Inspired EHRs
Designing for Clinicians

by

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Foreword

This book is dedicated to the development community working tirelessly to computerize the world of medicine, and to the patients and physicians who will benefit.

In the 1960s, the medical field began to take advantage of computing technology. Doctors realized that access to a patient's up-to-date information and medical history could be a useful, if not vital, asset to their work.

The Mayo Clinic in Rochester, Minnesota and the Medical Center Hospital of Vermont were two of the first clinics to start utilizing Electronic Health Record systems (EHRs). While evolving medical informatics systems promise to transform healthcare, this process takes the enormous combined effort of designers, analysts, software engineers, usability specialists, and medical professionals.

Today the functionality, design and implementation of EHRs have attracted large amounts of attention. These components have become subfields of study in and of themselves. Every day teams create and implement new designs, and the field is continuing to grow. Yet, while many currently available EHRs offer a wide range of functionalities, users also report significant usability issues. The challenge facing the EHR community is that of bridging the gaps between design, functionality, and what medical practitioners need to do when providing care.

This book aims to encourage the design of useful and usable EHRs by:

1. Providing a window into what medical practitioners need
2. Explaining some of the science behind how the human mind processes information
3. Providing design examples

We hope you will enjoy reading the book and playing with our interactive prototypes.

Jeff Belden, MD
Columbia, MO

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About This Book

Goal

Our goal in writing this book is to **inspire** useful and usable Electronic Health Record (EHR) interface design by providing clinical scenarios and insights with examples of interactive designs, guided by basic design principles.

Illustrative, Not Prescriptive

While meaningful use criteria influenced the choice of the book topics, we and our sponsors (California HealthCare Foundation and SHARP-C Project) want this book to be clinically relevant, illustrative, and inspirational —but **not prescriptive**. We hope our design examples will inspire our readers to improve their own EHR designs.

Audience

This book is written for **anyone who develops and implements health IT applications**, but particularly for electronic health record (EHR) vendor teams who want to learn more about human factors and design. Designers who want to learn about the needs of EHR users, medical informatics students, and EHR users who want to learn more about design principles might also benefit from reading this book.

Focus

1 **Clinical focus**: This book focuses on **ambulatory adult care**. Our examples especially emphasize the needs of **primary care** practitioners.

2 **EHR functionality focus:** Our design examples seek to address five specific areas: medication list, medication reconciliation, allergy list, e-prescribing and drug alerts.

We hope that future books will address other clinical needs and the many other elements that EHR designs require to be useful and usable, so they can be carefully implemented and seamlessly integrated into healthcare organizations.

Book Overview

The next five chapters each focus on a specific EHR functionality (medication list, medication reconciliation, allergy list, e-prescribing and drug alerts). Basic clinical needs and usability issues are discussed, with simple descriptions of how humans typically see, read, pay attention, think, remember, and decide when using EHR user interfaces.

Each chapter starts with one or more **clinical scenarios**. This brings a human perspective and will help readers empathize with EHR users and their struggles. Each chapter includes many **design examples**. We present simple examples with annotated figures (either single images or galleries showing a series of images). The more elaborate design examples use interactive prototypes that give readers a hands-on experience and video demonstrations. Finally, each chapter ends with a summary of the important points covered therein.

Those five chapters use plain language and are accessible for all readers. In addition they provide **links to related principles** found in the last three chapters for the benefit of those who wish to learn more.

The book's last three chapters cover **principles of design, human factors,** and **health IT usability**. They aim to provide readers with a basic understanding of relevant information about how the human brain works and fundamental principles of visual design to suggest steps developers can take to create usable user interfaces. The content herein provides an introduction to the subject, but we also offer recommendations for those interested in reading further.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

How to Use This Book

This book's chapters can be read in any order. Nevertheless, we encourage you to read them in the order our layout proposes. Chapter 2 (Medication List), for example, introduces basic concepts that are reused in subsequent chapters.

Tell Us What You Think

You can email us at feedback@inspiredEHRs.org. We welcome your comments. Please let us know what subjects you would like us to cover next. We will post the helpful examples or insights you send our way to Jeff Belden's blog at TooManyClicks.com.

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Medication List

Successful medication management is a key part of a patient's health care.

Medication lists record information about all the drugs a patient is currently receiving and their prescribed dosages. Medication lists come in many forms, but this chapter will only focus on three: **simple lists**, **interactive lists**, and **medication timelines**. We'll offer a few tips and challenges along the way.

Gallery 2.1

2.1 a **Simple List** — Helps physicians with a variety of tasks, such as making treatment decisions or e-prescribing.

Medication	Instructions
albuterol HFA 90	2 puffs every 4 hours as needed
aspirin 81 mg	1 daily
beclomethasone HFA 40	2 puffs twice a day
carvedilol 25 mg	1 twice daily
chlorthalidone 25 mg	1 daily
citalopram 20 mg	1 daily
gabapentin 600 mg	1 twice daily
insulin glargine 28 units	28 units at bedtime
losartan 100 mg	1 daily
metformin 1000 mg	1 twice daily
naproxen 500 mg	1 twice daily
omeprazole 40 mg	1 daily
prednisone 20 mg	2 daily
simvastatin 40 mg	1 daily
terbinafine 250 mg	1 daily for 12 weeks
zolpidem 5 mg	1 at bedtime

2.1 b **Simple List** — Also ideal for mobile which patients can access easily.

2.1 c **Interactive List** — Contains more details about the medications and helps physicians with tasks such as making treatment decisions or e-prescribing

Medication ▼	Dose	Frequency	Quantity	Refills	Condition ▼	Provider ▼	Prescribed ▼	2011 2012 2013 2014	Renew by ▼
albuterol HFA	2 puffs	q4h prn		12	Asthma	Barnes	12 Jan 2010		22 Nov 2013
aspirin	81 mg	1 daily			Diabetes	OTC			
beclomethasone HFA	2 puffs	bid		12	Asthma	Barnes	19 Feb 2011		19 Sep 2013
carvedilol	12.5 mg	1 bid	90	3	Hypertension	Barnes	12 Jul 2010		20 Feb 2014
chlorthalidone	25 mg	1 daily	90	3	Hypertension	Barnes	19 Sep 2006		19 Sep 2013
citalopram	20 mg	1 daily	90	3	Depression	Soto	23 Nov 2009		22 Nov 2013
gabapentin	600 mg	1 bid	60	11	neuropathic pain	Barnes	19 Apr 2012		22 Nov 2013
insulin glargine	28 u	daily	90	11	Diabetes	Ballard	19 Nov 2012		19 Sep 2013
losartan	100 mg	1 daily	90	3	Hypertension	Barnes	5 Mar 2012		28 Oct 2013
metformin	1000 mg	1 bid	180	3	Diabetes	Ballard	4 Mar 2008		19 Sep 2013
naproxen	500 mg	1 bid	90	0	Rheumatoid arthritis	Barnes	4 Mar 2008		19 Sep 2013
omeprazole	40 mg	1 daily			GERD	OTC			
prednisone	20 mg	2 d x5d prn	84	0	Asthma	Barnes	12 Sep 2010		19 Sep 2013
simvastatin	40 mg	1 daily	84	0	High cholesterol	Barnes	19 Mar 2010		30 Sep 2013
terbinafine	250 mg	1 daily	84	0	Onychomycosis	Foote	30 Jul 2013		19 Oct 2013
zolpidem	5 mg	1 hs	90	0	Insomnia	Barnes	15 Mar 2012		22 Sep 2013

Welcome — Today, 18 Sept 2013

Robert Martin
22 Feb 1953   Male

Medication List   Simple List   Timeline   Back to the Book   Feedback   Task List

show brand   prn   current (16)   all (23)

2.1 d **Medication Timeline —** Harnesses the power of information visualization and allows physicians to understand changes in medications over time.

Miranda Barnes, MD / All   Today, 18 Sept 2013

Robert Martin
22 Feb 1953   Male

Intake   Medication List   **Timeline**   Allergies   Medication Reconciliation   eRx

Show all   6 months   2 years   5 years   reset

	2009	2010	2011	2012	May	Sept	2013	Mar	May	Jul	Sept	Today Sept 18	Oct	Nov	Dec	2014
terbinafine												250				
insulin glargine				26							28					
omeprazole			40								40					
gabapentin			300 bid								600 bid					
zolpidem											5					
losartan			50								100					
QVAR HFA											40					
prednisone											20 prn					
carvedilol											25 bid					
simvastatin	80										40					
albuterol HFA											12 prn					
citalopram											20					
naproxen	250 bid										500 bid					
metformin	bid										1000 bid					
aspirin											81					
chlorthalidone											25					

terbinafine 250 mg
insulin glargine 28 u
omeprazole 40 mg
gabapentin 600 mg bid
zolpidem 5 mg
losartan 100 mg
QVAR HFA 40 u
prednisone 20 u prn
carvedilol 25 mg bid
simvastatin 40 mg
albuterol HFA 12 u prn
citalopram 20 mg
naproxen 500 mg bid
metformin 1000 mg bid
aspirin 81 mg
chlorthalidone 25 mg

2.1 The Simple List

The simple list displays bare-bones basic information. It's made to be read quickly, scanned at a glance. It's easy to scan visually to see the name, strength, and dosing of the medication. The list is alphabetical, which makes it easy to search for and locate particular items. It gives the user, usually a physician, a broad overview of the patient's medical history and their related medications. A physician quickly scanning the simple list can make initial observations such as, *"There are twenty-four medications here, but only two prescription medications for high blood pressure."* Good design can make such tasks easy; bad design can make them much harder.

We use the term "patient" to apply to either patients themselves, caregivers, or family members acting on their behalf. Similarly, we use the term "physician" to apply to physicians proper or other healthcare professionals with prescribing authority.

A Common Scenario: Going into the Exam Room

Dr. Barnes, a general internist is about to go into the exam room to see her patient Mr. Martin, a 60-year-old man with ten chronic diseases (diabetes, high blood pressure, high cholesterol, knee arthritis, depression, insomnia, etc.) who is taking seventeen medications. The physician notes that the patient's blood pressure is about ten points too high. She plans to ask the patient if he has been taking his blood pressure at home and what the results of any such tests have been.

In this scenario, the physician needs to have an overall awareness of the patient's medications, chronic problems, latest vital signs, and relevant lab test results fresh in her mind when the face-to-face visit begins. ("Is he taking insulin? Is he on any high-risk drugs like warfarin?") Armed with this background, the physician is able to give her full attention to the patient telling his story, and she won't have to keep glancing away from him and back at the EHR to be reminded of the medications. Giving full attention to his story shows the patient that she's listening to and cares about what he has to say. Establishing context will allow our physician to attend to the practicalities and the emotional tone of this encounter, and to frame this visit in relation to a bigger picture that includes the patient's past and current data, his story.

Situational Awareness

Situational awareness is having all the background information you need to make effective decisions while simultaneously being aware of what is currently happening around you and anticipating what will happen in the near future. For physicians managing chronic diseases during ambulatory visits, situational awareness consists of taking in a broad overview of key information about patients before walking into the exam room. Upon entering the exam room, the physician can then be mindful of and attuned to the patient sitting before them and the unfolding of their conversation.

If Dr. Barnes enters the exam room half-prepared

> due to time pressure or information chaos, then she'll struggle to listen to the patient's concerns. Information chaos (See Information Chaos in the Human Factors chapter) comprises information overload, underload, scatter, conflict, and erroneous information. Instead, she'll search through the EHR while the patient speaks, frantically trying to fill the gaps in her knowledge. The patient will sense the physician's distraction, and may feel that he's not being heard, that he is being left out of decisions that concern his body and wellbeing. The physician may miss something important, telling details about what the patient says because she is distracted.

Look at Figure 2.1 and Figure 2.2. As you can probably tell, one list looks cleaner than the other. Such simplicity makes it easy for people using this list to see the names of the drugs the patient is taking, which allows a quick overview. Given that it uses plain language like "twice daily," instead of Latin abbreviations like "b.i.d.," the list below would meet the needs of both physicians and patients.

Patients can also use this list. Patients can easily show this list to other physicians, dentists, emergency room staff, or their caregivers. Patients filling up weekly medication reminder boxes might, however, need a more detailed list —perhaps one that illustrates the contents of each compartment of their box, and more clearly differentiates the time of day at which they should take each dose of medication.

A physician or nurse would expect a progress note from a previous

Figure 2.1 **Before: An Awful Medication List**

Current medications: (selected)
Prescriptions
Ordered
- albuterol HFA prn (90 mcg/spray) (ProAir HFA) oral spray; 90
  mcg/spray, 2 puffs, oral, every 4 hours as needed, 21.6 mg/1 unit
- beclomethasone HFA (QVAR 40 HFA) oral spray; 40 mcg/spray, 2
  puffs, oral, twice a day, 9.6 mg/1 unit
- carvedilol 25 mg oral tablet; 25 mg 1 tablet, oral, 2 times a day, 180
  tablets
- chlorthalidone 25 mg oral tablet; 20 mg, 1 tablet, oral, daily, 90 tablets
- citalopram 20 mg oral tablet; 20 mg, 1 tablet, oral, daily, 90 tablets
- gabapentin 600 mg oral tablet; 600 mg, 1 tablet, oral, 2 times a day,
  180 tablets
- insulin glargine (Lantus) 40 units subcut at bedtime, 10 ml
- losartan 100 mg oral tablet; 100 mg, 1 tablet, oral, daily, 90 tablets
- metformin 1000 mg oral tablet; 1000 mg, 1 tablet, oral, 2 times a day,
  180 tablets
- naproxen 500 mg oral tablet; 500 mg, 1 tablet, oral, 2 times a day, 60
  tablets
- nitroglycerin 0.4 mg prn oral tablet; 0.4 mg, 1 tablet, under tongue,
  every 5 minutes as needed, 25 tablets
- prednisone 20 mg prn oral tablet; 20 mg, 2 tablets daily, oral, prn, 10
  tablets
- simvastatin 80 mg oral tablet; 80 mg, 1 tablet, oral, daily, 90 tablets
- terbinafine 150 mg oral tablet; 150 mg, 1 tablet, oral, daily for 12
  weeks, 84 tablets
- zolpidem 5 mg oral tablet; 5 mg, 1 tablet, oral, at bedtime, 90 tablets
Documented Medications
Documented
- aspirin 81 mg oral tablet; 1 tablet, oral, daily
- omeprazole 40 mg oral tablet; 1 tablet, oral, daily

Figure 2.2 **After: Simple Medication List Makeover**

Medications
Last updated 1 month ago

albuterol HFA 90 mcg/spray 2 puffs every 4 hr as needed

aspirin 81mg 1 tablet daily

beclomethasone HFA (QVAR HFA) 40 mcg/spray 2 puffs daily

carvedilol 25mg 1 twice daily

chlorthalidone 25mg 1 tablet daily

citalopram 20mg 1 tablet daily

gabapentin 600mg 1 twice daily

insulin glargine (Lantus) 40 units 1 at bedtime

losartan 100mg 1 daily

lisinopril 20mg 1 daily

metformin 1000mg 1 twice daily

naproxen 500mg 1 twice daily

nitroglycerin 0.4mg 1 as needed

omeprazole 40mg 1 daily

prednisone 20mg 2 daily as needed

simvastatin 80mg 1 daily

terbinafine 150mg 1 daily

zolpidem 5mg 1 at bedtime

visit, a dashboard overview, or a visit summary from an outside EHR to make use of this simple format. It's a quick snapshot, intended to be taken in at a glance. A physician doing a more complex task, like e-prescribing, might prefer an interactive display with more information, such as the interactive table or the medication timeline.

In this context, the physician just needs to quickly see the medications' names. Avoid the temptation to add extraneous detail here. Concise lists are easier to read. Physicians don't need to see the medications' quantities, start dates, or the number of refills in a given prescription to perform this task. If the list uses a brand name, be sure to include the product's generic name as well. Dealing with brand, generic, and compound names can be a challenge (see the following note).

Challenge: Handling Brand and Generic Names

This can get tricky. We'll admit right now: there may not be one correct answer to the problem of whether to show the brand name, the generic name, or both names by default in medication lists. It depends on the context and the people in the conversation. The EHR can offer easy access to both the generic and the brand names of all relevant drugs, but several factors complicate the question of the form this access could take.

Here are a few considerations.

Ideally, both names would be available on demand at just the right time. Sometimes it may be appropriate to display both generic and brand name —for example "furosemide (Lasix) 20 mg." For consistency, sort alphabetically by the generic name. But if you're working with a printed list, then you might have to choose a single method of display. People often prefer to use brand names in conversation because the generic names may be difficult to remember or pronounce, even for physicians. Say these three times fast:

- adalimumab — Humira
- ondansetron — Zofran
- furosemide — Lasix

The problems are compounded by the fact that some medications have many confusing non-interchangeable brand names. Diltiazem, for example, may be available as:

- Cardizem
- Cardizem LA
- Cardizem CD
- Cartia XT
- Dilacor XR
- etc., etc.

When discussing medications with patients, physicians need to be aware of the name of the drug as the patients know it. Patients may be more familiar

> with a particular version of a drug's name because it is
> what is written on the medication container dispensed
> by their pharmacy, or because that version of the
> name is easier to recall or pronounce. When speaking
> with patients, physicians might find it helpful to refer
> to drugs by both names ("Your furosemide, also called
> Lasix"). Having both names displayed, especially for
> less common drugs may decrease mental effort.

We can make medication lists easier to read by **emphasizing** the
names of drugs and de-emphasizing everything else. Physician's
eyes need to notice the names and strengths more than they need
to take in the whole line of text. Dosage instructions such as "take 1
tablet daily," while important in some contexts, are secondary pieces
of information. One method of denoting that these instructions are
of secondary importance is to use gray text. The difference between
this gray text and the rest won't be extreme, and thus won't be
visually jarring, but it will be immediately apparent to the human
brain's visual processing system (See How People Perceive in the
Human Factors chapter). Compared with this light gray text, the
black medicine names will possess the "preattentive attributes"
(See Preattentive Attributes in the Human Factors chapter) our
brains readily detect and flag as important.

On the other hand, sometimes a deliberately jarring (See The Dark
Side of Color in the Design Principles chapter) type style alerts
the user to pay attention. Some EHRs use **tall man lettering**
to differentiate look-alike and/or sound-alike drug names that
might otherwise be easily (and dangerously) confused. Tall man
lettering capitalizes the parts of a word that separate it from its

Gallery 2.2 **Adding Emphasis to Text**

2.2 a Too jarring

Lisinopril 20 mg 1 tablet daily

2.2 b Too subtle

Lisinopril 20 mg 1 tablet daily

2.2 c Invisible to color-blind users

Lisinopril 20 mg 1 tablet daily

2.2 d Making the visual emphasis just right

Lisinopril 20 mg 1 tablet daily

near-doppelgangers: hydrALAzine vs. hydrOXYzine. This unusual, seemingly "incorrect" capitalization says to the user, "Hey, pay attention here, the part I've emphasized is really important." HydrALAzine is a blood pressure medication, hydrOXYzine is an antihistamine. Small differences matter.

Preattentive Attributes

Preattentive attributes are the little visual things people unconsciously notice and understand quickly, so quickly that we have only noticed it at an unconscious level. Try this little exercise, which can help you understand what sort of things we're talking about.

How many 5's do you find in each rectangle below?

2	3	7	3	0	8	5
7	7	8	9	6	4	1
7	0	5	7	5	8	4
6	8	5	6	4	2	9
2	6	0	2	5	0	2
6	9	1	2	3	2	9
4	5	9	7	3	3	7

2	3	7	3	0	8	**5**
7	7	8	9	6	4	1
7	0	**5**	7	**5**	8	4
6	8	**5**	6	4	2	9
2	6	0	2	**5**	0	2
6	9	1	2	3	2	9
4	**5**	9	7	3	3	7

without our conscious volition.

When processing visual information, our brains combine very basic attributes (shape, size, orientation, motion) into "objects" that have some meaning to us

(face, pole, box). This happens very quickly, below the level of our conscious awareness. Some features stand out more readily and are noticed more quickly than others. Those features are called preattentive attributes (See Preattentive Attributes in the Human Factors chapter).

Alphabetize the list. Readers expect a list of text items to be alphabetical. This helps them find particular names quickly in long lists. "Are they taking warfarin?" Just jump to the "w" section to check.

Reduce visual noise. If a visual element doesn't add data or improve the perception or processing of information, try leaving it out. See Figures 2.3 and 2.4.

Borders don't add information, and removing gridlines can make your data less visually noisy (and thus easier to read).

Now, let's move on to the interactive table.

Figure 2.3 **Before: The Frame Creates Visual Noise**

Name of medication	Instructions
albuterol HFA	2 puffs every 4 hours as needed
aspirin 81 mg	1 daily
beclomethasone HFA 40	2 puffs twice a day
carvedilol 25 mg	1 twice daily
chlorthalidone 25 mg	1 daily
citalopram 20 mg	1 daily
gabapentin 600 mg	1 twice daily
insulin glargine 28 units	28 units at bedtime
losartan 100 mg	1 daily
metformin 1000 mg	1 twice daily
naproxen 500 mg	1 twice daily
omeprazole 40 mg	1 daily
prednisone 20 mg	2 daily
simvastatin 40 mg	1 daily
terbinafine 250 mg	1 daily for 12 weeks
zolpidem 5 mg	1 at bedtime

Figure 2.4 **After: Cleaner, Data Takes Center Stage**

Medication	Instructions
albuterol HFA 90	2 puffs every 4 hours as needed
aspirin 81 mg	1 daily
beclomethasone HFA 40	2 puffs twice a day
carvedilol 25 mg	1 twice daily
chlorthalidone 25 mg	1 daily
citalopram 20 mg	1 daily
gabapentin 600 mg	1 twice daily
insulin glargine 28 units	28 units at bedtime
losartan 100 mg	1 daily
metformin 1000 mg	1 twice daily
naproxen 500 mg	1 twice daily
omeprazole 40 mg	1 daily
prednisone 20 mg	2 daily
simvastatin 40 mg	1 daily
terbinafine 250 mg	1 daily for 12 weeks
zolpidem 5 mg	1 at bedtime

2.2 The Interactive Table

The interactive table allows users to sort, filter, and otherwise adjust their displays to meet the needs of the tasks at hand. This table is the standard workhorse of an EHR, and may sometimes be the only view available. The table is sufficiently flexible and powerful to adapt to fit a variety of tasks, but it can also be complex and may require more effort to learn and use than a simple list. Interactive lists help with a variety of tasks, such as making treatment decisions or e-prescribing. The list might even be able to draw on other data stored in the EHR, such as diagnoses, lab values or vital signs. Of our three examples, this list displays the most information and can provide the best support for cognitively intense tasks.

Interactive 2.1 shows an example of an Interactive Table. By default, such tables are sorted alphabetically by medication name. Physicians can sort columns of data to gain new insight into the medications and have support for various functions of medication renewals. Not all columns need to be sorted, however. For example, a physician would not find it helpful to sort by the instructions or quantity prescribed, but would find it useful to sort the list by drug names (allowing the physician to scan alphabetically, looking for a specific name), by dates (starting, renewal due, etc), diagnoses, and prescriber names.

Interactive 2.1 **Interactive Table Prototype**

Try it out: Inspiredehrs.org/interactive-table/

Download the code: github/goinvo/ehr

Returning to the Clinical Scenario — Blood Pressure (BP) Too High

Upon entering the room, Dr. Barnes learns that Mr. Martin has been exercising regularly and eating a healthy diet. He is on seventeen medications. He is tolerating them well, and taking them consistently. His blood pressure is about 10 points too high today, however, and it has been similarly elevated when he measured it at home. Dr. Barnes wants to adjust his blood pressure medications to achieve better control.

Dr. Barnes turns to the interactive medication list and sorts the medications by diagnosis. She can readily see that the patient is already on three medications for blood pressure. With some effort, she determines that all three medications are at their maximum dose. The patient will have to begin taking an additional blood pressure medication. She thinks prescribing lisinopril is the obvious next step, but given that this decision does seem so obvious, our physician wonders if there's some hidden reason why the patient isn't on lisinopril already.

Here's the mental task for our physician (see Figure 2.5):

- Review the medication list.

- Identify medications for treating high BP (antihypertensives) that the patient is taking.

- Determine if the patient is already taking the maximum dose of each of these medications.

  - If one or more of the current medications is not at the maximum dose, consider whether that medication's dosage could be increased (this may be preferable because it won't cost the patient a new co-pay, increase their potential drug interactions, or increase the number of pills the patient has to take).

  - If all the BP meds are at their maximum dose, then the physician must select an additional medication and add it to the treatment plan.

Juggling these considerations can be a lot of mental work. Fortunately, you can make the job much easier.

You can reduce the risk of error (missing one medication in the list) and decrease required mental effort (cognitive load) (See Information Chaos in the Human Factors chapter) by using smart design features.

Figure 2.5 **The Cognitive Load (See Cognitive Load in the Human Factors chapter) on Physicians Adjusting Blood Pressure Medications**

We have several suggestions for improving medication lists. Follow Effective Table Design guidelines (http://tinyurl.com/puxl2y3). For example, make sure table headers remain visible all the time and don't scroll out of view. The most important columns can be on the left (in this case, drug names). Make sure long names (like those of compound drugs) don't get truncated without leaving some visual indication that this is what happened, and make sure the entire names are quickly accessible. You can read more about table design at the SHARP-C website (https://sbmi.uth.edu/nccd/index.htm).

Allow users to sort the medication list by associated diagnosis. Humans' limited working memory can only hold three to four compound and complex items, like medications with associated strengths and daily dosing instructions, at a given time.

Working Memory

Working memory, or short term memory, enables us to recall manageable chunks of information —say phone numbers we're in the process of writing down or punching into our phones —that we need for less than a minute. We have to focus on something to keep it in our short term memory.

Asking people to look at information on one page and then remember it and use it on another page strains their short term memory. When designing interfaces, keep this in mind. Ask yourself if you can present information in a way that will allow users to focus on remembering the elements of their own tasks, rather

than on engaging with your system. Try to avoid having the user get information on one page and then needing to remember it in order to use it on another page.

Read more on Working Memory in the Human Factors chapter.

Sorting by diagnosis is only possible when previous physicians or providers have entered the information about the diagnoses that prompted a patient's prescriptions. Currently physicians aren't required to always give this information, and many don't because they don't see an obvious benefit to doing so. However with an EHR that effectively sorts by diagnoses, entering this information once for each medication will prevent a lot of unnecessary mental work in the future. When a physician prescribes a new medication, the system will present a list of the patient's current diagnoses or chronic problems. The physician can merely pick one or more of these from this list as applicable, or add a new diagnosis or chronic problem. This is essentially the same work physicians already have to do when sending out lab and imaging orders.

Sorting by diagnosis does, however, present designers and developers with additional challenges. Sorting medications that are associated with more than one diagnosis will be a design challenge. How should they represent medications associated with multiple diagnoses? How should an EHR deal with different providers' ontologies for diagnoses in the context of a health information exchange? A family physician might describe a condition as "chronic low back pain," while the orthopedic surgeon might call the same problem "lumbar spondylosis."

Gallery 2.3 **Easing Mental Work** — How many current medications for hypertension? Which medication was previously used for hypertension?

