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Original Paper

Applying Human Factors Principles to Mitigate Usability Issues Related to Embedded Assumptions in Health Information Technology Design

Michael C Gibbons^{1,2}, MD, MPH; Svetlana Z Lowry³, PhD; Emily S Patterson⁴, PhD

¹Johns Hopkins University, Departments of Medicine, Public Health, and Health Informatics, Baltimore, MD, United States

²Johns Hopkins Urban Health Institute, Baltimore, MD, United States

³National Institute of Standards and Technology, Information Access Division, Information Technology Laboratory, Gaithersburg, MD, United States

⁴The Ohio State University College of Medicine, Division of Health Information Management and Systems, School of Health and Rehabilitation Sciences, Columbus, OH, United States

Corresponding Author:

Michael C Gibbons, MD, MPH

Johns Hopkins University

Departments of Medicine, Public Health, and Health Informatics

615 N Wolfe Street

E4032

Baltimore, MD, 21205

United States

Phone: 1 410 502 3845

Fax: 1 410 502 7262

Email: mgibbon1@jhu.edu

Abstract

Background: There is growing recognition that design flaws in health information technology (HIT) lead to increased cognitive work, impact workflows, and produce other undesirable user experiences that contribute to usability issues and, in some cases, patient harm. These usability issues may in turn contribute to HIT utilization disparities and patient safety concerns, particularly among “non-typical” HIT users and their health care providers. Health care disparities are associated with poor health outcomes, premature death, and increased health care costs. HIT has the potential to reduce these disparate outcomes. In the computer science field, it has long been recognized that embedded cultural assumptions can reduce the usability, usefulness, and safety of HIT systems for populations whose characteristics differ from “stereotypical” users. Among these non-typical users, inappropriate embedded design assumptions may contribute to health care disparities. It is unclear how to address potentially inappropriate embedded HIT design assumptions once detected.

Objective: The objective of this paper is to explain HIT universal design principles derived from the human factors engineering literature that can help to overcome potential usability and/or patient safety issues that are associated with unrecognized, embedded assumptions about cultural groups when designing HIT systems.

Methods: Existing best practices, guidance, and standards in software usability and accessibility were subjected to a 5-step expert review process to identify and summarize those best practices, guidance, and standards that could help identify and/or address embedded design assumptions in HIT that could negatively impact patient safety, particularly for non-majority HIT user populations. An iterative consensus-based process was then used to derive evidence-based design principles from the data to address potentially inappropriate embedded cultural assumptions.

Results: Design principles that may help identify and address embedded HIT design assumptions are available in the existing literature.

Conclusions: Evidence-based HIT design principles derived from existing human factors and informatics literature can help HIT developers identify and address embedded cultural assumptions that may underlie HIT-associated usability and patient safety concerns as well as health care disparities.

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KEYWORDS

cultural ergonomics; culturally informed design; EHR; health care disparities; health information technology; human factors; patient portal; patient safety; usability; workflow

Introduction

Pervasive and intractable health care disparities have been convincingly documented at all levels of the US health care system. Health care disparities are associated with poor health outcomes, premature death, and increased health care costs [1,2]. Although a large body of work has demonstrated the existence of these disparities, there has not been any significant systematic and sustained improvement over time [3]. Furthermore, several national trends in the United States suggest that the scope and magnitude of these disparities are likely to increase, including the growth of racial, ethnic minority, immigrant, senior populations (eg, aging baby boomers), an aging health care workforce, and a significant problem with health literacy and English-language fluency among US residents [4]. These disparities are associated with excess morbidity and mortality, as well as increased health care costs and patient harm, among affected populations and society in general. It has been estimated that the combined direct and indirect cost of health disparities in the United States was \$1.24 trillion between 2003 and 2006 [2]. Despite many efforts to date, there has been no systematic and sustained reduction in any health disparity at the national level [5].

A number of federal agencies have called for an increasing role for health information technology (HIT) in health care delivery as a way to address health care disparities, in addition to improving efficiency, quality, and patient safety [6]. The Center for Medicaid & Medicare Services “meaningful use” program promotes the use of electronic health records (EHRs), primarily through financial incentives. Meaningful use has been implemented in three stages. Stages 1 and 2 are focused on introducing EHR use and integration within a health information exchange system [7]. To the extent that EHRs are increasingly becoming decision-making support tools for both providers and patients through associated patient portals, it will be important to both understand the impact of and effectively address utilization differences associated with embedded cultural assumptions. Indeed, reported disparities in EHR patient portal use may be associated with such inappropriate cultural assumptions [8-11].

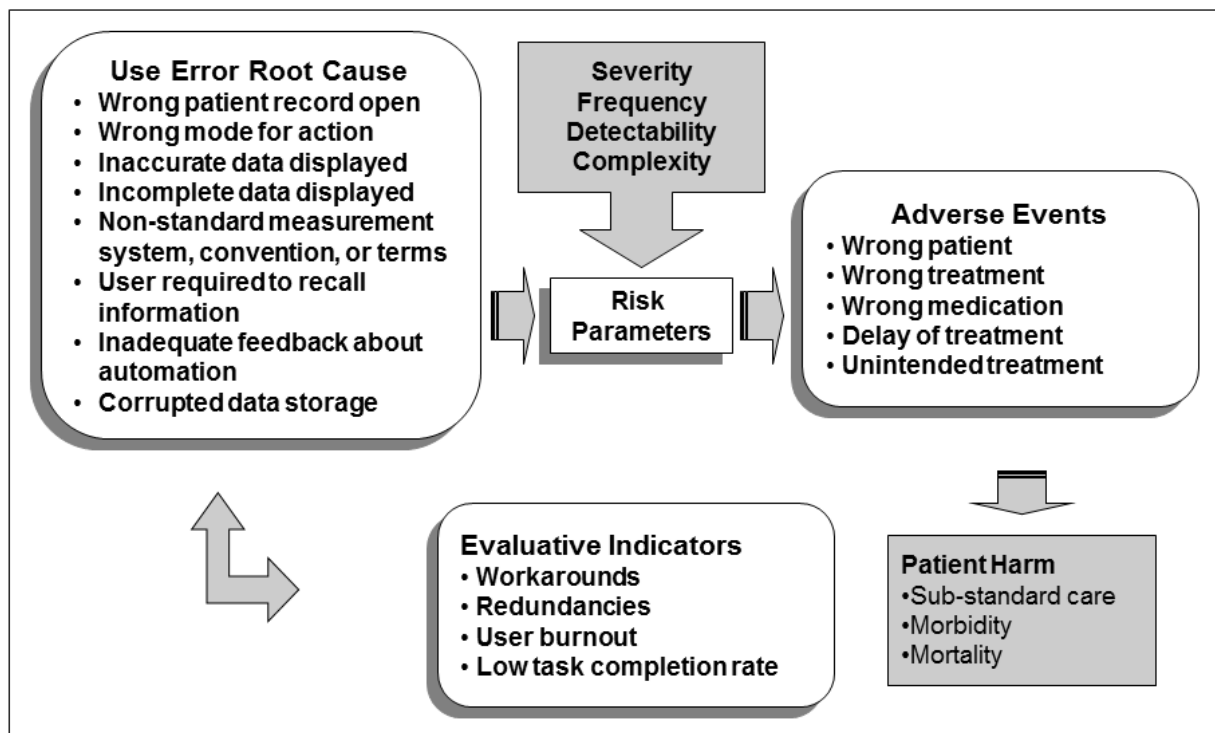
In the United States, populations affected by disparities include racial and ethnic minorities; persons of low socioeconomic status; and those who have limited English proficiency, are

living with disabilities, and are over the age of 65 [12]. The culturally informed design framework [13] is intended to provide conceptual guidance for designers of HIT who are interested in considering cultural factors in their system designs. The authors of this framework articulated 4 design dimensions in which cultural factors could impact usability: (1) technology platform, (2) technology functionality, (3) information content, and (4) HIT system-user interface. For example, regarding the technology platform, African Americans and Latinos are much more likely than other subpopulations to use mobile devices as their primary means of accessing the Web [14] when they use any technology. In terms of functionality, low-income racial and ethnic minorities are more likely than other populations not to use any technology at all. Among these individuals, 32% cite usability issues as the primary reason for not using technology [14].

Inappropriate embedded cultural assumptions that are associated with usability issues may also be associated with user and patient safety concerns as modeled by the EHR patient safety framework (Figure 1) [15-17]. This framework does not explicitly incorporate characteristics of EHR users such as culture, but it suggests that several types of design flaws induce use errors that can lead to patient harm. The frequency, detectability, and complexity of the user errors, as well as characteristics of patient populations, affect the potential magnitude of patient harm for a particular event [15-17]. Although this framework is designed to apply to EHR systems, we posit that it might also have utility with regard to EHR-associated patient portals and other consumer HIT.

Among HIT users who are members of racial and ethnic minority groups, it is possible that inappropriate embedded cultural assumptions in HIT may contribute to unique patient safety risks and/or concerns similar to risks stemming from off-label uses of medications that have not been tested with targeted patient populations. In other words, a design that is safe and effective for members of one population may create negative, unintended consequences for a population with different characteristics. A significant body of evidence from the medical, human factors, and ergonomics literature documents that these differing characteristics may be physical, cognitive, or cultural and that they can reduce the usability, usefulness, and safety of HIT systems [13,18,19].

Figure 1. A model for analysis and understanding the use related risks of EHR systems.



Methods

Overview

Existing best practices, guidance, and standards in software usability and accessibility were subjected to expert review by the study team. An iterative consensus-based process was used to derive evidence-based design principles. The study team was composed of a physician researcher with expertise in health disparities and informatics and two human factors experts in informatics. The team developed and followed the 5-step methodology through regular monthly conference calls to discuss emerging findings and achieve consensus. Input from team members was delivered verbally and electronically in additional exchanges between meetings. Peer reviewers of a draft document included professionals with clinical expertise, informatics expertise, and human factors expertise. The purpose of this review was to identify those best practices, guidance, and standards that could help identify and/or address embedded design assumptions in HIT that could negatively impact patient safety, particularly for non-majority HIT user populations. In the Results section, we detail those principles derived from the human factors literature that underlie existing best practices, guidance, and standards in software usability and accessibility that could help identify and/or address embedded design assumptions in HIT that could negatively impact patient safety, particularly for HIT users who are members of non-majority

groups. The 5-step methodology used to conduct the review and elicit applicable evidence is outlined below.

Step 1

First, the target user populations were defined as potential EHR HIT user populations at increased baseline risk for health care disparities. As is clear from the health care literature, these persons include HIT users of low socioeconomic status, users who are members of racial and ethnic minority groups, users who are non-native English speakers or users with limited English proficiency, users with disabilities or who have physical or cognitive impairments, and persons older than 65 years of age.

Step 2

Second, relevant risk characteristics of the target user populations that were likely to have EHR HIT design and/or usability correlates were identified. The culturally informed design framework describes 4 design dimensions (technology platform, functionality, content, and user interface) that are likely to influence HIT usability, acceptability, and effectiveness for a given cultural group. The culturally informed design framework also provides an evidence-based starting point for choosing those target population characteristics identified or hypothesized in the scientific literature to have EHR HIT design and/or usability correlates. The technology platform is defined as the type of HIT hardware in use. The functionality refers to

the types of actions that may be performed within the HIT system. Content refers to the message delivered by the HIT system to the user. The user interface refers to the presentation and organization of the content and functionality associated with the hardware in question. Relevant risk characteristics of the target user populations were considered within these 4 domains.

Step 3

Grounded Theory Approach

Third, a grounded theory approach was employed to identify potentially applicable best practices, guidance, and standards from industry and federal resources and from the scientific literature. The literature was reviewed and data extracted along the 4 design dimensions (technology platform, functionality, content, and user interface) suggested by the culturally informed design framework. The industry and federal resources and databases described below were assessed.

Standards of the International Organization for Standardization and International Electrotechnical Commission

The International Organization for Standardization (ISO) is the world's largest developer of voluntary international standards. International standards give state-of-the-art specifications for products, services, and good practices to help make industry more efficient and effective. Developed through global consensus, they help to break down barriers to international trade. The ISO was founded in 1947 and since then has published more than 19,500 international standards covering almost all aspects of technology and business. In addition, the International Electrotechnical Commission (IEC) is a not-for-profit, non-governmental organization founded in 1906 that develops international standards and conducts conformity assessments for all electrical, electronics, and related technologies. Because many industries around the world, including the technology industry, rely on these organizations for guidance and standards, relevant reports from these organizations were reviewed as part of this study.

Section 508

In 1998, the US Congress amended the Rehabilitation Act of 1973 [20] to require federal agencies to make their electronic and information technology accessible to people with disabilities. Section 508 was enacted to eliminate barriers in IT, to make available new opportunities for people with disabilities, and to encourage development of technologies that help achieve these goals. The Access Board, created by the US Congress in 1973, is an independent federal agency devoted to accessibility for people with disabilities and is the federal agency responsible for development and dissemination of Section 508 technical standards. The board develops and maintains design criteria for the built environment, transit vehicles, telecommunications equipment, and electronic and information technology. It also provides technical assistance and training on these requirements and on accessible design, and it continues to enforce accessibility standards that cover federally funded facilities.

The World Wide Web Consortium

The World Wide Web Consortium (W3C) is an international community that develops open standards to ensure the long-term growth of the Web. Web content accessibility guidelines (WCAG) are developed through the W3C process in cooperation with individuals and organizations around the world with the goal of providing a single, shared standard for Web content accessibility that meets the needs of individuals, organizations, and governments internationally. The WCAG guidelines explain how to make Web content more accessible to people with disabilities.

The National Institute of Standards and Technology

Founded in 1901 and now part of the US Department of Commerce, the mission of the National Institute of Standards and Technology (NIST) is to promote US innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve quality of life. One of the major research components of NIST is the Information Technology Laboratory (ITL), which has been charged with the task of utilizing existing and emerging IT to meet national priorities that reflect the country's broad-based social, economic, and political values and goals. Its extended charge under the Federal Information Security Management Act [21] is to continue to develop cybersecurity standards, guidelines, and associated methods and techniques.

