009	**H1**	**75358**	**Afwijkende Toediening**	**03/07/2009**	**06/07/2009**
06/10/2009	**B3**	**100871**	**Afwijkende Toediening**	**03/07/2009**	**06/07/2009**
06/10/2009	**4A**	**234001**	**Interactie**	**08/07/2009**	**31/07/2009**
18/07/2009	**7D**	**130945**	**Interactie**	**19/07/2009**	**27/07/2009**
15/07/2009	**2A**	**146001**	**Overdosering**	**22/07/2009**	**-**

Figure I.6: A sample screenshot of the data table. Not all mentioned features may be implemented in the prototype version which is shown here.

faculteitsraad	Nieuwsbrief: gezocht studentleden voor de faculteitsraad	28 January 2009	13:20
Chi redactie	Chi Nederland Nieuwsbrief Januari	19 January 2009	12:43
The Board of the University of Groningen...	Invitation RUG Lecturer of the Year 2008 Award Thursday Febru...	16 January 2009	19:28
Universiteitsraad RUG	Nieuwsbrief Universiteitsraad 35 (18.12.2008)	15 January 2009	20:18
Universiteitsraad RUG	Nieuwsbrief Universiteitsraad 35 (18.12.2008)	15 January 2009	20:18
Universiteitsraad RUG	Nieuwsbrief Universiteitsraad 35 (18.12.2008)	13 January 2009	23:14
faculteitsraad	Nieuwsbrief 14 januari 2009	14 January 2009	16:45
L.R.B.Schomaker@rug.nl	KIM.CSAI04.2008-2009.1b: Deadline essay: maandag 2 februari	6 January 2009	11:34
faculteitsraad	Nieuwsbrief 24 december 2008	24 December 2008	14:12

Figure I.7: An example of a threaded view of a list of e-mails.

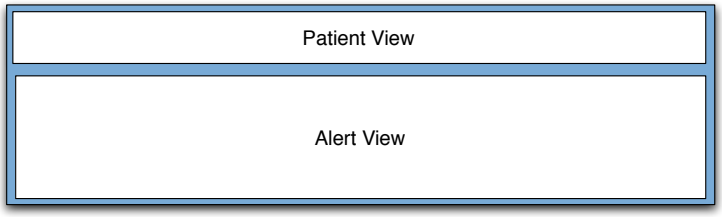


Figure I.8: The layout of panel D (as specified in Figure I.1). The content of the patient view and the alert view will be further specified below.

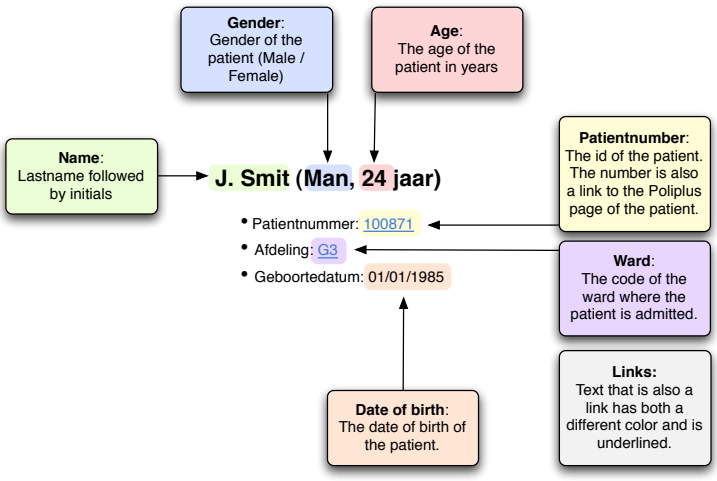


Figure I.9: The lay-out and content of the patient view.

