CHAPTER 5

# Usability in Health Information Technology

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## LEARNING OBJECTIVES

1. Define user-centered design.
2. Identify the importance of usability testing in health care.
3. Describe the iterative process of design and testing health information technologies.
4. Select among different methods of usability testing.

## KEY TERMS

Effectiveness
Efficiency
Health information technology (health IT)
Human–computer interaction
Iterative
Qualitative method
Quantitative method
Satisfaction
System development life cycle
Usability testing
User-centered design (UCD)
User experience (UX)

## Chapter Overview

The focus of this chapter is to understand a nurse's role in planning and implementing usability tests to study the effects of computer-based technology on the people who use it. Simply put, computers change the way people interact with others at work and with **health information technology (health IT)**. Whether computers are carried in pockets, embedded in medical equipment, or positioned on desks, these systems can lead to fundamental changes in workflow. It is this interaction between humans and computers that is central to usability and **usability testing.**

## Introduction

Usability has many definitions and attributes (Shultz & Hand, 2015). Most of the definitions of usability concern the interaction of health IT with users (nurses, physicians, patients, family members) in terms of ease of learning to use health IT (learnability), consistency of interface (memorability), effectiveness and efficiency to accomplish the goals of a task (productivity) and the satisfaction with the health IT (Shultz & Hand, 2015). Usability testing is concerned with functionality of health IT: It measures users' perceptions about the **effectiveness** and **efficiency** of the product, users' **satisfaction** with the product, and the tendency for errors with the product ("Usability Evaluation Basics," 2013). To illustrate usability, consider two common devices used to control traffic in the United States: traffic lights and four-way stop signs. A traffic light is a device that has three colors—green, yellow, and red. The colors are arranged either from top to bottom or left to right in the same order. Drivers know that green means go, yellow means prepare to stop, and red means stop. Traffic lights work because they are easy for people to understand, are used in a consistent manner, and are effective in controlling traffic. In contrast, four-way stop signs used at intersecting roads are not as effective, because drivers have to make decisions based on the context. Drivers must always stop at the intersection, look at traffic on the other three roads, and go *if they have the right of way.* The right of way is determined by who arrives at the intersection first. The rule is easy if only one car is at the intersection, but if multiple cars arrive at the same time, the car farthermost to the right leaves the intersection first. Using this illustration, usability testing can show that both types of traffic signals are effective—drivers follow consistent rules for stopping at intersections. However, drivers likely find that four-way stop signs are not as efficient, satisfying, or error free as traffic lights because of the multiple decisions about crossing the intersection.

Every piece of technology can be evaluated for its usability and compared to other similar technologies. The goal of usability testing in health care is to develop or purchase electronic health records (EHRs), medical devices, and other health IT that meet users' needs, improve productivity, and safeguard against errors.

The need for usability testing is significant because EHRs and other health IT have been shown to slow workflow, impair performance, and introduce new error-prone processes (Jones, Heaton, Rudin, & Schneider, 2012). Participants at the Institute of Medicine's (IOM) workshop on comparative user experiences for health IT called for public reporting of the usability of EHRs (IOM, 2011; Sinsky, Hess, Karsh, Keller, & Koppel, 2012). A panel of experts commissioned by the IOM called for public reporting, similar to reviews by *Consumer Reports* of other products to provide essential information to potential purchasers and lead to improvements made by vendors (Sinsky et al., 2012). They further proposed that usability testing of EHRs and other health IT should provide information about cognitive workload, accuracy of decision making, time required to perform tasks, and implementation experience, because these characteristics profoundly affect any healthcare provider's (HCP's) ability to deliver safe patient care. The federal government has a high stake in improving usability of all health IT. The Office of the National Coordinator (ONC) for Health IT in its Federal Strategic Plan for 2015–2020 (ONC, n.d.) lists "increase access to and usability of high-quality electronic health information and services" as a high priority objective to achieve *Goal 5*, which is to "advance research, scientific knowledge, and innovation" in health IT ("Federal Health IT Strategic Plan 2015–2020," n.d.)