The Office of Minority Health

The Office of Minority Health (OMH) was created within the US Department of Health and Human Services in 1986. It is one of the most significant outcomes of the 1985 *Report of the Secretary's Task Force on Black and Minority Health* [22]. The OMH is dedicated to improving the health of racial and ethnic minority populations through the development of health policies and programs that will help eliminate health disparities. Among other things, the OMH develops and promotes policies, programs, and practices to eliminate health disparities and achieve health equity.

Step 4

Fourth, all potential evidence extracted from the above-described literature was reviewed in detail. Inappropriate or otherwise inapplicable best practices, guidance, and standards were excluded on the basis of specific exclusion criteria. The exclusion criteria included (1) no plausible association between design feature guidance and a culturally based risk characteristic and (2) no available design enhancement to improve a design element that could contribute to HIT utilization disparities by increasing the risk of usability or patient safety challenges, particularly among the identified target user population.

Step 5

Fifth, best practices, guidance, and standards guidance were summarized and underlying principles were derived. A consensus-based approach was employed in which each member of the study team could suggest a principle derived from the included literature. This principle was then discussed among study investigators. Principles were iteratively revised and

amended. Final principles were included only if and when consensus was achieved. Consensus was sought regarding the state of the current evidence upon which the principle is based and the degree to which the principle provides actionable guidance.

Results

Overview

In reviewing the gathered documents, there appeared to be underlying principles from the human factors literature regarding how to discover unmet needs for a given population. In our review, the target population of interest included users of low socioeconomic status, users who are members of racial and ethnic minorities, users with limited English proficiency, persons older than 65 years of age, and users who have physical and/or cognitive impairments. It is important to realize that these principles do not apply exclusively to this target population. Rather, their importance is derived from the fact that, if significant attention is not given to these principles, the resulting HIT system designs may unintentionally result in avoidable usability and or patient safety challenges that differentially impact “non-typical” users.

Principle 1.0: Information Technology Should Be Designed Based Upon a Model of Error and Expertise in Practice

In 1996, Woods, Patterson, and colleagues defined three levels of practice-centered design: (1) understanding, (2) usefulness, and (3) usability [23,24]. At the level of usability, the interface and information design is analyzed for how easy it is for representative users to accomplish designed tasks. At the level of usefulness, evaluations of prototypes generate new ideas for features and alternative approaches to meet newly discovered requirements. At the level of understanding, for practice-centered design, the problem definition is more than merely learning about the field of practice and talking to the practitioners; the designer must understand the nature of errors that occur and how experienced practitioners develop and maintain expertise. At the level of understanding, the typical discovery is that an embedded assumption in the design of an HIT system is not supported when representative users are asked to perform a task. For example, a user might be expected to forget a password needed to use an HIT system if it is complicated, but it might be discovered that a common strategy is to write passwords into a text message that is sent to themselves and always maintained on their telephone. Thus, a more likely issue would be for someone else to find the text message with the passwords to avoid forgetting the login information. Whether assumptions are due to culturally influenced expectations or other means impacts the predictability of anticipating issues, but the underlying principle of having a practice-centered design to support learning more about the nature of how errors are made and which strategies are employed to meet needs remains the same [25].

Principle 2.0: Designing for Settings, Providers, and Users With Limited Resources Improves Usability for All Users

When designing HIT systems for persons with special needs or for those otherwise disadvantaged, a typical outcome is to reduce the resources required to easily use an HIT system. For example, rather than requiring two hands to use a device, a “swipe” method could be devised that would allow a task to be accomplished by using the same hand that holds a device. Similarly, a button could be enlarged to make it easier for an older adult user with tremor to tap, which also would make it easier for anyone to tap in a particular environment, such as while on a moving train. Therefore, in many cases, it is believed that designing HIT systems for populations with unique technological needs will not result in a design that is tailored in such a way that only a narrow user population would use it. In fact, it is expected that making interfaces easier to use for persons with lesser financial, cognitive, physical, and educational resources will result in the development of better HIT systems for all users. There will be exceptions for culturally informed design, such as culturally appropriate language and navigational expectations, but this is expected to form a small percentage of recommended changes when tailoring an HIT system to a target population.

Principle 3.0: Authentication Is Often One of the Most Complex Elements of an HIT System

A standard heuristic in Web site design is to avoid or delay authentication steps because many users will not pass beyond that step. Similarly, a common measure of Web site usability is “completion rates,” which is defined based on the proportion of users who complete a task that has been started. Authentication as it is currently performed with HIT systems is often challenging, even for extremely experienced users with a high degree of savvy regarding new technologies. Workarounds that are likely to be found with authentication, such as using memory aids with written passwords, sharing passwords with family members, and using variants of a single password for multiple HIT systems, often exist in all populations. As resources become more limited, it is predictable that these workarounds will be found or even increased. HIT systems that require particularly complex or rigid password structures are unlikely to work well without workarounds for these populations, which may reduce the integrity of protecting the information. In addition, because the health and medical literature suggests that health and health care decision-making and behaviors occur within a broader social context, particularly among racial and ethnic minority group members [26-28], as well as in situations where there are complex and dynamic relationships with extended family members and caregivers and management of multiple levels of access. In such circumstances, the presence of multiple users accessing information will likely require enhanced support.

Principle 4.0: Explicitly Design to Protect Against Undesired Use of Information by Unintended Users

For populations with a historical mistrust of the medical establishment, transparency about who is allowed to view private health information, as well as the protections provided for

breaches of confidentiality, is critical. Without addressing this aspect of HIT, it is possible that useful HIT systems will fail to be adopted by particular populations. Although this level of mistrust may not be exhibited by majority populations, a general principle for any HIT system design is to identify 3 common categories of users: primary users, secondary users, and unintended users. Primary users are the target population that directly uses the interface. Secondary users generally access information in an aggregated fashion from a database of information generated by primary users, but typically do not enter or modify data without permission granted for individual users. Unintended users are users who could generate negative consequences by accessing the data. This does not necessarily involve illegal access to the data, such as by people trying to steal an identity. It could include legal discovery of information used in lawsuits or companies that use information for marketing purposes to identify trends that help them to place advertisements for targeted populations. Explicitly recognizing and mitigating the risks due to unintended (but predictable) uses of information is not a new idea in HIT system design. For example, features that generate reports from trends tracked on the basis of multiple users could be designed to automatically remove any information that might inadvertently identify a particular user who has sensitive information available in the database.

Principle 5.0: Conduct Comprehensive Formative and Summative Testing With a Reasonable Set of Representative Target Users

With the burgeoning number of persons older than 65 years of age, rapidly growing numbers of immigrants with limited English proficiency, and surging numbers of racial and ethnic minorities projected for the US population over the next decade, the very notion of a “typical” user may need to be called into question. To help ensure broad accessibility and usability, it is imperative that testing involve both typical and non-typical users who are likely to use the HIT system. In addition to testing with representative users, it is important to use cases that allow the identification of culturally embedded assumptions that do not match the assumptions of intended users.

Discussion

Overview

To identify culturally embedded assumptions, we recommend that representative users from all anticipated markets for a product, including populations with unique technological needs, be sufficiently represented in summative usability evaluations and other design activities. Summative usability testing is generally conducted prior to implementation of an HIT system and involves having representative users interact with an HIT system to conduct tasks, including any tasks that are anticipated to be particularly challenging for any reason. Use cases are typically employed throughout the entire design cycle for any IT, from initial generation of rough mockups to summative usability evaluations. Explicitly designing use cases to support the discovery of embedded assumptions that would reduce willingness to adopt an HIT system or that could create a patient safety issue is recommended. Cultural differences in a majority

population will be unique for a specific population of interest. Some variables to consider when characterizing a population with respect to HIT use include health literacy; IT literacy; socioeconomic status; level of influence on decision-making by health care providers, family members, and religious or community leaders; native language; English proficiency; prevalence of disabilities; age; race; ethnicity; home environment; geographic location; and country of origin.

We take low-income African Americans as one example of a group with special HIT needs. For this group, some differences from majority populations might include lower socioeconomic status, limited English proficiency, low health literacy, limited access to health care, and a high level of mistrust of the health care system [3]. To design HIT systems for this population, one recommendation is to include disparities-oriented use case scenarios and user contexts as part of the EHR HIT system design and developmental planning process. Examples of disparities-oriented use cases could include use cases that include one or more of the aspects described below.

Safety Net Provider

Developing and applying use cases involving common tasks specific to clinical practice in safety net contexts are key to elucidating unrecognized user requirements. For example, a safety net provider may show a patient lab results by viewing them together on a desktop computer screen designed for the physician. In this use case, a patient may find it difficult to understand that hemoglobin A1c is a measure of blood sugar, for example. In addition, there are situations in which a patient with diabetes mellitus may be counseled to reduce blood sugar to a level below a normal range, and it may be difficult for physicians to explain the reason for this if the display labels a result as being within a normal range. An HIT system that does not address these embedded assumptions could lead to poor physician-patient communication and an increased likelihood of poor adherence to provider recommendations [13,29].

Adult Caregiver of a Senior Relative

In many families, the need for adult children to care for elderly parents is becoming increasingly common. This may be even more likely among patients who are members of disadvantaged populations, who may lack resources to provide alternate care arrangements for their elderly relatives. The cognitive and physical demands and stress of caregiving, combined with childrearing, homemaking, and holding one or more jobs, may create critical challenges for the safe and effective use of EHRs. For example, consumer HIT systems may need to be designed to minimize disruption of elder care, such as by having an option to use it in a dark room without generating a bright light while an elderly parent is sleeping.

Patients and Caregivers With Limited English Proficiency

Providing care to patients with limited English proficiency creates challenges for all involved parties. Employing a set of common “referent” terms and symbols that have been found to be common across cultures is recommended when available. When not available, including study participants within the range of a target population’s level of English proficiency during

usability evaluations is recommended, as well as ensuring that complex terms and constructs are included in the use case scenarios.

Electronic Health Record Use in the Context of Doctor–Patient Cross-Cultural or Communication Barriers

In some cultures, major decision-making is considered a family activity or at least a combined activity between spouses, family members, and sometimes close confidants (eg, clergy). However, informed consent and access to health information using a personal login is currently considered largely from a Western perspective (i.e., single users and individual rights). Usability, user experience, and user satisfaction implications with the application of such an EHR HIT system are not likely to be optimal. Design accommodations could help address the challenges created by these cultural differences, such as by allowing multiple users to employ the same login credentials to access information. In addition, representative user populations could be expanded to include all appropriate decision makers during the simulated sessions of a usability

test, or study participants could be explicitly asked about which other members of a family or social network might play a role in decision-making and how they could best access information.

Conclusions

We provide evidence-based examples and human factors–based principles to help HIT system designers recognize and address patient safety issues that may be due to inappropriate, embedded cultural assumptions in HIT. Matching embedded assumptions in designed HIT systems to cultural expectations of actual versus intended or perceived users will likely increase the usability, usefulness, and safety of HIT systems, particularly for user populations whose characteristics differ from those of the users anticipated by the original HIT system designers. In so doing, the likelihood of creating or exacerbating HIT system usability–related disparities would be significantly reduced. Much more work is needed, however, to empirically and definitively characterize the scope and magnitude of impact, as well as to rank the importance of usability issues, unique to populations whose characteristics differ from stereotypical users and to document the effectiveness of the design principles outlined in this review.

References

1. Waidmann T. Estimating the Cost of Racial Ethnic Health Disparities 2009. Washington, DC: The Urban Institute; 2009.
2. LaVeist TA, Gaskin DJ, Richard P. The Economic Burden of Health Inequalities in the United States. Washington, DC: The Joint Center for Political and Economic Studies; 2009.
3. Smedley BD, Stith AY, Nelson AR, Committee on Understanding and Eliminating Racial and Ethnic Disparities in Health Care. Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care. Washington, DC: National Academies Press; 2003.
4. National Center for Health Workforce Analysis. Changing Demographics: Implications for Physicians, Nurses, and Other Health Workers. Washington, DC: Bureau of Health Professions, Health Resources and Services Administration, US Department of Health and Human Services; 2003.
5. Agency for Healthcare Research and Quality. The National Healthcare Disparities Report 2012 (Publication 13-0003). Washington, DC: Agency for Healthcare Research and Quality; 2013.
6. Committee on Quality of Health Care in America, Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington, DC: National Academies Press; 2001.
7. Centers for Medicare & Medicaid Services. Meaningful Use. 2014 Oct 06. URL: http://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Meaningful_Use.html [accessed 2014-11-10] [WebCite Cache ID 6Tyt8XLH5]
8. Sarkar U, Karter AJ, Liu JY, Adler NE, Nguyen R, López A, et al. Social disparities in internet patient portal use in diabetes: evidence that the digital divide extends beyond access. *J Am Med Inform Assoc* 2011;18(3):318-321 [FREE Full text] [doi: [10.1136/jamia.2010.006015](https://doi.org/10.1136/jamia.2010.006015)] [Medline: [21262921](https://pubmed.ncbi.nlm.nih.gov/21262921/)]
9. Sarkar U, Karter AJ, Liu JY, Adler NE, Nguyen R, Lopez A, et al. The literacy divide: health literacy and the use of an internet-based patient portal in an integrated health system—results from the diabetes study of northern California (DISTANCE). *J Health Commun* 2010;15 Suppl 2:183-196 [FREE Full text] [doi: [10.1080/10810730.2010.499988](https://doi.org/10.1080/10810730.2010.499988)] [Medline: [20845203](https://pubmed.ncbi.nlm.nih.gov/20845203/)]
10. Roblin DW, Houston TK, Allison JJ, Joski PJ, Becker ER. Disparities in use of a personal health record in a managed care organization. *J Am Med Inform Assoc* 2009;16(5):683-689 [FREE Full text] [doi: [10.1197/jamia.M3169](https://doi.org/10.1197/jamia.M3169)] [Medline: [19567790](https://pubmed.ncbi.nlm.nih.gov/19567790/)]
11. Goel MS, Brown TL, Williams A, Hasnain-Wynia R, Thompson JA, Baker DW. Disparities in enrollment and use of an electronic patient portal. *J Gen Intern Med* 2011;26(10):1112-1116 [FREE Full text] [doi: [10.1007/s11606-011-1728-3](https://doi.org/10.1007/s11606-011-1728-3)] [Medline: [21538166](https://pubmed.ncbi.nlm.nih.gov/21538166/)]
12. Gibbons MC, Lowry S, Quinn MT. (NISTIR 7769) Human Factors Guidance to Prevent Healthcare Disparities with the Adoption of EHRs. Gaithersburg, MD: National Institute of Standards and Technology (NIST); Apr 07, 2011.