2.3 a **Sorted by Condition**

	Welcome							Today, 18 Sept 2013

Robert Martin			Medication List	Simple List	Timeline	Back to the Book	Feedback	Task List
22 Feb 1953 Male								

show brand   prn   current (16)   all (23)

Medication ▾	Dose	Frequency	Quantity	Refills	Condition ▾	Provider ▾	Prescribed ▾	2011 2012 2013 2014	Renew by ▾
nitroglycerin	0.4 mg	1 q5 min prn	25	12	Angina	Barnes	4 Jul 2012		
albuterol HFA	2 puffs	q4h prn		12	Asthma	Barnes	12 Jan 2010		22 Nov 2013
beclomethasone HFA	2 puffs	bid		12	Asthma	Barnes	19 Feb 2011		19 Sep 2013
prednisone	20 mg	2 d x5d prn	84	0	Asthma	Barnes	12 Sep 2010		19 Sep 2013
citalopram	20 mg	1 daily	90	3	Depression	Soto	23 Nov 2009		22 Nov 2013
aspirin	81 mg	1 daily			Diabetes	OTC			
insulin glargine	28 u	daily	90	11	Diabetes	Ballard	19 Nov 2012		19 Sep 2013
metformin	1000 mg	1 bid	180	3	Diabetes	Ballard	4 Mar 2008		19 Sep 2013
esomeprazole	40 mg	1 daily	90	2	GERD	Barnes	24 Oct 2010		
omeprazole	40 mg	1 daily			GERD	OTC			
simvastatin	40 mg	1 daily	84	0	High cholesterol	Barnes	19 Mar 2010		30 Sep 2013
atorvastatin	40 mg	1 daily	90		Hyperlipidemia	Barnes	25 Jun 2008		
carvedilol	12.5 mg	1 bid	90	3	Hypertension	Barnes	12 Jul 2010		20 Feb 2014
chlorthalidone	25 mg	1 daily	90	3	Hypertension	Barnes	19 Sep 2006		19 Sep 2013
lisinopril	20 mg	1 daily	90	3	Hypertension	Barnes	26 Sep 2011		
losartan	100 mg	1 daily	90	3	Hypertension	Barnes	5 Mar 2012		28 Oct 2013

2.3 b **Filtered by Condition**

| Welcome | | | | | | | | | | | | | Today, 18 Sept 2013 |

| | Robert Martin 22 Feb 1953   Male | | | | | **Medication List**   Simple List   Timeline   Back to the Book   Feedback   Task List |
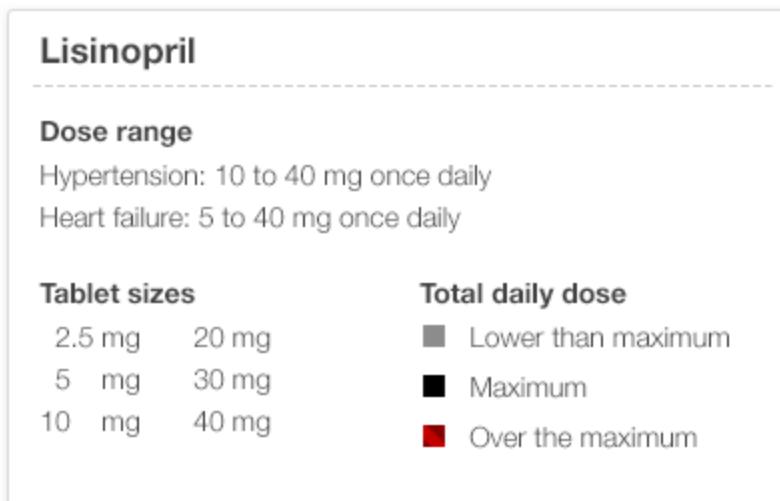
show brand   prn   current (16)   all (23)

Hypertension

Medication ▾	Dose	Frequency	Quantity	Refills	Condition ▾	Provider ▾	Prescribed ▾	2011	2012	2013	2014	Renew by ▾
carvedilol	12.5 mg	1 bid	90	3	Hypertension	Barnes	12 Jul 2010					20 Feb 2014
chlorthalidone	25 mg	1 daily	90	3	Hypertension	Barnes	19 Sep 2006					19 Sep 2013
lisinopril	20 mg	1 daily	90	3	Hypertension	Barnes	26 Sep 2011					
losartan	100 mg	1 daily	90	3	Hypertension	Barnes	5 Mar 2012					28 Oct 2013

Make **dose range information** available **with a click or a tap** by linking the medication name to reference information about that medication. Drug product information databases include information about the recommended dose range for each indication or diagnosis. The maximum dose might be higher for heart failure than it is for hypertension.

Make that same dose range information available at a glance by using an **icon or simple color scheme**. A simple color scheme in which light gray represents a low dose, darker gray a higher dose, solid black a maximum dose, and red a dose over the recommended maximum would reveal relative dosages in a way that elegantly meets physicians' needs. No clicks, no reading, and no math necessary.

Figure 2.6 **Shading Displays Information about the Maximum Dose**

Lisinopril

Dose range
Hypertension: 10 to 40 mg once daily
Heart failure: 5 to 40 mg once daily

Tablet sizes
2.5 mg   20 mg
5   mg   30 mg
10   mg   40 mg

Total daily dose
■ Lower than maximum
■ Maximum
■ Over the maximum

In any standard EHR table view, that maximum dose indicator could be added with a single small icon for each medication, shown here. This display would also help the patient better understand their medication. By creating visual designs like this that work equally well for physicians, nurses, and patients, we can make the EHR and associated care processes more understandable and transparent for patients.

Challenge: Identifying the "Maximum Dose"

Some medications have different minimum and maximum dose ranges depending on the diagnosis they're prescribed for. For example, 10 to 40 mg of lisinopril can be taken daily for hypertension, but a patient can take 5 to 40 mg daily for heart failure. The maximum dose for gabapentin is 3600 mg daily for partial seizures or neuropathic pain, and 1800 mg daily for post-herpetic neuralgia. For gabapentin, the maximum dose must be adjusted downward for reduced renal function and, as renal function declines, the maximum allowable dose drops from 1400 mg to 700 mg, and then to 300 mg daily. For patients on dialysis, however, the maximum dose of gabapentin is just 300 mg daily. Development teams will need to check with their pharmaceutical database provider to learn if data about maximum doses is available as discrete data rather than textual data. An EHR that signals maximum doses and provides information about patient characteristics

that supports dosage adjustments can help physicians make safe decisions.

For pediatric dosing, age and weight introduce further variables in maximum dose calculations. Some drug dosages should be based on the surface area of a patient's body (a function of weight and height). An EHR that provides this information in applicable cases will provide effective clinical decision support to providers.

In the examples ahead (Figure 2.7 and 2.8), we refer to the medication timeline (described in detail later in the chapter) embedded in the table view. It uses the same color scheme described earlier (light gray text represents a low dose, darker gray a higher dose, solid black a maximum dose, and red a dose over the recommended maximum).

Figure 2.7 **List with a Column for the "Maximum Dose" Icon**

Welcome
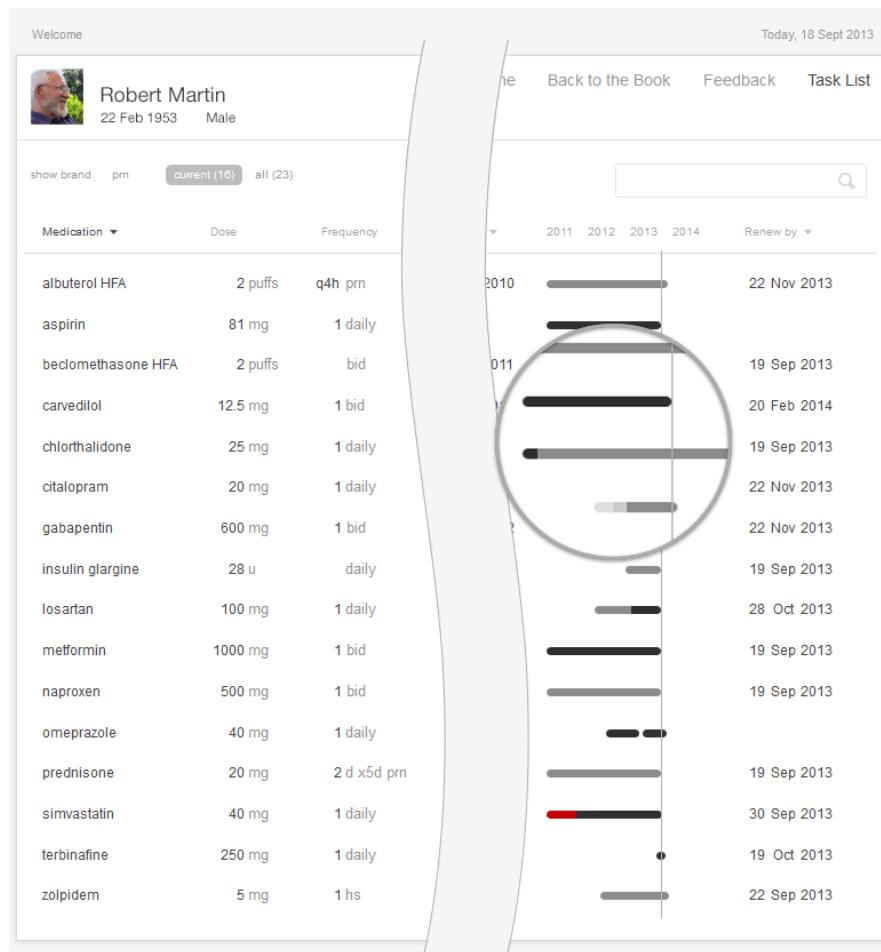
Robert Martin
22 Feb 1953   Male

show brand   prn   current (16)   all (23)

Medication ▼	Dose	Dose max	Frequency
albuterol HFA	2 puffs	■	q4h prn
aspirin	81 mg	■	1 daily
beclomethasone HFA	2 puffs	■	bid
carvedilol	12.5 mg	■	1 bid
chlorthalidone	25 mg	■	1 daily
citalopram	20 mg	■	1 daily
gabapentin	600 mg	■	1 bid
insulin glargine	28 u	■	daily
losartan	100 mg	■	1 daily
metformin	1000 mg	■	1 bid
naproxen	500 mg	■	1 bid
omeprazole	40 mg	■	1 daily
prednisone	20 mg	■	2 d x5d prn
simvastatin	40 mg	■	1 daily
terbinafine	250 mg	■	1 daily
zolpidem	5 mg	■	1 hs

Figure 2.8 **Mini-Timeline** — Shows maximum dose information for each medication

Try It Out

We've made an interactive prototype you might like to try out. Imagine a few clinical tasks (we've listed some suggestions below) and, as you work through them, compare this prototype to the tools in your existing EHR and see the difference our changes make in your user experience. Try timing yourself doing a task on the prototype and a friend or colleague doing the same task in your current EHR. Is one tool more accurate for you?

For this prototype, assume "today" is September 18, 2013.

Interactive 2.2 **Interactive Table Prototype**

Welcome · Today, 18 Sept 2013

Robert Martin
22 Feb 1953 · Male

Medication List · Simple List · Timeline · Back to the Book · Feedback · **Task List**

show brand · prn · current (16) · all (23)

| Medication ▾	Dose	Frequency	Quantity	Refills	Condition ▾	Provider ▾	Prescribed ▾	2011 2012 2013 2014	Renew by ▾
albuterol HFA	2 puffs	q4h prn		12	Asthma	Barnes	12 Jan 2010		22 Nov 2013
aspirin	81 mg	1 daily			Diabetes	OTC			
beclomethasone HFA	2 puffs	bid		12	Asthma	Barnes	19 Feb 2011		19 Sep 2013
carvedilol	12.5 mg	1 bid	90	3	Hypertension	Barnes	12 Jul 2010		20 Feb 2014
chlorthalidone	25 mg	1 daily	90	3	Hypertension	Barnes	19 Sep 2006		19 Sep 2013
citalopram	20 mg	1 daily	90	3	Depression	Soto	23 Nov 2009		22 Nov 2013
gabapentin	600 mg	1 bid	60	11	neuropathic pain	Barnes	19 Apr 2012		22 Nov 2013
insulin glargine	28 u	daily	90	11	Diabetes	Ballard	19 Nov 2012		19 Sep 2013
losartan	100 mg	1 daily	90	3	Hypertension	Barnes	5 Mar 2012		28 Oct 2013
metformin	1000 mg	1 bid	180	3	Diabetes	Ballard	4 Mar 2008		19 Sep 2013
naproxen	500 mg	1 bid	90	0	Rheumatoid arthritis	Barnes	4 Mar 2008		19 Sep 2013
omeprazole	40 mg	1 daily			GERD	OTC			
prednisone	20 mg	2 d x5d pm	84	0	Asthma	Barnes	12 Sep 2010		19 Sep 2013
simvastatin	40 mg	1 daily	84	0	High cholesterol	Barnes	19 Mar 2010		30 Sep 2013
terbinafine	250 mg	1 daily	84	0	Onychomycosis	Foote	30 Jul 2013		19 Oct 2013
zolpidem	5 mg	1 hs	90	0	Insomnia	Barnes	15 Mar 2012		22 Sep 2013

Try these Tasks

1. Is the patient taking insulin?

2. Is the patient taking any medication for diabetes? How many?

3. Is the patient taking any medication for high blood pressure (hypertension)? How many?

4. Could we safely increase the dose on any of those high blood pressure medications? If so, which ones?

5. For which medications is Dr. Barnes responsible?

Try it out: InspiredEHRs.org/interactive-table/

Download the code: github/goinvo/ehr

2.3 Medication Timeline

Physicians working with people who have many complex, chronic conditions (diseases), and managing many interventions, such as medications, laboratory tests, occasional procedures, and many visits with multiple health care providers at home, offices, and hospitals, yearn for a timeline that can help them manage all this complex data. Juggling all that data takes a tremendous amount of mental effort (cognitive load). A physician seeking to understand a patient's history with even a single medication may have to dig through progress notes, medication list tables, and years' worth of prescription renewals. The physician might then have to do the whole thing over again to understand the patient's history with a second or third medication.

A medication timeline harnesses the power of information visualization to:

1. Provide a chronological overview of the patient's medication history.

2. Enable physicians to zoom in on and filter the list.

3. Reveal details on demand.

The overview provides context and perspective, and may enable the user to make salient discoveries. ("Wow, all this patient's meds were changed six months ago.") The timeline visualization helps harness our fast thinking mind, which can quickly make sense of the start and stop images, rather than relying on our slow thinking mind to read dates and make calculations. Zooming and filtering can provide answers to preliminary questions or hunches. Physicians

can drill down to seek more specific details, such as the exact dates of medication changes, or related facts that could influence the medical chain of events.
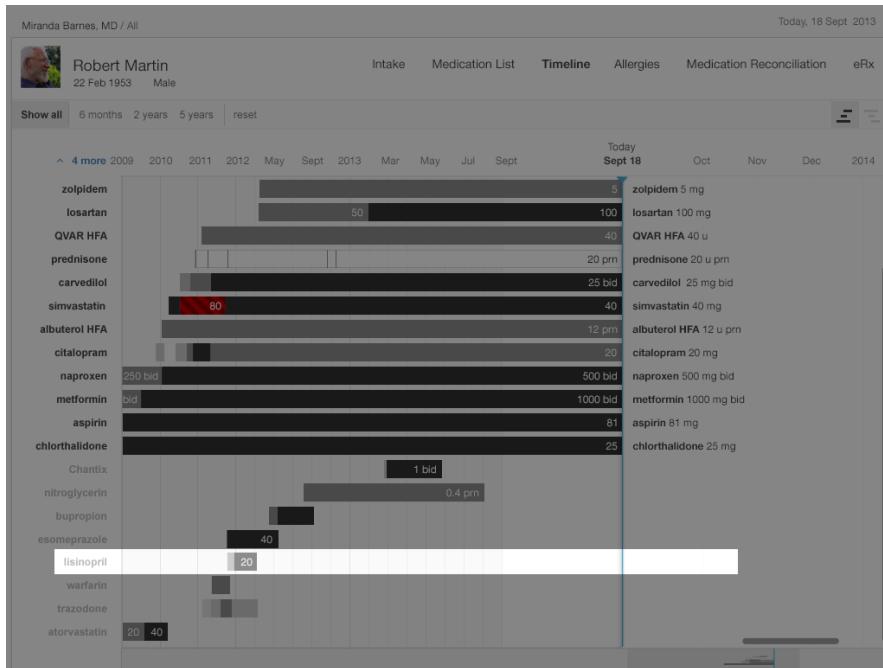
Returning to the Clinical Scenario — What Happened Before Today?

Dr. Barnes had determined that Mr. Martin's blood pressure was too high, and that it would be necessary to prescribe an additional drug. She wondered why lisinopril was not already on this patient's medication list, since it would normally be among the first three drugs she used for hypertension. So, turning to the medication timeline, she explores the patient's medication history by toggling from the "Active Medications" view to the "Active & Inactive Medications" view. She sees (Figure 2.9 below) that lisinopril had once been prescribed, but that the patient had only taken it for a few months. She wonders why. Doing a search of the chart, she finds a phone note reporting that the patient developed a persistent dry cough, which had resolved when he stopped taking lisinopril. There was no other record of that adverse effect in the chart, so Dr. Barnes added lisinopril to the allergy list, with "cough" as an "adverse effect." If her EHR supports the function, she might also write "cough" in the comment field associated with lisinopril under the "reason for stopping" column.
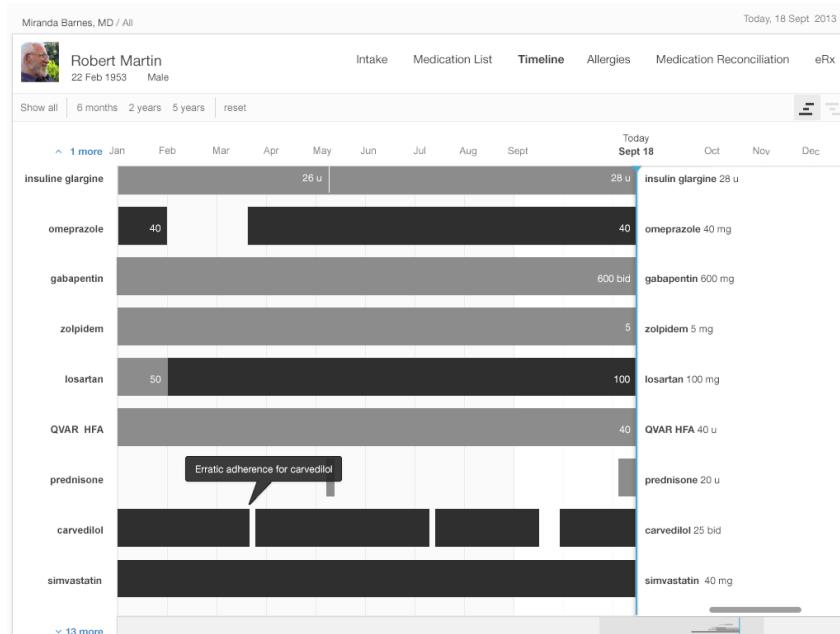
Figure 2.9 **Show All Medications (Active & Inactive)** — Lisinopril had been stopped.

Dr. Barnes now considers prescribing amlodipine to control the patient's high blood pressure, but wonders about the patient's adherence to the medications he's already on. Zooming in on the medication timeline, she finds that the patient was three weeks late refilling his Coreg, but had been embarrassed to admit to it. The patient had just requested a refill last night and planned to pick it up from the pharmacy after the visit today. Coreg's relatively high co-pay made the patient hesitant to refill his prescription in a timely manner. With this brought to her attention, the physician discussed less expensive alternatives in the beta-blocker class. Together they selected metoprolol XL 200 mg daily. You can read more about why patients might not be taking their medication as prescribed in Chapter 3, Medication Reconciliation.

Figure 2.10 **Zoom in to See Granular Details like Gaps in Medication Adherence**

A timeline offers a complete overview. At the top level, a timeline conveys details about when a patient starts and stops taking a medication, when that medication's dose changes, whether that change is an increase or decrease, and whether the dosage taken is the maximum one.
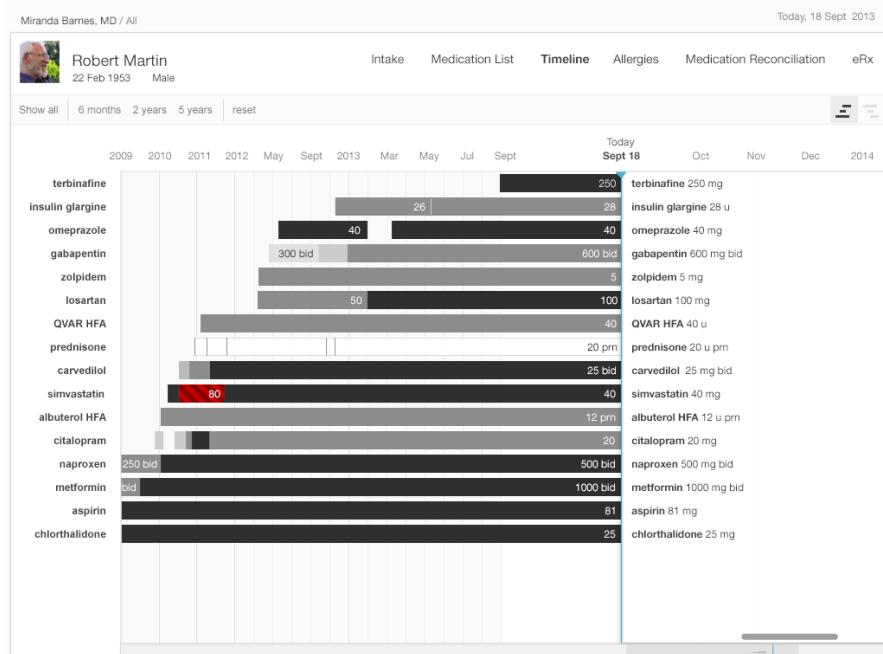
In the straightforward timeline presented in Gallery 2.4, each bar represents the history of a single medication (e.g. citalopram started at 10 mg, and the dosage progressively increased to 40 mg daily). The physician can adjust the timescale to give a wider or narrower view of the patient's medication history. Solid black represents the maximum dose of that particular medication, with shades of gray representing progressively lower doses (lighter means lower). This design presents the user with a wealth of information at a glance.

Highly usable EHR designs can accommodate large medication lists. Patients with an array of complex problems can have 15 to 20 medications on their active list, and ideally physicians dealing with challenging cases such as these won't have to scroll to view all of a patient's medications at once.
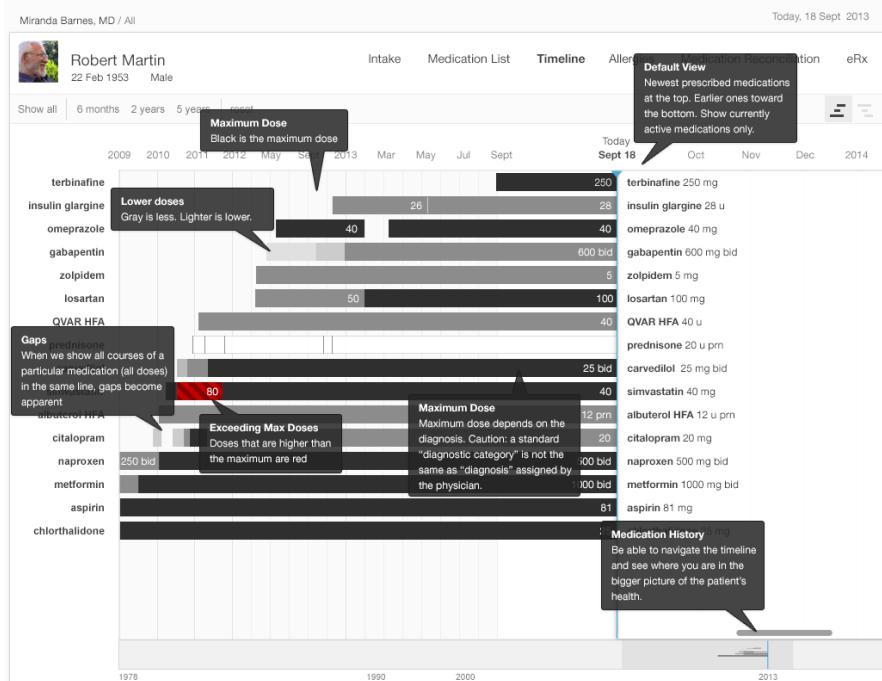
All instances of a medication (e.g. citalopram) will occur in the same timeline, even if they involve different tablet strengths (10 mg, 20 mg, or 40 mg) or occur at distinct points in time (say, an eight month course four years ago, and another course for the past twelve months).

Gallery 2.4 **Medication Timeline**
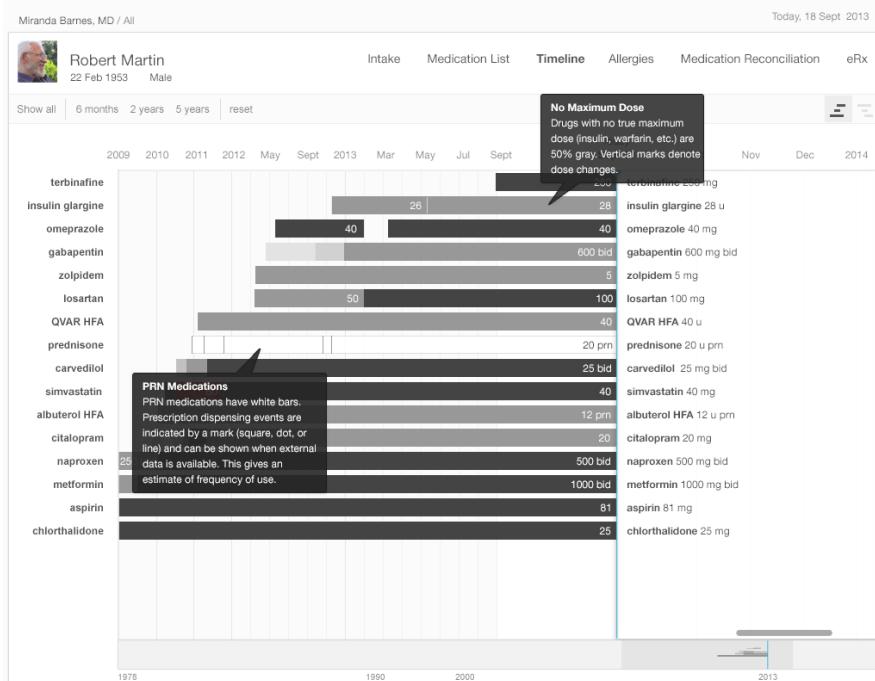
2.4 a **Medication Timeline Showing Drug Dosages for "Today"**

2.4 b How to Read the Timeline

2.4 c **Special Cases** — PRN (as needed) medications and
medications with no fixed maximum dose

The medication timeline we illustrate incorporates some innovative interface usability features predicated on cognitive science. The efficient "high-level overview" shows the timeline for a patient's complete list of medications in a single view. This tool will eliminate the need for the user to try and hold all these disparate pieces of information in her working memory, or to make written notes just to keep track of the details scattered across several EHR views. A physician looking at this visualization will pick up on preattentive attributes (See Preattentive Attributes in the Human Factors chapter) such as color, length, and proximity (See Proximity in the Human Factors chapter), and will be able to discern patterns in these far more easily than she might see them in text or numerical data.

Our physician will also be able to zoom in on areas of interest and explore them in more detail. The EHR can provide her with explanations, dose details, and even adherence information if pharmacy refill data or patient-reported adherence data is available. This will further assist our physician to confirm hunches and develop new questions to pursue.

The EHR can also display any episodic medications a patient has been prescribed, such as PRN medications for pain, nausea, asthma exacerbations, etc. In Gallery 2.5, these are represented by a white bar. The EHR will display that a patient has used these medications by means of additional visual cues. An EHR might indicate pharmacy dispense events with a square or dot, and patient reports of medication use with a small vertical hash mark.

EHR filtering can be capable of showing only active medications, discontinued medications, or both, as needed. This will help

physicians answer other questions that arise during their inquiries ("Why was this medication stopped last December, and what made the patient switch to this alternative medication?").

For the timeline, we used monochrome (grayscale) to convey most information. EHRs with specific color schemes could adapt our black scheme for conveying a maximum number to a "darkest blue" or "darkest green". We used color sparingly, to alert physicians to issues such as dosages over the recommended maximum dose. In general, it's a good idea to design in monochrome first. You can then add color sparingly to convey meaning in a way that won't distract the user. Remember that some users will not perceive color. In our example, we combined color and cross hatching when we needed to indicate a maximum dose to make sure that no one missed crucial information due to this quite common disability. You can make sure you've designed for maximum accessibility by printing your design in grayscale and checking that all the information it is supposed to convey is still visible.
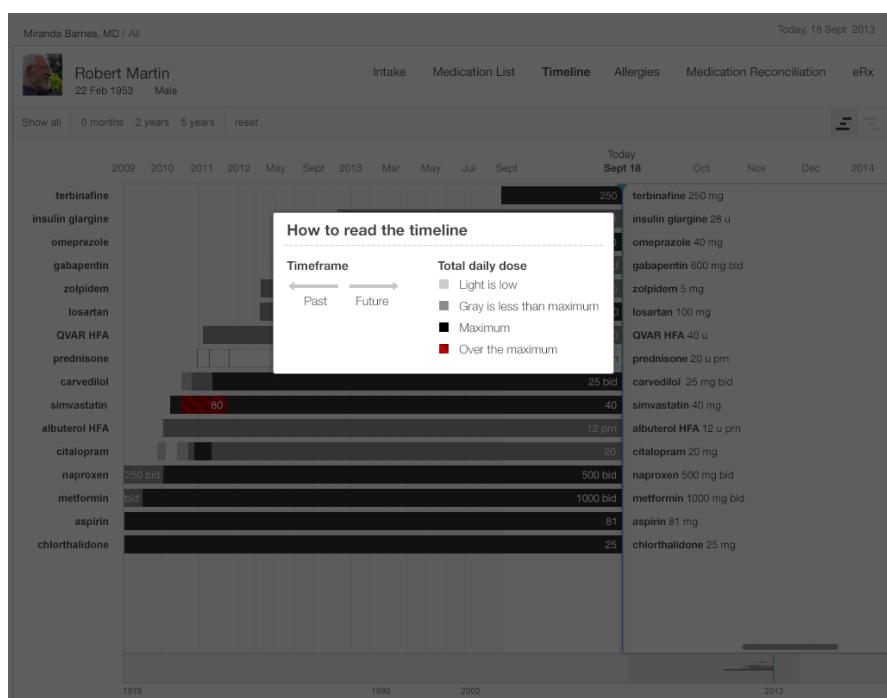
Above all, the text must be legible. On our timeline, the drug names are left-justified, which makes them easier to read. The dose, displayed in either black or white, contrasts with the background. Experienced, dexterous users can comfortably manually zoom in on our timeline, but even absolute beginners can use the buttons that allow them to quickly zoom in on commonly-used, useful time periods (such as "the last three months" or "the last year").