## Importance of Usability Testing

The ideal way to develop EHRs and health IT is to test usability as part of the design project plan. For vendors of EHRs and health IT, usability

testing implemented from the beginning of product development is less costly than later changes requiring major revision to the code (Shenoy, 2008). Even teamwork is hurt by late usability testing. Any computer programmer will agree that resistance to reworking code is "directly proportional to the number of lines of code that has already been written" (Shenoy, 2008). Usability testing is important enough that the National Institute of Standards and Technology, an agency of the U.S. Department of Commerce, issued a report outlining an EHR usability protocol for vendors to follow in the design of their products (Lowry et al., 2012).

Poor **user experience (UX)** with health IT occurs when the technology is mismatched to the needs of the user. Poor UX is frustrating, dissatisfying, and unlikely to get better without significant redesign of the health IT. Systems with poor UX are costly in terms of dollars, personnel turnover, and unnecessary medical errors. With most EHR systems priced in the range of millions of dollars, selection of a system with poor usability often cannot be undone. In other words, once a system has been purchased, the healthcare organization cannot return it for a better system, so the organization is burdened with poor usability for the life of that system. Even admirable efforts to customize the system are typically inadequate to overcome damage to workflow and the reduced productivity of HCPs. Providers can become so frustrated and dissatisfied that they leave the organization (Kjeldskov, Skov, & Stage, 2010). Poor usability can lead to medical errors and leave the potential for efficiencies and safety as unrealized goals (Horsky et al., 2010).

## The Role of Nurses in Usability

Nurses are the frontline providers in most healthcare settings—they interact with many different and complex health IT every day (Smallheer, 2015). The quality of nurses' experiences with health IT varies greatly depending on the design of the software and hardware of each system. For example, Cho, Kim, Choi, and Staggers (2016) evaluated the usability of six different EHRs focused on nursing documentation. They found that navigation patterns were different among the six systems, with two systems requiring multiple, complex interactions between nurses and the documentation system. These two systems had the lowest usability scores, as measured by the System Usability Scale, and the lowest nurse satisfaction scores (Cho et al., 2016). Network problems or interruptions in WiFi or Bluetooth connectivity cause dropped sessions during medication administration (Staggers & Sengstack, 2015). Hardware issues, such as small fonts on medical devices, poor illumination in darkened rooms, and handheld devices teetered with cords too short to reach patients, create usability problems for nurses (Staggers & Sengstack, 2015). However, the most prevalent usability problem is the misalignment of the health IT with nurses' cognitive and workflow processes (Siwicki, n.d.). Staggers, Iribarren, Guo, and Weir (2015) conducted usability testing on the electronic medication administration record (e-MAR) that is used by the Veterans Administration (VA) hospitals. They found 99 issues of usability with 15 being classified as catastrophic, which were due, in part, to interoperability problems between systems at the VA (Staggers et al., 2015).

Because nurses must use health IT to get their work done, they must also participate in the entire life cycle for health IT by being knowledgeable end users in user-centered design of health IT (described in the next section). Nurses must also speak up when usability problems exist and demand changes (Staggers & Sengstack, 2015). Nurses have power in numbers that can be manifest by submitting usability issues to the help desk, keeping logs of issues that could contribute to errors, and by reporting when workarounds are more expedient than the system as it was designed. Nurses should not just accept health IT with usability problems, but

should be the leading voice for change in their organization (Staggers, 2012).

Nurses can influence future purchases by participating in vendor demonstrations and thinking about the health IT in terms of usability. For example, a hospital plans to purchase new smart infusion pumps for all units and specialty areas. Nurses can provide informed feedback about the functions in the infusion pump as compared to needs in their area of practice. For nurses who work on general medical–surgical floors, an infusion pump with complex settings may not be perceived as an effective technology because only a few setting options would be needed for their work. On the other hand, nurses who work in an emergency department, surgery center, or intensive care unit might need more functions. Nurses could make purchase recommendations based on the functions of the infusion pump compared with the work functions in order to get the most usable infusion pump.