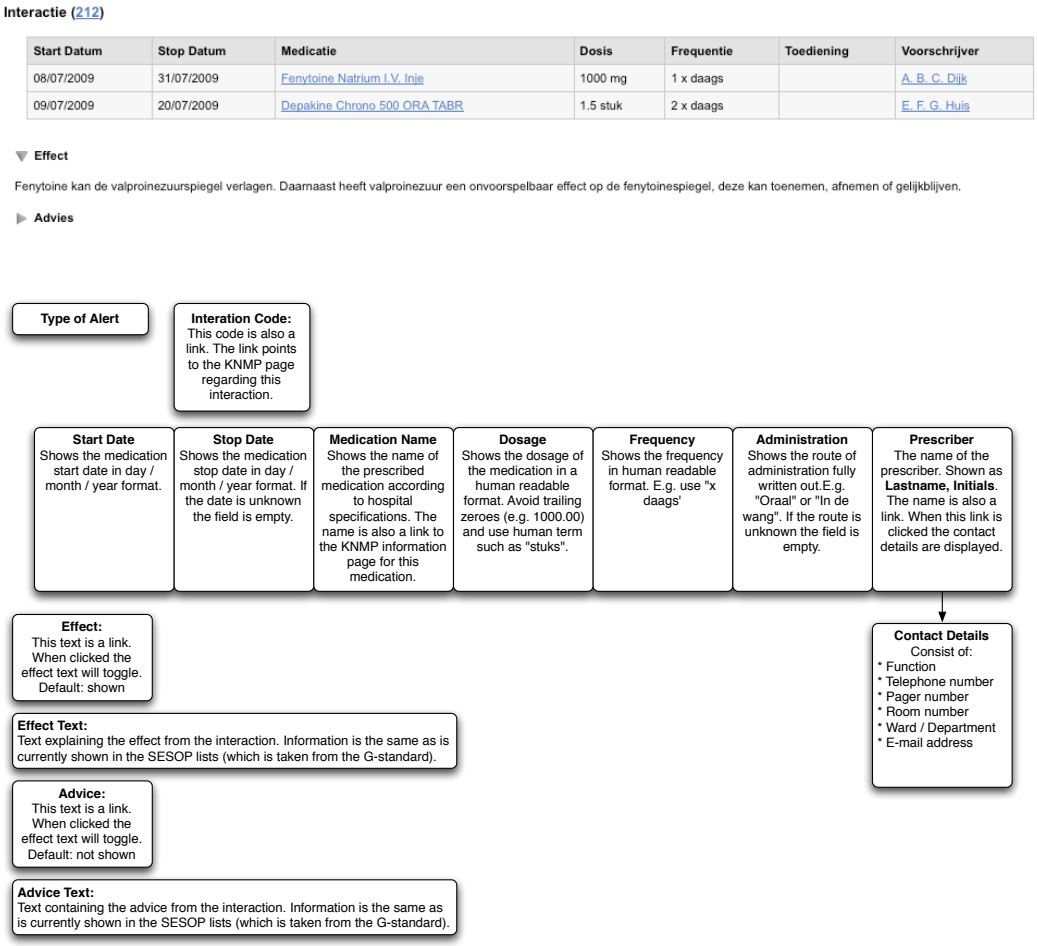


Figure I.10: An example of an interaction alert. The top is a screenshot of an interaction alert in the prototype and below there is a schematic overview of the specifications.

Figure I.11: An example of an overdose alert. The top is a screenshot of an overdose alert in the prototype and below there is a schematic overview of the specifications.