Our medication timeline aims to accommodate every conceivable user: physicians, nurses, patients, caregivers, pharmacists, mental health professionals, health coaches, and all other medical specialists. It can accommodate long lists of medications. A dozen
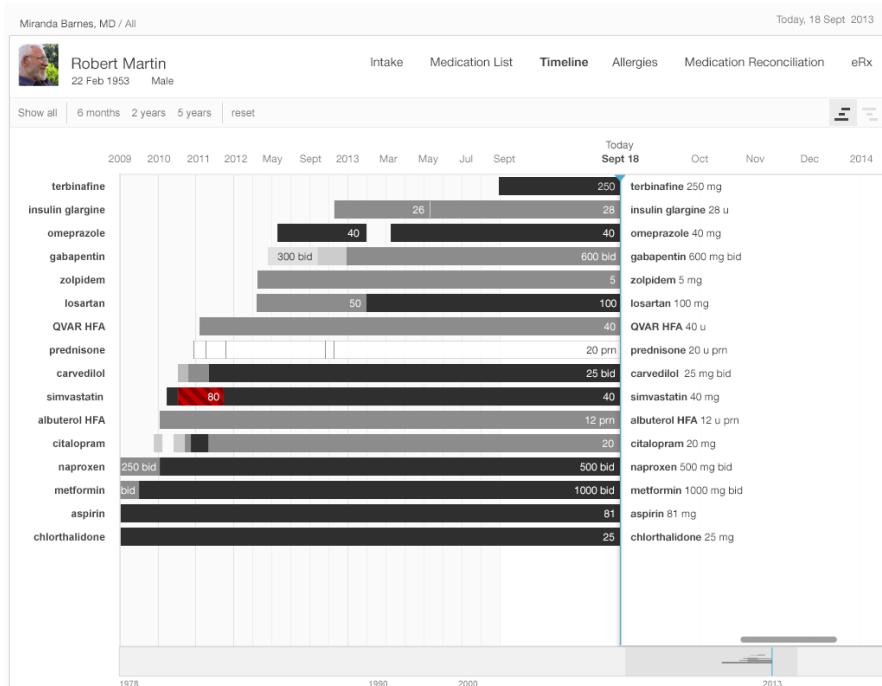
medications can be quite common. Twenty medications would not be surprising. Thirty medications, sadly, may not be rare. The medication timeline handles the visual burden with ease. It's a tool for data visualization, whose mantra is "overview first, then zoom and filter, then details-on-demand." Let's look at Gallery 2.5 to demonstrate how.

Gallery 2.5 **Medication Timeline**
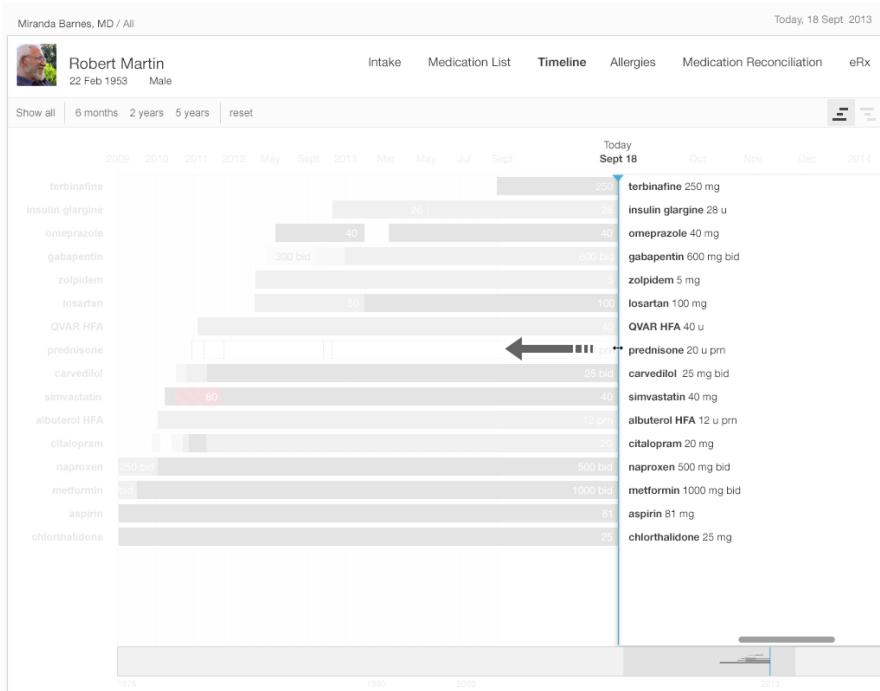
2.5 a **Instructions on How to Read the Timeline**

2.5 b **Active Medications in the Timeline**
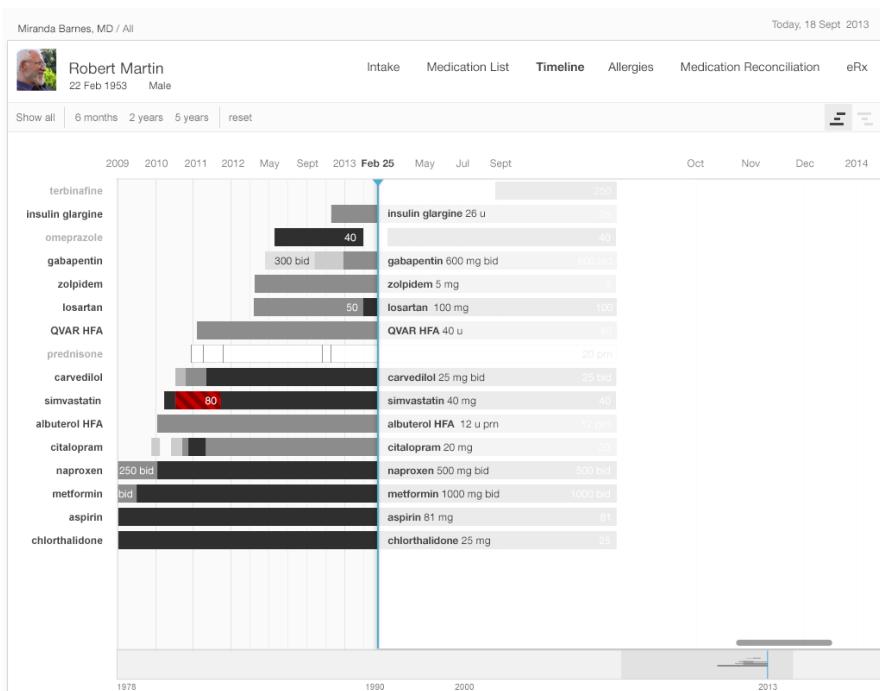
2.5 c **Grab the Scrubber** — Drag it across the timeline to look at more details about certain dates.
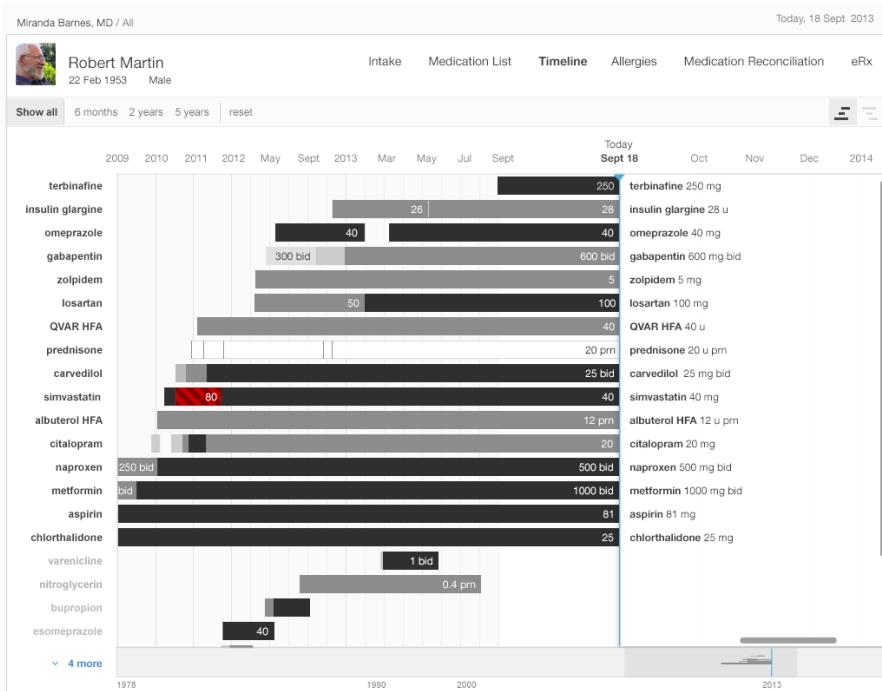
2.5 d Dragging the Scrubber Further Back in Time — Medications not yet prescribed appear as grayed out names, and the labels disappear.
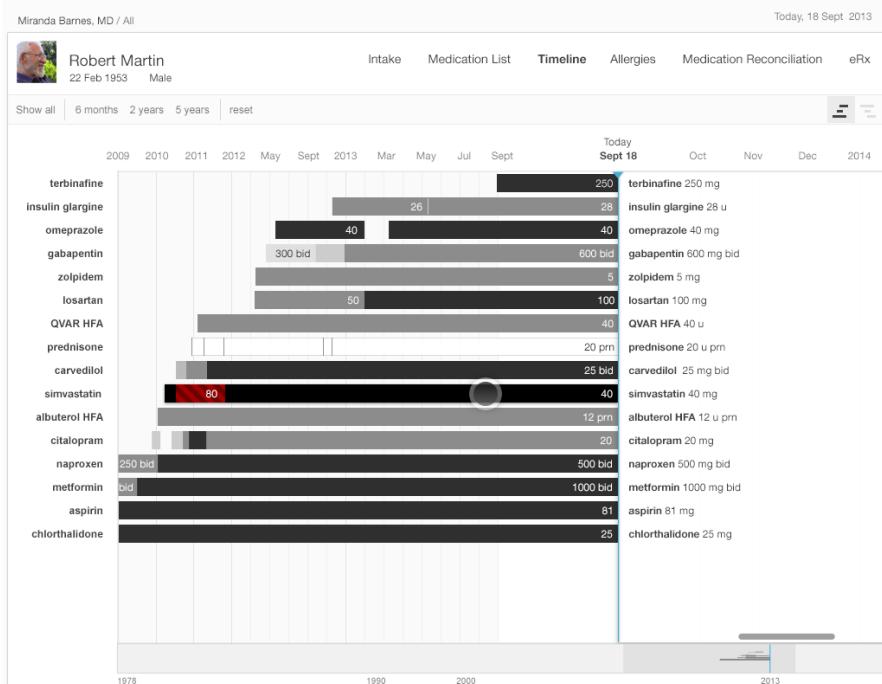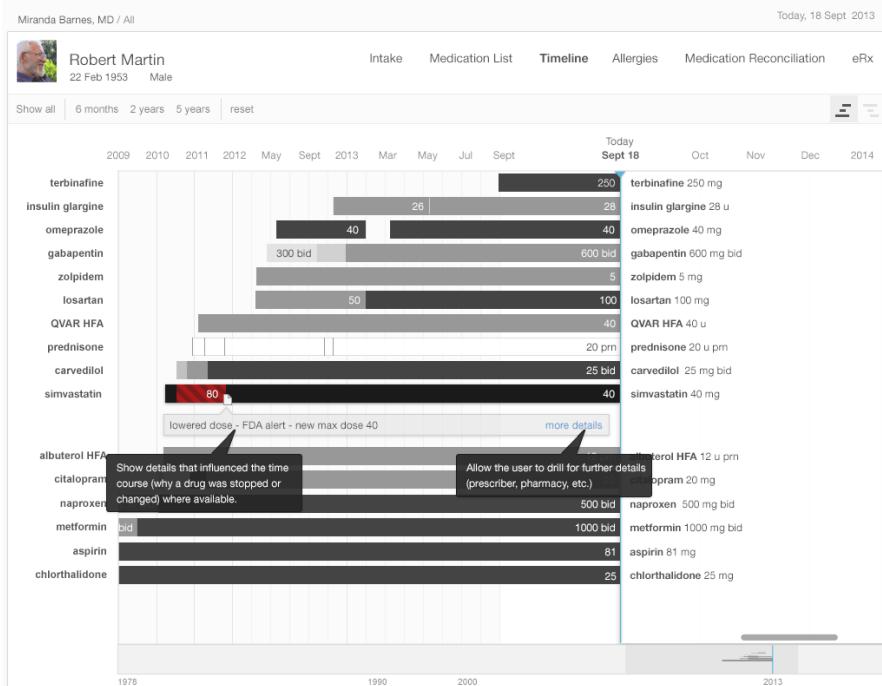
2.5 e **Show All Medications** — Active medications are at the top, inactive medications are at the bottom.
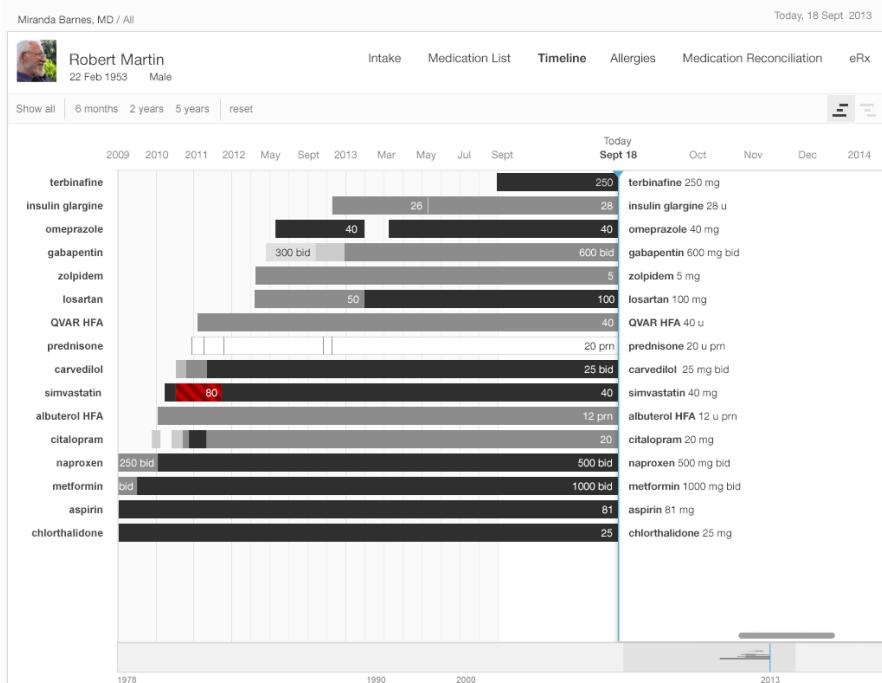
2.5 f **Tap on a Medication Line to See More Details**

2.5 g Expanding a Bar Reveals the Details that Influenced a Patient's History with a Medication — Such as their reason for discontinuing it. Access other details (pharmacy, prescriber, etc) by linking a drug timeline to that drug in the interactive table.

2.5 h Back to Where We Started

Try It Out

See the Timeline in action in this short demo video. (http://vimeo.
com/99496442)
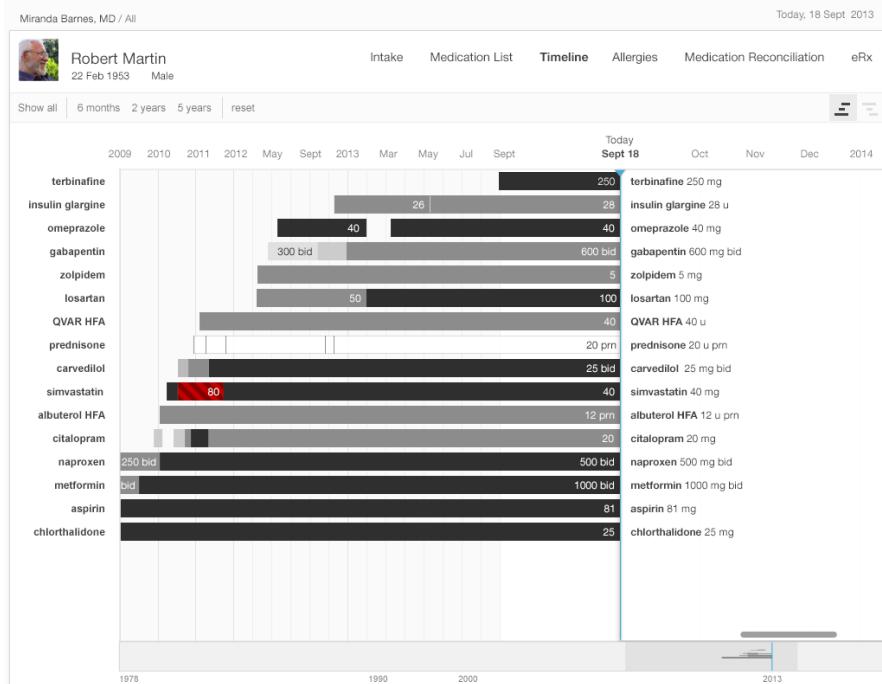
We've made an interactive prototype timeline you might like to try
out. Imagine a few clinical tasks (we've listed some suggestions
below) and, as you work through them, compare this prototype to
the tools in your existing EHR and see the difference our changes
make in your user experience. Try timing yourself doing a task on
the prototype and a friend or colleague doing the same task in your
current EHR. Is one tool more accurate for you?

For this prototype, assume "today" is September 18, 2013.

Interactive 2.4 **Medication Timeline Prototype**

Try it out: Inspiredehrs.org/timeline/

Download the code: github/goinvo/ehr

Try These Tasks

1. Navigate so that you can see the starting date, September 18, 2013, by dragging the gray shaded area (the scrubber) in the bottom timeline. (We set a current date of September 18th so our prototype will work both now and for years to come).

2. What medication did the patient start taking most recently? About when did he start taking it?

3. Which medication did the patient stop taking most recently?

4. Drag the scrubber at the bottom of the frame until you can see a 5-year timeline

5. Which drugs did the patient stop taking, and then start taking again?

6. Try dragging the list of medication names on the right side of the frame towards the left. Notice that some names disappear. Only the drugs and the dosages the patient was taking at the point in time you've moved the scrubber to will show up on the list.

Future Directions for Medication Timeline

Our timeline doesn't yet provide all the answers. We haven't attempted to address the data needs of complex regimens like chemotherapy, or the variables involved in pediatric dosing. Other clinical tasks really demand a historical view that integrates other clinical data. For example, warfarin anticoagulation management requires details about prior warfarin dose changes, other medication changes, and prothrombin time (also known as protime, or PT or INR) lab results. Insulin management requires physicians to be able to simultaneously view recent blood glucose

results, hemoglobin A1c results, diet and activity details, and sometimes other details about exceptions to the patient's usual condition or activities.

A graphical display of laboratory values to accompany the timeline may help physicians even more. An ideal timeline for cases such as these would allow physicians to see what medication changes, if any, preceded a rise in laboratory markers of liver injury, or how a blood pressure medication affected electrolytes and kidney function. This type of display could enhance patients' safety and quality of care by presenting information in a way that makes currently obscure patterns and phenomena crystal clear for the user.

Different Medication List designs Address Different Users' Tasks

For Prescribers

User Tasks	Simple List	Interactive Table	Medication Timeline
Scan the list quickly	●		
Manage treatment decision (big picture overview to guide decisions)	●	●	
Renew medications (for when to renew and for making adjustments)		●	
Perform medication reconciliation (comparing two or more lists at transitions of care)		● But see later chapter	●
Review time course			●
Manage temporary changes brief courses (steroid bursts or intermittent treatment such as chemotherapy) **Adjustments around procedures** (adjustments & temporary medications needed around the time of surgery)		● If sort by "expected stop date"	

For Prescribers (continued)

User Tasks	Simple List	Interactive Table	Medication Timeline
Recall tried & failed medication courses (What was effective, what wasn't, and why?)			● But only if the details are recorded by the users
Assess adherence (Are refills on time? Are does taken as planned?)			● Depends on additional data, such a dispense data or patient reporting

For Patients

User Tasks	Simple List	Interactive Table
Scan or remember the list	●	
Share the list with others	●	
Restock the pill organizer (Shows which pills go in which slots of those weekly little boxes) (http://en.wikipedia.org/wiki/Pill_organizer)		● Barely
Remember daily doses (Reminds users about daily and less frequent doses and "less than daily" doses. Enables users to check items off the list when they've taken them.)	●	●
Remember pharmacy refills (For coordinating trips to the pharmacy, and asking the doctor for renewals) *Would need data from pharmacy, or from bottle*		● Would need data from pharmacy, or from bottle
Update list at end of doctor visit (Creates a final list that takes into account all the changes to the medication list that have been made during a given clinical encounter.)		●

2.4 Summary

1. When designing EHR tools, consider the user and the task they'll be performing. This will help you decide what functions and details a physician needs when using a particular medication list view.

2. Use preattentive attributes (See Preattentive Attributes in the Human Factors chapter) (like color, size, shape and alignment) to draw the user's attention to the salient details.

3. Design in monochrome first, then add color sparingly and meaningfully where it can add information without distracting the user.

4. Remember that humans have very limited working memory (See Working Memory in the Human Factors chapter) especially for complex or compound items like medications and dosages. Where possible, put information directly in view. Eliminate the need for physicians to remember details from one step to the next in a task sequence.

5. Enhance users' situational awareness by giving them an overview of all the key details.

6. Reduce users' cognitive load (See Information Chaos in the Human Factors chapter). Do the math for them. Design to minimize repetitive reading. Present the information directly instead of requiring the user to recall it.

7. Remember the data visualization mantra: overview first, then zoom and filter, then details-on-demand.

8. Design to accommodate large medication lists. Remember that it's not uncommon for some patients to have 15-20 medications on their active list. Try to design lists that don't require users to scroll to see all the medications at once.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

References

1. Profile photo in interfaces by pedronchi. (https://www.flickr.com/photos/pedronchi/)

3

Medication Reconciliation

*Exploit human factors principles to facilitate this difficult
but important task.*

Medication reconciliation is the comparison and combining of two
or more medication lists. It usually involves a conversation between
the patient and a health care professional, and can occur in many
different situations. In this chapter, we will explore medication
reconciliation scenarios and EHR designs that might be facilitated
in inpatient and ambulatory settings. The first section focuses on
one example of medication reconciliation in an **inpatient** setting.
It describes a functional prototype called "Twinlist" and illustrates
how Twinlist could be used when a patient is being discharged
from the hospital. The second section focuses on medication
reconciliation in the **ambulatory** setting, and focuses on the
patient's role in annotating and correcting their EHR medication list
at the very beginning of visits.

3.1 Inpatient Medication Reconciliation

Consider this inpatient clinical scenario:

Inpatient Clinical Scenario — A Patient with Chest Pain Is Discharged from the Hospital

Mr. Jones is a 74-year-old, married businessman, now retired. He's being treated for coronary artery disease (he received a stent at age 70), constipation, diabetes, hyperlipidemia, GERD, hypertension, and mild dementia. His primary care physician, Dr. Barnes, sent Mr. Jones to the hospital Monday morning after his wife insisted he go to the clinic because he was having trouble breathing and was rubbing his chest. He had been doing fine until sometime the previous night. His wife said he had seemed quite well Sunday afternoon, when two of their sons came over to watch the game with him. They made it "a little tailgate party, hot dogs with sauerkraut and everything."

Examining Mr. Jones, the hospital physician found moderate pulmonary congestion, but no EKG changes. He tested negative for Troponin. Because of his past medical history and the strong history of Myocardial infarction (MI) in his family, he was admitted and treated. By Wednesday afternoon, Mr. Jones is ready to leave and can be discharged from the hospital. One of the medical house officers is discharging Mr. Jones, and as part of this process,
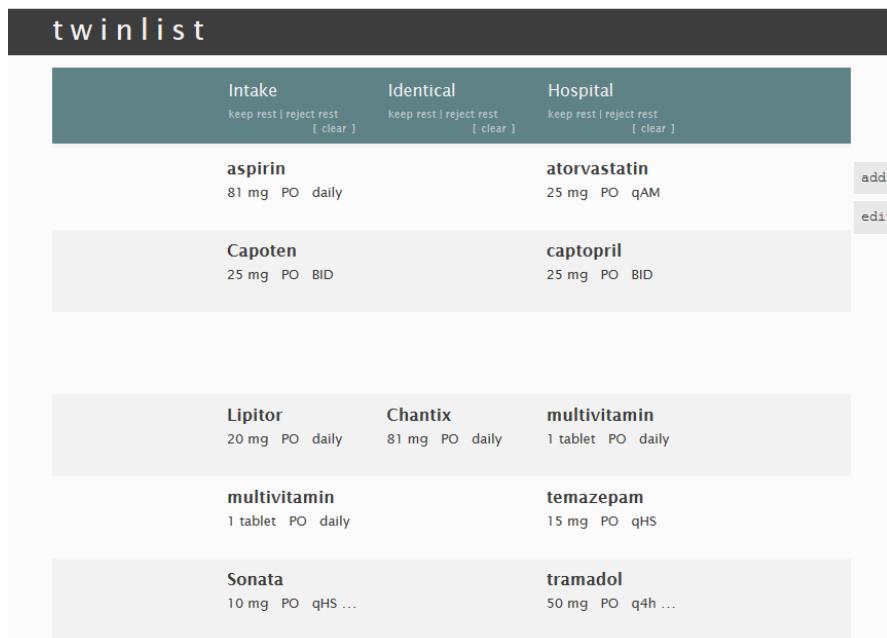
reconciling his medications.

3.1.1 A Prototype for Medication Reconciliation

In this scenario, the physician discharging the patient has to actively compare two lists:

1. The list of medications the patient was taking at home (e.g. recorded by an intake nurse when the patient arrived at the hospital, or obtained from a different EHR system).

2. The list of medications on the last day of the patient's hospital stay.

Interactive 3.1 **Interactive Demo of Twinlist**

Our physician will then decide which medications should be continued after the patient is discharged, and which should be stopped.

Let's watch a short video about a prototype called "Twinlist," an award-winning demonstration of a proposed medication interface (https://www.youtube.com/watch?v=YoSxlKlopC0).

If you'd like to explore Twinlist in more detail, try the interactive prototype (http://tinyurl.com/kljlkhs).

To learn more about Twinlist, visit the Twinlist project on the University of Maryland website (http://www.cs.umd.edu/hcil/sharp/twinlist/). You will find additional videos there that demonstrate advanced features and design variants. You can also experiment using Twinlist with larger datasets (http://tinyurl.com/k5b4kmx).

Here are some of Twinlist's features that make it an effective interface:

1. Spatial grouping (See Gestalts in the Human Factors chapter): The closer things are, the more alike they are.

2. Animation: Users can quickly learn how the drugs were grouped.

3. Highlighting: Key differences are visible and facilitate decision-making.

4. Rapid selection: The largest rectangular buttons that list drug information are easy to click.

Let's look through some individual images of Twinlist (Figure 3.1 to 3.5) to review the details. This illustrates medication reconciliation during hospital discharge.

Figure 3.1 **The Two Lists Side by Side** — Before Twinlist starts matching similar drugs

Figure 3.2 **The Identical Drugs Have Now Moved to the Center, While the Unique Drugs Have Moved to Their Respective Sides** — Similar drugs (e.g. Aricept and donepezil) have aligned below these, while the differences between the similar drugs highlighted in yellow.

Figure 3.3 **When the Pointer Hovers over a Drug (Here Amaryl), That Drug Is Highlighted with a Dark Background** — Similar drugs are also highlighted (here glimepiride). Additional details of the drug appear at the bottom of the screen

Figure 3.4 **Clicking on a Drug Selects It and Indicates That It Should Be Retained in the Medication List after Discharge** — The drug's background turns green. Clicking again (or using right-clicking if available) deselects the drug and indicates that the drug should be discontinued. Discontinued drugs are grayed-out. Similar drugs are automatically deselected (e.g. here glimepiride). Swiping gestures can be used on touchscreen devices such as the iPad.