Nurse informaticists should be members of every design team to select or develop usability testing plans. Because the nurse informaticists understand clinical work, they can select usability methods that are most likely to uncover usability problems. Selection should also be guided by the need for user feedback in each step of user-centered design (UCD): planning, designing, testing, and deploying. For example, in the testing phase, a nurse informaticist could develop several case studies to simulate patient care and HCPs' interaction with the target health IT. The case studies could require provider interactions, such as finding lab results, documenting interventions, and responding to alerts. Knowledge of the health IT and the nature of clinical work make nurse informaticists essential members of the design team in all phases of usability testing.

Nurses and nurse informaticists who use the language of usability will be able to harness power when participating with vendors, and purchasing departments in healthcare agencies. It is imperative to make the cognitive work of nurses visible and the focus of purchasing decisions so that health IT supports rather than hinders the nurses' work. To that end, the next sections on UCD and usability testing provide an introduction to the concepts and process of each.

## User-Centered Design

**User-centered design (UCD)** is a method for assessing usability throughout the **system development life cycle** (HHS, 2012). UCD means that the users' needs, desires, and limitations are the driving factors for design, not the capabilities of the technology. In other words, UCD would require a development team to create features valuable to end users and omit those of little importance, even if the features were technologically challenging or cool to the development team. UCD requires developers to understand **human–computer interaction** and to design a natural way for users to interact with the system that satisfies, rather than frustrates, them.

The design of health IT is beyond the scope of this chapter, but readers are encouraged to refer to McGonigle & Mastrian (2012) for a discussion of the system development life cycle. Smart design teams employ UCD and usability testing with HCPs throughout the system development life cycle. When conducted only by health IT designers, testing frequently will fail to uncover usability issues. When UCD and usability are intertwined and **iterative**, each step informs the next, resulting in health IT that is suited to the needs of HCPs. **FIGURE 5-1** illustrates the iterative design-test-redesign process. Even after health IT has been implemented, usability testing can uncover problems and frustrations experienced by HCPs that result in potentially unsafe workarounds. When health IT is found to have usability problems, it should be redesigned or retired. Subsequent sections of this chapter present different frameworks for and methods of usability testing.

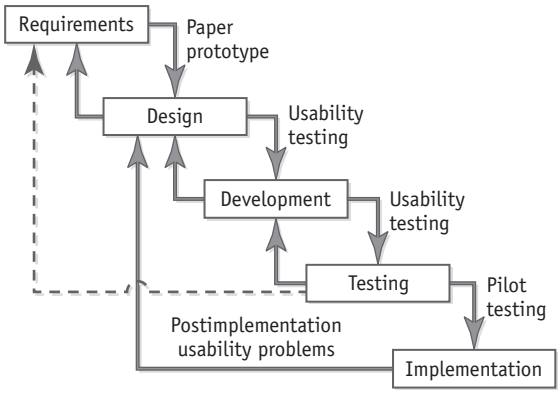


**FIGURE 5-1** User-centered design: Iterative process of usability testing and design in the system development life cycle

## Dimensions of Usability

The dimensions examined in most usability tests are effectiveness, efficiency, and satisfaction. The International Organization for Standardization (ISO, 1998) defines effectiveness as the "accuracy and completeness with which users achieve specified goals," efficiency as the "resources expended in relation to the accuracy and completeness with which users achieve goals," and satisfaction as the "freedom from discomfort and positive attitudes toward the user of the product" (p. 2).

### Measures of the Three Dimensions of Usability

Since the 1990s, published usability studies and systematic reviews have provided numerous measures appropriate to include in usability evaluations (Hornbæk, 2006; Horsky et al., 2010; Jaspers, 2009; Khajouei, Hasman, & Jaspers, 2011; Kushniruk & Patel, 2004; Park & Hwan Lim, 1999; Zhang & Walji, 2011). Measures can overlap, but most are associated with a particular usability dimension.