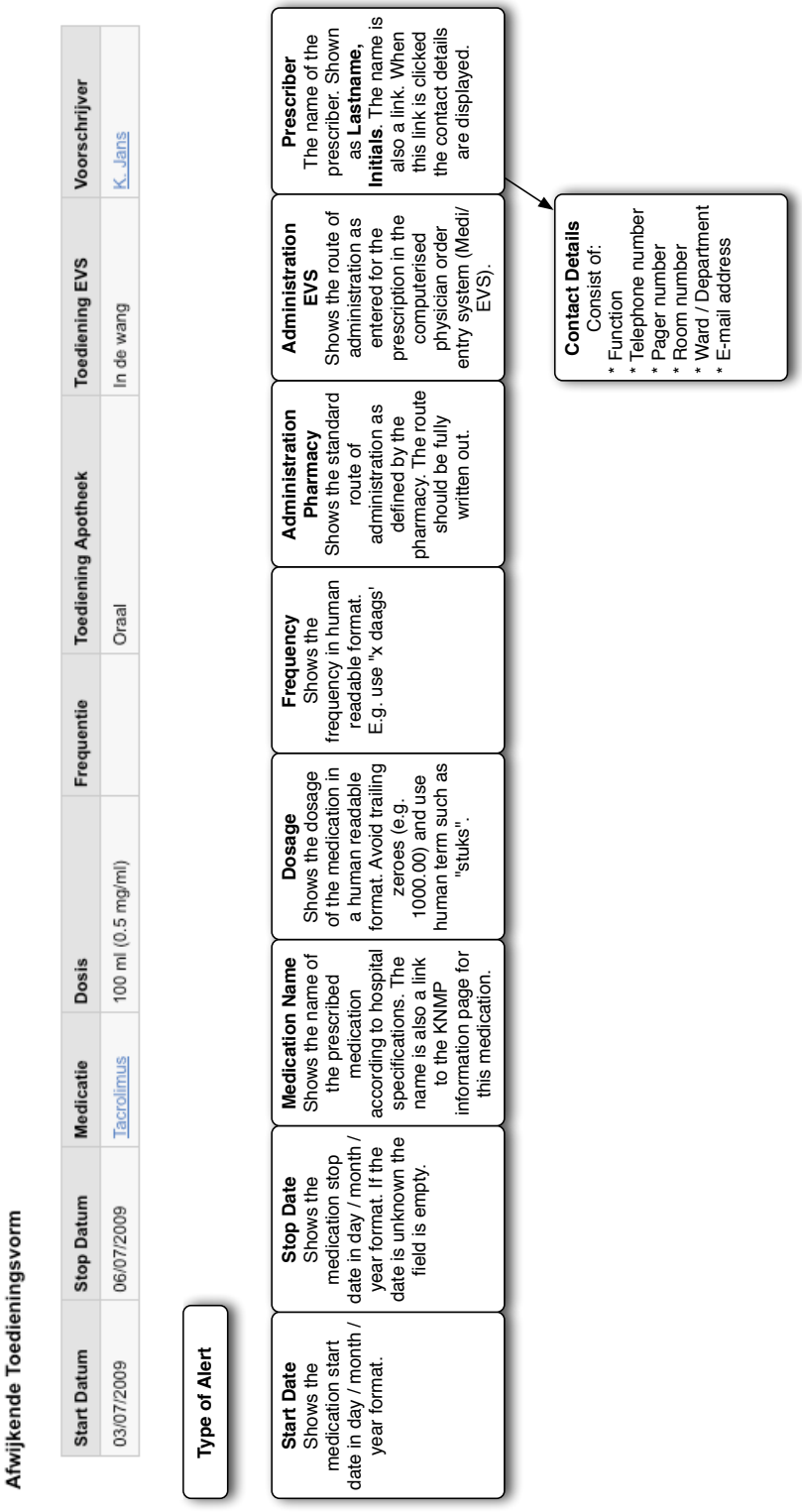


Figure I.12: An example of an route of administration alert. The top is a screenshot of an route of administration alert in the prototype and below there is a schematic overview of the specifications.

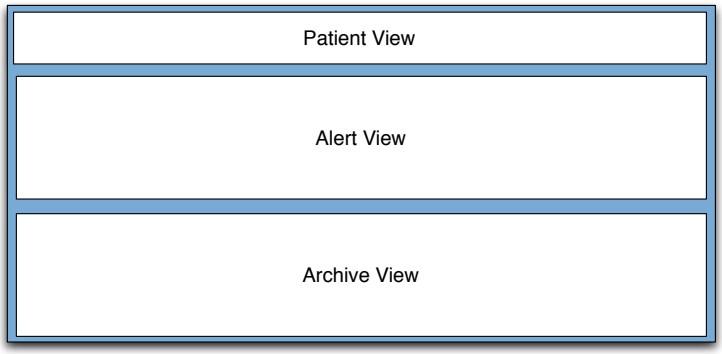


Figure I.13: The D-panel when viewed in either the archive or monitor view.

Afhandeling

Datum Afhandeling:	10/07/2009
Apotheker:	D. A. Plats
Advies:	Verlaag dosering
Onderbouwing:	Deze dosering is veel te hoog.
Opmerkingen:	Lijkt veroorzaakt door een typfout.
Contact:	E-mail contact met Afdeling 2A via a2@umcg.nl.
Resultaat Contact:	De frequentie wordt aangepast in Medi-EVS.

Review

Date Reviewed
Shows the date and time the alert was reviewed,
Format: hh:mm day/month/year (24h clock)
Example 15:32 21/12/2009

Reviewed By
Shows the name of the pharmacist that reviewed the alert.
Format: Lastname, Initials

Advice
The advice as given by the pharmacist. Taken from the drop down list or the "Other" field.

Motivation
Shows the motivation given by the reviewing pharmacist. If no motivation was given the field is empty.

Remarks
Shows the remarks given by the reviewing pharmacist. If no remarks were given the field is empty.

Contact
An overview of the contact between the pharmacist and the clinic.
Format: TYPE OF CONTACT contact with NAME CONTACT (as a link to their contact details) via CONTACT DETAIL.
Example: Phone contact with Doe, J.A. via 2345

Result Contact
Result of the contact with the clinic where a result was entered. When no result is known the field is empty.

Figure I.14: A breakdown and example of the table which shows how an alert was handled.