13. Valdez RS, Gibbons MC, Siegel ER, Kukafka R, Brennan PF. Designing consumer health IT to enhance usability among different racial and ethnic groups within the United States. *Health Technol* 2012;2(4):225-233. [doi: [10.1007/s12553-012-0031-6](https://doi.org/10.1007/s12553-012-0031-6)]
14. Rainie L. 2013 Nov 05. The State of Digital Divides (Video & Slides) URL: <http://www.pewinternet.org/2013/11/05/the-state-of-digital-divides-video-slides/> [accessed 2014-05-07] [WebCite Cache ID 6POhHN7Pw]
15. Lowry SZ, Quinn MT, Ramaiah M, Schumacher RM, Patterson ES, North R, et al. (NISTIR 7804) Technical Evaluation, Testing and Validation of the Usability of Electronic Health Records. Gaithersburg, MD: National Institute of Standards and Technology (NIST); Feb 21, 2012.
16. Lowry SZ, Quinn MT, Ramaiah M, Brick D, Patterson ES, Zhang J, et al. (NISTIR 7865) A Human Factors Guide to Enhance EHR Usability of Critical User Interactions When Supporting Pediatric Patient Care. Gaithersburg, MD: National Institute of Standards and Technology (NIST); Jun 2012.
17. Patterson ES, Zhang J, Abbott P, Gibbons MC, Lowry SZ, Quinn MT, et al. Enhancing electronic health record usability in pediatric patient care: a scenario-based approach. *Jt Comm J Qual Patient Saf* 2013;39(3):129-135. [Medline: [23516763](https://pubmed.ncbi.nlm.nih.gov/23516763/)]
18. Brown CR. Human factors problems in the design evaluation of key-entry devices for the Japanese language. In: Chapanis A, editor. *Ethnic Variables in Human Factors Engineering*. Baltimore, MD: Johns Hopkins University Press; 1975.
19. Chapanis A. *Ethnic Variables in Human Factors Engineering*. Baltimore, MD: Johns Hopkins University Press; 1975.
20. US Access Board. Section 508 Standards for Electronic and Information Technology. Washington, DC: US Access Board; 2001 Dec 21. URL: <http://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards/section-508-standards> [accessed 2014-11-10] [WebCite Cache ID 6Tyw4M12M]
21. Federal Information Security Management Act of 2002. Public Law 107-347, 44 USC ch 35, subch III, § 3541 et seq. 2002 Feb 17. URL: <http://csrc.nist.gov/drivers/documents/FISMA-final.pdf> [accessed 2014-11-10] [WebCite Cache ID 6TywcNWZm]
22. US Department of Health and Human Services. Report of the Secretary's Task Force on Black & Minority Health. Bethesda, MD: National Institutes of Health; Oct 16, 1985.
23. Woods DD, Patterson ES, Corban JM, Watts JC. Bridging the gap between user-centered intentions and actual design practice. *Proc Hum Fact Ergon Soc Annu Meet* 1996;40(19):967-971. [doi: [10.1177/154193129604001903](https://doi.org/10.1177/154193129604001903)]
24. Roth EM, Patterson ES, Mumaw RJ. Cognitive engineering: issues in user-centered system design. In: Marciniak JJ, editor. *Encyclopedia of Software Engineering*. Volume 1. 2nd edition. New York, NY: John Wiley & Sons; 2002:163-179.
25. Renaud K, Ramsay J. Now what was that password again? A more flexible way of identifying and authenticating our seniors. *Behav Inf Technol* 2007;26(4):309-322.
26. Thorpe RJJ, Bowie JV, Wilson-Frederick SM, Coa KI, LaVeist TA. Association between race, place, and preventive health screenings among men: findings from the exploring health disparities in integrated communities study. *Am J Mens Health* 2013;7(3):220-227. [doi: [10.1177/1557988312466910](https://doi.org/10.1177/1557988312466910)] [Medline: [23184335](https://pubmed.ncbi.nlm.nih.gov/23184335/)]
27. Gotay CC, Wilson ME. Social support and cancer screening in African American, Hispanic, and Native American women. *Cancer Pract* 1998;6(1):31-37. [Medline: [9460324](https://pubmed.ncbi.nlm.nih.gov/9460324/)]
28. Bhattacharya G. Self-management of type 2 diabetes among African Americans in the Arkansas Delta: a strengths perspective in social-cultural context. *J Health Care Poor Underserved* 2012;23(1):161-178. [doi: [10.1353/hpu.2012.0035](https://doi.org/10.1353/hpu.2012.0035)] [Medline: [22643469](https://pubmed.ncbi.nlm.nih.gov/22643469/)]
29. Forsythe DE. New bottles, old wine: hidden cultural assumptions in a computerized explanation system for migraine sufferers. *Med Anthropol Q* 1996;10(4):551-574. [Medline: [8979239](https://pubmed.ncbi.nlm.nih.gov/8979239/)]

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Original Paper

Narrowing the Skills Gap for Innovation: An Empirical Study in the Hospital Sector

Casimiro Dias¹, MPH; Ana Escoval², PhD

¹World Health Organization, Health Systems and Public Health, Copenhagen, Denmark

²University Nova Lisboa, School of Public Health, Lisbon, Portugal

Corresponding Author:

Casimiro Dias, MPH

World Health Organization

Health Systems and Public Health

UN City, Marmorvej 51

Copenhagen, DK-2100

Denmark

Phone: 45 45 33 66 39

Fax: 45 45 33 66 39

Email: diasc@who.int

Abstract

Background: The current financial crisis and the increasing burden of chronic diseases are challenging hospitals to enhance their innovation capacity to deliver new and more effective health services. However, the shortage of skills has been widely recognized as a key obstacle for innovation. Ensuring the presence of a skilled workforce has become a priority for the health system in Portugal and across Europe.

Objective: The aim of this study was to examine the demand of new skills and their influence in both investments in innovation and development of skills.

Methods: We used a mixed-methods approach combining statistical analysis of data survey and content analysis of semistructured interviews with the Administration Boards of hospitals, using a nominal group technique.

Results: The results illustrate an increasing demand of a broad range of skills for innovation development, including responsibility and quality consciousness (with a significant increase of 55%, 52/95), adaptation skills (with an increase of 44%, 42/95) and cooperation and communication skills (with an increase of 55%, 52/95). Investments in the development of skills for innovation are mainly focused on aligning professional training with an organizational strategy (69%, 66/95) as well as collaboration in taskforces (61%, 58/95) and cross-department teams (60%, 57/95). However, the dynamics between the supply and demand of skills for innovation are better explained through a broader perspective of organizational changes towards enhancing learning opportunities and engagement of health professionals to boost innovation.

Conclusions: The results of this study illustrate that hospitals are unlikely to enhance their innovation capacity if they pursue strategies failing to match the skills needed. Within this context, hospitals with high investments in innovation tend to invest more in skills development. The demand of skills and investments in training are influenced by many other factors, including the hospital's strategies, as well as changes in the work organization. Relevant implications for managers and policy makers can be drawn from the empirical findings of this paper, building on the current efforts from leading innovating hospitals that are already defining the future of health care.

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KEYWORDS

hospital administration; organizational innovation; management information systems; clinical skills; staff development; personnel management

Introduction

The increasing burden of chronic diseases, the aging population, and the current financial crisis are challenging hospitals to reinvent their health care delivery models, restructure their organizations, and redefine their value. Tackling such challenges require new skills for enhancing organizational flexibility, improving performance, and promoting innovation [1,2].

The shortage of skills remains a key obstacle for innovation, particularly in hospitals pursuing radical and disruptive changes. Innovation depends largely on the health professionals who are able to create and apply new ideas and knowledge in their daily work [3,4]. Therefore, it has become important to ensure that a skilled workforce is present for delivering high quality health services to strengthen the health system in Portugal, as well as across Europe. Such emphasis on skills and innovation is reflected by several efforts to bridge and narrow the current skills and productivity gap [5,6].

Hospitals have long focused on the development of skilled health professionals through continuous efforts in training and education. As they struggle to ensure the right skills for innovation, it is particularly relevant to better understand the different types of skills needed for innovation and the best ways to ensure continuous improvement.

However, previous efforts to make explicit the links between specific skills and innovation have proven difficult [7-9]. The broad definitions of skills and innovation, as well as the difficulty of measuring them have limited the identification of such relationships [10,11].

Previous research has been focused on the demand of skills to make the best use of the new technologies, while the investments in skill development by hospitals has been significantly less studied [12]. However, such narrow approach might result in several drawbacks, including an increased number of unsuitably qualified professionals or discouraging their engagement in innovation activities.

Recognizing the relevance of the dynamics between skills and innovation, current initiatives from the European Commission and Organisation for Economic Co-operation and Development (OECD) are supporting significant advances in this area. The New Skills for New Jobs initiative from the European Commission sets out to promote better anticipation of future skills needs, to reach a better match between skills and labour market needs as well as to bridge the gap between education sector and the labour market [13].

Empirical evidence suggests that the right combination of technological and organizational innovations may result in high relevance of interpersonal competencies or so called “people skills” as well as non-routine problem-solving [14,15].

Furthermore, OECD Skills Strategy provides an integrated strategic framework to better understand effective ways of skills development for economic growth. The strategy takes a whole-government approach in order to match the supply and demand of skills for innovation [16]. The global independent commission on health professional education for the 21st century

has proposed a strategic framework on health professional’s education for the next century with the objective of reaching a balance between population health needs, health-system demand for skills, and what the educational system can offer [17,18]. The Commission proposes a new era of health professional education is mainly based on transformative learning and interdependence in education. All these initiatives highlight that the future will be based on adjustments of skills to specific contexts, which draws on the power of flows of information and knowledge.

This paper takes a dynamic approach with a focus on the changing trends with specific definitions in three dimensions. Technological innovation refers to the development and dissemination of new technologies, including information and communication technologies (ICT). Organizational innovation refers to changes in the work organization including investments in new skills and competences. Finally, skill changes reflect the combination of these factors, thus redefining the skills within new organizational processes. Such trends are particularly relevant to better understand how the hospital sector is being reshaped to improve innovation capacity. Empirical evidence suggests that the right combination of technological and organizational innovations may result in high relevance of interpersonal competencies, as well as non-routine problem solving [19,20].

The aim of this paper is to explore the relationship between skills and innovation. It analyses the interaction between supply and demand for skills within a dynamic approach, such that both innovation and skill requirements are also changed. Throughout the hospital sector, there are several forward-thinking hospitals, which are developing new skills for enhancing their innovation capacity. Therefore, we will further explore the way innovating hospitals are already matching both skills and innovation development.

Methods

Overview

A mixed methods design was used to explore the relationship between skills and innovation development at the hospital sector. This study systematically integrates multiple forms of quantitative and qualitative data collected through a survey, a series of interviews and a technical nominal group.

Demand of Skills and Work Organization

Primary data was collected through a survey in order to examine the changes in the skills supply and demand, and their impact on innovation capacity of hospitals. A revised version of the survey Danish System of Innovation in a Comparative Perspective (DISKO) developed by the Danish Research Unit for Industrial Dynamics (DRUID), was used and adapted to the hospital sector [21]. This survey is based on the search for “organizational traits” related to the hospital capacity to adapt changing and unstable environments. The survey measures the changes in terms of skills, work organization, as well as innovation capacity of hospitals during a period of 3 years since 2007. The survey was submitted to a pre-test in 6 different hospitals to assess its validity, reliability, and comprehensibility.

The paper-survey was submitted by post mail to a national sample of 136 hospital boards, identified from the official list of hospitals in the Portuguese public sector. A total number of 95 administrators from hospital management boards replied to the survey during a period of three months, corresponding to a response rate of 70%.

Statistical analysis of the data was performed in order to examine the current trends for the skills needed for innovation in the hospital sector. In all cases, the level of significance was $P < .05$. All statistics were calculated with SPSS version 15.0 (SPSS Inc, Chicago, IL, USA).

Development of Skills for Innovation

A series of interviews were carried out in 5 hospitals, which were selected based on the highest levels of investments in both innovation and skills development, according to the survey data. Semistructured and face-to-face interviews were undertaken with the aim of identifying the major mechanisms for matching skills and innovation development at the hospital sector.

The data from the interviews was submitted for content analysis, which consisted of a comparative assessment of the frequency and significance of the different categories.

Dynamics Between Skills and Innovation Development

Finally, the nominal group technique was applied to the data with the objective of consensualizing the major findings in terms of the relationships between skills and innovation development. The group included experts from hospital administration, financing, information system, and human resources development. A modified nominal group technique was applied by introducing evidence for discussion in a stepwise way before voting. The use of votes by the experts was to overcome an unequal representation of different opinions.

The analysis of both qualitative and quantitative data has brought a comprehensive picture of the interaction between skills and

innovation at the hospital level, which might have been overlooked by a simpler method.

Results

Overview

The results revealed the main trends of the skills demand, as well as their influence in the innovation capacity of hospitals. It further explores the complementarities between skills and innovation, as well as major mechanisms for advancing both at the hospital level.

Demand of Skills and Organizational Innovation

The administration boards of hospitals were explicitly asked about changes in the demand for skills during a period of three years. The demand of skills was analysed in four dimensions: responsibility and quality consciousness, ability of adaptation to change, cooperation and communication skills, as well as vocational qualifications.

Table 1 shows an increasing demand of a broad range of “generic” skills, including responsibility and quality consciousness (52/95, 55%), adaptation (42/95, 44%), and ability to cooperate and communicate (52/95, 55%).

However, there were significant differences in terms of the skills needed according to the innovation capacity of hospital. Therefore, the total number of hospitals was clustered by the innovation rate, which was measured as the number of innovations developed by the hospital per year. The two clusters by innovation capacity included 38 innovating and 57 non-innovating hospitals.

However, innovating hospitals revealed a significantly higher demand of skills for innovation, including a 72% (28/38) increase in the demand for responsibility and quality consciousness ($P = .02$), and 63% (24/38) increase for adaptation skills ($P = .03$), as well as an increase of 62% (24/38) for communication and cooperation skills ($P = .02$).