#### Effectiveness

Measures that assess the health IT's fit with the work to be done are typically used in the effectiveness dimension (**TABLE 5-1**). Work domain saturation refers to the number of work functions available in the health IT compared to the number of work functions in a job. For example, HCPs could use an information system to manage immunizations. The information system might have functions for documentation, alerts for missed immunizations, a quick reference guide for the immunization schedule, inventory management with alerts, and printable immunization cards. If the HCP only needs to document, use the reference, and print immunization cards, the information system has more functions than are needed by the user. Sometimes the mismatch of the information system to the work results in a more complicated system that reduces the efficiency and satisfaction of users. Other measures in the effectiveness domain are task completion, accuracy, recall, and quality of outcomes. Task completion and accuracy measure the users' interaction with health IT's features to complete work functions. Recall of the interface is also an effectiveness measure, because when users recall the layout or content, the interface can be a good fit with the work domain. The final measures of effectiveness are quality of outcomes. Effective health IT helps users meet their work goals in an acceptable manner.

**TABLE 5-1** Effectiveness Measures Used in Usability Studies

| Measures | Definitions |
|---|---|
| Work domain saturation | Ratio of work functions in software to work functions in domain |
| Task completion | Percentage of tasks completed during a defined session |
| Accuracy | Percentage of errors in a task |
| Recall | User's memory of design and content in interface |
| Quality of outcome | The extent to which software meets the user's goals |
| Expert assessment | Usability expert's evaluation of quality of outcomes |

## Efficiency

Measures in the efficiency dimension are designed to assess how easy health IT is to learn and use (**TABLE 5-2**). Using specified tasks, the number of trials to completion, time on task, and input rate can be quantified. Success on tasks in short periods of time indicates an efficient system. Efficiency can be assessed by users' mental efforts to interact with health IT; systems that require little thinking to complete tasks are considered efficient. Patterns and numbers of features used in the system can indicate resources users need to complete tasks. Usage patterns that deviate from ideal patterns or pathways can indicate inefficiencies in the interface. System errors reduce the efficiency of health IT. Measures include the incidence of errors and the percentage of time required by the system to recover from errors. Experts use heuristics or rules of thumb to assess the design of a system's interface. A well-known set of heuristic assessment of a system was developed by Nielsen (1995) and can be found on the companion website to this text.

## Satisfaction

Satisfaction, the third dimension of usability, is a subjective measure of the user's approval of health IT. Satisfaction is most commonly assessed with questionnaires (Bangor, Kortum, & Miller, 2008; Chin, Diehl, & Norman, 1988; Davis, 1989; Lewis, 1993; Lund, 2001). These tools can query users on the perceived ease of use, usefulness, ease of learning, satisfaction with work completed, and overall satisfaction. Some satisfaction measures ask for user preference by asking them to rank the choice of features or functions. Others ask opinions about the content, features, outcome or interactions with software, or an overall experience rating (Hornbæk, 2006). Most satisfaction questionnaires use a Likert rating scale with five or seven answer options. Semantic differential scales are also used and have a line with bipolar adjectives at each end. Users mark how close they feel with respect to one of the two opposite adjectives (see **FIGURE 5-2**). Readers who wish to locate satisfaction questionnaires should refer to the references in this chapter.

# Research Methods for Examining Usability

Usability studies often employ mixed research methods to understand the effectiveness, efficiency, and satisfaction of users with health IT. **Quantitative methods** produce numbers such

**TABLE 5-2** Efficiency Measures in Usability Studies

| Measures | Definitions |
|---|---|
| Learnability | Number of trials to reach a performance level |
| Time | Time on task |
| Input rate | Rate to add data with a mouse, keyboard, or other input device |
| Mental effort | User's cognitive function in software used |
| Usage patterns | Count of how much a function in software is used |
| Error prevention | Error occurrence rate or error recovery rate |
| Expert assessment | Usability expert's evaluation of efficiency using heuristics |