Figure 3.5 **The Final Reconciled Medication List Can Be Reviewed** — Look at all the bright green (See The Dark Side of Color in the Design Principles chapter) selected drugs, and it's clear what lists they've come from.

3.1.2 Human Factors Principles Used in Twinlist

The Twinlist prototype uses a number of human factors principles to make it efficient and safe:

1. Identifying similar drugs is facilitated by preprocessing the data.

   a. An algorithm matches 'identical' medications and merges them, thus reducing the physician's mental effort (cognitive load).

   b. An algorithm matches 'similar' medications and aligns them on the same horizontal row. This reduces the need for repetitive visual scanning of the two lists.

   c. 'Unique' medications appear in only one column and move to the perimeter of the display.

2. The prototype takes advantage of the way the human brain processes information (specifically "preattentive attributes") (See Preattentive Attributes in the Human Factors chapter) by spatially grouping like items together.

   a. These spatial groupings (See Gestalts in the Human Factors chapter) allow physicians to quickly identify the key groups of medications (those which are identical, similar, and unique). The more different two drugs are, the farther apart they appear horizontally. Identical drugs are in the center.

   b. Differences between similar but non-identical medications are highlighted in golden-yellow, which reduces the need for physicians to repeatedly scan, read, and compare the list items.

3. The animation helps users quickly learn and understand the groupings of drugs. As the user grows familiar with the tool, the animation can be sped up or turned off.

   a. Making the list compact helps save vertical space. Similar but non-identical drugs, which physicians may have to think harder about how to reconcile, are together in the lower section of the screen.

   b. Identical drug pairs merge into the center of the chart and are thus visually identified as perfect matches.

4. Physicians can interact with the interface to discover more relationships.

   a. Hovering over a drug displays more details about the drug at the bottom of the screen, such as drug class or indication (i.e. the problem being treated). It also highlights similar drugs. Clicking to select a drug in a "similar but not identical" group rejects the others.

   b. The menu functions in a way that allows users to take actions on multiple drugs at the same time.

   c. Users can easily change or reverse their decision by clicking on drugs to toggle them through accepted, rejected, or undecided states.

5. The interface keeps the information users need to make decisions visible and minimizes the need for users to rely on their ability to recall off-screen information.

3.1.3 Other Considerations

Inpatient medication reconciliation also involves adding new drugs, e-prescribing, and generating documentation. It involves conversations with the patient and caregivers, at the time of admission and again at the time of discharge. To successfully reconcile inpatient medication lists, physicians must understand two aspects of medication management:

1. Medication administration

   a. How much insulin and analgesics were prescribed to this patient in the last few days?

   b. Did the patient receive all the doses, or were some doses delayed or not administered?

   c. Did the patient receive any PRN doses (i.e. administered as the situation arises)? How many doses were given?

2. Clinical assessment

   a. Since the patient will be leaving the hospital, intravenous medications need to be switched to oral versions. Will the patient be able to tolerate the oral version?

   b. What should be the starting dose of that medication in the oral version?

   c. How soon after the patient leaves the hospital will the doses need to be adjusted, and who will adjust them?

   d. Can the patient afford the needed medications? Will the insurance cover the medications?

Physicians commonly care for patients who have moved from one unit to another. A patient might even move several times during the course of one visit —for example, from the emergency room to a general nursing unit, intensive care unit, step-down unit, and back to general nursing unit again. Critically ill inpatients may be unable to take their medications orally and may be receiving several medications intravenously in the intensive care unit. As patients begin to recover, they might resume their previous medications at reduced doses which may gradually change throughout their hospital stay. When patients are discharged from the hospital, they may need to resume taking home medications, some of which may need dosage adjustments, and patients may need to take some additional medications.

Figure 3.1 **Simplified Medication Reconciliation Workflow in Ambulatory Setting**

3.2 Ambulatory Medication Reconciliation

Physicians use two medication lists to reconcile medications in an ambulatory setting:

1. What it says in the EHR

2. What the patients report they actually take

Healthcare team members can collect information about patients' adherence to their medication regimens either by interviewing the patients or by giving the patients a form to fill out. The latter option may save the office staff time. The diagram below shows a simplified workflow for medication reconciliation in the outpatient setting.

The medication reconciliation workflow may vary from clinic to clinic, depending on what roles said clinic assigns various members of its staff. In some clinics, nurses interview patients and update the medication list, adding annotations about patients' adherence where necessary. Physicians subsequently confirm these annotations with the patients and seek clarification about any uncertain details. Other clinics give patients printouts of their current medication list as recorded in the EHR, which the patients can then annotate. In other clinics, physicians review medication lists with the patients in the course of their visits.

Some specialists, particularly those in surgical subfields, may review medication lists less precisely, focusing only on the medications they have prescribed, such as post-operative antibiotics or pain medications. These specialists need to be able to reconcile the medications they're responsible for without assuming responsibility for the entire medication list. Reconciliation interfaces might offer a means of conveying that specialists have reconciled the

medications they're responsible for, and only those medications. It might be accomplished by giving users the option of clicking on 'Acknowledged' or 'Reviewed but not approved' in addition to the fuller 'Reconcile & Sign.'

During the visits, patients and physicians agree upon new plans of action. Physicians might then prescribe and makes other changes in the medication list. Patients then get updated copies of their list to take home.

Ambulatory Clinical Scenario — Patient with Chronic Pain Reports Changes Other Physicians Have Made to Her Medication List

Mrs. Stanton is a high school teacher who was seriously injured in a motor vehicle accident. Mrs. Stanton is under the care of an orthopedic surgeon and a pain management specialist as well as her primary care doctor. Today's visit with Dr. Barnes, her primary care doctor, involves several changes in her medication list.

At the beginning of the visit Mrs. Stanton receives the medication list her primary doctor has on file for her. She notices it's not quite up to date. It does not record that her pain specialist recently started her on a new medication, nortriptyline, and stopped another one, hydrocodone-acetaminophen, or that her orthopedic surgeon increased her dose of Celebrex. Mrs. Stanton needs to indicate those three changes on the list.

3.2.1 The Patient Reviews the Medication List

The three discrepancies the patient noted in the above scenario are typical of the type of problems patients flag when reviewing their medication lists in ambulatory, primary care settings. For the EHR to offer safe, effective clinical support (e.g. drug alerts and decision support), it needs to work with an up-to-date medication list.

Below, you'll find a design for a simple interface that allows patients to review and update their lists using tablets or desktop computers. Each screen shows only one medication, with its associated details (strength and dosage instructions). This allows the patient to answer questions carefully for each drug. Afterwards, patients can review the list as a whole. They can add drugs and include comments or questions. If the patient knows which of their medications need to be renewed, they can also indicate that.

We offer a design example with the following series of images (Figures 3.7 to 3.12), illustrating a patient reviewing her medication list for a physician visit.

Figure 3.7 **The Interface Presents Each Drug in the Patient's Medication List One at a Time, Offering a Few Clearly-Marked Choices** — The mode of presentation is well suited to a touch interface. A progress bar indicates how many drugs are in the list (and can help users get into a flow state) (See Go with the Flow in the Human Factors chapter).

Your medications

acetaminophen-hydrocodone 325 mg - 5
Norco 5/325
1 tablet at bedtime   Show details

Yes, I'm taking
1 tablet at bedtime

Yes, I'm taking, but
not as directed

No, I'm not taking it

Not sure

Back   Next
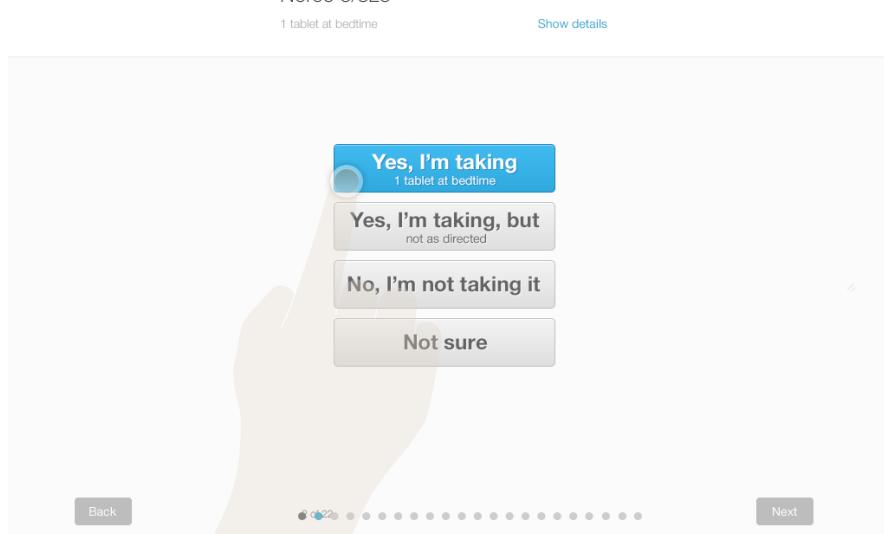
Figure 3.8 **The Patient May Not Be Taking a Drug for Various Reasons** — A physician countermanded that order, the patient did not tolerate the medication, never filled the prescription, etc.

Your medications

clonazepam 1 mg
1 twice daily   Show details

Yes, I'm taking
1 twice daily

Yes, I'm taking, but
not as directed

No, I'm not taking it

Not sure

6 of 22

Back   Next
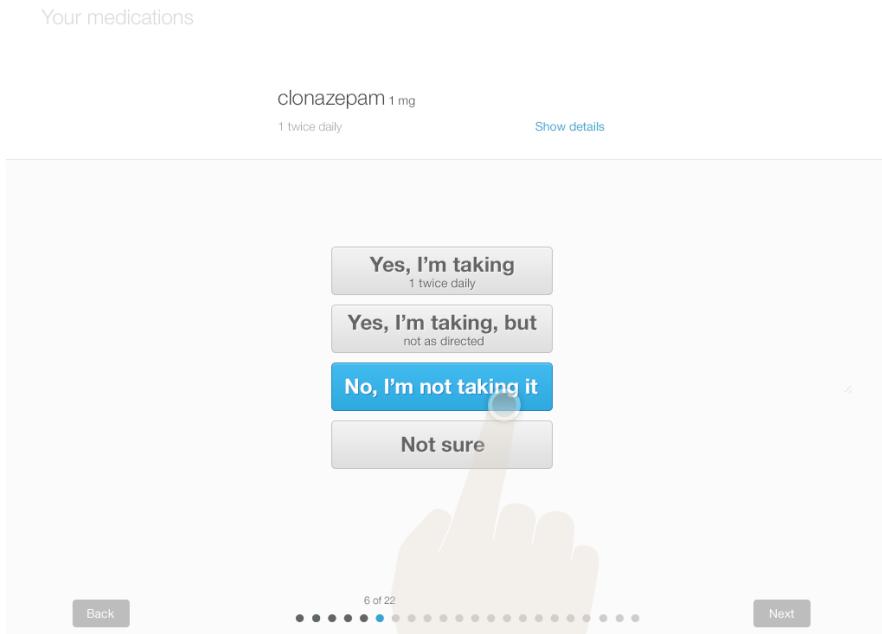
Figure 3.9 **"Yes, I'm taking but not as directed."** — The answer is enough to prompt the physician to start a conversation about adherence.

Your medications

naproxen 500 mg
Aleve
1 twice daily   Show details
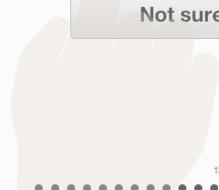
Yes, I'm taking
1 tablet at bedtime

Yes, I'm taking, but
not as directed

No, I'm not taking it

Not sure

13 of 22

Back   Next

Figure 3.10 **The Patient May Be Unsure about a Particular Medication** — She may not recognize the medication name, may be unsure about the exact dose, or may be unsure about something else.

Your medications

prednisone 20 mg
2 tablets a day for 5 days, as needed   Show details

Yes, I'm taking
1 tablet at bedtime

Yes, I'm taking, but
not as directed

No, I'm not taking it

Not sure

Back   18 of 22   Next
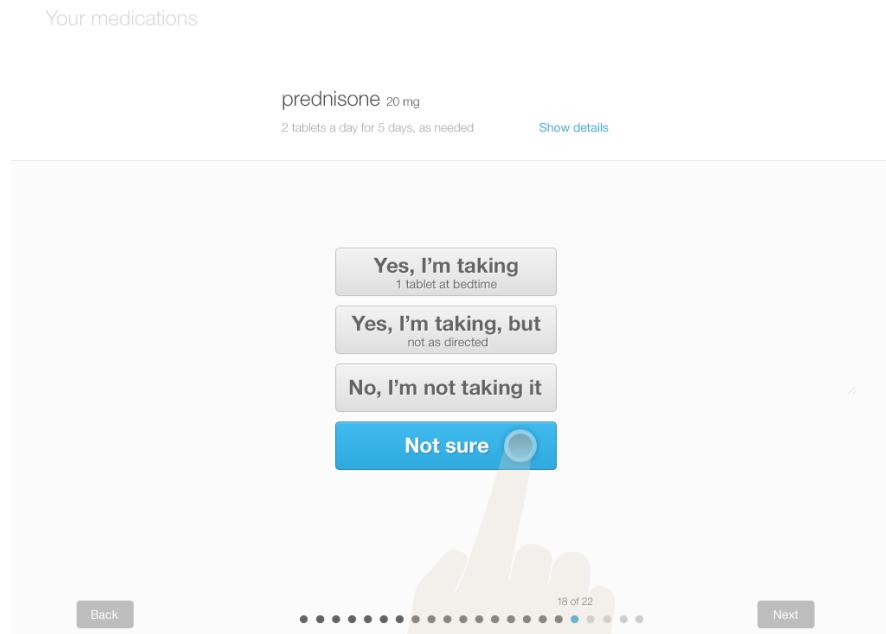
Figure 3.11 **The Patient Has Reviewed All the Medications** — The prompt reminds her to add missing prescriptions. It also prompts her to add any other items she might be taking. The interface allows for fuzzy misspelling and suggests appropriate possible names as the patient begins to type.

Figure 3.12 **Final Review from the Patient's Perspective**: The patient can review the entire list, and can add comments and mark the medications she needs the physician to renew.

After the patient has reviewed the medication list, the physician must review the patient's annotated list. They'll have a conversation about any discrepancies and uncertainties in an effort to resolve them. Then those curated details would be added to the patient's record.

Challenge - Medication Adherence

The Capture of Adherence Information

There are two main ways to capture information about patients' medication adherence (or lack thereof). One is to ask patients to provide the information, and the other is to track information about prescription fills from the e-prescribing network. At the moment, not all pharmacies, pharmacy benefit managers, and insurance plans are linked with e-prescribing networks, but even incomplete databases can complement patients' reports and help draw more accurate pictures of patients' adherence patterns.

Non-adherence Is Widespread

A significant number of patients never fill their prescriptions. In developed countries, an average of 50% of patients with chronic diseases neglect to do so[1]. Patients commonly over-report their degree of adherence, as well. Physicians are encouraged to use language that is non-judgmental. User interfaces can use similar language as well, to encourage patients to give accurate answers. The medication reconciliation process aims to uncover the truth, and from there

to allow the patients and physicians to collaboratively align their goals and come up with a plan of care that both parties can get behind.

Why Patients Stop Taking Their Medication

Why don't people take the medications prescribed for them? They may simply never fill the prescription. Sometimes they fill the prescription but don't take the medication. On other occasions they take the medication for a while, but then stop. Here are a few common reasons behind patients' non adherence:

1. The patient did not purchase the medication because it was costly.

2. The patient stopped taking the medication after experiencing side-effects.

3. The medication's side effects outweighed its benefits.

4. The patient was afraid of the side-effects.

5. The patient didn't benefit from the medication.

6. The patient didn't believe the medication would help them.

7. The patient misunderstood the expected benefits of the medication.

8. The patient didn't trust the physician who prescribed the medication.

> Knowing why patients do not take their medication can help physicians make well informed decisions. The physician doesn't want to increase a patient's dose of antihypertensive medication if non-adherence is behind uncontrolled blood pressure.

3.2.2 After the Patient Annotates Her List, the Physician Reviews It

Now let's examine the workflow of physicians as they review and reconcile a patient's medication list after the patient has annotated it. The patient's list could be displayed via an interface similar to Twinlist (http://tinyurl.com/kljlkhs), or the physician can work with whatever single-list interface the patient just used to review the entire list and enter annotations. Entirely different interfaces are also possible.

The list is ready for the physician to review, with the patient's annotations included. Let's look at our design example. (Figures 3.13 to 3.16)

Figure 3.13 The List Is Now Sorted According to the Answers Provided during the Review — Actionable items are grouped together: new medications will probably need to be added, medications the patient reports not taking may need to be adjusted or removed, medications the patient is unsure about will have to be discussed, etc. The red and green bars on the left side show whether the patient is "taking" or "not taking" the specific medications.

Figure 3.14 **The Physician Can Clarify the Details during a Conversation with the Patient, and Then Edits the Comments**

Figure 3.15 **The Physician Can Move a Medication from One Group to Another, Either with a Drag and Drop Gesture or Using Menu Selections** — Ideally, by the end of the interview, all the drugs on the list will have moved into the "taking" or "not taking" category. In this figure, Celebrex has been moved to the "taking" category.

Figure 3.16 **The Physician Has the Option to Confirm the Status of All or Some of the Medications**

The list in Figure 3.16 is the physician's final review of medication list. Once the physician approves the list by pressing the "Confirm Review" button in the upper right, the EHR updates the medication list in the patient's record and saves all comments about adherence. The category in which a medication has been placed in the list specifies how the final reconciled medication list is saved in the patient's record.

Category	Consequence
Not sure	Keep the medication in the reconciled list, but mark as "not sure."
Not Taking	Remove the medication from the reconciled medication list.
Taking	Keep the medication in he reconciled list.
Taking (but annotated as "not taking" or "not taking as prescribed" by the patient)	Keep the medication, but preserve the adherence comment from the patient in the first record.

In this design physicians would need to learn the drag and drop functionality (or alternate menu functions and affordances) (See Our Eyes Have Expectations in the Human Factors chapter) that allow moving medications from one category to another.

After the medication reconciliation at the start of the visit, the physician takes further information about the patient's medical history, does an examination, makes clinical decisions, and collaborates with the patient to make a plan of action. Their plan might include changing or adding to the patient's medications.

Challenge: Capturing and Presenting Uncertainty

Patients often report uncertainty about their medication list. For instance, patients may not be able to recognize or pronounce the names of medications they've been taking for some time. Some people may refer to medications by intended purposes: "a blood pressure medicine." Conversations outside the formal office visit (via phone or email) may have conveyed information that didn't make it to the patient's record.

Medication reconciliation implies certainty: after it's recorded, the data acquires the status of fact. That certainty is not always justified. We need methods to represent uncertainty in these human aspects of technology. An EHR might represent uncertainty by including text comments or with quantitative measures such as confidence ratings or likelihood algorithms.

About Using Pill Pictures to Resolve Uncertainty

Images of the pills may help patients identify the medications they are taking. Unfortunately we cannot count on current EHR medication lists to have the right images because there may be dozens of potential images for a single medication (153 images for lisinopril on drugs.com's pill identifier http://www.drugs.com/imprints.php, and 423 results at http://pillbox.nlm.nih.gov). Patients might also confuse similar looking medications and misidentify what they are taking. Still, having access to pictures during the interview process might be helpful for "simpler" medications that have only a limited number of distinct images.

3.3 Summary

1. Algorithms that group or align (See Gestalts in the Human Factors chapter) drugs to help physicians recognize their similarities and differences reduce cognitive load.

2. Make lists easy to scan visually. Don't truncate medication names or important details in table views.

3. Add typographic emphasis (See Our Eyes Have Expectations in the Human Factors chapter) by using bold or larger font where appropriate.

4. Allow medication sorting and filtering (e.g. by prescriber, by diagnosis and/or renewal status)

5. Where possible, display a limited number of options. Reveal further options when necessary.

6. Ask patients simple, clear questions using plain, non-judgmental language. (See Terminology in the Design Principles chapter)

7. Offer patients simple, clear choices of categorizing and documenting their adherence (e.g. Taking as prescribed; Taking, but not as prescribed; Not taking at all). Include "Other" or "Not sure" options. Provide users with a means to document uncertainty, and make sure that uncertainty is visible in the review list.

8. Offer cognitive support for adding new medications. Allow for fuzzy misspelling. Suggest appropriate drug names as the patient begins to type.

9. Experiment with innovative methods for capturing uncertainty and improving adherence recording.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

For information about the empirical testing of Twinlist see the Twinlist project webpage. (http://www.cs.umd.edu/hcil/sharp/twinlist/)

References

1. Bosworth, Hayden B., Bradi B. Granger, Phil Mendys, Ralph Brindis, Rebecca Burkholder, Susan M. Czajkowski, Jodi G. Daniel, et al. "Medication Adherence: A Call for Action." *American Heart Journal* 162, no. 3 (September 2011): 412–24. doi:10.1016/j.ahj.2011.06.007.

2. Profile photo in interfaces by David Amsler. (https://www.flickr.com/photos/amslerpix/)

4

Allergy List

Streamline data entry and create clear, uncluttered displays to highlight important allergies.

Medication Allergy Lists (or simply Allergy Lists) currently include a patient's known medication allergies, but they could include more.

Historically, physicians, nurses, patients, and pharmacists have included patients' true drug allergies, other adverse drug reactions (also known as side-effects or adverse effects) such as nausea or drowsiness, and allergic reactions in their allergy lists. In this chapter, we will focus on true drug allergies and adverse drug reactions. Physicians often also include patients' allergies to substances other than medications (such as latex, adhesive tape, peanuts and other foods) in Allergy Lists.

Other Kinds of Allergies

Inhalant allergies (such as asthma, hay fever, or allergies to dust and mold) are usually not included in the Allergy List, but rather in the Problem List. Very few food allergies could have an effect on prescriptions. A few injectable medications use peanut oil, glucosamine tablets may be derived from shellfish, and patients with egg or soy allergies should not be prescribed propofol.

In one way, the Allergy List is the safety net that supports the Medication List. Physicians check the medication list against this list of allergies in order to ensure patient safety. Allergic reactions can range from minor to fatal, so the Allergy List needs to be kept current to prevent these events. Good design can simplify correcting errors in the Allergy List.

4.1 Three Main Tasks

Developers might design Allergy Lists keeping in mind a user's three main tasks: glancing, exploring, and changing the list.

Glancing at the list may reveal that a patient has "no known medication allergies" – or that he's deathly allergic to the medication the physician is about to order for him. Often, ideally every time they prescribe or administer a new medication, doctors and nurses will need to quickly refer to the Allergy List.

Exploring the details may help a physician decide whether a drug's benefits outweigh the risks.

Adding new entries to the list can be quick and straightforward. **Editing the list** can be fast, assured, and flexible, requiring minimal details.

Let's consider the clinical scenarios prompting our three tasks, and some design makeovers that better address the needs of these scenarios and tasks.

4.2 Glancing at the Allergy List

Clinical Scenario — Considering a New Prescription

A young woman visits Dr. Barnes with what seems to be a simple bladder infection. Dr. Barnes would normally prescribe the antibiotic sulfamethoxazole / trimethoprim (or Bactrim) for this complaint, but a quick glance at the allergy list in the patient's demographic banner reveals that this patient is allergic to sulfa drugs such as Bactrim. Instead, Dr. Barnes prescribes ciprofloxacin, a suitable and equally inexpensive drug.

Every time they prescribe new medication, doctors will need to quickly refer to the Allergy List and may ask patients if they are allergic to the drugs in question.

For this task, physicians need to be able to glance at a short list that only contains the names of the drugs a patient is allergic to. This list could be clearly visible when physicians are prescribing or administering, but they don't need to see it when performing unrelated tasks, such as documenting the visit in a note. The list could be included in the patient demographic banner, where it would always be visible even while physicians do tasks that don't require it.

Developers can work to minimize physicians' cognitive loads, or the mental effort they must expend to perform this task, by making the information physicians need easy to find, and by not over-burdening them with unnecessary details. Navigating through the EHR requires time and effort, and remembering where they need to look increases the cognitive load on often already-overburdened health care providers.

We've mocked-up "before and after" versions of an allergy list (Figures 4.1 and 4.2) to illustrate what we mean.

This example (Figure 4.1) uses some of its limited space to list symptoms. The total number of items in this potentially long list is not visible unless the user hovers over the list with a mouse. The user may, however, be using a touch interface, and touch interfaces don't allow users to hover in the same way. The interface can quickly become a confusing collection of gestures that complicates interaction. Thus information stored in this format isn't easily accessible to some users; making use of a click or tap instead of hover will help. Listing additional substances here would actually help physicians out more. Physicians need to know, at a glance, if they're seeing all the substances on the Allergy List, or if what they're looking at has been truncated.

Figure 4.1 **Before: Glancing at the List** – A design that hides key details

Figure 4.2 **After: Glancing at the List** – A design that brings key details to the forefront

In our "after" example (Figure 4.2), by not listing the symptoms we were able to show more substances. The "5 more" indicator is more obvious and helpful than the hover-function it replaces, clearly telling users that the patient has five more drug allergies which are not displayed in this concise view. The number without the word "more" could be confusing. At first glance, our minds will try to jump to a conclusion about what the number means (Is it a "total of 5", or are there "5 more" to be seen?).

Including the Allergy List in the patient demographic banner, as we've chosen to do, is one means of incorporating this list into the workflow. The Allergy List could only pop up in the workflow when the physician enters a new medication prescription or renewal (Figure 4.3). This would still make the Allergy List readily available to a physician making prescriptions. Most other workflows such as reviewing lab results or vital signs or reading reports, don't require that the physician be aware of a patient's medication allergies.

Figure 4.3 **Add Prescriptions**

4.3 Exploring the Details

Sometimes a physician wants to know a bit more detail about a drug allergy on the list. How accurate is the information? Are the potential risks of using the drug outweighed by strong benefits, such as increased effectiveness or significantly lower costs?

Clinical Scenario — Reviewing Allergy Details

Dr. Barnes is seeing a 38-year-old father of four. For the last two days, the patient's throat has been getting increasingly sore. Five days ago, one of his children came home from school with a fever and headache. The patient's rapid strep test indicates that he has strep throat.

Dr. Barnes would usually prescribe penicillin because it's cheap and effective. A few years ago, however, the patient had a severe reaction to penicillin, which included hives and a swelling of the lips. The physician's next choice would be cephalexin (Keflex). Because penicillin and cephalexin are chemically similar, if the patient's allergic reaction to penicillin was truly severe, he might also have an allergic reaction to cephalexin. Other times it may perfectly safe to prescribe.
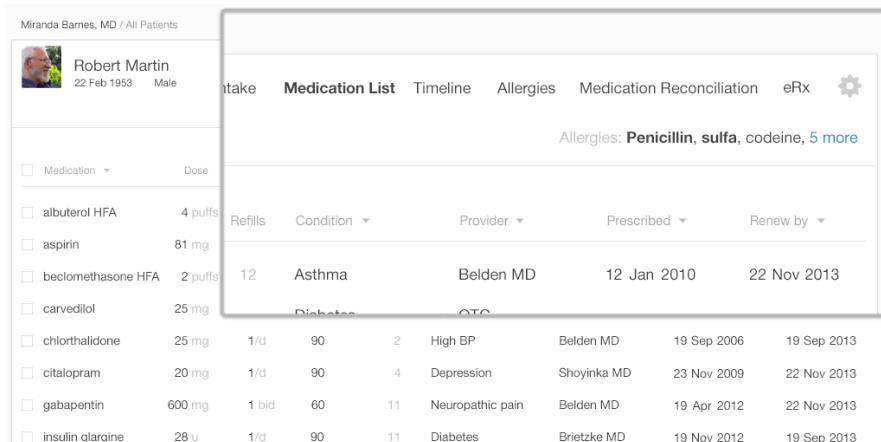
Cephalexin can be perfectly safe for people with a mild penicillin allergy. However people with a

severe penicillin allergy should avoid cephalexin.
The third-choice alternatives would be clindamycin
or azithromycin (Z-Pak), both of which are more
expensive.

Glancing at the patient demographic banner (Figure 4.4), the physician can see some information, but she still needs more details. What exactly happened when the patient took this drug? Was the patient's reaction severe?

Figure 4.4 **Patient Demographic Banner** – Shows only medication names.

To get this additional information, the physician will have to use the detailed table view (Figure 4.5).

Figure 4.5 **Medication Allergy List** – Table view shows details.

Allergy ▾	Reaction	Category ▾	Severity ▾	
codeine	nausea	side effect	mild	⌄
Imitrex	contraindicated due to patient's coronary disease	allergy	mild	⌄
Latex	**rash, swollen lips**	**allergy**	**moderate**	⌄
Levaquin	**tendonitis**	**side effect**	**moderate**	⌄
Lisinopril	**--**	**allergy**	**moderate**	⌄
peanuts	**itching, rash**	**allergy**	**moderate**	⌄
penicillin	anaphylaxis	allergy	severe	⌄
Sulfa	Stevens Johnsons syndrome	side effect	severe	⌄

With this list (Figure 4.5), the physician or nurse can see the information they need. More important information is on the left, and less important information is on the right. The table is simple and effective. It shows limited information and reduces the visual load on the user. By drilling a step deeper, the user can access further details.