Table 1. Number of hospitals with increasing demand of specific skills in a three years period.

Skills	Innovating hospitals (n=38)	Non-innovating hospitals (n=57)	All (N=95)
	n (%)	n (%)	n (%)
Responsibility and quality consciousness	28 (72)	24 (42)	52 (55)
Adaptation	24 (63)	18 (32)	42 (44)
Communication and cooperation	24 (62)	28 (32)	52 (55)
Vocational qualifications	21 (56)	18 (31)	39 (41)

Table 2 shows the main changes of work organization, which are related to the development of skills in the hospital sector. These new forms of work organization are mainly focused on the increase of delegation of tasks by 21% (20/95), transversal work groups by 13% (12/95), integrated services delivery by 14% (13/95), as well as quality circles, which has increased by 8% (8/95). Other organizational changes including remuneration based on performance (5/95, 5%), systems of gathering proposals from health professionals (2/95, 2%), and planned

work rotation (5/95, 5%) are significantly less widespread in the hospitals.

The increasing use of these new forms of work organization is significantly higher in innovating hospitals. This is particularly true regarding the 22% (9/38) increase of transversal working groups ($P = .01$), a 17% (6/38) increase of quality circles and services integration ($P = .04$), as well as a 14% (5/38) increase for remuneration based in performance ($P = .01$).

Table 2. Number of hospitals with an increasing adoption and use of new forms of work organization in a three-year period.

	Innovating hospitals (n=38)	Non-innovating hospitals (n=57)	All (N=95)
	n (%)	n (%)	n (%)
Transversal work groups	9 (22)	3 (5)	12 (13)
Quality circles	6 (17)	2 (3)	8 (8)
Systems of gathering proposals from health professionals	2 (5)	0 (0)	2 (2)
Planned work rotation	2 (6)	3 (5)	5 (5)
Delegation of functions	15 (39)	5 (9)	20 (21)
Integrated services delivery	7 (17)	6 (10)	13 (14)
Remuneration based in performance	5 (14)	0 (0)	5 (5)

The survey data brings further insights in terms of the main drivers behind these trends. Such changes are mainly driven by the need to establish better contacts with users (52/95, 55%) and the introduction of new technologies (47/95, 49%). In less extension, they are also motivated by demands from health professionals (31/95, 35%), opportunities for skill development (31/95, 33%), need to establish better contacts with subcontractors (31/95, 33%), as well as the need for higher work flexibility for health professionals (31/95, 33%). Other drivers like competition (25/95, 26%) and the development of new products or services (23/95, 24%) are the least relevant to explain such trends in work organization.

Development of Skills for Innovation

Given the increasing demand of skills for innovation, we further examined the way and the extent in which hospitals invest in skills development.

Table 3. Number of hospitals using specific mechanisms for the development of skills in different extension degrees (N=95).

	High	Medium	Low	None
Professional training based on organizational needs	66 (63)	22 (21)	6 (6)	1 (1)
Organization by working teams	58 (55)	25 (24)	8 (8)	0 (0)
Cross- department cooperation	57 (54)	27 (24)	7 (7)	4 (4)
Long term plans for professional training	57(54)	27 (26)	4 (4)	6 (6)
Standard training courses	37 (35)	35 (33)	23 (22)	0 (0)
Time available for learning with other professionals	27 (26)	51 (49)	16 (15)	1 (1)
Planned job rotation	26 (25)	43 (41)	24 (23)	2 (2)

Dynamics Between Skills and Innovation Development

The content analysis of interviews highlights the dynamic nature of skills and innovation development and the relevance of matching both processes.

The interviews to the administration boards of hospitals revealed that these hospitals are looking for the necessary skills in order to realize their strategy over the next years. Daily problem solving is preferred as a major mechanism to ensure the right skills for innovation by 32% (30/95) of the hospitals rather than traditional standard training, as referred by 26% (25/95) of the hospitals.

The majority of hospitals consider investments in skills development as key for innovation. However, the main differences lie in specific mechanisms of skills development for innovation. Table 3 shows the different use degree of mechanisms for the development of skills in the hospital sector.

Hospitals recognize the need to align professional training to the organization needs, as used in high extension by 63% (66/95) of the total number of hospitals. Other major mechanisms include the organization by working teams (58/95, 55%), as well as cross-department cooperation and long term planning of professional training, both extensively used by 54% (57/95) of hospitals.

However, external cooperation is the key mechanism for matching the demand and supply of skills for innovation as mentioned by 42% (40/95) of the hospitals. The relevance role of external cooperation has been revealed both by the content analysis of the interviews as well as the expert panel, since it was not included in the survey.

Through the nominal group technique, the expert panel has agreed on the main priorities for matching match innovation and skills development at the hospital level. The expert panel has identified the development of integrated information systems as the top priority for sharing information and creating knowledge to boost organizational learning towards innovation.

Other long-term measures included dynamic planning of human resources and streamlining the management of human resources. Furthermore, it was identified that management by objectives and professional development were “quick-win” measures. These priority measures reflect the key role of human resources management and planning in order to advance innovation capacity of hospitals.

Discussion

Demand of Skills and Organizational Innovation

Our results suggest that a broad range of skills is engaged in innovation development in the hospital sector. These include not only specific technical skills but also higher-level problem solving skills. In fact, innovation encompasses a broad range of activities, requiring the engagement of many different groups of health professionals. Such change relies largely on learning by doing while designing and implementing innovations in the hospital sector. Therefore, the so-called “generic” skills, including responsibility and quality consciousness, capacity to adapt, and communication and cooperation are particularly relevant for innovation development.

The results also suggest that organizational changes are a key factor for explaining the current demand of skills. New forms of work organization are mainly aimed at enhancing organizational flexibility. These measures include decentralization of management mechanisms, as well as dissemination of teamwork across the organization. This is particularly true to innovating hospitals, which tend to be highly collaborative with an emphasis on multifunctional teams engaged in problem-solving cycles supported by spaces for constructive dialogue. Therefore, health professionals must be able to take on different tasks and responsibilities through effective cooperation across hospital departments and other organizations. Rather than specific skills to perform standardized and isolated tasks, knowledge of the wider process in which they are involved is preferred.

Development of Skills for Innovation

Hospitals are looking for highly skilled health professionals who are able to use and improve new technologies and services. Results suggest that hospitals with higher investments in innovation are also more willing to invest in skill development. Innovating hospitals differ especially in their demand for flexibility and communication abilities.

Increasing investments in skills development focus on informal ways of learning across the hospital’s departments, for example, through learning-by-doing and teamwork, rather than the traditional standard courses.

Both the hospital administration boards and the expert panel highlighted the transformative role of ICT in the hospital sector. The main argument for connecting investments in the development of skills and ICT is that skilled health professionals are able to ensure higher performance through the use of these technologies. However, the transformation of the health sector is probably better understood through a broader perspective of changes in the work organization.

Organizational innovations put a premium on the learning capability of hospitals to absorb change, as well as of the skills of interaction and communication. Such results point out the importance for supporting the creation of “learning organizations”. Within this context, investments in skills development further improve the innovative potential of hospitals by valuing the creative efforts and multiplying opportunities for learning across the hospital.

Dynamics Between Skills and Innovation Development

Innovating hospitals pursue high value-added strategies, which typically involve strong emphasis on research, high technologies, and skill-intensive work. In many hospitals, financial incentives encourage short-term efficiency but fail to recognize the importance of experimentation to achieve innovation and greater efficiency. For example, some innovating hospitals allow their health professionals to spend one-sixth of their time on any project that interests them.

These hospitals also encourage collaborative arrangements with other organizations in order to gain long-term advantages from interactive learning, even if there are additional short-term costs. This is best achieved by confronting hospitals not with a single best practice model, but rather by encouraging a stepwise transformation. While such an approach might not be applicable to all hospitals, it has been proven to enhance health professionals’ commitment and motivation to boost innovation.

External cooperation with other organizations, for example, universities and research institutes, is another key mechanism. The way hospitals are engaging in these collaborative networks is critical for ensuring the right skills for innovation by sharing ideas and information, as well as redefining and reinventing their value.

The coordination of processes and collaboration among the broad range of stakeholders requires the capacity for monitoring and evaluating performance, including the value of interventions along the health care continuum, as well as the health outcomes for the patient measured over their lifetime. Innovating hospitals are already enhancing smart decision-making through the development of integrated information systems at the point of care. The capacity of hospitals to collect and store, use, and share information becomes a critical skill for innovation strategies. These new skills have the potential to transform the hospital sector by shifting from reactively treating diseases to a more proactive approach of health promotion. It is within this context that the knowledge created across the hospital sector can be translated into practice more effectively, with health professionals, researchers, and informatics collaborating in real time.

Conclusions

The paper reveals the difficulty to disentangle the skills driving innovation from those as a result of change. The relationship between skills and innovation becomes circular and cumulative overtime.

A broad range of workforce skills are involved in the development of innovation in the hospital sector. This is particularly relevant in the hospital sector where incremental

change in products, services, and processes remains as the predominant form of innovation. However, as most notably demonstrated in this paper, skills are a necessary but not sufficient condition for successful innovation. The demand of skills and investments in training are influenced by many other factors, including the hospital's strategies, as well as changes in the work organization.

Empirical findings of this paper have relevant implications for managers and policymakers. While many decisions in terms of human resources remain at the core of the hospital management, national policies also have significant scope to influence such decisions. In particular, policies enabling organizational flexibility and facilitating investments in training may support hospitals in their innovation efforts. However, current policies have remained mainly as a top-down, fragmented approach, with a particular focus on the supply of skills for innovation. There is the need to adopt a more dynamic approach to reflect the interactions between innovation and skills. The development of such a comprehensive strategy for skills development, well aligned with organizational changes, might expand the set of potentially successful innovators in the hospital sector.

Three main policy options should be jointly taken, including the development of flexible learning schemes, strengthening cooperation between universities and hospitals, as well as the

integration of information systems throughout the hospital sector. Besides the initial university education, health professionals need to continuously update their knowledge and upgrade their skills. Such training at the workplace builds work-related competencies and support health professionals to deal with change. The external cooperation with other stakeholders from the health, education, and research sectors are increasingly critical to improve the innovation capacity of hospitals. This can be mainly facilitated through an integrated information system across the different stakeholders engaged in the innovation process. However, policies for skills' development further needs to be coherent and provide a supportive environment for innovation by enabling health professionals to develop the right skills and support their optimal use at work.

These policy and management implications should build on current efforts from innovating hospitals, which are already matching skills and innovation, as identified in this study. They are mainly focusing on person-centered health care, partnering with a broad range of stakeholders outside the traditional borders, and integrating information across the hospital sector in order to support smart decision-making. These innovating and high performing hospitals are already defining the future of health care.

Authors' Contributions

CD wrote the article, developed coordinated the study, prepared instruments for the study, collected and analysed the data. AE developed and supervised the study. All authors approved the final manuscript.

Conflicts of Interest

None declared.

References

1. Dias C, Escoval A. Improvement of hospital performance through innovation: toward the value of hospital care. *Health Care Manag (Frederick)* 2013;32(3):268-279. [Medline: [24902144](#)]
2. Nakamura A, Osonoi T, Terauchi Y. Relationship between urinary sodium excretion and pioglitazone-induced edema. *J Diabetes Investig* 2010 Oct 19;1(5):208-211 [FREE Full text] [doi: [10.1111/j.2040-1124.2010.00046.x](#)] [Medline: [24843434](#)]
3. Turner S, Allen P, Bartlett W, Pérotin V. Innovation and the English National Health Service: a qualitative study of the independent sector treatment centre programme. *Soc Sci Med* 2011 Aug;73(4):522-529. [doi: [10.1016/j.socscimed.2011.06.014](#)] [Medline: [21782302](#)]
4. García-Goñi M, Maroto A, Rubalcaba L. Innovation and motivation in public health professionals. *Health Policy* 2007 Dec;84(2-3):344-358. [doi: [10.1016/j.healthpol.2007.05.006](#)] [Medline: [17618010](#)]
5. Audretsch DB, Martínez-Fuentes C, Pardo-del-Val M. Incremental innovation in services through continuous improvement. *The Service Industries Journal* 2011 Sep;31(12):1921-1930. [doi: [10.1080/02642069.2011.552977](#)]
6. Nakamura A, Osonoi T, Terauchi Y. Relationship between urinary sodium excretion and pioglitazone-induced edema. *J Diabetes Investig* 2010 Oct 19;1(5):208-211 [FREE Full text] [doi: [10.1111/j.2040-1124.2010.00046.x](#)] [Medline: [24843434](#)]
7. Leiponen A. Skills and innovation. *International Journal of Industrial Organization* 2005 Jun;23(5-6):303-323. [doi: [10.1016/j.ijindorg.2005.03.005](#)]
8. Leiponen A, Helfat CE. Innovation objectives, knowledge sources, and the benefits of breadth. *Strat. Mgmt. J* 2009;31(2):224-236. [doi: [10.1002/smj.807](#)]
9. Lloyd-Ellis H, Roberts J. Twin Engines of Growth: Skills and Technology as Equal Partners in Balanced Growth. *Journal of Economic Growth* 2002;7(2):87-115. [doi: [10.1023/1015633528122](#)]
10. Bauer TK, Bender S. Technological change, organizational change, and job turnover. *Labour Economics* 2004 Jun;11(3):265-291. [doi: [10.1016/j.labeco.2003.09.004](#)]
11. Mohnen P, Röller L. Complementarities in innovation policy. *European Economic Review* 2005 Aug;49(6):1431-1450. [doi: [10.1016/j.eurocorev.2003.12.003](#)]