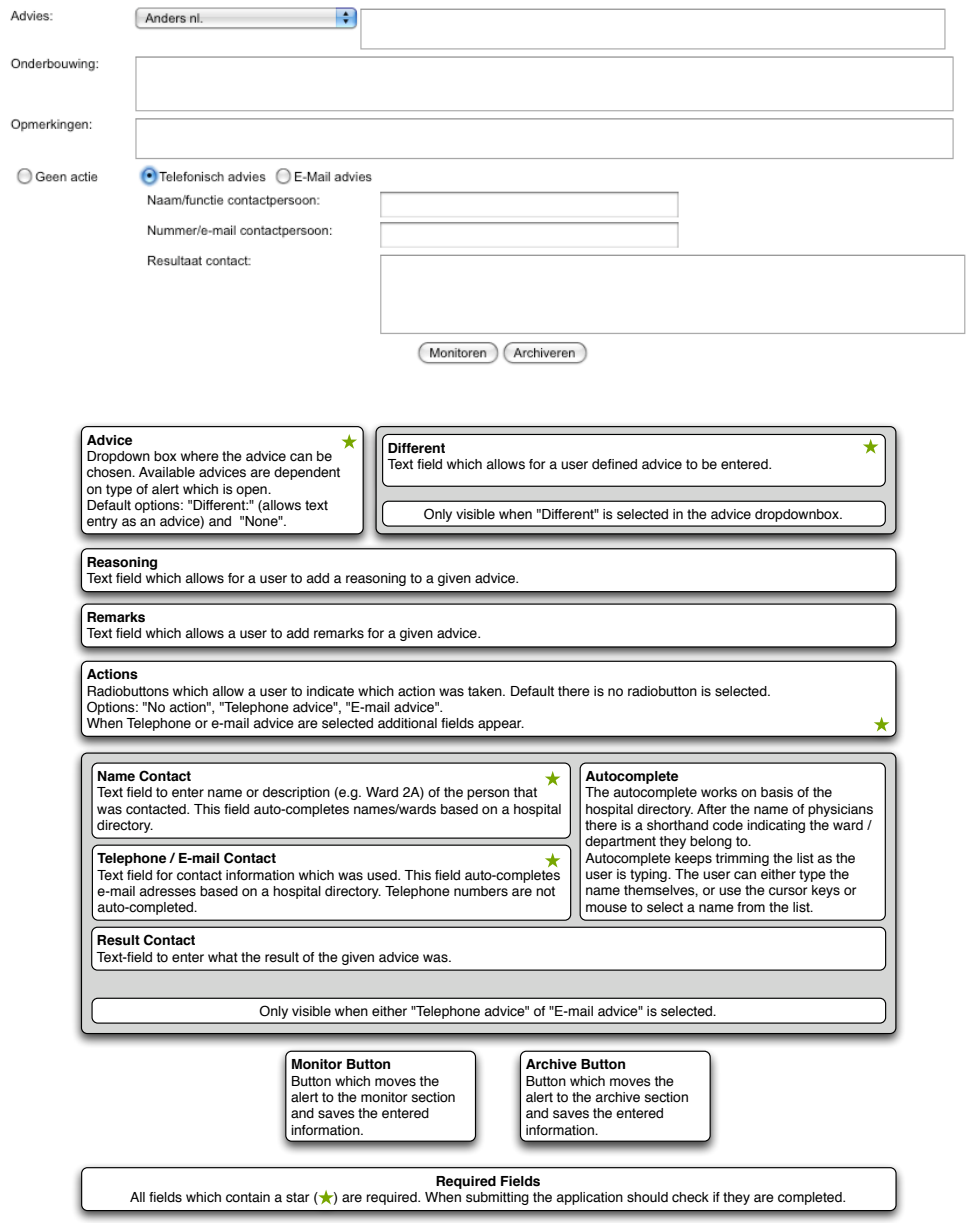


Figure I.15: An overview of the action view with all fields visible. During normal usage some fields may be hidden, this is indicated in the graphic. The required fields (which should be checked before an alert may be archived or monitored) are indicated with a star.

Figure I.16: An example of a drop-down window with medication options.

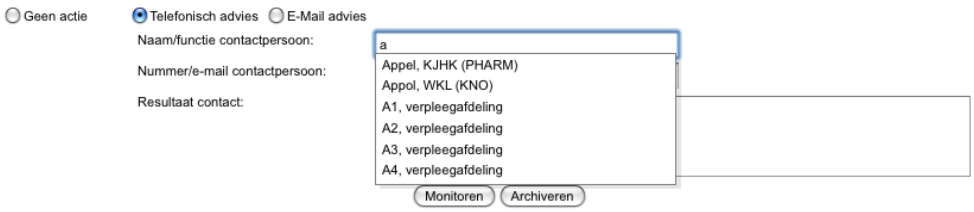


Figure I.17: An example of the autocomplete function in the name field.