Figure 4.6 **Users Can Click Rows to Either Edit Them or to See More Details**

What Allergy List Details are Important to Physicians?

Know your user and their needs. We sent a convenience-sample survey to mostly academic health center physician faculty members and residents at several institutions, asking what they felt was important to include in a Medication Allergy List. We had 52 responses. Our survey didn't consider regulatory requirements, which might change over time.

Figure 4.7 **What Allergy List Details are Important to You?**

Very important   Somewhat important   Not important

Medication allergies
Contrast agent allergies
Reaction description
Severity Documented
Contact allergies
Comment field to add details
Medication Intolerances
Bee stings
Food allergies
Source information
Date of onset
Show inactive allergies

These users don't often need to know about inactive allergies, allergies' dates of onset, or the source of the EHR's information about these allergies. It's safe to hide this information in the course of regular usage.

4.4 Changing the Allergy List (Adding and Editing)

Clinical Scenario — Modifying the Allergy List

Dr. Barnes is seeing an adult patient who has had a sinus infection for the past two weeks. Dr. Barnes would like to prescribe the antibiotic Augmentin. As she prepares to do so, she asks the patient whether he has any drug allergies, while simultaneously glancing at the patient's allergy list in the demographic banner.

The patient's allergy list currently includes Augmentin, but gives no details about his reaction to the drug. Dr. Barnes decides to take advantage of this opportunity to add some detail to the medication allergy list.

The patient reports that he took Augmentin years ago and became nauseated. During their conversation, the patient reveals that, since then, he has taken amoxicillin with no ill effects. Augmentin and amoxicillin are both in the penicillin family, and thus Augmentin should be safe to prescribe.

To correct the allergy list, Dr. Barnes will recategorize the Augmentin allergy as a side effect.

4.4.1 Editing the Allergy List

Our physician wants to quickly edit two parts of the EHR's entry for the patient's reaction to Augmentin. She wants to provide information about the patient's symptom, nausea, and to change the reaction's category from allergy to side-effect. The doctor wants to work quickly, because other clinical tasks demand her attention. The developer's task is to make adding and removing substances from the Allergy List quick and intuitive. Here are some details for developers to keep in mind while creating EHRs that meet physicians' needs:

- Physicians often take on new patients and need to add several allergies to their lists, so make adding entries quick and effortless.

- Younger patients often have no known medication allergies, so make it equally quick and effortless to record, "No known medication allergies."

- Make recording the details of a reaction (the symptoms, date and severity) optional. Patients may not know or remember the details, and just recording the drug name can be enough to ensure the patient's safety.

- Include an optional comment field for further information.

- Make it easy to correct erroneous information.

- Make it easy to find out who made entries or edits to the Allergy List. This field can be auto-populated with the active user's name. Trustworthiness of the given information can vary depending on the source.

- Allow drug allergies on the list to be inactivated and removed. Otherwise, physicians will need to repeatedly override drug-allergy

alerts while prescribing medications, even when no allergies or adverse effects exist.

Take a look at how these two displays enable users to add allergies (Figures 4.8 and 4.9). Which one looks easier? Why? Are they both equally safe?

Figure 4.8 **Before: Adding an Allergy to a Visually Busy Dialog**

Figure 4.9 **After: Simplified Dialog Requires Only Key Details –** Removes less important information to a box in the lower screen.

The "after" example looks more straightforward, but is it as safe as the "before" example? Let's look at the design details.

In the following screenshot (Figure 4.10), only the highlighted areas are essential to the task of adding a substance to the Allergy List. The information we haven't highlighted is optional, but physicians trying to complete this task still have to look at it, evaluate it, and ignore it. This unnecessary information overwhelms the physician, leading to information overload (See Information Chaos in the Human Factors chapter).

Our "after" example (Figure 4.11) only includes the necessary data fields. The shaded section at the bottom offers physicians the ability to enter optional details. Our "after" design exemplifies the principle of least effort (See How People Perceive in the Human Factors chapter).

Figure 4.10 **Before: Essential Data Elements Are Highlighted for Adding a Drug Allergy**

Figure 4.11 **After: Simple, Sequential Design for Adding a Drug Allergy**

4.4.2 Adding to the Allergy List

When adding new entries to the Allergy Lists, nurses and physicians might:

1. Find the name of the drug or substance from a list of possible choices.

2. Find the symptoms that characterized the patient's reaction from a list of symptom choices.

3. If desired, add additional details such as the type of reaction, the dates it occurred on, the source of this information, etc.

Compare two examples of ways to add new allergies to lists below (Gallery 4.1).

Gallery 4.1 **Make It Simple to Add New Allergies**

4.1 a **Before: First, Find the Name of the Drug or Substance**

4.1 b **Before: Next, Add the Reaction Symptoms**

4.1 c After: Simplified Visual Path with Fewer Fields

The simplified example's design (see Gallery 4.1 c) should be faster and easier to use. It has a clear visual sequence, which makes it easier to navigate and thus more likely to be completed.

4.4.2 Predictive Search Fields

Predictive search fields can substantially reduce the mental effort and time it takes physicians to add entries to an Allergy List. Pushing the most likely results to the top of the list of predictive search results will make it easier for users to find what they're looking for. Users are far more likely to want to enter a simple description, like "cough," than they are to want to enter a more detailed result, such as "whooping cough" or "smoker's cough."

Figure 4.12 **Before: Searching Symptoms to Add a New Allergy** — The search result listing shows the primary term, "cough," far down a visually busy list.

Figure 4.2 **After: Searching Symptoms to Add a New Allergy** — List displays fewer results and pushes simpler, more frequently-chosen results to the top.

As you can see, it is difficult to find the simple term "cough" in our "before" example (Figure 4.12). The term is about a third of the way down the list, buried among many other terms.

In our "after" example (Figure 4.13), the simple cough is at the top of the list. Other options are listed alphabetically further down the list, after a visual break.

4.5 Summary

1. Consider the users and their tasks. This will help you decide what details and functions to incorporate in a particular Allergy List view.

2. Create a clear, uncluttered navigation path through the form physicians use to input allergy information.

3. Reduce information chaos by eliminating unnecessary details to reduce the amount of reading users must do to accomplish the targeted display.

4. Hide unessential details to reduce the amount of reading users must do to accomplish the targeted task.

5. Reduce cognitive load and reduce errors by offering a predictive search function.

6. Make adding the details of reactions (such as symptoms, dates and severity) optional.

7. Make recording that a patient has "no known medication allergies" effortless.

8. Make correcting erroneous information from previous entries easy.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

References

1. Profile photo in interfaces by pedronchi. (https://www.flickr.com/photos/pedronchi/)

5

E-Prescribing and Computerized Physician Order Entry (CPOE)

E-Prescribing offers an opportunity to improve user accuracy and efficiency, a satisfying experience.

E-Prescribing (eRx) can be one of the most satisfying tasks for the physician because it saves the duplication of effort involved in hand-writing prescriptions, updating the list of medications, and including the changes in the office notes. E-Prescribing can also be frustrating when the EHR does not provide adequate data entry support. E-Prescribing offers the opportunity to reduce the medication errors that can result from pharmacists misreading prescriptions, dispensing an incorrect dose, or even prescribing the wrong drug because its name was similar to the name of the drug the physician actually intended.

The back-end process of e-prescribing sends discrete electronic data to a central hub, which then distributes the prescription message to the target pharmacy electronically (or via fax, if the target pharmacy lacks e-prescribing capabilities). The pharmacy can also send messages for renewal request to the prescribing physician. A new feature, not yet widely adopted, allows prescribers to send a message electronically to a pharmacy to cancel a previously prescribed medication or prescription.

Clinical Scenario — New Prescription for Newly Diagnosed Diabetes

Mr. Martin is a 53-year-old construction supervisor. Three months ago, he was diagnosed with diabetes by Dr. Barnes, his family physician. Despite some healthy lifestyle changes, his weight is unchanged. His fingerstick blood sugars are improving, but are still too high at around 200. His goal is 80-140.

*Dr. Barnes wants Mr. Martin to take a new medication named metformin to control his blood sugar. Together they look at the EHR screen and see that metformin is on Mr. Martin's insurance formulary, and has the lowest-tier co-pay. Both are pleased. Mr. Martin wants to start with just a 30 day prescription from his local pharmacy in case he has any side-effects. The new prescription is sent electronically to the local pharmacy.*

5.1 Searching for a New Medication

Typically, physicians will have a particular medication in mind when they write prescriptions. In that case, choosing from a "favorites" list or searching for the drug are the quickest routes to new prescription. An EHR can help physicians make the right choices and enter the correct details. In most cases, having the EHR pre-populate the prescription forms will save physicians time and mental effort (cognitive load), and will reduce the risk of errors. It will help the physicians' search speed and accuracy if the EHR pre-populates the search results from the drug database as the physician types. A predictive algorithm that uses data from the Problem List or Diagnosis List is able to promote likely matches farther up the search result list.

Gallery 5.1 **Making Prescription Search Results Robust**

5.1 a **Typing Causes the List to Pre-Populate** — User favorites can jump to the top of the list.

From Cerner PowerChart. © 2014 Cerner Corporation. Reproduced by permission of Cerner Corporation.

5.1 b Typing More Characters Produces a Closer Match — Additional details (tablet strength "500") may be added to the search string.

5.1 c Allow Users to Type a Portion of the Drug Name, and Then Skip to Additional Details — Here the physician added the dosing frequency "bid."

5.1 d Adding the Number of Tablets Makes the Top Choice Exactly What the Doctor Ordered

5.1.1 Prescribing a New Medication

Once a physician finds the medication she's looking for, she needs to manage additional details like adding or reviewing the dosage strength, instructions, quantity to dispense, and number of refills to authorize. A thoughtful design will pre-populate fields associated with the medication with, possibly, the instructions for the usual starting dose. The EHR system could recommend a physician's frequently-used choices or favorites. For a returning patient, it could recommend their chosen pharmacy.

In the United States, health insurance plans often include drug formularies, which are a list of prescription drugs that will be covered by the insurance plan. Within the formulary, the drugs are grouped into a tier assignment that determines the patient's portion of the drug cost. A typical plan includes three or four tiers:

- Tier 1 usually includes generic medications (the least expensive).

- Tier 2 usually includes "preferred" brand name medications.

- Tier 3 usually includes "non-preferred" brand name medications.

- Tier 4 usually includes specialty medications (the most expensive).

If the system knows the patient's pharmacy benefit plan, it can display the associated formulary information, indicating the tier information at a glance. Also, the system can allow the prescriber to view more detail on demand.

An EHR that provides these details reduces the mental effort a physician needs to expend to accomplish this task, and thus reduces their cognitive load. This EHR can also enhance patients' safety by eliminating physicians' distractions and reducing the margin for error.

Some of the details of the prescription will depend on a patient's preferences:

	Physician Considerations	Developer Challenges
30 or 90 day supplies?	Patients will choose larger or smaller supplies of drugs depending on what a drug costs, how convenient it is to refill their prescription, or whether they're new to the drug and want to try out first to determine their tolerance for it and its effectiveness.	Insurance companies typically offer 30 or 90 day supplies of medications. The EHR can calculate the amount of medication to order based on the medication's dosage requirements and the number of days' supply a physician orders. This mathematical decision support is particularly helpful for performing more complicated calculations including: weight-based pediatric dosing, calculating the amount to be dispensed for liquids, and the amount to be dispensed for inhalers (a single inhaler often, but not necessarily, comes with a 30 day supply).

	Physician Considerations	Developer Challenges
Which pharmacy does the patient wish to use?	Patients may have one or several preferred pharmacies. Some people use a combination of suppliers to meet their needs: a mail-order pharmacy that offers them a good deal on a certain drug, a favorite local pharmacy, and another local pharmacy with some logistical advantage (one closer to work, home or the doctor's office, or one with more convenient hours).	An EHR may allow at least three patient-preferred pharmacies. Allow the physician to remove a pharmacy that the patient no longer prefers, because insurance plans (in the U.S.) change almost annually, and the patient's preferred pharmacies may need to change with them.
Are there dose limitations to consider?	Patients may be taking other drugs that contain the new drug being prescribed. This is particularly common with pain relievers. People may be taking Tylenol (acetaminophen) alone, in combination with cough and cold remedies, or in prescription combination analgesics like Vicodin or Percocet.	Consider providing dose-limit calculations to help physicians avoid overdosing their patients. Add warnings to the patient that advise, for example, not to exceed the acetaminophen maximum total daily dose (4 grams/day). If the EHR flags this issue, then the physician can also call the patient's attention to it.

	Physician Considerations	Developer Challenges
Are there formulary limitations to consider?	Patient's out-of-pocket prescription drug costs are rising at an alarming rate in the U.S. Formulary information can help physicians give patients some advance warning about what to expect at the pharmacy cash-register. That information empowers the patients and physicians, where possible, to find affordable alternatives for expensive medications before the office visit ends. If a patient first discovers the high cost of a given medication at the pharmacy, this can cause them to delay filling a prescription, and cause extra effort for the patient, pharmacy, and physician down the line.	At a minimum, show whether the drug is on-formulary. Show the tier, the amount of the co-pay (if available), and whether there are prescription quantity limits (it is common for proton-pump inhibitors like Prilosec or Nexium to have a limit of 30 tablets a month; not 60). Show if prior authorization will be required before allowing the pharmacy to dispense, and when possible include the criteria for prior authorization approval, including the contact number for obtaining prior authorization.

5.1.2 Review the New Prescription Order before Sending It Out

The physician will need to review the final configuration of the new prescriptions. The EHR can flag missing elements. The physician may still need to make last minute modifications after verbally reviewing the prescriptions with the patient.

Instructions for tapering doses need to be clearly worded and can be available as preconfigured text. Here is an example of instructions for tapering doses of prednisone 10 mg tablets for poison ivy/oak/sumac: "4 tablets once daily for 3 days, then 3 tablets once daily for 3 days, then 2 tablets daily for 3 days, then 1 tablet daily for 3 days, then stop." If there are transition instructions (stopping another medication a few days before or after starting the new one), the physician can add these.

The EHR can display drug alerts passively before the physician gives the final order. Interruptive alerts appear before the final order is submitted.

5.1.3 Changing the dose

Most medications have a range of possible doses, so modifying a dose is a very common prescriber activity. It can be as simple as switching from the current dose to a new dose, or as complicated as titrating upward using different tablet sizes over an extended period of time. Sometimes the change will involve splitting tablets (if it's safe to do), using multiple tablets of the prior dose, or spreading the dose out through the day (2 in the morning, 1 at lunch, 2 at bedtime) to achieve a more even therapeutic effect or to reduce an adverse

effect. The physician can convert from one prescription strength to another using the EHR. The system can preserve the order details, such as quantity, number of refills, pharmacy, and associated diagnoses.

Clinical Scenario — Increasing the Dose

A few years later, Mr. Martin's diabetes is well controlled, but he has developed high blood pressure (BP). Three months ago, he started on lisinopril 10 mg daily for his high blood pressure (it also protects the kidneys in people with diabetes). Today his BP is at 153/96, which is still just a little high (the readings of his BP he's taken at home are likewise high). Mr. Martin is tolerating the medication well, so his physician wants to increase the dose to 20 mg daily. Mr. Martin has just received a 90 day supply in the mail last week, so he asks if he may use up his current supply of 10 mg tablets by taking 2 tablets daily for a while.

Mr. Martin is afraid that he'll get a new bottle of 20 mg pills six weeks before he really needs them. He asks his doctor how he can avoid that. Can he take a printed prescription to submit later? Can the EHR send a message to the pharmacist instructing her not to fill the prescription until the patient makes contact to request that it be filled? Can Mr. Martin just call later for the new prescription? (Note: His physician's office prefers to avoid the later calls, because it would be an inefficient use of office staff and physician time.)

5.1.4 Changing the Current Order to a New Order

Discarding an old prescription and starting over can require a lot of time and mental effort, and can introduce the risk of error. Often, the physician only needs to change the strength of the tablet. An EHR that allows users to pick from a list of the strengths for a medication can save time. A physician may also need to adjust the number of tablets she has prescribed. Occasionally, the patient may choose to use a different pharmacy, or may request a two to four week prescription that they can fill locally while awaiting a mail-order 90 day supply.

Figure 5.1 **Allow Physicians to Modify the Display Quickly by Offering the Most Common Detail Choices for a Particular Medication —** These include strength, instructions, quantity, and number of refills.

5.1.5 Allow Association of a Diagnosis or Chronic Problem

Users often want to filter and sort medication list displays by diagnosis. Some medications are prescribed to alleviate multiple problems, and an EHR thus may need to be able to associate medications with multiple diagnoses. The 'multiple diagnosis' function also helps patients understand the roles of multi-purpose medications in their care plan. It also informs a variety of caregivers of all the reasons someone prescribed this medication. If a subsequent physician is considering changing a medication's dose or stopping it entirely, they'll need to know this information.

Why Automatically Assigning a Therapeutic Class Won't Work

Some EHR vendors may be tempted to use a drug's therapeutic class instead of relying on physician-assigned diagnoses. They may be concerned that physicians won't be willing to assign diagnoses to medications, which may be true if there is no return on the time investment for the physician. However, if the physicians receive a benefit (better sorting and filtering of medication lists, better clinical decision support fueled by that data, and better patient awareness of the reason for the medication) then physicians have an incentive to make the diagnosis assignment.

Using a therapeutic class (instead of the actual diagnosis selected for the individual patient) does

not achieve the desired result. The physician and patient need to know why this medication has been prescribed for this particular patient. Knowing that a drug is a beta-blocker (the therapeutic class) is not sufficient, because a beta-blocker might be used for any of these diagnoses: hypertension, angina, coronary artery disease, atrial fibrillation, supraventricular arrhythmias, tremor, migraine, and portal hypertension. The therapeutic class will often be meaningless to the patient.

Figure 5.2 **Allow Association of One or More Diagnoses per Medication**

5.1.6 Stopping a Medication

Removing a medication from the list can be easy. It could also be easy (though optional) for a user to record why a physician or patient stopped a medication. Common reasons for stopping a medication include:

1. The medication's high cost, which can take the form of coverage, co-pays, or cash out-of-pocket

2. The medication's inefficacy

3. The medication's side-effects

4. The medication's side effects outweighing its benefits

5. Patients don't understand the medication's possible benefits

6. Patients or physicians don't trust whoever prescribed the medication

Medication timelines are richer and more informative when they capture why medications were stopped. Timelines that give users insight into patients' history with given medications can eliminate the need for time-consuming searching, paging through progress notes, or laboriously exploring historical medication list entries.

Figure 5.3 **Medication Timeline Shows Details Like "Reason for Stopping" When User Selects a Timeline Bar**

5.1.7 Renewing Medications

Clinical Scenario — Renewing Medications Due before the Next Appointment

Mr. Martin has been seeing his family physician every three to six months, but his medications often come due for annual renewal before his upcoming appointments. Because of this disparity, Mr. Martin sometimes doesn't get his refills in time, and has to go without some of his medications for several days. Mr. Martin's refills also come in at different times throughout the month, and so he has to make several trips to the pharmacy to pick up his various prescriptions. Mr. Martin wishes his 'medication procurement' schedule could be simplified and consolidated, so that he only had to make one trip.

Mr. Martin's physician also finds the situation frustrating. If the patient came in before the renewals came due, the physician could determine whether the medication was effective, and whether the dose was right before signing off on the next round of pills. The physician feels the out-of-sync schedule they've established is a time-wasting hassle, inefficient, unsafe, inaccurate, inconvenient and pointless.

An EHR can allow a physician to renew multiple medications at the same time. This saves time and reduces the margin for error.

Designing an EHR that can sort and filter the medication list by "renewal due date," "pharmacy," and "prescribing physician" will minimize physicians' cognitive load and allow them to provide better patient-centered service.

Patients with multiple prescriptions and prescribers are often burdened with poor refill synchronization. Their refills come in on several different dates each month, and their annual renewal due dates are scattered throughout the calendar year. If physicians could easily discern which prescriptions require renewal before the next planned appointment, the physicians could consolidate their patients' prescriptions. This would reduce the physicians' workload and would be more convenient for the patients[1].

Designers could allow users to easily modify existing prescriptions, preserving existing details and offering easy access to common alternative details where users might need to make changes (changing from 10 mg to 20 mg, from 1 tablet to 2 tablets, or from 30 days to 90 days, etc.).

Gallery 5.2 **Allow Sorting and Filtering to Efficiently Facilitate Renewals**

5.2 a **Sorting the List by Renewal Due Date —** Makes it easier to group and manage the medications due for renewal.

		Today, 18 Sept 2013
Welcome		

Robert Martin
22 Feb 1953   Male

Medication List   Simple List   Timeline   Back to the Book   Feedback   Task List

show brand   pm   current (16)   all (23)

Medication ▾	Brand ▾	Dose	Frequency	Quantity	Refills	Condition ▾	Provider ▾	Prescribed ▾	2011	2012	2013	2014	Renew by ▾
beclomethasone HFA	QVAR HFA	2 puffs	bid		12	Asthma	Barnes	19 Feb 2011					19 Sep 2013
chlorthalidone		25 mg	1 daily	90	3	Hypertension	Barnes	19 Sep 2006					19 Sep 2013
insulin glargine	Lantus	28 u	daily	90	11	Diabetes	Ballard	19 Nov 2012					19 Sep 2013
metformin		1000 mg	1 bid	180	3	Diabetes	Barnes	4 Mar 2008					19 Sep 2013
naproxen	Aleve	500 mg	1 bid	90	0	Rheumatoid arthritis	Barnes	4 Mar 2008					19 Sep 2013
prednisone		20 mg	2 d x5d pm	84	0	Asthma	Barnes	12 Sep 2010					19 Sep 2013
zolpidem		5 mg	1 hs	90	0	Insomnia	Barnes	15 Mar 2012					22 Sep 2013
simvastatin		40 mg	1 daily	84	0	High cholesterol	Belden	19 Mar 2010					30 Sep 2013
terbinafine		250 mg	1 daily	84	0	Onychomycosis	Foote	30 Jul 2013					19 Oct 2013
losartan		100 mg	1 daily	90	3	Hypertension	Barnes	5 Mar 2012					28 Oct 2013
albuterol HFA	ProAir HFA	2 puffs	q4h prn		12	Asthma	Barnes	12 Jan 2010					22 Nov 2013
citalopram		20 mg	1 daily	90	3	Depression	Soto	23 Nov 2009					22 Nov 2013
gabapentin		600 mg	1 bid	60	11	neuropathic pain	Barnes	19 Apr 2012					22 Nov 2013
carvedilol		12.5 mg	1 bid	90	3	Hypertension	Barnes	12 Jul 2010					20 Feb 2014
aspirin		81 mg	1 daily			Diabetes	OTC						
omeprazole		40 mg	1 daily			GERD	OTC						

5.2 b Filtering the List by Prescriber — Makes it even easier to focus only on the selected medications, eliminating distracting items.

A bar graph data visualization (Figure 5.4 below) displaying "renewal due dates" reduces users' cognitive load. It allows physicians to note which items need to be managed during the current visit by doing a quick visual scan. The physicians recognize what medications they need to focus on by picking out preattentive attributes, such as color and line length, rather than by having to do complex mental calculations involving reading dates, quantities, and number of refills.

Figure 5.4 **Icons for "Refills Remaining"** — Icons use preattentive attributes to reduce cognitive load during the medication renewal process.

5.2 Computerized Physician Order Entry (CPOE)

A CPOE (also sometimes referred to as Computerized Provider Order Entry) is an electronic entry of patient care orders that is digitally transmitted to the departments (lab, radiology, etc.) or outside organizations that will fulfill it. CPOE orders can be distributed more quickly than their predecessors. They eliminate errors based on handwriting, and can prevent duplicate orders by checking new orders against existing orders.

Clinical Scenario — Placing Future Lab Orders

Mr. Martin has achieved good control of his diabetes, blood pressure, and lipids. For the past year, he's been on stable doses of his medications, and his lab results have been stable as well. He can now settle into a more predictable routine and won't need to visit the office or undergo lab tests as frequently. In about six months, Mr. Martin will need to come in for a hemoglobin A1c lab test and then a visit. Another six months after that, he'll need to come in for further tests (another hemoglobin A1c a fasting lipid profile and a urine microalbumin test, both for his diabetes) followed by another office visit.

5.2.1 Display Pre-Existing Orders to Prevent Duplication

A patient's EHR often contains unfulfilled orders. Patients forget tests or can't find the time to get them done. If physicians can't see patients' existing future orders or recent lab results, they may accidentally order tests that have already been done or ordered, or they may order very similar tests. This would duplicate their colleagues' work and spend resources wastefully.

When users place new orders, they can simultaneously see the work that's already been done, without navigating away from their own unfinished orders and losing their work.

Figure 5.5 **Before: Interruptive Dialog Box — Doesn't allow the physician to see existing prescription orders.**

Figure 5.6 **After: Non-interruptive Dialog Box —** Allows users to see existing orders using a separate panel or by making the dialog box non-interruptive.

5.2.2 Make It Easy to Find the Right Orders

Naming orders can be a challenge, because tests and procedures can have several commonly used names. Different organizations may use different names for the same test. The physician ordering procedures might not be familiar with precise names listed in the EHR order catalog. The EHR might formally call a chest x-ray "XR chest." A physician, however, might look for it under:

- chest x-ray (or variant spellings like "xray")

- chest XR

- XR chest

- X-ray chest

- Chest x-ray 2 views

- Chest x-ray PA and Lateral

- CXR (fastest way to hand-write the order)

These are all correct ways to name a chest x-ray. Thus, the interface could allow physicians to find tests and procedures listed under their various commonly used designations.

5.2.3 Preconfigure Orders with as Much Detail as Possible

Tests physicians order in ER or urgent care scenarios are often high priority and need to be done STAT. Routine tests physicians order in primary care settings will almost always be lower priority. They'll need to be completed today, in the near future, or at some specified

future time. An EHR that could be easily configured to a specific care setting, one that established default "priorities" for the orders it processed, would be a powerful support tool.

Setting the Date for Orders: Using Fuzzy Dates

Sometimes orders demand a precise date and time. Repeating a Prothrombin Time (PT) lab test in exactly three days helps assure safe dosing of warfarin, a clot preventer.

Other times, less precise dates would be more helpful. If a physician orders a lab for "one year from now," but the patient shows up eleven months later, telling the patient she's too early and sending her home would be counterproductive. The EHR needs to allow its users to set somewhat flexible "fuzzy dates." This will allow healthcare organizations to be adaptable and to work with patients to find times and dates convenient for them.

Figure 5.7 **Before:** The physician needs to expend a lot of effort to fill in the many missing details. There are many opportunities for error.

Figure 5.8 **After:** The EHR pre-completes key fields. Less frequently needed details are displayed less prominently.

5.2.4 Assign the Correct Diagnosis for an Order or Prescription
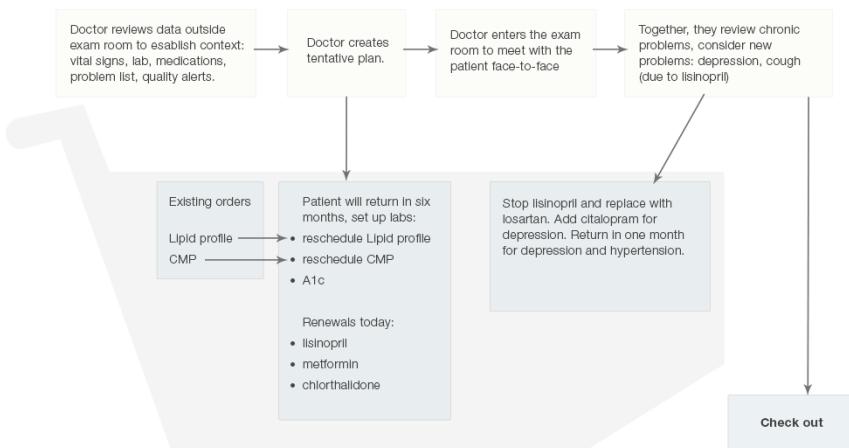
The EHR can make the problem and diagnosis lists readily available to physicians entering orders. It could also allow users to add new diagnoses on the fly, without having to exit the ordering tool to add them.

The EHR can provide clinical decision support by suggesting probable diagnoses based on patients' list entries and lab results. Some orders are almost exclusively associated with a single diagnosis, and in these cases, the system could assign this diagnosis to these orders by default. For instance an order for a hemoglobin A1c lab test will almost always be associated with a diagnosis of diabetes or hyperglycemia.