12. European Commission. New Skills for New Jobs: Anticipating and matching labour market and skills needs. Luxembourg: Office for Official Publications of the European Communities; 2010. URL: <http://ec.europa.eu/social/BlobServlet?docId=1496&langId=en> [WebCite Cache ID 6SlfNphCu]
13. Levy F, Murnane R. The new division of labor: how computers are creating the next job market. Princeton, NJ: Princeton University Press; 2004.
14. Borghans L, ter Weel B, Weinberg BA. Interpersonal Styles and Labor Market Outcomes. *Journal of Human Resources* 2008;43(4):815-858. [doi: [10.1353/jhr.2008.0029](https://doi.org/10.1353/jhr.2008.0029)]
15. Development OOFECA. Innovative Workplaces: Making Better Use of Skills within Organisations. Paris: OECD Publishing; 2010.
16. Etheredge LM. A rapid-learning health system. *Health Aff (Millwood)* 2007;26(2):w107-w118 [FREE Full text] [doi: [10.1377/hlthaff.26.2.w107](https://doi.org/10.1377/hlthaff.26.2.w107)] [Medline: [17259191](https://pubmed.ncbi.nlm.nih.gov/17259191/)]
17. Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T, et al. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. *Lancet* 2010 Dec 4;376(9756):1923-1958. [doi: [10.1016/S0140-6736\(10\)61854-5](https://doi.org/10.1016/S0140-6736(10)61854-5)] [Medline: [21112623](https://pubmed.ncbi.nlm.nih.gov/21112623/)]
18. World Health Organization. Transforming and scaling up health professionals' education and training: World Health Organization Guidelines. Geneva: World Health Organization; 2013. URL: http://apps.who.int/iris/bitstream/10665/93635/1/9789241506502_eng.pdf [WebCite Cache ID 6SlhGtmDQ]
19. Levy F, Murnane RJ. The new division of labor: how computers are creating the next job market. Princeton, NJ: Princeton University Press; 2004.
20. Borghans L, ter Weel B, Weinberg BA. Interpersonal Styles and Labor Market Outcomes. *Journal of Human Resources* 2008;43(4):815-858. [doi: [10.1353/jhr.2008.0029](https://doi.org/10.1353/jhr.2008.0029)]
21. Lund R, Gjerding A. The flexible company: innovation, work organization and human resource management. Copenhagen: Danish Research Unit for Industrial Dynamics; 1996. URL: http://www.druid.dk/uploads/tx_picturedb/dw1997-315.pdf [WebCite Cache ID 6SlhPOIUJ]
22. OECD. Skills Outlook 2013: First Results from the Survey of Adult Skills. Paris: OECD Publishing; 2013. URL: http://skills.oecd.org/OECD_Skills_Outlook_2013.pdf [WebCite Cache ID 6Slf9OxM]

Abbreviations

DISKO: Danish System of Innovation in a Comparative Perspective

DRUID: Danish Research Unit for Industrial Dynamics

ICT: information and communication technologies

OECD: Organisation for Economic Co-operation and Development

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Original Paper

Testing Usability and Acceptability of a Web Application to Promote Physical Activity (iCanFit) Among Older Adults

Yan Hong¹, PhD; Daniel Goldberg^{2,3}, PhD; Deborah Vollmer Dahlke⁴, Dr PH; Marcia G Ory¹, PhD, MPH; Jessica S Cargill⁵, MPH; Rachel Coughlin¹, BS; Edgar Hernandez⁶; Debra K Kellstedt¹, MPH; S Camille Peres¹, PhD

¹School of Public Health, Texas A&M Health Science Center, College Station, TX, United States

²Department of Geography, Texas A&M University, College Station, TX, United States

³Department of Computer Science and Engineering, Texas A&M University, College Station, TX, United States

⁴DVD Associates, Austin, TX, United States

⁵St Joseph Regional Health Center, Bryan, TX, United States

⁶Environmental Geosciences Program, Texas A&M University, College Station, TX, United States

Corresponding Author:

Yan Hong, PhD

School of Public Health

Texas A&M Health Science Center

1266 TAMU

College Station, TX, 77843

United States

Phone: 1 9798621700

Fax: 1 9794584264

Email: yhong@sph.tamhsc.edu

Abstract

Background: Most older Americans do not exercise regularly and many have chronic conditions. Among an increasing number of fitness mobile and Web apps, few are designed for older adults with chronic conditions despite high ownership rates of mobile tools and Internet access in this population. We designed a mobile-enabled Web app, iCanFit, to promote physical activity in this population.

Objective: This study aimed to test the usability and acceptability of iCanFit among older adults in a community setting.

Methods: A total of 33 older adults (aged 60 to 82 years) were recruited from communities to test iCanFit. Of these 33, 10 participants completed the usability testing in a computer room of a senior community center. A research assistant timed each Web application task and observed user navigation behavior using usability metrics. The other 23 participants used the website on their own devices at home and provided feedback after 2-3 weeks by completing a user-experience survey assessing ease of use, helpfulness, and satisfaction with iCanFit.

Results: Participants completed all 15 tasks on the iCanFit site in an average of 31 (SD 6.9) minutes; some tasks required more time or needed assistance. Participants' comments were addressed to improve the site's senior friendliness and ease of use. In the user-experience survey, participants reported high levels of usefulness and satisfaction. More than 56% (13/23) of participants indicated they would continue using the program and recommend it to their families or friends.

Conclusions: Testing usability and acceptability is a very important step in developing age-appropriate and user-friendly Web apps, especially for older adults. Testing usability and acceptability in a community setting can help reveal users' experiences and feedback in a real-life setting. Our study suggested that older adults had a high degree of acceptance of iCanFit and could use it easily. The efficacy trial of iCanFit is currently underway.

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KEYWORDS

physical activity; mobile health, older adults; usability testing; user experience

Introduction

As of January 2014, 87% of American adults have used the Internet. Even among older adults, 88% of those aged 50 to 64 years are online and more than 57% of those older than 64 years are online [1]. More than 58% of American adults own a smartphone and 42% own a tablet computer [1]. With such ubiquity of Internet access and high ownership rates of mobile tools, mobile health programs have gained increasing popularity with thousands of Web and mobile apps available for fitness and healthy living.

Approximately 13% of the American population is older than 65 years, and by 2030 older adults will account for 20% of the US population [2]. In addition, more than two-thirds of older Americans have multiple chronic conditions and medical treatment for this population accounts for 66% of the country's health care budget [3]. Regular physical activity can prevent many chronic diseases and significantly improve quality of life for those with chronic conditions. Yet, more than 80% of older adults do not meet the guidelines of regular physical activity [4]; a recent nationwide study showed that less than 10% of adults report being active as assessed by accelerometers [5]. An urgent need exists to implement innovative and cost-effective interventions to promote healthy lifestyles among older adults.

National surveys suggest that older adults who use the Internet are more likely to seek health information online [6,7]. However, among the thousands of online apps and mobile tools available to promote physical activity, few are designed or marketed for older adults [8]. Goldberg and colleagues commented on the gap between needs and availability, stating: "The question now is not whether the public is ready for eHealth information, but whether eHealth information is ready to meet the public's expectation" [9].

In-line with efforts to promote physical activity among older adults with chronic conditions, especially cancer, we developed a mobile-enabled Web app called iCanFit [10] based on intensive formative research. We conducted in-depth interviews, surveys, and group discussions with older cancer survivors (60 years and older), care providers, and community leaders. They identified lack of motivation, lack of tracking, inadequate social support, and limited knowledge of appropriate exercise as the main barriers to regular exercise [11]. These formative data informed the design of the iCanFit Web application, which

includes 4 key functions: Goals (physical activity goal setting and tracking), Community (an online network for users), Tips (regularly updated tips on healthy living), and Resources (active links to reliable health information) (see Figure 1 for screenshots of iCanFit). Note the Goals and Community functions in iCanFit are only available to registered users because the program is currently under efficacy trial. Of these functions, Goals is the most important tool (Figure 2) because it motivates participants to exercise regularly through goal setting, activity tracking, personalized feedback, and progress reviews. After a participant creates an account and logs onto the site the first time, s/he is invited to set a long-term goal; for example, "Over the next 6 months, I will go from walking 3 times a week to walking 5 times a week." Participants are then asked to set a short-term goal, usually a weekly goal. They can use dropdown menus to select a type of activity (eg, walking, dancing), frequency per week, and duration of the activity. The system will automatically calculate total minutes for each activity and all activities (Figure 2). On an interactive calendar, participants can enter their activity and log the total number of minutes they exercised on a selected day (Figure 3). Their activity log will be compared to their goals and they will receive tailored messages based on this comparison; for example, "Congratulations, you've achieved your goal, keep up the good work!" or "Sorry you did not meet your goal. You may consider setting a more realistic goal. Keep moving!" (Figure 3). The tailored message is sent automatically from iCanFit using a predesigned database that contains more than 100 messages for different conditions of meeting goals. Finally, View Progress allows users to track their progress through various metrics, including total energy expenditure (metabolic equivalent of task, also referred to as MET), total minutes exercised, number of days exercised, and comparisons between actual activity and their preset goals (Figure 4). For MET and total minutes exercised, users have the option to view their progress as bars, lines, and/or a calendar. Under the Days Exercised view, their activities are marked against the goals they set (Figure 4).

During the iCanFit protocol development, we conducted an iterative heuristic evaluation with experts from behavioral sciences, computer science, human factors and ergonomics, exercise sciences, public health, and gerontology. The goal of the current study was to test usability and acceptability of iCanFit among older adults.

Figure 1. Screenshots of iCanFit.

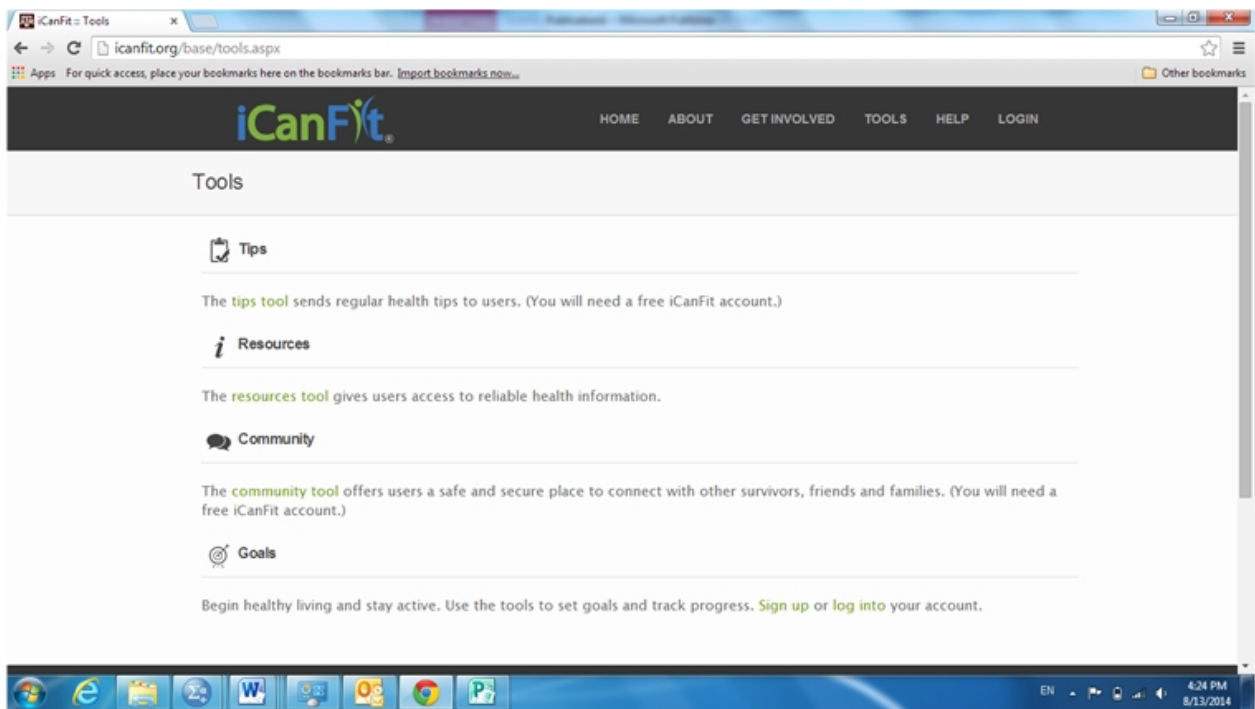


Figure 2. Goals function in iCanFit.

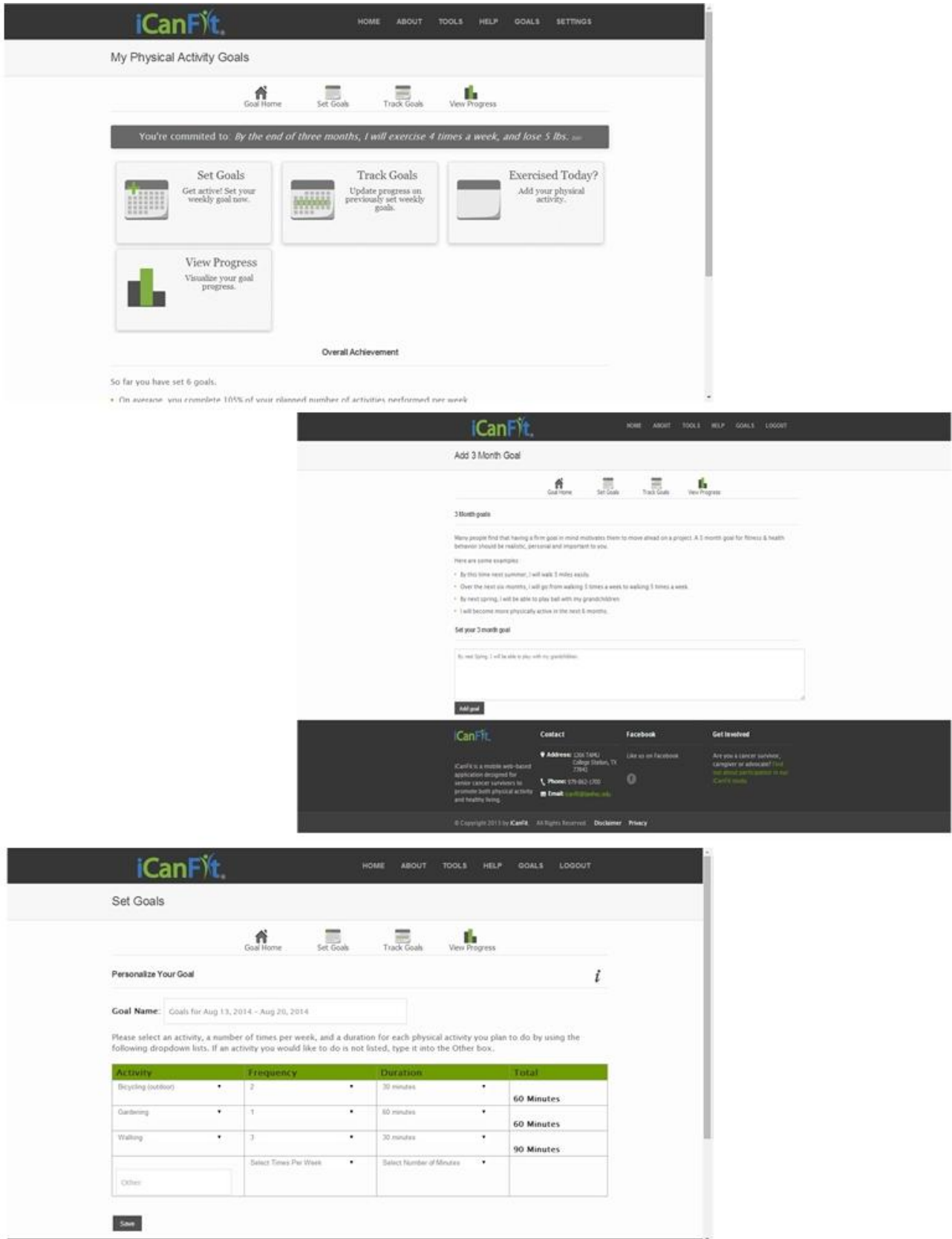


Figure 3. Entering, tracking, and receiving feedback of physical activity on iCanFit.