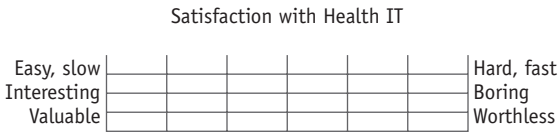


**FIGURE 5-2** Example of semantic differential scale

as counts, frequencies, and ratios. Quantitative methods might include assessments of tasks, surveys, usage logs, and error logs. **Qualitative methods** produce text, video, or audio. Sometimes qualitative data can be converted to quantitative data by counting, for example, instances of users having difficulty finding information on a website. Qualitative methods can include interviews, focus groups, direct or video-recorded observation, "think-aloud" techniques, and task analysis. In simple terms, quantitative methods can show how many usability problems exist, whereas qualitative methods can uncover why usability problems exist and sometimes how to fix them. Because of the complementary nature of the methods, the combination is found to be more successful in the design-redesign cycle (Horsky et al., 2010).

## Planning Usability Testing

Planning for usability testing is done at the beginning of a project, not after health IT has been fully developed. In fact, it is an iterative process of development-testing-redesign so that results from usability testing serve as feedback for the next steps of development. Most experts advocate for no more than five users in a round of usability testing, because 85% of usability problems can be found with five and having more users simply takes longer and costs more money (Krug, 2010; Nielsen, 2000). Usability testing should be conducted regularly; monthly half-day testing with users is recommended (Krug, 2010). A guide with 234 tips for finding

and recruiting participants for usability testing is available for free on the companion website to this text (Sova & Nielsen, 2003).

The design team creates a detailed plan for development and testing, using Gantt charts, flowcharts, and other management tools. The plan includes tasks, start and end dates, milestones, and resources allocated to the various tasks. Because the plan is detailed and shared among team members, specialized project management software is used. Project software can also automate email reminders, calculations of costs associated with tasks, and revisions to the timeline, if milestones are missed. **FIGURE 5-3** illustrates a typical Gantt chart that design teams use to manage the system development life cycle, including plans for usability testing.

## Phases of Usability Testing

### Planning

In the early stages of UCD, usability is focused on analysis of users' needs and tasks before any design discussions begin. Methods appropriate in the analysis phase to understand users' needs include focus groups, individual interviews, and contextual interviews (HHS, 2012). **BOX 5-1** provides a list of questions that the design team could use to develop specific questions for focus groups and interviews. Two other methods used to understand tasks to be implemented in the proposed health IT are task analysis and card sorting (UsabilityNet, 2006).

### Designing

In the design phase, the development team changes focus from understanding needs to brainstorming ideas for the health IT solution. Usability experts advocate for extremely early usability testing; one such technique is called napkin testing. While talking with friends, designers can draw some rough ideas about a design and get the immediate impressions of the design (Krug, 2010). **FIGURE 5-4** illustrates a simple napkin test. Even more formal design work, such as single prototyping, parallel designs, and storyboarding, are still started on paper or using software programs to draw designs (UsabilityNet, 2006). Paper prototyping illustrates the user interface based on a set of requirements for health IT. Parallel designs illustrate more than one design based on the same set of requirements, so users can select among designs. Storyboarding shows the relationships among all screens of health