5.2.5 EHRs Can Adapt to Users, Not Users to EHRs

An adaptable EHR can let physicians "add to the shopping cart" (Figure 5.9), then "continue shopping" without checking out right away. This allows the physicians and patients to make preliminary decisions and act on them immediately, but also allows them to make adjustments as the visit unfolds.

Figure 5.9 **New Order Workflow** — EHRs must offer users the option of building sets or collections of orders to facilitate their workflow.

| Doctor reviews data outside exam room to esablish context: vital signs, lab, medications, problem list, quality alerts. | Doctor creates tentative plan. | Doctor enters the exam room to meet with the patient face-to-face | Together, they review chronic problems, consider new problems: depression, cough (due to lisinopril) |

Existing orders

Lipid profile
CMP

Patient will return in six months, set up labs:
• reschedule Lipid profile
• reschedule CMP
• A1c

Renewals today:
• lisinopril
• metformin
• chlorthalidone

Stop lisinopril and replace with losartan. Add citalopram for depression. Return in one month for depression and hypertension.

Check out

5.2.6 Building Groups of Related Orders Function like Checklists

EHRs must offer users the option of building sets or collections of orders to facilitate their workflow. This offers users personalized clinical decision support and frees them from having to depend on their memories or external reference materials to complete involved tasks. Well Child Visits, for example, follow predictable patterns. They involve immunizations at regular, predetermined intervals, specific counseling (anticipatory guidance), and set follow-up visits.

A four-month-old's Well Child Visit would include:

• Scheduling the next visit, at six months

• Administering several specific vaccines

  • Hemophilus B

  • Rotavirus

  • Pneumococcal 13-valent

  • Combination of diphtheria / hepatitis B / pertussis - acellular / polio / tetanus

5.3 Summary

EHRs can:

1. Make it easy for users to select new orders by offering a predictive search function that suggests appropriate results.

2. Fill in the blanks with probable default settings (such as 30 or 90 day prescription supplies) where possible.

3. Remember patients' pharmacy preferences, and allow users to remove pharmacies patients no longer prefer from the list.

4. Use preattentive attributes, such as color and typographic emphasis to help physicians quickly find the results that are more likely to be relevant quickly. Use color iconography to graphically display medication renewal due dates.

5. Let physicians review e-prescriptions before sending so that they can correct any errors.

6. Allow users to sort and filter medication lists to speed up the renewal process.

7. Allow users to modify existing orders without forcing them to start over from scratch.

8. Allow users to personalize the interface and build detail-rich collections of related orders that function like checklists.

9. Allow users to select specific or flexible dates for new lab orders.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

Additional Resources

From the National Center for Cognitive Informatics & Decision Making in Healthcare

EHR Safety Enhanced Design Briefs:
Preventing Electronic Medication Order Errors (E-Prescribing) (https://sbmi.uth.edu/nccd/SED/Briefs/sedb-mu05.htm)

References

1.   Choudhry NK, Fischer MA, Avorn J, et al. The Implications of Therapeutic Complexity on Adherence to Cardiovascular Medications. Arch Intern Med.2011;171(9):814-822. doi:10.1001/archinternmed.2010.495.

2.   Profile photo in interfaces by David Amsler. (https://www.flickr.com/photos/amslerpix/)

6

Drug Alerts

Effective alerts increase patient safety while reducing physicians' cognitive load.

A report (http://www.ahrq.gov/research/findings/factsheets/errors-safety/aderia/index.html#MedicationErrors) from the Agency for Healthcare Research and Quality estimates that adverse drug events annually result in over 770,000 injuries and deaths and cost up to $5.6 million dollars per hospital. A system that alerts prescribing physicians to medication conflicts can help reduce the number of adverse drug events. To be effective, however, a physician must notice, read, understand, and respond to the alerts. How well they do this depends, in part, on the design of the alerting system, including the alert rules and the methods used to display and interact with the alerts. An effective alerting system needs to strike a balance, alerting physicians to real safety risks without overwhelming them, causing alert fatigue and increasing their cognitive load. If the system gives too many nuisance alarms, or the alarms are hard to read and understand, physicians will quite reasonably begin to ignore the alerts. This chapter will focus on how developers can apply user interface and interaction design principles to create effective alerts. We consider two types of drug-related alerts: drug-allergy alerts and drug-drug interaction alerts.

6.1 Drug Allergy Alerts

Drug allergy alerts inform physicians that their patient may be allergic to whatever they've just prescribed. The physician may have accidentally overlooked the allergy. They'll need to weigh the drug's potential risks against its potential benefits, and either go forward with the prescription or cancel it. Let's look at a simple clinical scenario.

Clinical Scenario — Drug Allergy Alert

Mr. Martin is a 58-year-old who, barring one exception, was in good health until a decade ago when he was hospitalized after a severe automobile accident. At that time, he had a documented allergy (generalized hives, itching, and facial swelling) to the IV drug Unasyn, an antibiotic drug combination that contains sulbactam and ampicillin, which is a member of the penicillin family.

Today he is visiting Dr. Barnes, his primary care doctor, with symptoms of acute sinusitis. The problem has been going on for almost two weeks and is not improving. Dr. Barnes's first choice of treatment is Augmentin (clavulanate plus amoxicillin, which is also a member of the penicillin family). She glances at the allergy list in the patient header, looking for the word "penicillin" but does not see it. The term "Unasyn" did not catch her attention, perhaps because she wasn't thinking

about compounds that contained drugs closely related to penicillin. She enters an e-prescription for Augmentin, but then a drug alert interrupts her workflow. The alert identifies the patient's allergy to Unasyn, the symptoms, severity, and Unasyn's chemical similarity to Augmentin. Dr. Barnes reconsiders her decision and chooses doxycycline, a different antibiotic.

Alerts can support the physician's thinking process by addressing five questions:

1. How serious is the problem?

2. What is the nature of the problem?

3. What can the physician do to avoid or mitigate the effects of the problem?

4. If the physician does not address the problem, what will the consequences be?

5. Where can the physician learn more about this problem?

Figure 6.1 demonstrates how a typical alert in current EHRs addresses these questions. This design doesn't direct the user's eye to the information she needs to answer the questions. The alert contains a lot of text, but since it is all roughly the same size and none of it has been given any emphasis, it looks like all the information is equally (un)important. Some text (such as the window title, "Medication Clinical Decision Support" and "The new order has been created...") convey little to no relevant

information. The visual elements, such as the alignment of text and the arrangement of the page's white spaces, do little to direct the eye. The page contains three hyperlinks, but two of these lead to the same reference information, which is unlikely to aid the decision-making process.

Figure 6.1 **Before: A Penicillin Family Drug-Allergy Alert**

Figure 6.2 **After: A Penicillin Family Drug-Allergy Alert — A** simplified design with fewer options and concise text.
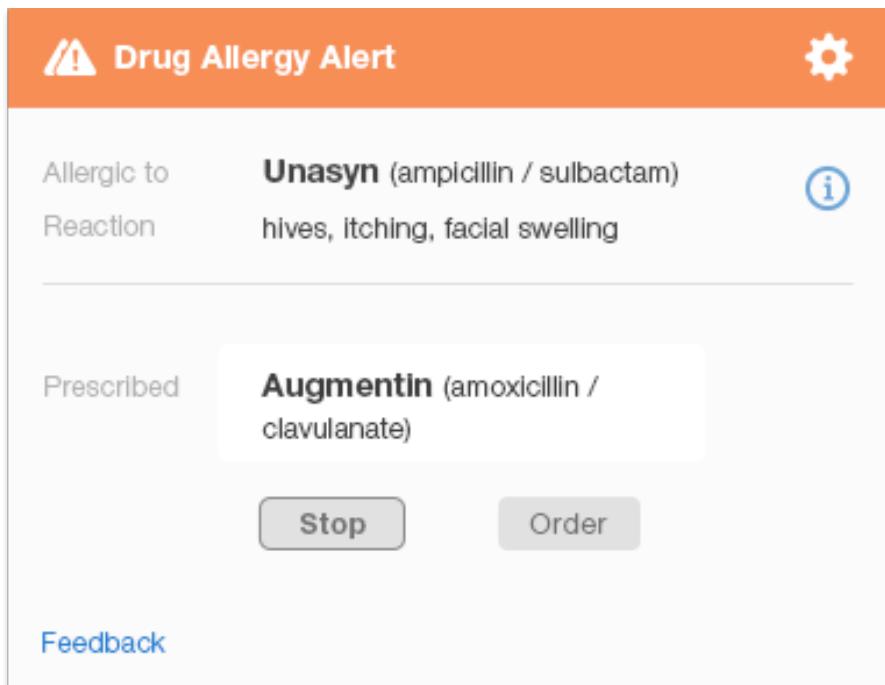
Figure 6.2 is a redesigned version of the same penicillin family drug-allergy alert. It allows the physician to see at a glance that the alert indicates a serious drug allergy (as noted by the two caution icons). The alert conveys the names of the drugs involved, and key facts about the patient's reaction. It shows the physician what actions she can take and which one is recommended ("Stop Augmentin," where "Stop" is the more prominent button). The design visually indicates the importance of key information using different font sizes, boldface, and colors to direct the user's eye. Gray or smaller text denotes that the information written in it is less important.

The design shows what information is related by grouping related items together, and using whitespace to separate different groups of items. We eliminated much of the text that appears in the original design (Figure 6.1) to protect the user from cognitive overload (information overload). Clicking the 'i' (information) icon to the right of the name of the drug the patient is allergic to brings up additional information about the patient's allergic reaction. This redesigned alert allows the user to find the important information about a drug allergy quickly. If desired, they can then learn more about less vital information, like the specific details of the patient's reaction. The 'feedback' link allows the user to provide feedback to the clinical decision support team.

6.2 Drug-Drug Interaction Alerts

Drug interactions are far more complex than drug allergies. A drug allergy either exists or doesn't, though there is some room for doubt about whether an allergy was truly the issue at the time, whether the allergy still persists, and what the nature of the reaction was. With drug interactions, there are more variables: the strength of scientific evidence for the interaction, the severity category for the interaction (usually 3-5 levels from mild to severe), the organizational threshold for displaying alerts based on alert severity, and patient variables (age, weight, pregnancy, and renal function).

Clinical Scenario — Severe Drug Interaction

Mr. Martin, our 58-year-old who was involved in a motor vehicle accident, suffers from chronic pain. The problem requires a multi-pronged treatment approach which includes several different medications. He is taking the muscle relaxant tizanidine to treat his low back spasms. In the past two days, Mr. Martin has needed to urinate frequently and urgently, and urination has been painful. Dr. Barnes diagnosed him with a bladder infection. As she started to order the antibiotic ciprofloxacin, a passive, non-intrusive alert appeared in the corner of the screen (see Figure 6.3). Rather than completing the prescription details and selecting the pharmacy, she stopped and chose a different antibiotic for which there were no drug interactions.

Figure 6.3 **A Passive Alert**

The passive alert appears in the corner of the EHR screen, but does not interrupt the physician's workflow. The yellow bar with an alert icon that appears in the user's peripheral vision is a salient visual signal because it is based on preattentive attributes. Without reading it, the physician can detect both the alert's existence and it's degree of severity.

If the physician completes the order, selects a pharmacy, and sends an e-prescription, an interruptive alert will pop up to ensure patient safety. The interruptive alert stops the physician's workflow completely, demanding the physician's full attention. The physician must select one of the three available choices before the system activates the "Continue" button to allow the physician to

move forward (Figure 6.4). After making a selection, the physician confirms her choice by hitting the keyboard "Enter" key or clicking the aforementioned "Continue" button (Figure 6.5). This additional step allows the physician a chance to correct a mistake.

Interruptive alerts annoy physicians and reduce the overall effectiveness of such alerts, which causes physicians to miss alerts that truly are important. Interruptive alerts can be used sparingly. Some EHRs allow users to customize what alerts appear to what healthcare providers. Thus the EHR might use interruptive alerts only for truly serious alerts when a physician is working with it and use both serious and mild alerts when the dispensing pharmacist is working with it. One empirical study of alerting systems suggests that physicians are more likely to comply with a tiered alert system (passive for lower risk and interruptive for higher risk alerts)[1].

Figure 6.4 **An Interruptive Alert** — Requires the user to make a choice before dismissing the alert.
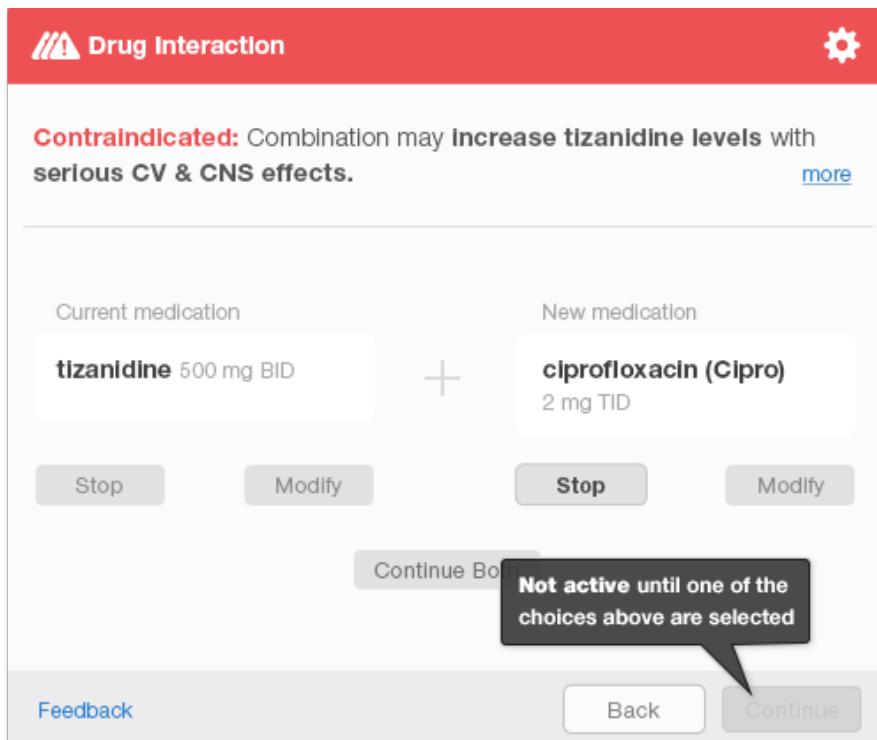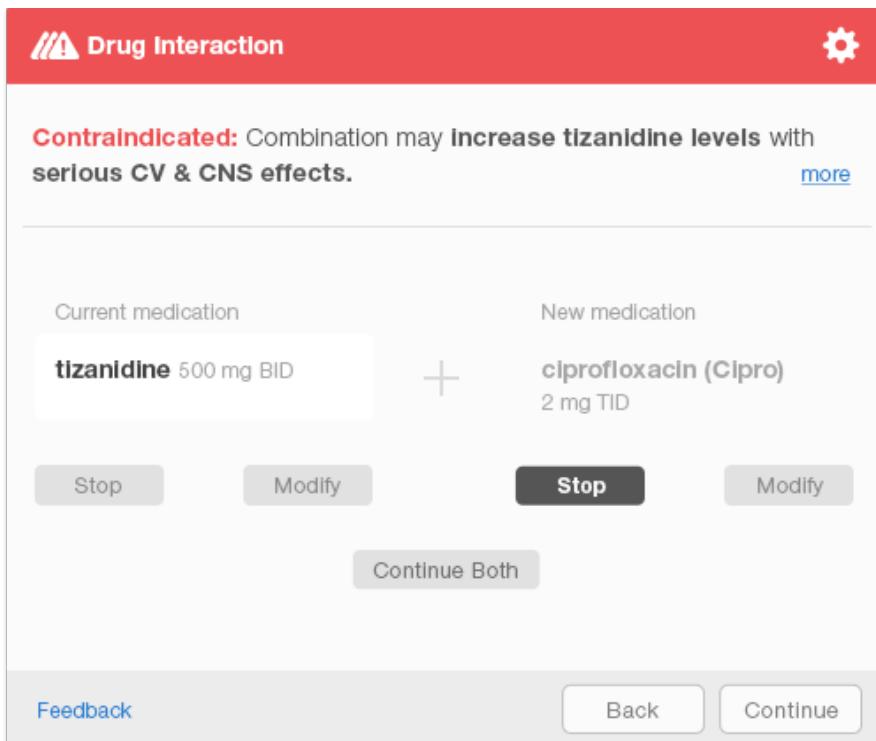
Figure 6.5 **Once the Physician Makes a Choice, the System Enables the "Continue" Button** — Gives users a chance to confirm their choice, but also adds an extra step, so it is best used when overriding higher severity alerts and can be customized with user preferences.

6.3 User Preferences to Dismiss Future Alerts

When users are presented with a high frequency of low value alerts, they develop alert fatigue and begin to dismiss the alerts before they fully read them or consider their implications.

Alert fatigue can be mitigated in a variety of ways:

1. Prevent alerts where possible:

    a. Offer only choices that will not trigger alerts (for instance, only offer available dosage forms)

    b. Provide cognitive support to help physicians make decisions that will not trigger alerts

    c. Adjust alert thresholds to present users with only the most important alerts

2. Use a tiered alerting system (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2605599/): make lower risk alerts passive and less visually obtrusive. Use interruptive alerts only for those with the highest risk (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3628052/).

3. Present passive alerts as early as possible during decision making. For example, by providing a visible indication of drugs that conflict with patient allergies or current drugs while the physician is choosing from a list or typing in a drug.

4. Allow users to customize their alert settings and turn off alerts that are of no value to them.

5. Make alerts easier to read. Write concise descriptions, put

important words first, and use visual features (font size, emphasis, color, whitespace, alignment, and spatial grouping) to indicate the importance and relationships among the information.

6.4 Customizing Alerts for Individual Physicians

Some alerts will be predictably and safely dismissed 100% of the time, and can reasonably be eliminated. Perhaps a patient has been taking a medication for a long time without incident, but an alert still appears every time the prescription is renewed. Here are some common examples:
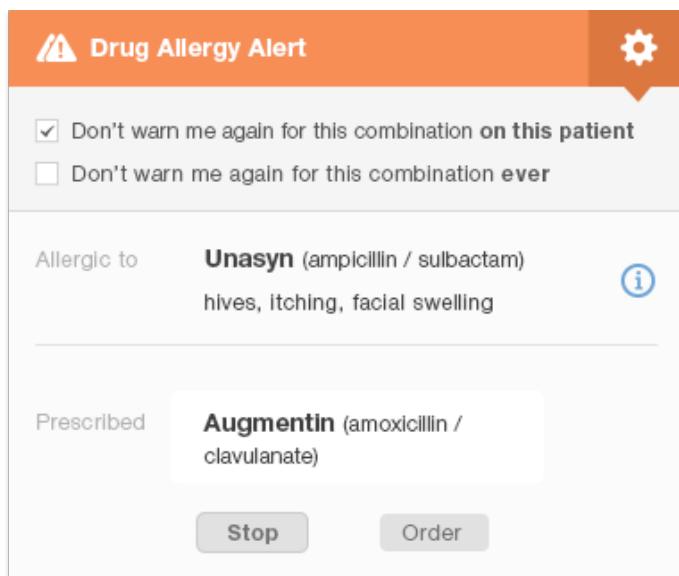
> *The patient is allergic to sulfa, but has been taking a distant chemical relative of sulfa drugs, such as the diuretics hydrochlorothiazide or chlorthalidone (both very commonly prescribed), without incident for some time. In this context, the EHR need never again warn the physician about this particular patient's allergy to sulfa.*
>
> *Lisinopril (an ACE inhibitor) gives this patient a cough, and an alert appears when the physician tries to prescribe an ARB such as losartan or valsartan, because these two classes of drugs are somewhat related. However, ARBs are known to never cause the cough that ACE inhibitors may cause. The EHR need never again warn the physician about this particular side-effect for any patient.*

It would be safe to allow physicians to permanently suppress alerts in the two circumstances above (Figure 6.6). It is more challenging to define rules for drug interactions or drug-disease interactions when the dosing or disease severity can vary over time.

Figure 6.6 **Allow Users to Customize Certain Drug Alerts**
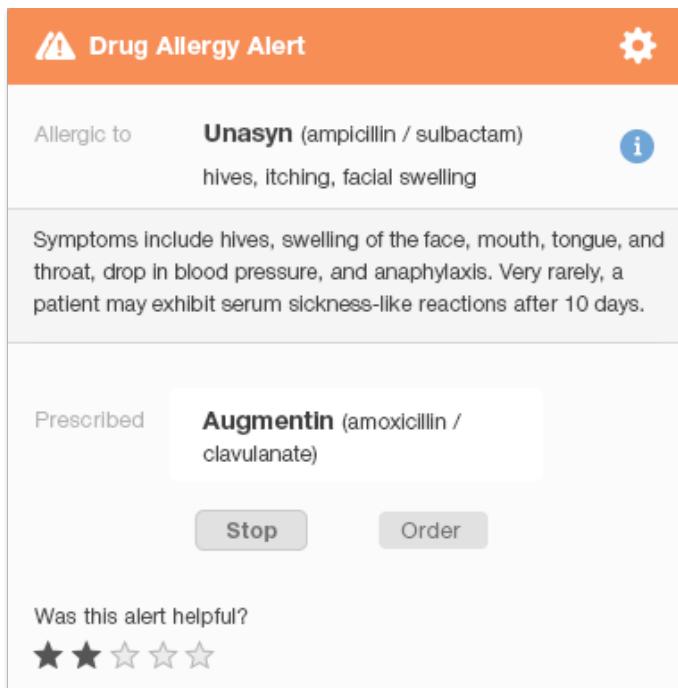
Collecting Feedback about the Usefulness of Alerts

Let data drive the rules for alerts. Currently, EHRs can collect structured data about the reason for alert overrides, but no EHR we know of can systematically collect data about whether prescribers consider particular alerts useful.

Only a handful of companies provide data that fuels drug allergy and drug interaction alerts. These companies don't receive direct feedback from clinician users: their relationship is mediated by their EHR vendor. If EHR vendors could tell drug data vendors that nearly all users found a particular alert to be unhelpful, then the vendors could reassess that particular data element. Figure 6.7 shows how an EHR could unobtrusively collect feedback from physicians.

Legal teams may feel that more warnings amount to greater safety, but the situation is more complicated than that. Physicians need to practice medicine efficiently, and too many alerts can cause alert fatigue and even put patients at risk.

Figure 6.7 **Allow Users to Offer Feedback about the Usefulness of Particular Drug Alerts**

6.5 Multiple Drug Alerts

Sometimes an EHR needs to present multiple alerts to the user. These may be multiple alerts for a single medication, or several alerts for a number of different medications. Would the EHR display these alerts one at a time or all at once? If they're displayed all at once, physicians can see the big picture: all of the drug-allergies and drug-drug interactions in play. Without having to navigate to read each alert, physicians can run down the list and make decisions for each item. Showing all the alerts simultaneously, however, may visually overwhelm the users. It might also be difficult to simultaneously show both all alerts and the clinical information that physicians need to act on these alerts.

Figure 6.8 shows one possible way of presenting multiple alerts on a single screen. This design shows each alert's severity using small icons in the left column. New drug orders and either the allergy or interacting drug are displayed just after the severity icons. The rightmost column shows the actions that a physician can take to address each alert. The action buttons include both the actions and the drug names (e.g., Stop Augmentin) to help the physician understand what each button does. The design uses bold text on action buttons to show recommended actions for each alert. Figure 6.9 shows the display after the user has made decisions about the first two alerts. The "Continue" button activates after the user addresses all the alerts (Figure 6.10).

It's more challenging to display multiple alerts on small mobile devices. Gallery 6.1 shows a way to display and address multiple alerts on a mobile phone. The first screen presents an overview of all the alerts, grouped by type. Tapping an alert brings up details about it, as well as possible actions the physician can take.

Figure 6.8 **Presenting All Alerts in a Single Screen** — Bold type indicates preferable, safer choices.

Figure 6.9 **Multiple Alert Screen** — After the physician has made some choices, the system visually shows his selections.

Figure 6.10 **Multiple Alert Screen** — Once the physician has addressed all alerts, the system activates the Continue button.

This gallery shows a design option for displaying multiple drug alerts on a smartphone.

Figure 6.1 **Displaying Multiple Drug Alerts on a Smartphone**

Figure 6.1 a **One Allergy Alert and Three Drug-Drug Interactions**
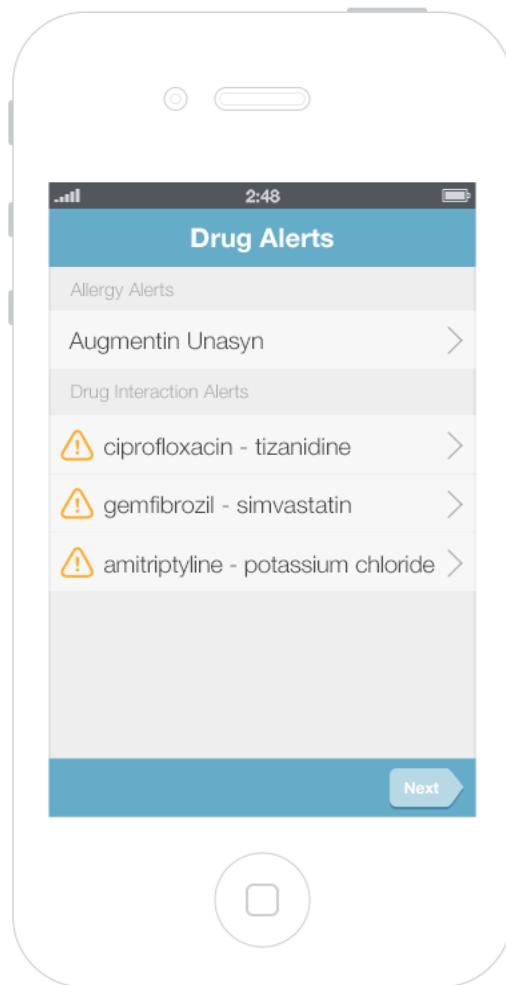
Figure 6.1 b **More Detailed Display** — Allows the physician to address the allergy alert.
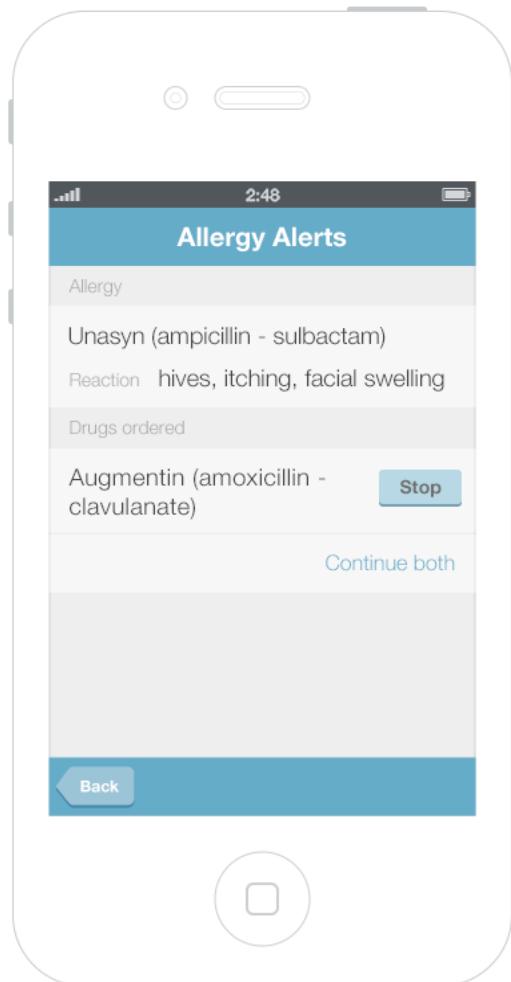
Figure 6.1 c **Physician Taps the "Stop" Button** — The display moves on, bringing up the next alert screen.
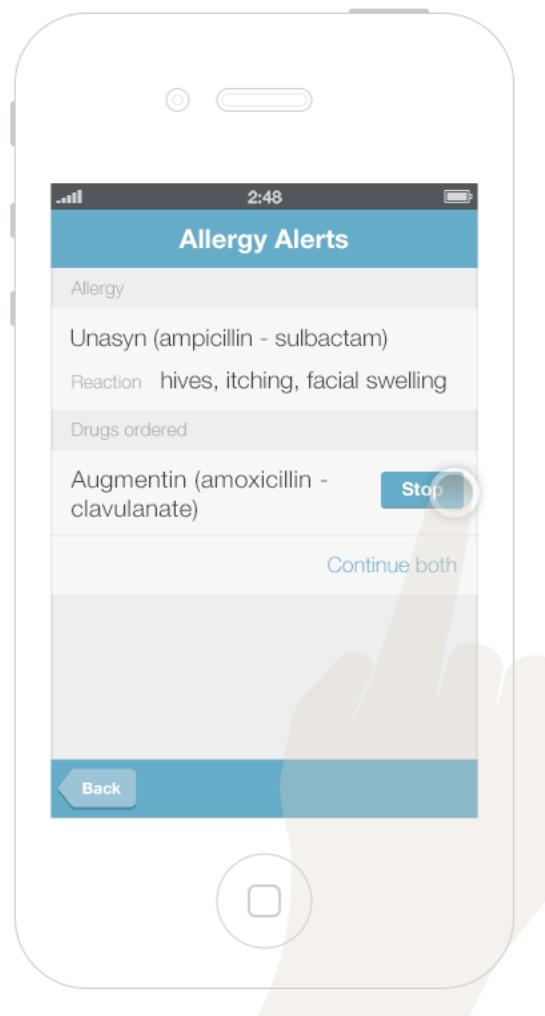
Figure 6.1 d **Drug-Drug Interaction Alert with Three Possible Actions** — Stop the first drug, stop the second, or continue both.