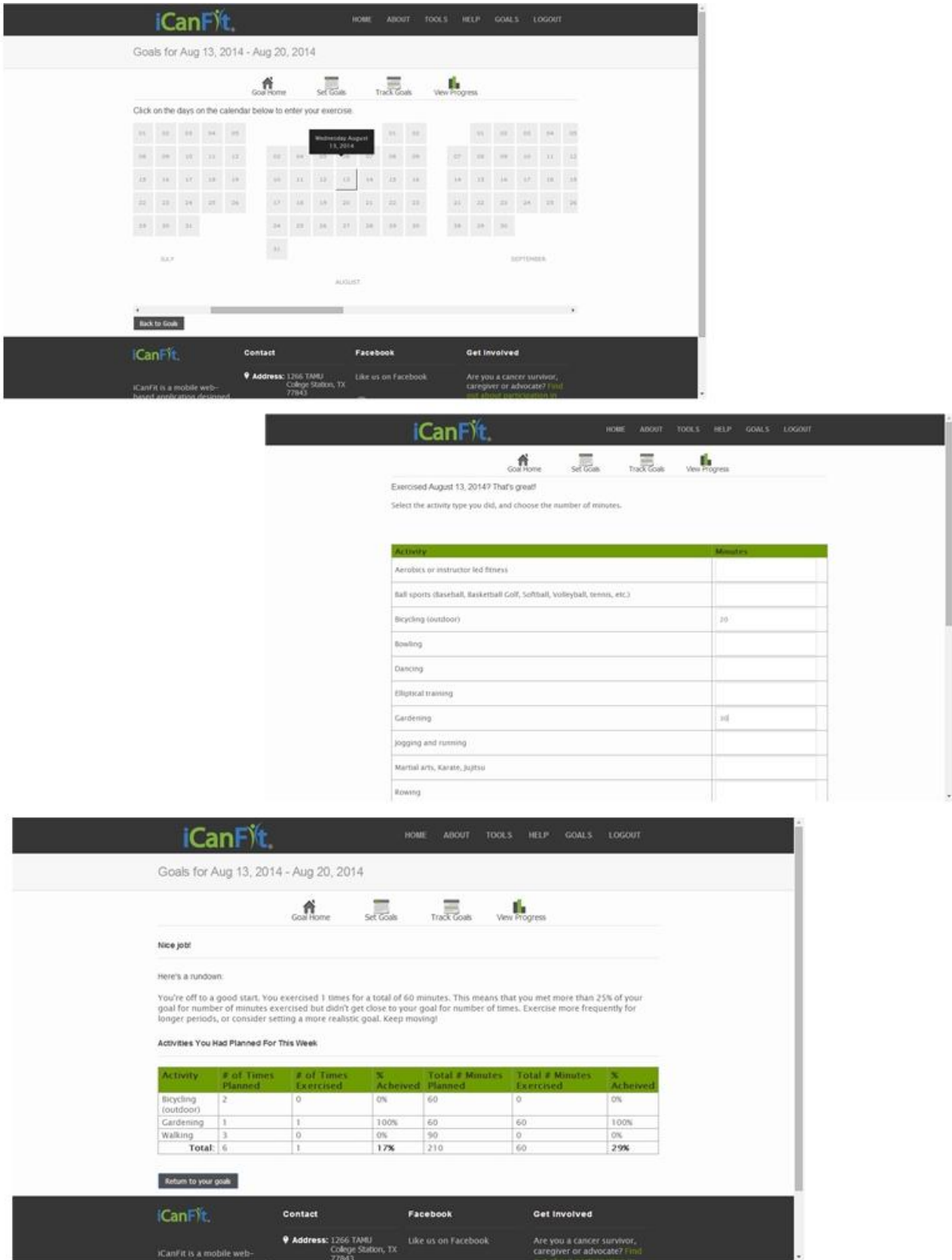
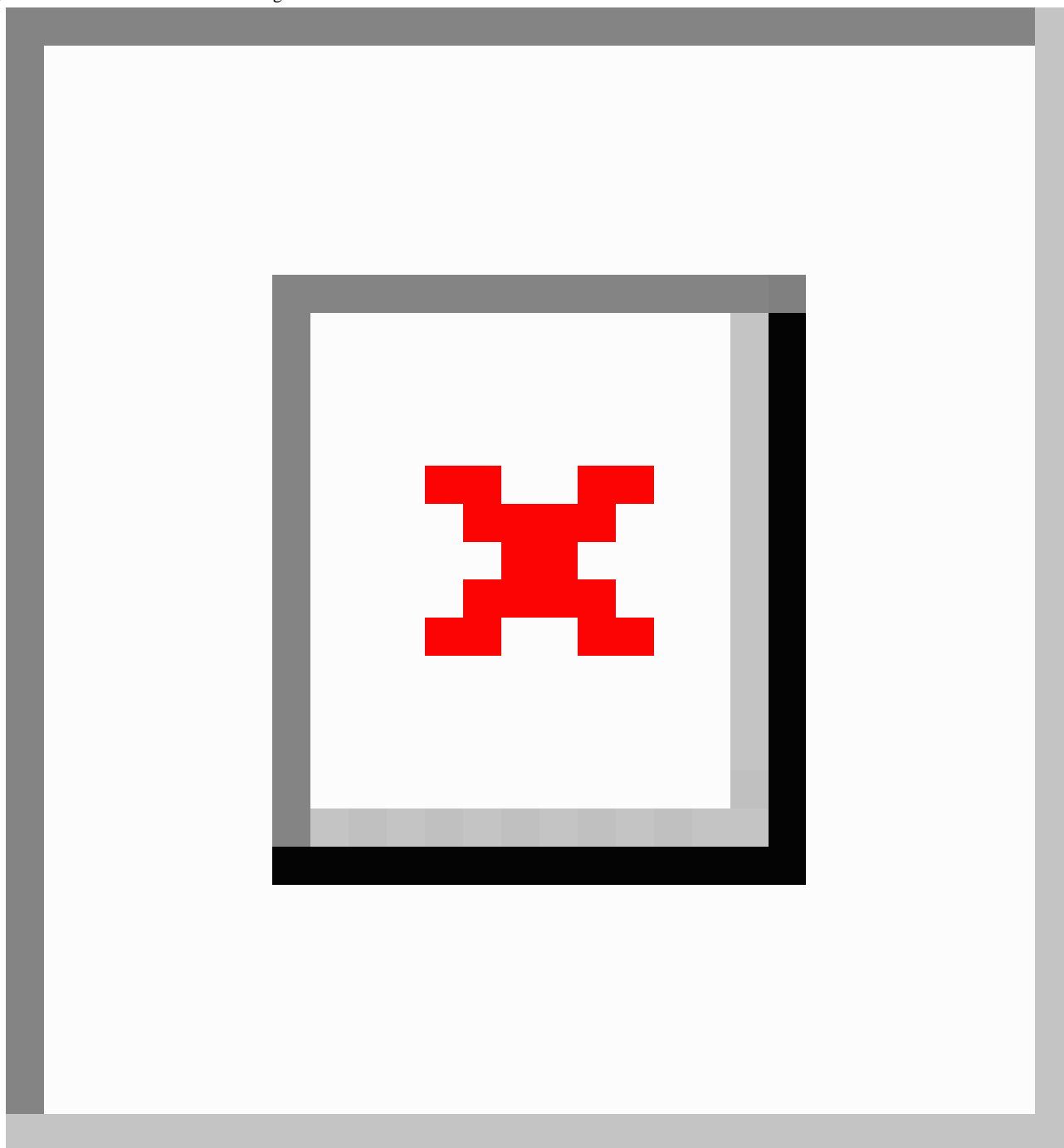


Figure 4. Different modes of View Progress on iCanFit.



Methods

Study Design Overview

The study took place in a college town of central Texas from April to June 2014. Following the usability testing methods proposed by Kushniruk et al [12] and Schneiderman [13], we aimed to test usability and acceptability of iCanFit. Usability measures technical effectiveness and efficiency. Technical effectiveness is measured by recording whether the users can complete a given task or not and if they completed the task, whether they did so without error. Efficiency measures how much time it takes to complete each task [12,13]. Acceptability measures users' overall experience with an application, including perceived ease of use, usefulness of the information,

and satisfaction of the experience [14,15]. Our plan was to make changes to iCanFit based on data from usability testing; after the changes were completed, we proceeded with acceptability testing.

Considering significant variance in computer skills of older adults, testing in a laboratory may not reflect users' experience in a real-life setting [16,17]. Thus, we planned to conduct the usability and acceptability testing in a community setting. Finally, based on theories regarding an appropriate sample size for usability testing and prior studies [18-21], the sample size for usability testing was set at approximately 10 and the sample for acceptability testing was set at approximately 20.

Based on these theories and rationale, our testing of iCanFit was designed to include 2 phases. The first phase was usability testing in a computer room at a senior community center. The participants were given the name of the website and asked to explore the site on their own. During this phase, a research assistant (RA) measured and observed the user's navigation using usability testing metrics (see [Multimedia Appendix 1](#)). Based on data from usability testing, the Web application was improved by removing bugs and refining to be more senior-friendly. The second phase was acceptability testing. The participants were instructed to use the iCanFit on their own devices at home for 2-3 weeks and then give feedback through a user-experience survey (see [Multimedia Appendix 2](#)).

Testing Tools Development

We developed a protocol of usability and acceptability testing that guided every step of the process. The protocol included recruitment scripts, a recruitment flyer, usability testing metrics, and a user-experience survey. We conducted intensive training with RAs to ensure the testing protocol was followed with fidelity.

Usability testing metrics (see [Multimedia Appendix 1](#)) were developed based on prior testing metrics employed in usability testing of online programs and mobile health technologies [12,14,22,23]. The metrics included 15 tasks to complete navigation of the site and detailed observation metrics to measure technical effectiveness and efficiency (eg, how much time it takes to complete a task and what errors occur during the navigation). It also included space for the RA to document users' comments and behaviors during the testing.

The user-experience survey (see [Multimedia Appendix 2](#)) was developed from the IBM computer user satisfaction questionnaire [24], which has been widely used in similar acceptability testing studies [14,20]. It is a semi-structured interview with 57 questions on users' experience with iCanFit. The survey included the following major components: (1) modes and frequency of accessing iCanFit and time spent on the site, (2) Likert scales on ease of use (1=very difficult, 4=very easy) and perceived usefulness (1=useless, 4=very useful), (3) open-ended questions on users' satisfaction with each function and overall experience with the Web application, and (4) users' comments on how to improve iCanFit and suggestions on how to promote physical activity among older adults.

Participant Recruitment

We recruited our participants through active community outreach. Flyers were posted at senior community centers and public libraries and announcements were made during breaks of classes or programs for seniors. Participants who were aged 60 years or older and had used the Internet were invited to participate in our study. A total of 33 participants were recruited for the study; 10 conducted usability testing in a computer room in a senior center and the remaining 23 participants performed acceptability testing by using iCanFit for 2-3 weeks at home followed by a user-experience survey. The study protocol was approved by the Institutional Review Board at the Texas A&M University.

Usability Testing Procedure

In the first phase of usability testing, the participants were invited to a computer room in a senior center. The RAs first introduced themselves and explained the purpose and procedure of the testing. Participants were assured of their privacy and verbal consent was obtained. An RA was paired with a participant. There was enough space between desktop computers to ensure proper testing and observation. A brief survey on participant demographics was administered before the testing. The participant was then given the website name and asked to explore the site on their own. The RA sat behind the participant and gave no instruction to the participant unless the participant could not proceed after repeated efforts. The participant was also encouraged to make comments during the navigation. The RA recorded the participant behavior and comments using observation metrics and took detailed notes. The metrics included 15 tasks to complete on the website, time needed on each task, and if a task was performed without error, with error, or needed assistance. Each participant received a US \$20 gift card as compensation for their participation.

Acceptability Testing Procedure

In the second phase of acceptability testing, another sample of 23 participants was recruited to test iCanFit on their own devices independently. When participants responded to our flyer by calling or speaking to our RAs at community outreach, they were instructed to visit the iCanFit site and use it for 2 to 3 weeks. An interview was then scheduled at the participant's convenience to solicit their feedback on the website, including how difficult was it to navigate the site, the usefulness of each function and the site in general, and how satisfied they were with the website. Some interviews were conducted in-person at a community center and some were conducted over the phone. Verbal consent was obtained before the interview and each participant received a US \$20 gift card as compensation for their participation.

Data Analysis

All data were saved and analyzed in SPSS 16.0 (SPSS Inc, Chicago, IL, USA) and descriptive statistics were used to explore the mean usability and acceptability scores. All text data were extracted from SPSS and entered into ATLAS.ti (Berlin, Germany) for further analysis. We identified the most frequently used phrases or keywords, and delineated a range of responses for each task on iCanFit and their overall experience.