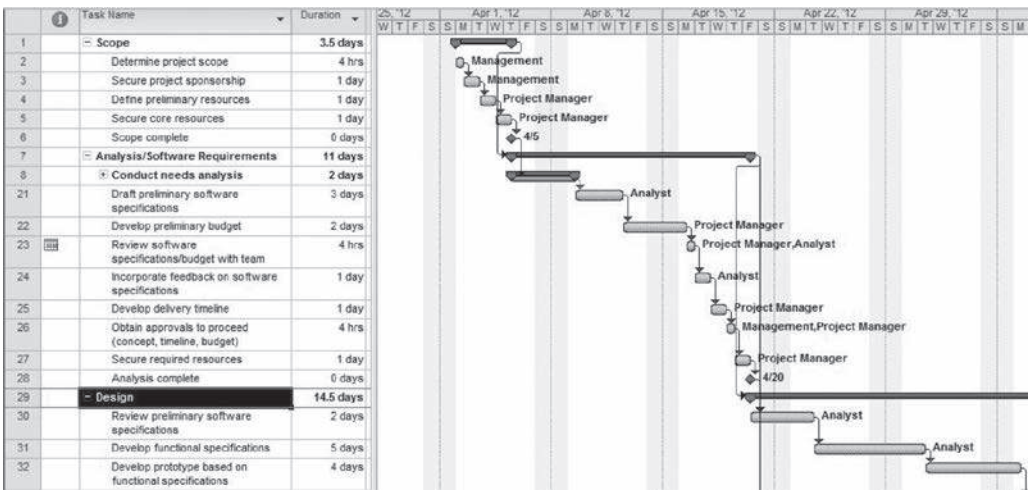


**FIGURE 5-3** Example of a Gantt chart

Used with permission from Microsoft.

**BOX 5-1** User-Centered Questions for the UCD Planning Phase

Who are the users of the health IT?
Why, when, and where will users access the health IT?
What are the critical needs of users for the health IT?
Which health IT features are important to users?
Which activities are core to the interaction of users with the health IT?
Which activities must be completed quickly by users of the health IT?
What is the level of satisfaction that users can expect from interacting with the health IT?
How much training on use of the health IT can end users tolerate?

Modified from U.S. Department of Health and Human Services. (n.d.). *Questions to ask at kick-off meetings.* Retrieved from http://www.usability.gov/basics/ucd/

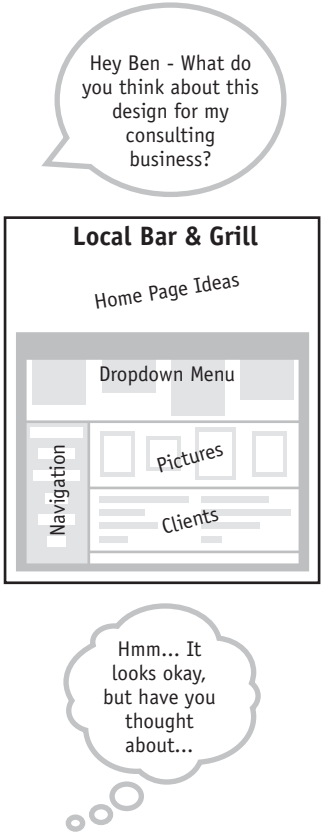


**FIGURE 5-4** The napkin test

IT. All of these methods bring user feedback to the design team and are important in the early designs to avoid the expense of rewriting code.

## Testing

After the team has a working prototype, usability testing involves people outside of the design team: UX experts and actual users. Regardless of the method or the people involved in usability testing, the main point is to understand what users experience and improve health IT. Methods for the testing phase include heuristic evaluation, cognitive walkthroughs, the think-aloud method, user interviews, surveys, critical incident analysis, and satisfaction questionnaires (HHS, 2012; UsabilityNet, 2006). Frith and Anderson (2012) beta-tested nurse staffing decision-support software with five nurse managers in a community hospital. Several usability testing methods were used including cognitive walkthroughs, weekly user interviews, daily logs, and user surveys. The beta test was 3 months long, and redesign of software was batched so that users could be kept informed about changes. Users gave valuable feedback about the software. For example, the software was designed to refresh data every 4 hours, but users in the beta test wanted more frequent refresh rates (at least hourly). Usability testing also revealed other needs—nurse managers wanted graphs to trend data over time, to save and print graphs, and to annotate saved data for productivity reports. These features were not originally planned, but became priorities for redesign (Frith & Anderson, 2012).

Software programs such as Morae can record user mouse actions when users are asked to

complete tasks to test the efficiency of health IT (Clearleft, 2013; TechSmith, 2013). The design team would develop structured tasks and quantify the time to complete tasks, the number of wrong mouse actions, and the completion rate for tasks by reviewing the software captures. Video cameras can add facial expressions and verbal responses to the usability testing. Specialized hardware can monitor the eye movements of users to determine if they are confused about the layout of health IT. A demo usability test recorded by Krug (2010) is freely available via YouTube, and the link to the video is found on the companion website for this text. It is worth the 25 minutes of time to watch a real usability test!