Figure 6.1 e **Stopping Cipro Calls Up the Next Drug-Drug Alert**
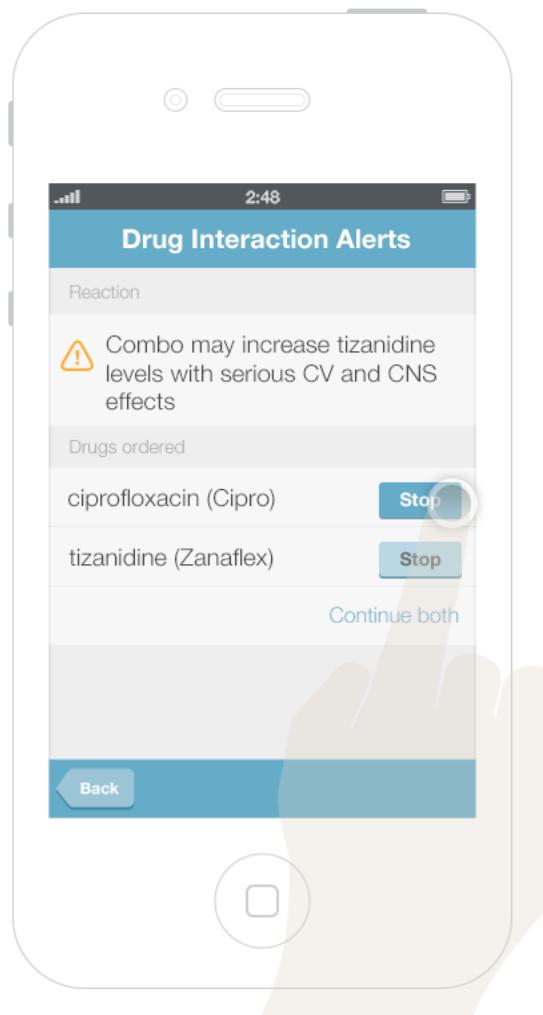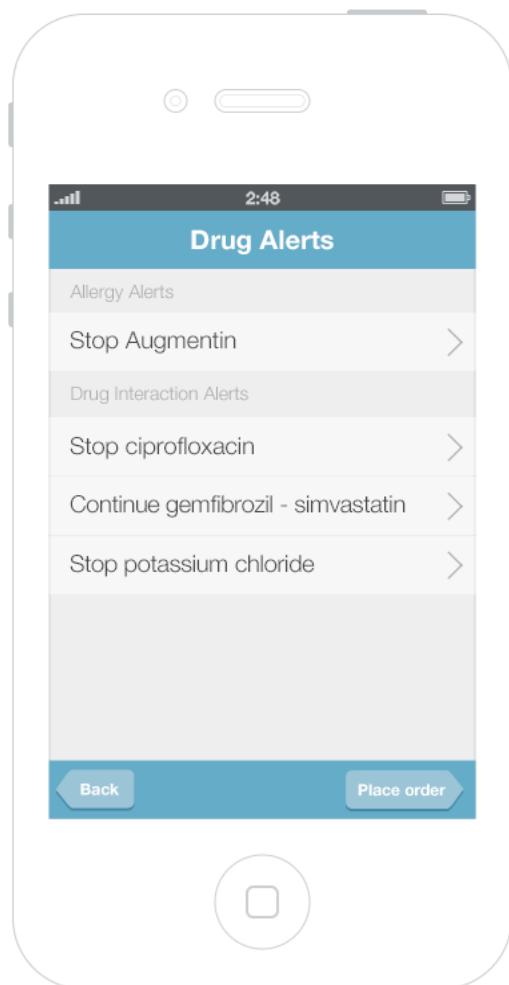
Figure 6.1 e After the Physician Has Addressed All the Alerts—
He can use the final review screen to look over and modify his
decisions.

6.6 Summary

1. An effective alert is one that physicians notice, read, understand, and respond to. We can facilitate this process by designing alert systems that use sound human factors principles.

2. Alerts interrupt users to different degrees. Passive alerts appear when triggered, but do not require the user to attend to them immediately. Interruptive alerts stop the user's workflow and require the user to respond before continuing his work.

3. Make only high-risk alerts interruptive.

4. Reduce users' cognitive load by simplifying the visual presentation of drug alerts.

5. Use preattentive attributes (like color, size, shape, alignment) to draw users' attention to the most important information in Drug Alerts.

6. Treat alerts differently depending on their severity. Low-risk alerts can be passive. They offer the physician decision support without interrupting his workflow, unless he chooses to stop and attend to them. High-risk alerts could initially generate passive notices, but these can be followed by an active notice if the physician fails to attend to the issue. Physicians should be notified about possible issues via passive notices as early as possible.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

Additional Resources

From the National Center for Cognitive Informatics & Decision Making in Healthcare

EHR Safety Enhanced Design Briefs:
Drug-drug, drug-allergy interaction checks (https://sbmi.uth.edu/nccd/SED/Briefs/sedb-mu01.htm)

Clinical Decision Support (https://sbmi.uth.edu/nccd/SED/Briefs/sedb-mu04.htm)

References

1. Paterno, Marilyn D., Saverio M. Maviglia, Paul N. Gorman, Diane L. Seger, Eileen Yoshida, Andrew C. Seger, David W. Bates, and Tejal K. Gandhi. "Tiering Drug-Drug Interaction Alerts by Severity Increases Compliance Rates." *Journal of the American Medical Informatics Association* : JAMIA 16, no. 1 (2009): 40–46. doi:10.1197/jamia.M2808.

2. Profile photo in interfaces by David Amsler. (https://www.flickr.com/photos/amslerpix/)

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7

Human Factors Principles

*Systems that complement how we see, read, think and decide
can improve our performance.*

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Multiple Drug Alerts

Human Factors Engineering seeks to improve human performance by designing systems that are compatible with our perceptual, cognitive, and physical abilities. Imagine an EHR that requires a physician to cancel a prescribing task, then navigate through several screens, remember a value, and navigate back to complete the prescription. This EHR taxes the well-known limits of human memory. Over-taxing users' memory causes them to make errors, especially if they're interrupted while using the system – a common occurrence in healthcare.

In contrast, an EHR that allows a physician to see at a glance how well a patient is controlling his diabetes and hypertension gives the physician the situational awareness (and time) he needs to begin to address his patient's current concerns. The physician can focus attention on understanding the story of the human sitting across the room, instead of on remembering and finding the necessary information to make decisions.

The Fundamental Theorem of Biomedical Informatics states "that a person working in partnership with an information resource is 'better' than that same person unassisted." Human Factors

Engineering involves building this partnership, designing hardware and software that make it as easy as possible for users to do tasks safely and efficiently. An EHR based on sound human factors engineering principles can help clinicians focus on the difficult task of caring for patients, rather than on figuring out how to use or work around the EHR. We must understand the ways people see, read, think, and decide so that we can use this information to build systems that enhance people's job performance.

7.1 How People Perceive

7.1.1 Our Eyes Have Expectations

Our eyes are drawn to familiar patterns. Sometimes we even see patterns we know and expect instead of what's actually there.

Your eyes take in data, but your brain 'perceives' this data and parses it into meaningful visual information. Our brains create shortcuts to help us make sense of the estimated 40 million sensory inputs they receive per second. They use our expectations, past experiences, associations, and learned rules of thumb to make guesses about what it is we're looking at. Everyone has seen something at a glance and thought it was a certain object, and then focused on it and realized it was actually something else.

Most people read the following as "The cat," even though the middle letter in each word is exactly the same, and neither is a perfect H or A. Our perceptual system uses context (the letters around the middle letter) and expectations (predicated on our familiarity with common English words) to allow us to cope with and make sense of imperfect, noisy input. But the same properties that make our perceptual system robust can also lead us astray. For instance, can you name the first drug on this prescription (Figure 7.2)?

The cardiologist who prescribed the medication wrote 'Isordil,' but the pharmacist read it as 'Plendil.' After taking the prescribed medication for two days, the patient had a heart attack. Several days after that, he died[1]. In this case, the pharmacist was led astray by the very same perceptual system that enabled him to do

Figure 7.1 **Read the Following Words:** 'Tae Cat' looks like 'The Cat' when the tops of the A's are cut off

Figure 7.2 **Handwritten Prescription** — Name the first drug on the list (from Western Journal of Medicine).

his job correctly most of the time. Our perceptual system makes assumptions so automatically that we often don't even realize that it is doing so.

Users come to computers with expectations (mental models) based on what they have seen before, and with a built-in tendency to make assumptions about what it is they're seeing. When we scan a screen, we look for digestible chunks: familiar things like navigation bars, buttons and logos. We also tend to look at the center of the screen rather than at the edges, because we expect the edges to display less important things, like logos and tools not relevant to the task at hand. We expect the core components of an interface to be front and center, easy to find.

Affordances tell users at a glance that particular elements of the graphical user interface are functional devices. Well-designed affordances also give users an idea of what will happen when they use them.

Figure 7.3 **An Unclear Layout** — Adding allergies without good 'workflow' guidance from the interface.

Figure 7.4 **Meeting Our Expectations** — We're still adding an allergy, but now the format is more familiar, and lists the tasks users need to complete in a sequential order.

Figure 7.5 **A Few Common Affordances** — 1) These three words look like buttons, so users understand that if they click one, that will do something. 2) Users understand that the small icon of a calendar will expand into a full calendar menu if they click it.

Figure 7.6 **Disclosure Arrow Affordance** — In this image, the arrow affordance lets users know that they can expand or collapse the entry to access more information.

Figure 7.7 **Sort Arrow Affordance** — Here, the arrow indicates the ability to sort the list by different columns.

7.1.2 We See in Gestalts

People perceive whole shapes, or gestalts, rather than disconnected forms.

Gestalt is a German word for form or shape. In English, it has come to have connotations of 'wholeness.' When you walk into a room, you immediately form an overall sense of what's going on therein and its corresponding emotional tone. Most people understand when they've come in and interrupted a fight, even if they heard none of the previous conversation. When you view a webpage for the first time, you get a similar overall impression of it. You can say pretty quickly whether you think the site looks cluttered or appealing, modern or out of date. Several design elements feed into our gestalt impressions of sites and applications.
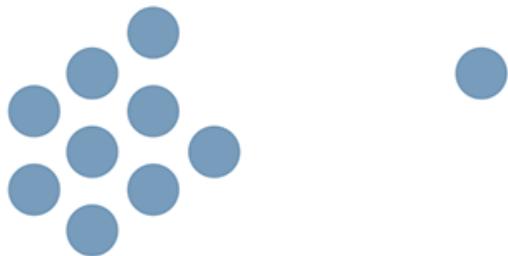
Proximity

The distance between objects determines what we perceive the relationships between those objects to be. If things are close together, we assume that's significant and 'group' them in our minds. If elements in a designed object are grouped together, we assume this was intentional and is meaningful.

Figure 7.8 **Proximity** — Our eyes notice the distribution of these dots...

Figure 7.9 ...and our brains group the closer objects automatically.

Example: The medication reconciliation view below (Figure 7.10) breaks medications into groups. It then places these groups in the same columns. Users can tell there are different groups (columns) at a glance, without having to focus on, read, and understand all the information on the chart.

Figure 7.10 **Ambulatory Medication Reconciliation Workflow** — Items in the center are most alike, and those at the sides are most different. Items in between need clarification.

Closure

Our brains fill in visual blanks for us and draw conclusions with less than complete information. This helps us make sense of the world quickly. Sometimes we can draw the wrong conclusions, misleading our users. We need to keep the advantages and shortcomings of this perceptual habit in mind when we design systems. Designers can make use of our brains' tendency to fill in the blanks to help users to quickly understand a whole idea based on a partial picture, but design can also accidentally lead users to unintended and unhelpful 'false' gestalt impressions.

Example: Our minds take lines or curves and build objects out of them. This is how we can know we're looking at something that's supposed to represent a person when it's a stick figure. Even though the lines below don't add up into a circle and a rectangle, people can
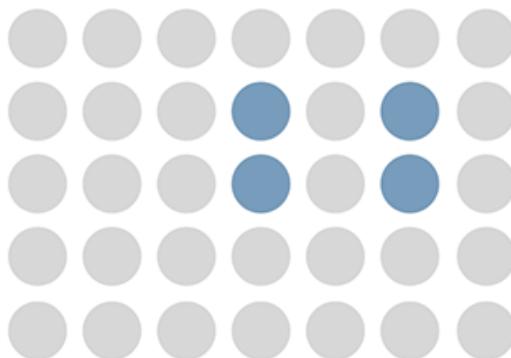
Figure 7.11 **Closure**

Similarity

We perceive visual elements that look **similar** as parts of a group. Designers can indicate that two objects are similar, and thus related, by giving the objects the same sizes, shapes or colors. Interfaces that visually group related items are easier to use than those that don't. As a general rule, items that users must process together could be grouped together, while items that need to be processed separately are not.

Figure 7.12 **Users Perceive That the Blue Dots Are Associated**

Example: In the medication reconciliation interface we looked at earlier, proximity marked certain groups of items as categories (columns). Now, when we add color, we create new groups (Figure 7.13). Medications the user approves turn green, and medications the user deselects fade to light gray.

Figure 7.13 **Color Creates New Groups**

Symmetry

Our minds like to make sense of complex visual fields by assigning them a perceived center and attendant **symmetry**.

Example: Figure 7.14 shows us how our minds like to see two symmetrical diamonds rather than other, equally possible (but less pleasingly symmetrical) shapes.

Figure 7.14 **Symmetry** — Our brains try to resolve complex visual fields into combinations of simple, symmetrical shapes.

Example: When we first glance at Figure 7.15, below, we see two columns. In fact, a series of individual entries creates the illusion of columns.

Figure 7.15 **Symmetry in Medication Reconciliation**

Intake	Hospital
keep rest | reject rest [clear]	keep rest | reject rest [clear]
acetaminophen 650 mg PO q4h prn	acetaminophen 650 mg PO q4h prn h…
Aldactone 100 mg PO daily	aspirin 81 mg PO daily
Amaryl 4 mg PO daily	cimetidine 800 mg PO q12h
Ambien 10 mg PO qHS prn	Coreg 6.25 mg PO BID
Aricept 10 mg PO daily	donepezil 10 mg PO qAM
aspirin 81 mg PO daily	furosemide 40 mg PO BID
cimetidine 800 mg PO BID	glimepiride 4 mg PO qAM
Colace 100 mg PO BID	lorazepam 1 mg PO qHS prn inso…
Coreg 6.25 mg PO BID	losartan 50 mg PO qAM
Cozaar 25 mg PO daily	magnesium hydrox… 30 ml PO daily prn co…

Figure / Ground

Our brains perceive objects either as figures in the foreground or as part of the background. Whatever we're focusing on becomes the figure, and everything else shifts into the background accordingly.
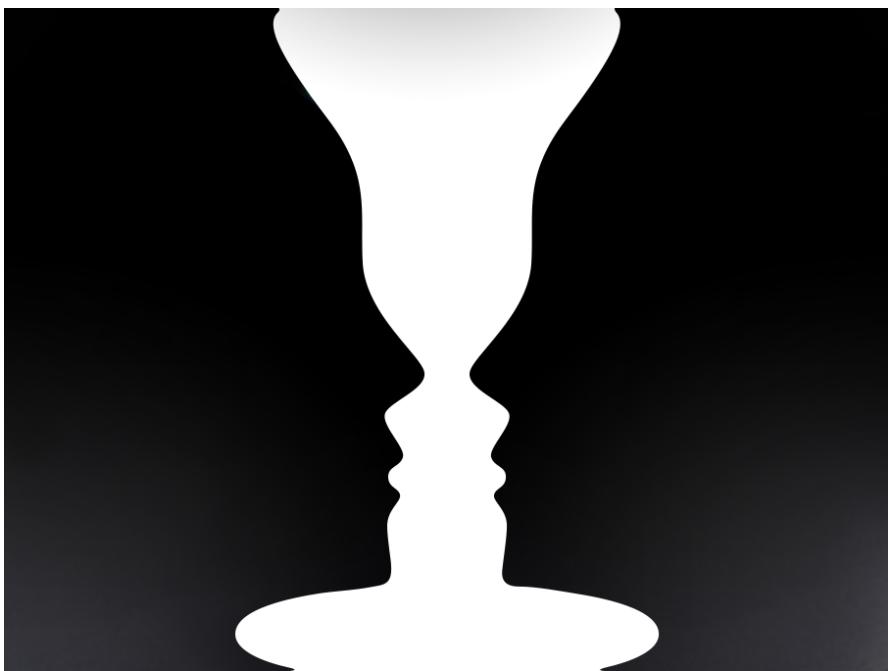
Example: In Figure 7.16 below, the ampersand is the figure, distinct from the blue rectangle that serves as its ground or background. As the designer intended, users understand the figure to be more important than the ground.

Figure 7.16 **Figure / Ground**

Example: Figure 7.17 below is the classic Edgar Rubin image in which viewers see either two faces or a vase, depending on where they focus their attention. Rubin was a practitioner of gestalt psychology.

Figure 7.17 **Ambiguous Figure/Ground Relationship**
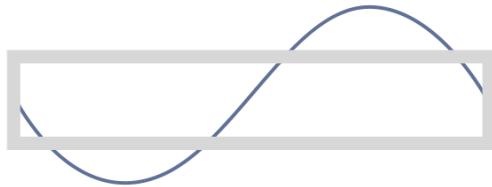
Continuity

In day to day life, our perception combines and relies on all of these components. Alignment creates groupings of items, and these groupings are said to have **continuity**. Our brains expect and try to reconcile contours into continuous objects.
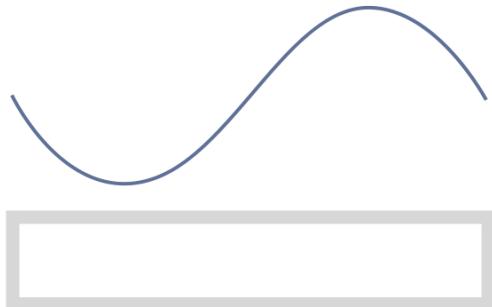
Example: In Figure 7.16 below, the ampersand is the figure, distinct from the blue rectangle that serves as its ground or background. As the designer intended, users understand the figure to be more important than the ground.

Gallery 7.1 **The Continuity Principle**
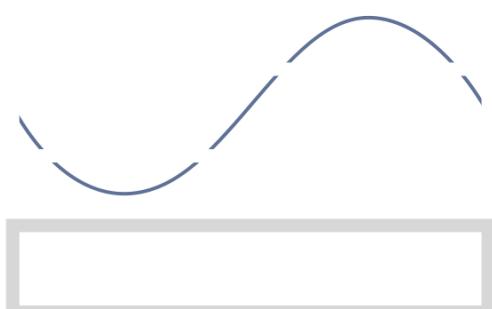
7.1 a Though a rectangle 'blocks' parts of this curve...

7.1 b ...humans perceive both the curve and the box as whole, uninterrupted entities...

7.1 c ...rather than as a box and some line segments.

Example: Figure 7.18 demonstrates several of the things we've been talking about. When we look at it, our brains detect the proximity of different medication lists and categories and the similarity of 'selected' and 'deselected' groups of medications. The list also takes advantage of the contrast we perceive between figure and ground. The dark text seems closer to us, and the faded text seems further away.

Figure 7.18 **Continuity in Medication Reconciliation**

Intake unique	Intake similar	Identical	Hospital similar	Hospital unique
keep rest	reject rest [clear]	keep rest	reject rest [clear]	keep rest	reject rest [clear]	keep rest	reject rest [clear]	keep rest	reject rest [clear]
Ambien		aspirin		furosemide
10 mg PO qHS prn		81 mg PO daily		40 mg PO BID
Colace		Coreg		lorazepam
100 mg PO BID		6.25 mg PO BID		1 mg PO qHS prn inso…
				magnesium hydroxi…
				30 ml PO daily prn con…
	acetaminophen		acetaminophen	
	650 mg PO q4h prn		650 mg PO q4h prn h…	
	Aldactone		spironolactone	
	100 mg PO daily		100 mg PO qAM	
	Amaryl		glimepiride	
	4 mg PO daily		4 mg PO qAM	

7.1.3 I Can't See It but I Use It

We use our peripheral vision to get a big picture of what we're seeing, and we use that big picture to help us decide what to focus on.

Our visual system consists of our eyes and the brain processes that work with them. This system does an amazing job of seeking out and providing us with visual information. It does so mostly without our being consciously aware of it. We are barely aware that only the very central part of our vision provides us with a sharp-focused image, detail rich, with color information. The periphery of our vision (outside of the central "peephole") is fuzzy, and drained of color. That peripheral part of the vision is, however, able to detect features such as motion, edge, and contrast. These features guide our brains in making their "visual query" of the views before us.

Rapid eye movement enables our brains to sample the environment. The task we're trying to accomplish determines the details we unconsciously seek out. If we're looking for a friend, we notice faces in the crowd. If we're trying to find our way through the crowd, we notice the gaps between people.

Animated ads are effective (and annoying) because our peripheral vision detects motion. We want to ignore the ads, but their design takes advantage of the way vision works. Our eyes are drawn to anything that stands out. Our brains are trying to recognize threats in our environment, and our peripheral vision is always alert to differences and changes.

Example: When we look at Figure 7.19, below, our eyes first do a quick visual query. They seek out major landscape elements and the details that will help us accomplish whatever we're using this display to do. What we notice in the scene below will vary depending on whether we're driving, deciding if we need to mow the lawn, or assessing if the weather will be suitable for a picnic this afternoon.

Figure 7.19 **Visual Queries in the Real World**

Example: When we look at a display like Gallery 7.2 below, we think we see something like the first image. Actually, what we really see at any given instant is something more like the second image. We only focus on a small area at any given moment. Our visual brain first latches onto a preattentive attribute like the red text, and is disproportionately drawn to that element. Then our eyes automatically scan to find the next point of visual interest.
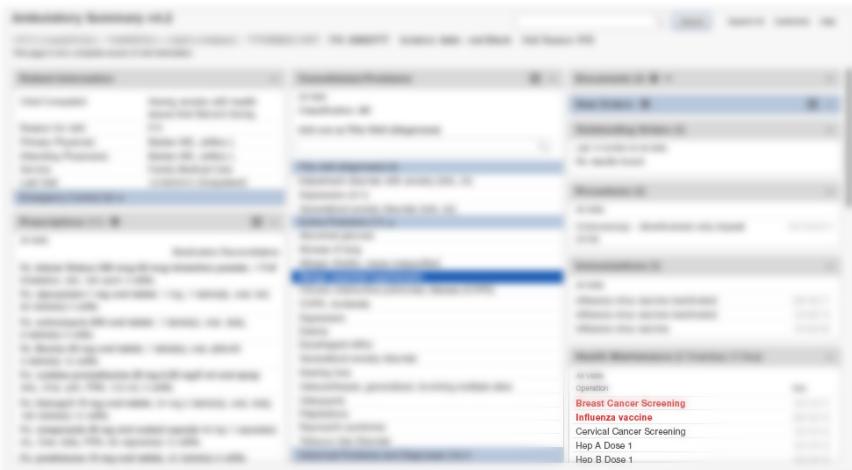
Gallery 7.2 **Visual Queries in EHRs**

7.2 a **We Think We See This**

7.2 b **But We Actually See This**

A peripheral glance tells people where they are and what to expect, helping us decide what to focus on. We can only truly see what we focus on. The display can only effectively convey that information at any given time.

Design tip: Feedback and error messages can pop up near an area people will already be focusing on. While we do use our peripheral vision to orient ourselves and scan for things, we also tend to ignore our peripheral vision when we're trying to focus on the task at hand.
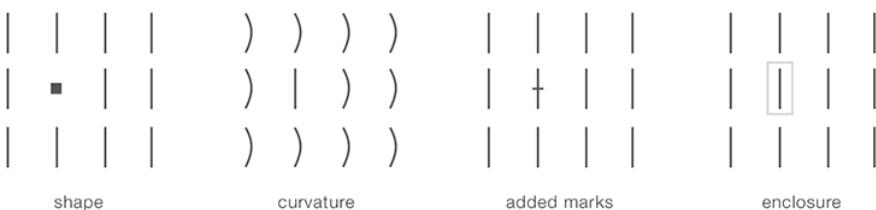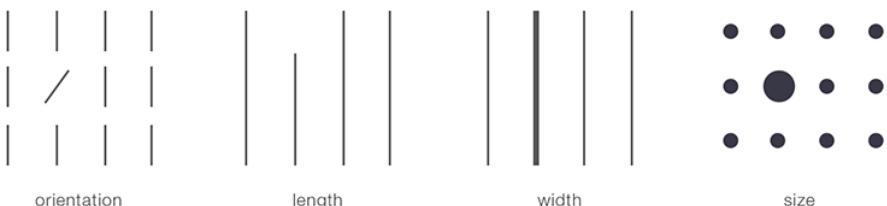
7.1.4 Preattentive Attributes

Little, visual things people notice and understand quickly.

We notice some visual features, such as color, size, shape, orientation, and motion, more quickly than others. We call the things that especially stand out to us **preattentive attributes**. Before we fully process visual information, our minds prompt us to focus on these attributes. Things that stand out from the rest of their environment, as in Figure 7.20 below, do so because of their attention-catching preattentive attributes.

Figure 7.20 How can we use preattentive attributes to facilitate data presentation?

Form

orientation   length   width   size

shape   curvature   added marks   enclosure

Color

shade   hue

Spatial Position

2d position

7.2 How People Think

7.2.1 The Two Ways People Think

Everyone has two modes of thinking. There's a rapid mode that requires little conscious effort and a slower mode that requires focus.

If a system is easy to understand and work with, users don't have to engage with it via their 'slow, focused' mode of thinking. They can just use their rapid mode and save their mental energy for more important matters. Daniel Kahneman wrote a great book about these modes, and our thinking builds on his work.

The rapid mode of thinking is automatic and almost effortless. People often don't experience a sense of voluntary control over it. This mode allows us to:

- See that something is larger than something else

- Answer simple computations, like 2+2 = 4

- Read words on a billboard

- Understand simple sentences

- Make rapid and simple associations, such as stereotypes (positive or negative)

- Notice preattentive attributes

Our focused mode of thinking is effortful and allows us to perform more complex mental activities. We associate this mode of thinking with our experiences of agency, choice, and concentration: in short, with our 'consciousness.' This mode allows us to:

- Focus on listening to one voice in a noisy room

- Recall information, like addresses and phone numbers

- Evaluate the validity of a complex argument

- Scan for a particular piece of information in a long article

When creating an application, ask yourself whether you have any opportunities to convert tasks that require focused thinking into tasks that only require rapid thinking. Making the application perform complex calculations, sort information, and concisely present key details can free people up to do the focused thinking that only humans can.

The Twinlist medication reconciliation prototype, Figure 7.21, makes the focused task of scanning two lists and finding similar drugs into a rapid one. The prototype identifies similar drugs and sorts them onto the same row. Twinlist also makes it easy for users to see the differences between similar drugs by highlighting these differences in yellow. A slow, visually and cognitively demanding search task involving two separate lists becomes a matter of brisk perception with Twinlist.

Figure 7.21 **The Twinlist Prototype Facilitates Fast Thinking**

Intake unique	Intake similar	Identical	Hospital similar	Hospital unique
keep rest | reject rest [clear]	keep rest | reject rest [clear]	keep rest | reject rest [clear]	keep rest | reject rest [clear]	keep rest | reject rest [clear]
Ambien 10 mg PO qHS prn		aspirin 81 mg PO daily		furosemide 40 mg PO BID
Colace 100 mg PO BID		Coreg 6.25 mg PO BID		lorazepam 1 mg PO qHS prn inso…
				magnesium hydroxi… 30 ml PO daily prn con…
	acetaminophen 650 mg PO q4h prn		acetaminophen 650 mg PO q4h prn h…	
	Aldactone 100 mg PO daily		spironolactone 100 mg PO qAM	
	Amaryl 4 mg PO daily		glimepiride 4 mg PO qAM	

7.2.2 Working Memory

Working memory demands effort and is limited. Try to design systems that place limited demands on users' working memory.