Results

Participant Characteristics

As shown in [Table 1](#), 10 participants completed the usability testing in the computer room of a senior center. They were aged between 60 to 78 years with a mean of 68 (SD 6.3) years; 7 participants were female and 3 were male. Seven participants had some college education and the remaining 3 had high school education or less. All participants used the Internet and their computer experience varied from 3 to 30 years. The most typical mode of Internet access was desktop (60%, 6/10), followed by laptop (30%, 3/10), and tablet (10%, 1/10). All participants owned smartphones, but most used them primarily for making

phone calls, whereas some used them for checking emails or using apps.

Table 1. Characteristics of participants in usability testing and user-experience survey of iCanFit.

Characteristics	Utility testing sample (n=10)	User-experience survey sample (n=23)
Age (years)		
Mean (SD)	67.60 (6.3)	67.6 (6.5)
Range	60-78	60-82
Gender, n (%)		
Male	7 (70)	4 (17)
Female	3 (30)	19 (83)
Education, n (%)		
≤High school	3 (30)	6 (26)
>High school	7 (70)	17 (74)
Internet use (years)		
Mean (SD)	20.30 (10.5)	20 (8.0)
Range	3-38	6-30
Common mode of Internet access, n (%)		
Desk top	6 (60)	11 (52)
Laptop	3 (30)	8 (35)
Tablet	1 (10)	2 (8)
Smartphone	0	1 (4)

A total of 23 participants completed the user-experience survey; their ages were between 60 to 82 years (mean 68, SD 6.5). Of these 23, 19 (80%) were female and 17 (74%) had more than high school education. Approximately 52% (11/23) participants used a desktop as their primary mode of Internet access, followed by laptops (35%, 8/23), and tablets (8%, 8/23).

Usability Testing: Effectiveness and Efficiency

Table 2 reports technical effectiveness (whether participants were able to perform tasks without errors) and relative user efficiency (how much time needed to complete each task) from

usability testing. All participants were able to complete the 15 tasks in an average of 31 minutes (range 22-40 minutes). For each task, the completion time varied from 0.7 to 9.2 minutes.

The most difficult task appeared to be creating an account. It took participants an average of 9.2 minutes to create a user account. In all, 40% (4/10) could perform this task without error, 40% (9/23) completed the task with error, and 20% (2/10) needed assistance. Only 30% (3/10) watched the instructional video under the Help tab or logged out of the site after they completed all other tasks.

Table 2. Usability testing results of iCanFit (N=10).

Task	Time to complete (min)		Perform without error, n (%)	Perform with error, n (%)	Need assistance, n (%)
	Mean (SD)	Range			
Find the website	2.4 (2.3)	1-3	6 (60)	2 (20)	2 (20)
Create an account	9.2 (5.2)	1-17	4 (40)	4 (40)	2 (20)
Log into the account	2.7 (4.1)	0.5-11	8 (80)	1 (10)	1 (10)
Find Healthy Tips and read it	1.1 (1.6)	0-5	8 (80)	1 (10)	1 (10)
Find Resources and read it	3.4 (6.3)	0-20	9 (90)	0	1 (10)
Find the Facebook account through the link on the site	1.1 (1.3)	0-3	7 (70)	1 (10)	2 (20)
Find the Goal Home	0.7 (0.6)	0-2	7 (70)	1 (10)	2 (20)
Set a long-term goal	2.1 (2.3)	0-7	6 (60)	1 (10)	3 (30)
Set a short-term goal	1.4 (1.3)	0-4	6 (60)	1 (10)	3 (30)
Track the short-term goal by entering physical activity	3.4 (3.8)	0-8	5 (50)	2 (20)	3 (30)
Enter physical activity without tracking the short-term goal	2.1 (1.7)	0-5	9 (90)	1 (10)	0
View physical activity progress through View Progress	0.9 (1.1)	0-3	9 (90)	1 (10)	0
Switch view modes in View Progress	0		10 (100)	0	0
Find help	1 (1)	0-2	3 (30)	0	0
Log out			3 (30)	1 (10)	6 (60)
Time to complete the entire site	31.4 (6.9)	22-40			

Improving iCanFit After Usability Testing

Through the observations and participants' comments we obtained from the usability testing, we were able to identify and make the necessary changes to the iCanFit application to improve usability and senior friendliness. For example, comments from some of the participants indicated that some fonts and icons needed to be changed to be more visible for older adults. To address the problems participants had with goal setting, some words were changed to avoid confusion. For instance, after setting a short-term goal, the "Add Activity" button was changed to "Save."

We also added some hot buttons for frequently used functions. For example, the "Exercised Today?" button was created allowing participants to enter activity before going to Goals and the "Log out" button was placed in a more visible location. During usability testing, we also learned that some pages of iCanFit did not display well on Internet Explorer 7.0 or lower, so we modified our site to make it compatible with more browsers.

Two major complaints from the participants were that they did not know what to do after they went onto the website and that they had trouble creating an account. Therefore, we changed our instructional video and made 3 separate videos, ranging from 30 seconds to 2 minutes in length, and explained (1) what iCanFit is and how to use it, (2) how to create an account, and (3) how to use Goals so that users can easily find the help they need.

Acceptability Testing: User Experience and Satisfaction

Table 3 shows results from the user-experience survey. Most participants learned about iCanFit from a flyer at community centers. They typically accessed the website through a desktop (44%, 10/23) or a laptop (30%, 7/23), and the rest used a tablet (17%, 4/23) or a smartphone (9% 2/23). Most participants accessed the website approximately once a week or less and reported spending an average of 21.6 (SD 4.0) minutes on the site in the past week.

Table 3. Results of user-experience survey (N=23).

Variable	n (%)	Mean (SD)
Sources of knowing iCanFit website		
Flyer at community center	15 (65)	
Email listserve	2 (9)	
Friend/relative	5 (22)	
Other	1 (4)	
Mode of accessing iCanFit		
Desktop	10 (44)	
Laptop	7 (30)	
Tablets	4 (17)	
Smartphone	2 (9)	
How often use iCanFit		
<Once/week	9 (39)	
Approximately once/week	9 (39)	
2-3 times/week	3 (13)	
4-5 times/week	1 (4)	
Every day	1 (4)	
Total time on iCanFit in past week (minutes; range 0-60), mean (SD)		21.6 (4.0)
Difficulty (range 1-4) ^a		
Creating account		3.2 (0.4)
Long-term goal setting		3.7 (0.2)
Short-term goal setting		3.8 (0.3)
Short-term goal tracking		3.3 (0.3)
View progress		3.7 (0.2)
Overall difficulty		3.6 (0.3)
Usefulness (range 1-4) ^b		
Instructional video		3.7 (0.3)
Healthy tips		3.5 (0.2)
Resources		3.2 (0.2)
Facebook page		3.1 (0.3)
Overall usefulness		3.4 (0.3)
Communication of iCanFit		
Ever talked to family/friends about iCanFit	13 (56.5)	
Would recommend iCanFit to family/friends	13 (56.5)	

^a Difficulty score: 1=very difficult, 2=somewhat difficult, 3=somewhat easy, 4=very easy.

^b Usefulness score: 1=useless, 2=a little useless, 3=somewhat useful, 4=very useful.

When asked to rate how difficult it was to use each function, most participants reported no difficulty or little difficulty in completing the major functions of the site with a score range of 3.2 to 3.8 (1=very difficult, 4=very easy). The overall difficulty for the major function of Goals was rated 3.6 (SD 0.3). When asked to rate usefulness of each function, most participants gave a rating of 3.1 to 3.7 (1=useless, 4=very useful). Participants gave the iCanFit website an average overall

usefulness rating of 3.4 (SD 0.3). More than half (57%, 13/23) of the participants had talked to their family or friends about the iCanFit program and the same number of participants would recommend iCanFit to their family or friends.

Approximately 30% (7/23) of participants reported preferring to track physical activity in Goals through the “Exercised Today?” hot button and only 9% (2/23) liked to track activity

through Track Goals; 22% (5/23) indicated having no preference because both were easy to use (data not shown).

Our qualitative data from the user-experience survey revealed that with different prior online experiences and varying statuses of current physical activity, participants had different experiences with iCanFit. For some participants who exercised regularly, they felt that the program added little to their current life: "I am doing exercise regularly, and I have a pedometer." A couple of participants who did not use the computer often made remarks such as: "I prefer hardcopies of goals that can be stuck to the refrigerator so I can check it easily." Most participants, however, were very positive about their experience with iCanFit, making comments such as: "Super great program, keep it up," "It increased my activity because I was trying to get 100% of my goals," and "It's great to see how many times I have exercised; it gave me a kick to get up and accomplish something every day."

Participants also offered suggestions on how to use mobile tools for older adults. For example, a 71-year-old male user commented, "It has to be something automatic or very easy to use. I like the dropdown menu when entering activities so I don't need to type." A 65-year-old female user added, "It would be nice if it has function to remind me to exercise, since we don't remember things well at this age. And I like the graphs to see my progress." They also shared thoughts on how to motivate older adults to exercise regularly. For instance (shared by a 68-year old female user), "If we can get people to start a program that combines a fitness class and how to use this site (iCanFit), you can motivate many sedentary people." A 62-year-old male user suggested, "For those living alone, it is more about helping them find friends and getting them involved."

Discussion

Older adults from the community were recruited to test the usability and acceptability of a Web application designed to promote physical activities for older cancer survivors. Usability and acceptability was tested in settings familiar to the participants and on devices they often used to maximize their real-life experience. The relative user efficiency data, such as time to complete the tasks and errors made in first-time use, were within an acceptable range and reflected the anticipated usability gap between expert and novice users [22]. During the usability testing, the main challenge for users was account creation. Such a challenge might be because participants were new to the website and not aware that they needed to create an account before the major functions could be used. Some users did not know they would need to check their email to retrieve a password when setting up an account. These challenges and other errors identified through the usability testing were corrected and the site was further improved following users' suggestions. The acceptability testing revealed a high level of ease of use and usefulness of iCanFit. Further, most participants reported they would continue using the program or recommend it to their families and friends.

As the use of mobile tools continues to increase, especially among older adults, mobile technology is being used

increasingly as an efficient tool for health promotion [8]. Meanwhile, as the aging of the US population continues to accelerate, the need for cost-effective tools to address older adults' health needs increases as well. We need more online or mobile programs designed for older adults, especially those with chronic conditions [8]. When developing and testing Web or mobile applications for older adults, the heterogeneity of this population should be considered because some seniors are savvy or expert users, whereas others are still new to computers or other mobile tools. Prior research indicates that many older adults are eager to obtain authoritative up-to-date health information and are willing to overcome barriers if appropriate assistance is offered [8,9,25]. This underscores the importance of designing age-appropriate programs for older adults.

In addition, when developing mobile programs for older adults, it is important to involve end users from early stage of design and conduct on-going usability testing [15,25]. From testing usability and acceptability of iCanFit among older adults, we learned that when conducting usability testing among older adults it is more efficient to start with some expert users. After critical errors are fixed, the application can be further tested with more typical users [15]. Finally, when testing acceptability and user experience, it is important to include clear instructions on what is being tested and how to use the application in the Web or mobile format, preferably by utilizing step-by-step instructions with pictures or video demonstrations.

Several limitations of the study should be noted. First, iCanFit was originally designed to promote physical activity among older cancer survivors [11] and usability and acceptability testing might be restricted to this population. However, the participants who completed the usability and acceptability testing in our study were older adults with a variety of chronic conditions, including cancer survivors. This expansion reflects the reality that the majority of older cancer survivors have existing comorbidities. Another reason for utilizing a less disease-specific user participant group was that we intend to expand the use of iCanFit to all older adults and our data have showed high levels of usability and acceptability of iCanFit among older adults. Second, we had a convenience sample recruited from a small city in central Texas, and most of our participants were white, female, had some college education, and were experienced with computers. The results may not be generalizable to older adults in other geographic locations or cultural settings. Third, because of the small sample size in the user-experience survey, we were not able to do comparisons between subgroups; for instance, differences in user satisfaction stratified by age, gender, computer skills, and chronic conditions. Future research should include a larger sample size and longer testing time to maximize end users' inputs in site development. Finally, although we used mixed methods in the study, the qualitative questions were imbedded in a semi-structured interview and most users only provided short answers to those questions, thus giving us only limited qualitative data. Future research needs to include some in-depth interviews to explore the specific reasons users had for liking or disliking the application.

Despite these limitations, to the best of our knowledge, our study was one of the first to report testing of usability and

acceptability of a Web app to promote physical activity among older adults. Our findings underscore the importance of using validated metrics and mixed methods to test multidimensional usability and acceptability of an application. An efficacy trial of the iCanFit Web application and development of iCanFit mobile app are both currently underway. After the trial and further refinement, it will be scaled up to assist a large population of older adults with chronic conditions. We are aware that there are many mobile and Web apps that serve similar

purposes as iCanFit and users always have many options in terms of mHealth tools. iCanFit was not meant to replace existing physical activity applications; instead, we believe it is a beneficial supplement to the existing ones. Because few mobile or Web apps involved usability testing in older adults [15,25,26], our study represents an effort to voice older adults' needs in the rapidly growing field of mobile health. We anticipate that in the near future, mHealth tools such as iCanFit will be more widely used by older adults to improve their healthy living.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

iCanFit usability testing metrics.

[PDF File (Adobe PDF File), 19KB - [humanfactors_v1i1e2_app1.pdf](#)]

Multimedia Appendix 2

iCanFit user-experience interview guide.