### Deploying

The real test of users' experiences with health IT is when they use it in training or for the first several months. Of course, there are methods to collect data about how well health IT is performing in relation to the usability goals set for it. Usage and error logs can be collected automatically from health IT if the code for logging such activities was designed in health IT. Other manual ways to collect deployment usability data are to note problems with use during training sessions and to log calls to a support center. The usability problems noted in the deployment stage must be fixed quickly to avoid frustrating users.

## Examples of Usability Testing in Health Care

Health IT usability testing is appropriate for EHRs, decision-support software, medical devices, and any other health IT–supported functions.

**BOX 5-2** Usability Case Study

An EBP team at a medical center wanted their sepsis protocol implemented in the electronic medical record as clinical decision support. They contacted the information technology department to work with them on the design of the clinical decision support they would call *SepCol*. The design team developed a UCD plan with three major steps that integrated different usability methods. In the first step, the evidence-based practice team translated sepsis protocol into algorithms for patient screening and treatment. Next, the EBP team developed case studies to understand how HCPs would use the algorithms in a clinical context. Meanwhile, the IT design team added SepCol to the electronic medical record software, which created prompts for HCPs to screen or treat patients for sepsis if data triggered sepsis criteria. In the second step, the IT design team asked HCPs to use a prototype of the SepCol and to think aloud while they completed several tasks. The HCPs identified confusing instructions in the decision support, so the IT design team revised the instructions to better fit the practice of nurses and physicians. In the final step of usability testing, HCPs were asked to use the SepCol with real patients. The EBP team counted the number of SepCol prompts to initiate the use of the sepsis protocol. The design team found that nurses who used the SepCol initiated significantly more treatments for sepsis as compared to the standard system used before the usability testing of the new decision support.

#### Check Your Understanding

1. What was the benefit of using different usability tests in the three phases of development of SepCol?
2. What other methods could have been selected to test usability?

Modified from Anderson, J. A., Willson, P., Peterson, N. J., Murphy, C., & Kent, T. A. (2010). Prototype to practice: Developing and testing a clinical decision support system for secondary stroke prevention in a veterans healthcare facility. *CIN: Computers, Informatics, Nursing, 28*(6), 353–363. By permission of Lippincott Williams & Wilkins.

**BOX 5-3** Websites for Usability Testing

### Matrix of Usability Methods Based on Their Role in User-Centered Design

- Usability.gov: http://www.usability.gov/methods/index.html
- UsabilityNet: http://www.usabilitynet.org/tools/methods.htm
- Nielsen Norman Group: http://www.nngroup.com/articles/which-ux-research-methods/
- Nielsen Norman Group, "10 Usability Heuristics for User Interface Design": http://www. nngroup .com/articles/ten-usability-heuristics/
- Nielsen Norman Group tips for recruiting users: http://www.nngroup.com/reports/tips/recruiting
- Human Factors International: http://www.humanfactors.com/services/usabilitytestingchart.asp
- Usability Body of Knowledge: http://www.usabilitybok.org/methods

### Demo Usability Test

- Steve Krug: http://www.youtube.com/watch?v5QcklzHC99Xc&feature5player_embedded

### User Experience

- UX Matters: http://www.uxmatters.com/index.php
- *UX Magazine:* http://uxmag.com/

The case study presented in this chapter was reported in the literature by Anderson, Willson, Peterson, Murphy, and Kent (2010). The case study shows a variety of usability tests used to improve a clinical decision-support system (see **BOX 5-2**).

If you were asked to participate in usability testing and could select only one method, which one would you select and why?

## Summary

Usability testing in health care is an integral part of the design of health IT. **BOX 5-3** provides helpful links to usability resources available on the Internet. Usability testing should be a regularly scheduled activity in the design plan. When usability is iterative with design, the needs of users become central to the design. The purpose of usability testing is not to prove anything; rather, it is to improve the design and function of health IT. The three dimensions of usability testing—effectiveness, efficiency, and satisfaction—can be measured with a variety of qualitative or quantitative methods. Usability testing should improve health IT so that HCPs can give care in an efficient manner and safeguard against medical errors.

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