Working memory, or short-term memory, holds items like phone numbers until we can write them down or punch them into our phones. This type of memory stores information for less than a minute and demands focused thinking.

Design tip: Try not to ask people to look at information on one screen, remember it, and then enter it into another field on another screen.

If you ask people to use their working memories, make sure that what you're asking them to remember is uncomplicated. Don't distract them with additional demands, information and options while they're focusing on remembering a given bit of information. A system that interrupts people while they're trying to use their working memories causes them to forget what they're doing and wastes time.

People only keep three to four compound or complex items in their working memories at a time. The way interfaces display bits of information can influence users' working memory, however. If a design groups items together or breaks information down into manageable chunks, people can remember that information better. A phone number, for example, is easier to remember if it's been broken into chunks. Compare these numeric strings:

Difficult: 9121889874

Easier: 912-188-9874

Easiest: (912) 188-9874

The first phone number is difficult to even just dial. If the interface asks users to enter phone numbers, it can allow them to enter these with or without the intervening hyphens or parentheses. It could display them, however, in the easy-to-read format. When the interface needs to display an unmanageable amount of information, and the design has done all it can to alleviate this, the interface can then 'chunk' its information in the manner of the phone number example.

7.2.3 Cognitive Load

Loads are heavy, even mental ones. Help lighten the user's load.

Our brains manage motor, visual and cognitive loads. The strain of managing and manipulating items within our working memory generates cognitive load. Motor load is the easiest for the brain to manage, while cognitive load is the most difficult.

Designers seeking to lighten users' cognitive loads need to bear these details in mind:

• Focused thinking causes greater cognitive strain than rapid thinking. People can give a task about ten minutes of focused attention, but then they'll need a short break, unless they're particularly interested in the task or are in a flow state.

- People can't truly multi-task. We can only attend to one task at a time. When we think we're multitasking, we're actually rapidly switching tasks, start-stop-start-stop-start-stop. This can tire us out and cause us to make mistakes.

- Recognizing is easy, remembering is difficult. We can recognize complex things like a map of Europe instantly, but most of us would likely have a hard time drawing such a map ourselves. Likewise, we find it easier to recognize patients' names than to recall them.

- Problem-solving and calculating are hard, while learning from experience and performing learned actions is easy.

Example: Figure 7.22 below demonstrates the mental work a doctor does when she reviews a medication list to try to understand what medications a patient is taking to control his blood pressure. She must read the list, recognize drugs' names, remember whether given drugs are prescribed for hypertension, recall from memory what the maximum doses for these medications are, and then check whether the patient has reached the maximum dosages for these medications. That's a lot of mental effort!

Figure 7.22 **Scanning for Hypertension Medications**

Figure 7.23, below, sorts the list of drugs alphabetically by diagnosis. This allows our physician to access the same information, but costs her far less mental effort. Lightening the effort she has to expend on this task increases the amount of effort she can spend on other more important tasks.

Figure 7.23 **Sort by Diagnosis** — Makes it easier to search for hypertension medications

If the interface can indicate whether a medication has reached the maximum dose, this will save the doctor the effort of making a series of annoying calculations.

Example: Auto-complete functions can also lighten users' cognitive loads. Users typing in the name of a drug in a window with a predictive text function can employ low-impact recognition mental processes rather than more difficult recollection processes. If users employ rapid thinking at this stage of the proceedings, however, there's a danger that they might mistake similarly-named drugs. Employ tallman lettering to alert users to be aware that a similar-looking drug exists.

Figure 7.24 **Recognizing Rather than Recalling** — Drug searches that utilize auto-complete functions

clo
clobazam
clobetasol topical
Clobex
clocortolone topical
Cloderm
clofazimine
Clolar
Clomid
clomiphene
clomipramine
clonazepam
clonidine

7.2.4 Everybody Likes a Chunk

Breaking information down into small, digestible chunks helps people make sense of it.

Human brains can only apply focused thought to a relatively small amount of information at a time. Interfaces must break information into chunks. They can give users information in manageable, controlled courses, like a formal dinner.

Progressive disclosure gives people the information they need when they need it. The interface gradually provides users with more and more detail. Designers need to develop a good knowledge of how their users will be working to understand what information they could begin with, and then what details can be introduced at successive stages. Keep in mind that people can only hold three to four things in their mind at once.

Example: The list in Figure 7.25 shows essential allergy information in four columns. The user has all the information she needs about the patient's medication allergies to make prescription decisions. If she needs additional information about the patient's allergies, she can select an entry to see more details.

Figure 7.25 **Progressive Disclosure in an Allergy List**

7.2.5 Goal, Execute, and Evaluate!

Humans have a thought cycle that guides decision making and it is 'Goal, Execute and Evaluate.'

How do we get anything done? No, really. We start by forming a goal: get some food, edit a word document, impress our boss with our design skills, etc. Next we choose and execute actions that we think will help us accomplish that goal. Finally, we evaluate how well our actions worked. Were we able to accomplish our goal, or to at least make progress towards accomplishing it?

Interfaces can support clinical decision making if their designers establish a shared understanding of goals with physicians. The interfaces must then provide users with clear paths by which to accomplish these goals, useful 'action' choices, and the feedback they need to quickly and accurately make choices and evaluate their progress. If interfaces don't provide appropriate or sufficient feedback, users make errors and find the interface unsatisfying to use. This is a common problem with interfaces.

7.2.6 Go with the Flow

People like to get into flow states; if we're engrossed in what we're doing, everything else falls away.
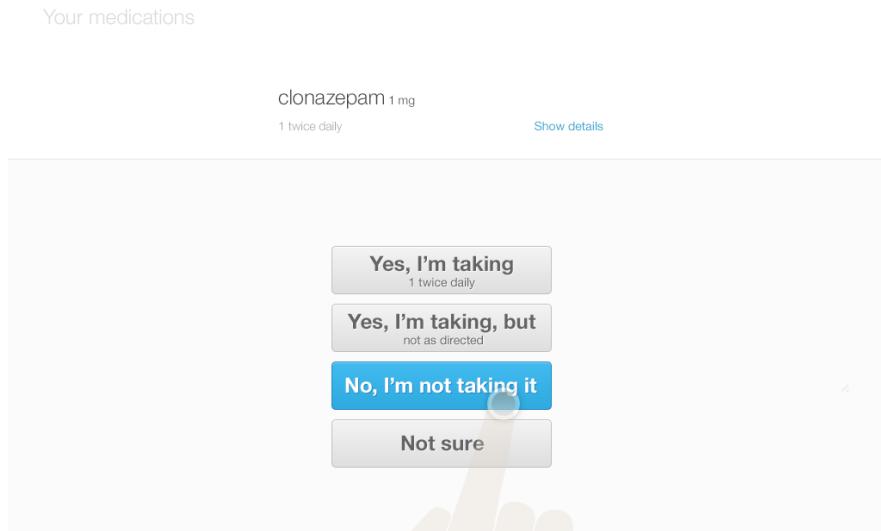
We've all had moments where we get so involved in what we're doing that we lose track of time and get a lot done. This situation is called a 'flow state,' and you can enter it doing professional or (more likely) recreational tasks. No one likes having their flow state interrupted.

Interfaces can help users get into and stay in flow states. Some facts to remember:

• People like being in control of themselves. Giving them control over their activities will help them get into the flow.

• Distractions, in the form of noisy interfaces or interruptions from co-workers, interrupt peoples' flow.

• People like goals that are challenging but achievable.

• Break difficult tasks down like you would unmanageable amounts of information. Allow users to complete long or difficult tasks in clearly-defined stages.

• Give users feedback on their progress. Seeing how far they've come and how far they still have to go can motivate people.

Example: Figure 7.26 shows a medication list that a patient is in the process of updating. The page indicator on the bottom shows the patient that he's on step 2 of 22. This information about his progress may help the user get into a flow.

Figure 7.26 **Tracking Progress via Page Indicators** — The dots along the bottom of the screen show the user where he is in the process.

Your medications

clonazepam 1 mg
1 twice daily   Show details

Yes, I'm taking
1 twice daily

Yes, I'm taking, but
not as directed

No, I'm not taking it

Not sure

7.3 How People Manage Information

7.3.1 Information Chaos

Too much information going through my brain, too much information driving me insane.

- The Police

Five things lead to a state John Beasley and his colleagues have called information chaos: information overload, information underload, information conflict, erroneous information, and information scatter.

Information overload happens when we're being asked to make sense of information quickly, but there's too much information for us to do so. This makes us tired and even anxious. It also reduces our situational awareness. Without good situational awareness, we can miss important information because we're 'unable to hear the signal for the noise.'

Information underload happens when we lack sufficient information to make decisions.

Information conflict happens when an interface gives us contradictory information or information contradicting what we already know.
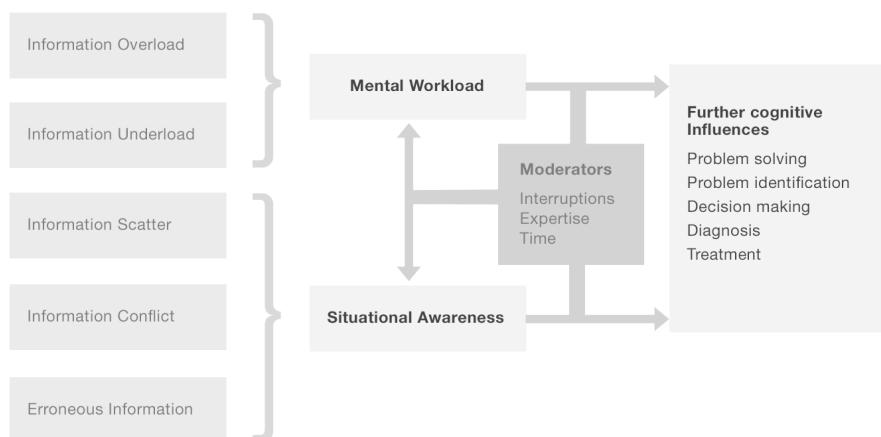
Erroneous information is information that, for whatever reason, isn't correct.

Information scatter happens when someone has access to all the information they need, but it's in several locations or formats and can't easily be reconciled into a complete picture.

If an interface allows for any of the above issues, a doctor could miss noticing important information, like a dangerously high blood pressure reading, and put her patient at risk.

Example: This walkthrough demonstrates the factors involved in information chaos.

Figure 7.22 **Information Chaos**

Information Overload		Mental Workload		Further cognitive Influences
Information Underload				Problem solving
		Moderators		Problem identification
Information Scatter		Interruptions		Decision making
		Expertise		Diagnosis
Information Conflict		Time		Treatment
		Situational Awareness		
Erroneous Information				

7.3.2 Situational Awareness

Interfaces must help users put all the elements of complex situations into perspective so they can make good choices.

Situational awareness is an important component of everything from ordinary tasks like driving a car to emergency services. Effective EHR displays can improve users' situational awareness by presenting them with key information without disrupting their work.

It's difficult to design EHRs that can improve users' situational awareness, however, because the information users need varies depending on both the user and the task at hand. What's important for the user to know about one patient may not be important for them to know about another. Yet despite the situation's complexity, designers can meet this challenge. If a patient has a chronic disease such as diabetes or hypertension, an interface can help users quickly assess and manage these conditions. The interface need never force users to stop, for example, writing up an e-prescription to go look for the lab result they need in order to calculate a proper dose. Designers need to strike a balance between giving users lots of information to boost their situational awareness, and overwhelming them (see information overload).

Users' situational awareness suffers when they're distracted. If two children are arguing in the back seat, the car's driver won't be able to give her full attention to the road. Similarly, alerts about laboratory values may be important, but they may also distract a physician who's trying to order a medication and cause her to make a mistake.

7.4 Summary

1. Human Factors Engineering seeks to improve human performance by designing systems that are compatible with our physical, cognitive, and perceptual abilities.

2. We subconsciously use expectations, past experience, associations, and rules of thumb to make guesses about what we are seeing. This lets us cope with noisy, incomplete data, but can also lead us astray.

3. We have two modes of thinking, fast thinking that happens with little conscious effort and slow thinking that takes focus. Good design lets us use our fast system to do as much as possible.

4. Working memory is limited to four things. Good design minimizes the need to use working memory.

5. The more we have to remember and calculate in our heads, the higher the cognitive load. Good design reduces cognitive load by reducing the need to remember information and displaying information that can be used in decision making without additional calculations or navigation.

6. Good information system design allows a user to quickly gain or maintain the situational awareness needed to make safe and effective decisions.

The designs in this book were created by our team and reviewed by a national panel of clinical and human factors experts, but have not been empirically tested against existing designs.

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Design Principles

Design is a response to specific problem. You are given a problem, and then you let the problem itself tell you what your solution is.

<div align="right">- Chipp Kidd</div>

8.1 Mental Models

If you don't know where you are, you can't get to where you want to go.

Good software design starts with a deep understanding of what users need the product to do. In other words they need to understand the product's utility. It may sound simple, but what is truly helpful to a designer is understanding the product's current utility and the user's mental model of what that utility should be. A mental model is an explanation of someone's thought process about how something works in the real world and how it fits into their workflow.

People's understanding of the world is predicated on their worldview: a complicated, integrated and contextually-dependent construct, an estuary where a person's unique experience of the world meets the social, cultural, and environmental factors that condition their existence. A person's worldview is not just a lens that colors their perceptions, it is the means by which that individual perceives and understands the world. A person's worldview determines how that person will experience your product. They won't just be looking at the system in isolation, they'll bring with

them a mental model of what the system should be. The model will have developed out of their past experiences and their perspective, and it will define how they think about and use your product.

Software products must thus not only function well, they must successfully engage with users' mental models of the types of products they're supposed to be. Users will find a product that meets their expectations in this regard usable and desirable. Users' mental models are the fundamental starting point of the product design roadmap, and they'll serve as the baseline for design decisions throughout the product's lifecycle.

Key Ideas:

- Establishing the proper mental model is fundamental to driving the product design process.

- Designers discover users' mental models through research and craft the proper metaphor that will best fit with how users will be using the product. For example, the desktop metaphor used by modern operating systems represents a very specific and intentional mental model.

- Simplicity is the hallmark of a strong mental model. Users should intuitively understand the model they are presented.

8.2 Removing Complexity

Complexity increases at an exponential rate as a factor of the number of items presented.

Extra visual noise, repetitive information and symbols, and having too many controls for the same action (possibly all of which are visible at the same time) can all cause redundancy. Redundancy can be good at times, like having an emergency break in a car, but it literally means a state of being that is no longer needed or useful. Redundancy in an interface is often unhelpful, add valueless complexity, and can interfere with an interface's utility on visual, informational and behavioral levels.

Imagine attempting to drive a car with three dashboards and four steering wheels down a highway with road signs that have been duplicated on both sides of the road. The engineers involved may have thought they were giving the driver extra resources, but it would be an understatement to say that their attempts to help the user have ultimately made things more difficult.

Key Ideas:

• Visual: Remove all extraneous noise and ornamentation. Achieve visual simplicity before adding flourishes for decoration or emphasis.

• Informational: Watch out for repetitious, proximate words and symbols in your design. Consolidate these where possible.

• Behavioral: Pick a primary method for performing an action and feature it prominently. Controls and interactions that duplicate the behavior can be hidden one level deeper.

8.3 Terminology

Always ask, 'What is this?' about your chosen terminology until you are sure of the final answer.

Marketing is meant to sell, and, in order to do so, it generates saleable names. These names and this process aren't the best means of denoting terminology inside a functional interface. As much as marketing managers want to control the design of a product, their skill set, as it's currently understood, doesn't serve the product or the user well in this capacity.

Generally speaking, terminology can be as uncomplicated and natural as common language used in everyday conversation.

Don't try to be clever when it comes to terminology. There's no need to construct complex neologisms that would prompt the use of a dictionary. Just call things what they are. It's really that simple.

Key Ideas:

- The interface is no place for marketing labels. Call things what they are.

- Use industry standard language when possible. For example, designers know that "leading" is the measurement between two baselines in body copy. To refer to "leading" as "line height" will simply confuse the target audience.

- If you use a term in the interface that you can't easily define in one sentence or less, chances are you've misused the term.

8.4 Emphasis

When everything is important, nothing is important.

If the design treats every feature, control, and piece of data in the software application as vitally important, the end product won't be very useful. Contrast and emphasis allow users to make sense of what would otherwise be a swamp of features.

Designers and developers must regularly ask themselves (and the users) how important given features are in relation to one another.

Key Ideas:

- Screens in an EHR could have a single focus that acts as a visual anchor. This point doesn't have to be semantically important to the user, it just has to make the layout comprehensible.

- Create boundaries and limit the scope of the application to the user task at hand. Limit the number of emphasized options or controls a given screen displays. Three is a good baseline to shoot for, while more than five is too many.

- Establish consistent rules about what makes controls or features high priority and then stick to those rules. For example, to determine any control or feature as high priority, it must be used by 75% of the user base at least 25% of the time. Any other feature would not be considered a high priority and could be given secondary significance or dropped entirely.

8.5 Typography

When in doubt, follow the rule of two.

One of the most straightforward problems to fix in almost any design is the poor application of basic typographical rules.

Words are the functional equivalent of icons. When you read a body of text, you are not parsing individual letters, like "d - e - s - i - g - n." You are actually seeing a concise symbol that is parsed as a single object, "design."

An inconsistent jumble of typefaces distracts users. It's the typographical equivalent of wearing several clashing fabrics. Limit yourself to no more that two types and six to eight fonts throughout the application.

"Type" is defined as a font face like Helvetica or Georgia. "Font" is defined as the combination of the font face, color, size, and variant (italic, bold, etc). For example, 11pt Helvetica colored as #333 and 11pt Helvetica Italic colored as #333 are considered two different fonts, just as they would be considered different fonts if they were different shades of blue, or if one was 11pt and the other was 18pt.

Once your type is under control, you can choose the optimal spots to use fonts to add emphasis.

Key Ideas:

- As a starting point, use no more than two types in the design of the product.

- Before deviating from the 'no more than eight fonts' rule, first force yourself to solve the design problem within the rule's constraints.

8.6 Color

When used effectively, color informs, and even calms the user.

Where type communicates, color provides context. The use of color should be constrained like the use of type. Just like its typographical counterpart, an application's color palette must be considered judiciously.

Developers must carefully avoid making extraneous or random additions. Color, after all, has a direct, visceral effect on the user that type lacks.

Key Ideas:

- Define the product's color palette. Pick a color system that also serves the needs of the product at a functional level, rather than that solely serves a marketing or branding agenda.

- Picking a base color is a good place to start. From there pick up to three complementary colors and one highlight color. It is also a good idea to define your levels of black and white.

- Before deviating from your defined color palette, force yourself to solve the design problem within your defined constraints.

8.7 The Dark Side of Seeing Color

Color has it uses, but if one is not careful, color can become useless.

Color is useful beyond just having things look pleasing to the eye, it can create distinctions and be used to draw attention to things we want people to look at. However color has its limits as a communication tool and it's important to keep these limitations in mind if you want to use color effectively.

The first thing to keep in mind is that 9% of men and 0.5% percent of women are color blind. Color blind people can see color, but can't see the differences between some colors the way most people can. There are different types of color blindness but the most common one makes it hard to see the difference between reds, yellows, and greens.

Another tricky element to color is that different cultures can have different associations for the same color. So while red can mean bad, danger, or stop to many Western users, in some Asian cultures red is associated with happiness or good fortune. Designers need to take into account the cultural context of likely users, and to use color in a way that doesn't unduly inconvenience color-blind users.

Some colors don't play well together. In combinations clashing colors can make things hard to look at and difficult to read. For example red and blue or red and green overlapping each other cause this effect but there are many colors that are opponent colors and clash. It would be a good idea to consult a color guide when choosing your colors.

Converting the colors in your design to gray scale can be useful to check if your color differences are strong enough to be noticeable. The color differences that most color blind people have a hard time seeing are discernible to them even in color if the differences are detectable once the design has been converted to grey scale. This also helps make sure your color differences are strong enough for non color blind people to detect.

Color is useful, but don't let it stand alone. Use other cues to complement it.

Key Ideas:

- Avoid subtle color differences. Our eyes have evolved to see strong contrasts. A trick is to convert a project to grayscale. If it's too hard to see the difference between your colors in grayscale it's a good bet the colors are not different enough to avoid causing confusion.

- Keep in mind that color displays are not all created equal on the hardware side. The display capacity of the monitor screen, for example, can affect an application's appearance. Video card quality can also have an effect.

- Colors have natural pairs, but watch out for clashing colors and color blindness.

- When used sparingly, color can work to draw the eye where you want it to go. When overused, color loses its effect.

9

Health Information Technology and Usability

Work smarter, not harder.

9.1 Usability

In layman's terms usability refers to how easy or intuitive an interface is to use. Successful designers go beyond this vague notion of "user friendliness" and have a thorough understanding of their user's community and the tasks they need to accomplish. They also use methodologies validated during decades of research (http://www.measuringusability.com/blog/usability-history.php) on human computer interaction.

The International Standards for Human Computer Interaction (HCI) and usability (i.e., ISO 9241-11) define usability as the "effectiveness, efficiency, and satisfaction of a user performance within a specific context, such as physical and social environment." But usability alone is not enough, an interface must also have good utility. Good utility means the interface provides the features needed to complete users' tasks. Successful applications combine good utility and good usability.

Health Information Technology (Health IT) usability issues are similar to the information technology usability issues of other life-critical systems such as air traffic control or nuclear power plants.

Users in all of these fields are experts in their domain, but they need rapid, error free information technology performance to do their jobs effectively.

Usability problem areas in an interface design might be indicated by workarounds, redundancies, or slow task completion, all of which could possibly lead to general user burnout. Health IT applications with usability problems are more than just annoying to use, they can cause serious patient harm (e.g. wrong medication or dangerous dosage, wrong treatment, missed results, wrong patient selection leading to a patient not receiving treatment and another receiving unintended treatment, etc.).

There is an art as well as a science to good interface design. Donald Norman's seminal book: *The Design of Everyday Things* (initially named *The Psychology of Everyday Things*), highlighted the importance of balancing the imperatives of efficiency and aesthetics in the design process.

The 5 measures of usability are as follows:

- Learnability: How easy is it for first time users to accomplish basic tasks using this system? How easily can users discover and access the system's more advanced features?

- Efficiency: How quickly can users perform tasks using this system?

- Memorability: If physicians stop using the system for some time, how easily can they re-establish their former proficiency with the system?

- Errors: How many errors do users make while interacting with the system? How severe are these errors, and how easily can users

correct them?

- Satisfaction: How pleasant do users find their experience of interacting with the system?

The human factors chapter covers the large body of evidence from many different sources that illustrate the importance of usability. If an interface is difficult to use, people will simply not use it or experience a decline in productivity when they are forced to use it.

9.2 Methodologies

Usability is an increasingly important consideration in organizational and product planning. The good news is that there are many methodological tools that have been developed by researchers to aid in designing and evaluating the usability of computer systems in general. More recently researchers have begun developing specific guidance for EHRs in particular.

Development methodologies, such as contextual design, helps developers by offering validated processes with predictable schedules. Ethnographic, or user group, observation can guide task analysis and complement user participatory design processes. Writing scenarios help developer teams to build a common understanding of design goals. These scenarios can also help plan usability tests. Logs of current Health IT system usage can provide valuable data about task frequencies and sequences that lead to design refinements. These methods will provide the developers with valuable information about how the users go about their work and how frequently they perform various tasks. Armed with this information, the developers will be able to refine their designs.

Specific guidance for EHR design and evaluation is becoming more and more available. For example there is now a NIST publication (http://www.nist.gov/manuscript-publication-search.cfm?pub_id=909701) that summarizes the rationale for an Electronic Health Record (EHR) Usability Protocol (EUP) and outlines a three-step process. These three steps consist of:

1. EHR Application Analysis

2. EHR User Interface Expert Review

3. EHR User Interface Validation Testing

The TURF Usability Toolkit (https://turf.shis.uth.tmc.edu/turfweb/) developed at the University of Texas can help create, organize, and analyze usability of EHRs. Other Health IT and general usability and design resources are provided at the end of the chapter.

Usability evaluations provide developers with subjective and objective data for improving the user interfaces. For practical results, five to eight people participating in a pilot study using most methods, can already provide valuable feedback and suggestions for improvements. A group of sixteen to twenty participants will start to consistently report similar issues with the design. At this point, the developers can study these results and refine the design accordingly. The developers can run several testing cycles to make sure they address all the program's significant problems.

Other methodologies for evaluating or creating designs and evaluation include:

Method	Description	Purpose
Card sorting	A categorization method wherein users sort cards depicting various concepts into groups.	Card sorting helps developers organize a program's content. It helps them design better overall information architecture and better menus. It can also help physicians and programmers work together to effectively label a program's various functions.

Method	Description	Purpose
Cognitive Walkthrough	A team of evaluations walk through a paper or working prototype, discussing the usability issues they encounter as they go.	This process helps identify additional application functions necessary for the tasks in a workflow process.
Exit Interview (Retrospective Think Aloud)	After a prior usability test, a moderator asks a user questions about how the system performed.	Provides meaningful qualitative information, as well as highlighting what's working, what's not, and why.
Focus Group	A moderator guides a discussion about the application being developed with a group of users.	Focus groups help developers understand the factors that affect individuals' relationship to the application's needs and design.
Heuristic Evaluation (Expert Review)	Usability and design experts examine the product and determine whether it meets industry standards.	Experts who know key factors of good design and can quickly identify trouble areas, even subtle ones, that other methods might miss.

Method	Description	Purpose
Paper Prototyping	Low fidelity usability testing of product concept made from paper or some simple tool.	Paper prototyping has a high value in the iterative design process. A design can be worked and reworked over and over again, especially when combined with cognitive walkthroughs, to quickly design a prototype.
Survey or Questionnaire	A survey or questionnaire asks specific questions about an application's effectiveness or collects information about user demographics, preferences, and experiences with the tool.	Surveys can provide developers with feedback about a variety of design issues throughout the product's lifecycle.
Think Aloud (Concurrent)	Participants in testing express their thoughts on the application while executing set tasks. Think alouds are also used in an exit interview when the user is shown a recording of their session and asked to express their thoughts in retrospect.	This process can help gain insight into the thought flows of actual users as well as help answer questions about why users are performing tasks a certain way.

Method	Description	Purpose
Usability Testing/Task Performance	Presents representative end-users with scenarios or specific tasks, designed to cover the major functionality of the software system and to simulate expected real-life usage patterns.	This process determines if the design works for the intended task or has gulfs between the user's expectations of the design and the developer's concept of functionality.
Field Testing	Researchers evaluate products in the contexts in which those products would normally be used.	People use things differently in different settings. Collecting data in the field can provide new insights that are not always discoverable in a lab or test center.

9.3 Recommended Reading

9.3.1 Usability and EHR

Health Information Management Systems Society (HIMSS)
EHR Usability Basics (http://www.himss.org/resourcelibrary/
TopicList.aspx?MetaDataID=1719&navItemNumber=17121)

HIMSS is a global, cause-based, not-for-profit organization
that focuses on improving healthcare through improving and
distributing information technology (IT). This site includes
resources related to EHR usability evaluation and design.

National Institute of Standards and Technology
Health Information Technology / Usability (http://www.nist.gov/
healthcare/usability/)

This site summarizes NIST's work on Health IT. It contains links
to selected publications, and to records of NIST's conference
proceedings. See in particular:

(NISTIR 7741) NIST Guide to the Processes Approach for Improving
the Usability of Electronic Health Records (http://www.nist.gov/
manuscript-publication-search.cfm?pub_id=907313)

(NISTIR 7804) Technical Evaluation, Testing and Validation of
the Usability of Electronic Health Records (http://www.nist.gov/
manuscript-publication-search.cfm?pub_id=909701)

Strategic Health IT Advanced Research Projects (SHARP
HealthIT.gov (http://www.healthit.gov/policy-researchers-implementers/strategic-health-it-advanced-research-projects-sharp)

SHARP's research works to address problems that impede the adoption of Health IT. See in particular: TURF EHR Usability Toolkit (https://turf.shis.uth.tmc.edu/turfweb/)

Special Section of ACM Interactions (Nov/Dec 2011) (http://dl.acm.org/citation.cfm?id=2029976&picked=prox)
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- Hochheiser, H., & Shneiderman, B. (2011). Electronic medical records: usability challenges and opportunities. *ACM Interactions*, 18(6), 48-49.

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Usability.gov This is a valuable general resource on usability methods and principles.

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