[PDF File (Adobe PDF File), 49KB - [humanfactors_v1i1e2_app2.pdf](#)]

References

1. Pew Research Internet Project. 2014 Jan. Internet User Demographics URL: <http://www.pewinternet.org/data-trend/internet-use/latest-stats/> [accessed 2014-03-02] [WebCite Cache ID 6Nm3n9Gyj]
2. Department of Health and Human Services, Administration on Aging. 2013. Aging Statistics URL: http://www.aoa.gov/Aging_Statistics/ [accessed 2013-07-11] [WebCite Cache ID 6I1ojlqWD]
3. National Center for Chronic Disease Prevention and Health Promotion. State of Aging and Health in America. Atlanta, GA: Centers for Disease Control and Prevention; 2013. URL: http://www.cdc.gov/features/agingandhealth/state_of_aging_and_health_in_america_2013.pdf [accessed 2014-08-16] [WebCite Cache ID 6RrHpB1DS]
4. 2008 Physical Activity Guidelines for Americans: fact sheet for health professionals on physical activity guidelines for Americans. Atlanta, GA: Centers for Disease Control and Prevention, Division of Nutrition, Physical Activity, and Obesity; 2009 Jun. URL: http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Fact_Sheet_OlderAdults.pdf [accessed 2010-12-21] [WebCite Cache ID 5v8F3OIEz]
5. Troiano RP, Berrigan D, Dodd KW, Mâsse L, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008 Jan;40(1):181-188. [doi: [10.1249/mss.0b013e31815a51b3](https://doi.org/10.1249/mss.0b013e31815a51b3)] [Medline: [18091006](https://pubmed.ncbi.nlm.nih.gov/18091006/)]
6. Fox S, Duggan M. Health Online 2013. Washington, DC: Pew Internet & American Life Project; 2013 Jan 15. URL: <http://bibliobase.sermais.pt:8008/BiblioNET/Upload/PDF5/003820.pdf> [accessed 2014-08-15] [WebCite Cache ID 6Rr6eruXw]
7. Miller LM, Bell RA. Online health information seeking: the influence of age, information trustworthiness, and search challenges. *J Aging Health* 2012 Apr;24(3):525-541. [doi: [10.1177/0898264311428167](https://doi.org/10.1177/0898264311428167)] [Medline: [22187092](https://pubmed.ncbi.nlm.nih.gov/22187092/)]
8. Center for Technology and Aging. 2008, The New Era of Connected Aging. Berkeley, CA: Center for Technology and Aging; 2014. URL: <http://www.techandaging.org/ConnectedAgingFramework.pdf> [accessed 2014-08-15] [WebCite Cache ID 6Rr6MQsGZ]

9. Goldberg L, Lide B, Lowry S, Massett HA, O'Connell T, Preece J, et al. Usability and accessibility in consumer health informatics current trends and future challenges. *Am J Prev Med* 2011 May;40(5 Suppl 2):S187-S197. [doi: [10.1016/j.amepre.2011.01.009](https://doi.org/10.1016/j.amepre.2011.01.009)] [Medline: [21521594](https://pubmed.ncbi.nlm.nih.gov/21521594/)]
10. iCanFit. URL: <http://www.icanfit.org/> [accessed 2014-09-25] [WebCite Cache ID 6SsPFnnh4]
11. Hong Y, Dahlke DV, Ory M, Hochhalter A, Reynolds J, Purcell NP, et al. Designing iCanFit: A Mobile-Enabled Web Application to Promote Physical Activity for Older Cancer Survivors. *JMIR Res Protoc* 2013 Feb;2(1):e12 [FREE Full text] [doi: [10.2196/resprot.2440](https://doi.org/10.2196/resprot.2440)] [Medline: [23612053](https://pubmed.ncbi.nlm.nih.gov/23612053/)]
12. Kushniruk AW, Patel VL, Cimino JJ. Usability testing in medical informatics: cognitive approaches to evaluation of information systems and user interfaces. *Proc AMIA Annu Fall Symp* 1997:218-222 [FREE Full text] [Medline: [9357620](https://pubmed.ncbi.nlm.nih.gov/9357620/)]
13. Shneiderman B, Plaisant C, Cohen M, Jacobs SL. *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Boston: Addison-Wesley; 2010.
14. O'Malley G, Dowdall G, Burls A, Perry IJ, Curran N. Exploring the usability of a mobile app for adolescent obesity management. *JMIR Mhealth Uhealth* 2014 Jun;2(2):e29 [FREE Full text] [doi: [10.2196/mhealth.3262](https://doi.org/10.2196/mhealth.3262)] [Medline: [25098237](https://pubmed.ncbi.nlm.nih.gov/25098237/)]
15. Grindrod KA, Li M, Gates A. Evaluating user perceptions of mobile medication management applications with older adults: a usability study. *JMIR Mhealth Uhealth* 2014 Mar;2(1):e11 [FREE Full text] [doi: [10.2196/mhealth.3048](https://doi.org/10.2196/mhealth.3048)] [Medline: [25099993](https://pubmed.ncbi.nlm.nih.gov/25099993/)]
16. Demiris G, Rantz M, Aud M, Marek K, Tyrer H, Skubic M, et al. Older adults' attitudes towards and perceptions of "smart home" technologies: a pilot study. *Med Inform Internet Med* 2004 Jun;29(2):87-94. [doi: [10.1080/14639230410001684387](https://doi.org/10.1080/14639230410001684387)] [Medline: [15370989](https://pubmed.ncbi.nlm.nih.gov/15370989/)]
17. Kaufman D, Patel VL, Hillman C, Morin PC, Pevzner J, Weinstock RS, et al. Usability in the real world: assessing medical information technologies in patients' homes. *J Biomed Inform* 2003;36(1-2):45-60 [FREE Full text] [Medline: [14552846](https://pubmed.ncbi.nlm.nih.gov/14552846/)]
18. Nielsen J. Nielsen Norman Group. 2000 Mar 19. Why you only need to test with 5 users URL: <http://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/> [accessed 2013-01-03] [WebCite Cache ID 6DOOIFdCW]
19. Faulkner L. Beyond the five-user assumption: benefits of increased sample sizes in usability testing. *Behav Res Methods Instrum Comput* 2003 Aug;35(3):379-383. [Medline: [14587545](https://pubmed.ncbi.nlm.nih.gov/14587545/)]
20. Landman A, Neri PM, Robertson A, McEvoy D, Dinsmore M, Sweet M, et al. Efficiency and usability of a near field communication-enabled tablet for medication administration. *JMIR Mhealth Uhealth* 2014 Jun;2(2):e26 [FREE Full text] [doi: [10.2196/mhealth.3215](https://doi.org/10.2196/mhealth.3215)] [Medline: [25100043](https://pubmed.ncbi.nlm.nih.gov/25100043/)]
21. Ehmen H, Haesner M, Steinke I, Dorn M, Gövercin M, Steinhagen-Thiessen E. Comparison of four different mobile devices for measuring heart rate and ECG with respect to aspects of usability and acceptance by older people. *Appl Ergon* 2012 May;43(3):582-587. [doi: [10.1016/j.apergo.2011.09.003](https://doi.org/10.1016/j.apergo.2011.09.003)] [Medline: [21962327](https://pubmed.ncbi.nlm.nih.gov/21962327/)]
22. Bevan N. *Interactions*. 2006. Waits and Measures: Practical Issues in Usability Measurement *Interactions* URL: <http://interactions.acm.org/archive/view/november-december-2006/practical-issues-in-usability-measurement1> [accessed 2014-01-20] [WebCite Cache ID 6MleWoI3a]
23. Kushniruk AW, Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. *J Biomed Inform* 2004 Feb;37(1):56-76 [FREE Full text] [doi: [10.1016/j.jbi.2004.01.003](https://doi.org/10.1016/j.jbi.2004.01.003)] [Medline: [15016386](https://pubmed.ncbi.nlm.nih.gov/15016386/)]
24. Lewis JR. IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use. *International Journal of Human-Computer Interaction* 1995 Jan;7(1):57-78. [doi: [10.1080/10447319509526110](https://doi.org/10.1080/10447319509526110)]
25. Lorenz A, Oppermann R. Mobile health monitoring for the elderly: Designing for diversity. *Pervasive and Mobile Computing* 2009 Oct;5(5):478-495. [doi: [10.1016/j.pmcj.2008.09.010](https://doi.org/10.1016/j.pmcj.2008.09.010)]
26. Pak R, Price MM, Thatcher J. Age-sensitive design of online health information: comparative usability study. *J Med Internet Res* 2009 Nov;11(4):e45 [FREE Full text] [doi: [10.2196/jmir.1220](https://doi.org/10.2196/jmir.1220)] [Medline: [19917549](https://pubmed.ncbi.nlm.nih.gov/19917549/)]

Abbreviations

MET: Metabolic equivalent of task

RA: research assistant

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Original Paper

Acceptance of New Technology: A Usability Test of a Computerized Adaptive Test for Fatigue in Rheumatoid Arthritis

Stephanie Nikolaus^{1,2}, PhD; Christina Bode¹, PhD; Erik Taal¹, PhD; Harald E Vonkeman^{1,3}, MD, PhD; Cees AW Glas⁴, PhD; Mart AFJ van de Laar^{1,3}, MD, PhD

¹University of Twente, Department of Psychology, Health & Technology, Enschede, Netherlands

²Radboud University Medical Center, Expert Center for Chronic Fatigue, Nijmegen, Netherlands

³Medisch Spectrum Twente, Department of Rheumatology and Clinical Immunology, Enschede, Netherlands

⁴University of Twente, Department of Research Methodology, Measurement and Data Analysis, Enschede, Netherlands

Corresponding Author:

Christina Bode, PhD

University of Twente

Department of Psychology, Health & Technology

PO Box 217

Enschede, 7500 AE

Netherlands

Phone: 31 534896044

Fax: 31 534892895

Email: c.bode@utwente.nl

Abstract

Background: Little is known about the acceptance and usability of computerized adaptive tests (CATs) among patients with rheumatoid arthritis (RA). The main difference between completing a CAT and a traditional questionnaire concerns item presentation. CATs only provide one item at a time on the screen, and skipping forward or backward to review and change already given answers is often not possible.

Objective: The objective of this study was to examine how patients with RA experience a Web-based CAT for fatigue.

Methods: In individual sessions, participants filled in the CAT while thinking aloud, and were subsequently interviewed about their experience with the new instrument. The technology acceptance model (TAM) was used to structure the results.

Results: The participants were 15 patients with RA. They perceived the CAT as clear, brief, and easy to use. They were positive about answering one question per screen, the changing response options, layout, progress bar, and item number. There were 40% (6/15) of the participants that also mentioned that they experienced the completion of the CAT as useful and pleasant, and liked the adaptive test mechanism. However, some participants noted that not all items were applicable to everybody, and that the wordings of questions within the severity dimension were often similar.

Conclusions: Participants perceived the "CAT Fatigue RA" as easy to use, and also its usefulness was expressed. A 2.0 version has been improved according to the participants' comments, and is currently being used in a validation study before it will be implemented in daily clinical practice. Our results give a first indication that CAT methodology may outperform traditional questionnaires not merely on measurement precision, but also on usability and acceptance valuation.

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KEYWORDS

usability test; technology acceptance; computerized adaptive test (CAT); fatigue; rheumatoid arthritis

Introduction

Innovative Technology and Health Care

The use of Web-based technology to monitor disease course and quality of life of patients will increase tremendously in the

future due to demand for greater transparency in health care and innovations in the use of Web-based measurement technology. At least for patient reported outcome measures, patients themselves will directly use this technology, and information on technology acceptance is therefore of crucial importance to estimate the benefits and long-term effectiveness

of innovative technology in health care [1]. The availability of this modern technology enables computer adaptive testing (CAT), but little is known about the impact of Web-based measurements and CAT on patients, and how they experience their use. This study investigates the usability of a Web-based computer adaptive test for fatigue in rheumatoid arthritis from the patients' perspective.

Rheumatoid arthritis (RA) is a chronic auto-immune disease that is characterized by inflammation of the joints [2]. Typical symptoms are pain, fatigue, tender and swollen joints, stiffness, and functional limitations. Many patients report fatigue as being an annoying symptom with far-reaching consequences for daily life on a physical, emotional, and social level [3-6]. Several circular and interdependent processes between disease processes, cognitive/behavioral, and personal aspects are probably responsible for the occurrence of fatigue [7,8]. However, causal pathways are still unknown and no standard treatments are as yet available [9,10]. To gain more insight into its aetiology and treatment options, it is essential to be able to accurately measure fatigue in RA. Existing fatigue questionnaires have several disadvantages, for example, containing generic fatigue items that might be confounded by disease specific disability or disease activity, or being unidimensional, which is not in line with the patients' experience. Usual questionnaires have a traditional, fixed-length format. Consequently, patients may feel that questions do not match with their individual level of fatigue or are redundant. Therefore, we developed a computerized adaptive test (CAT), which was based on the perspectives of patients with RA [11].

Computer Adaptive Testing

In a CAT, items are successively selected from a large item bank, based on the patient's previous answer. Measurement is thus tailored to the individual level, leading to greater measurement precision, with need of fewer items than traditional questionnaires [12]. For the construction of a CAT, an item pool has to be scaled using item response theory (IRT). With this method, item characteristics can be estimated for each item independently [12], and items can be placed on a continuum, ranging from no fatigue to severe fatigue. This information is required to ideally match the items to the patient's previous answer, and ensures interindividual comparisons, even if patients filled in different items.

The CAT Fatigue RA has been constructed with multidimensional IRT [11], and consists of 196 items and three dimensions of fatigue (severity, impact, and variability). It provides separate estimates of each fatigue dimension, and the cross-information gained from items of correlated dimensions facilitates the selection of the next most informative items, and the final estimation of fatigue with optimal precision [13]. With this innovative method, measurement of fatigue in RA has become much more precise, and at the same time, more user friendly.

However, relatively little is known on how patients experience the use of CATs in the measurement of patient reported outcomes (PRO)'s. A few previous studies have shown that the overall user acceptance was quite high. Participants mainly expressed criticism on layout issues [14,15], and about half of

the participants rated the assessment as useful [16]. However, these results are difficult to generalize due to differences between the CATs and the study designs. The aim of the present study was to examine how patients use and experience the CAT Fatigue RA.

We were especially interested in whether patients would face any problems while filling in the CAT, and whether they would perceive it as a useful instrument. These aspects of usability are properly included in the Technology Acceptance Model (TAM) [17]; Figure 1 shows this model.

The TAM explains user acceptance of new technology by two main determinants: (1) perceived usefulness (PU), and (2) perceived ease of use (PEOU). PU refers to the degree to which a person believes a system to be worth using, for example, advantageous. PEOU refers to the degree to which a person believes that using a system does not cost much effort. Davis [17] suggests that the easier the use of a system is perceived, the higher the probability is that a person experiences the system as useful, and subsequently is willing to use it. Over the last decades, the TAM has been widely applied and has demonstrated its ability as theoretical model to guide understanding and explanation of technology acceptance [18]. An important model extension is the concept of perceived enjoyment [19], defined as "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" [20]. All variables together explain the attitude toward using a new technology, the behavioral intention to use it, and finally its actual use.

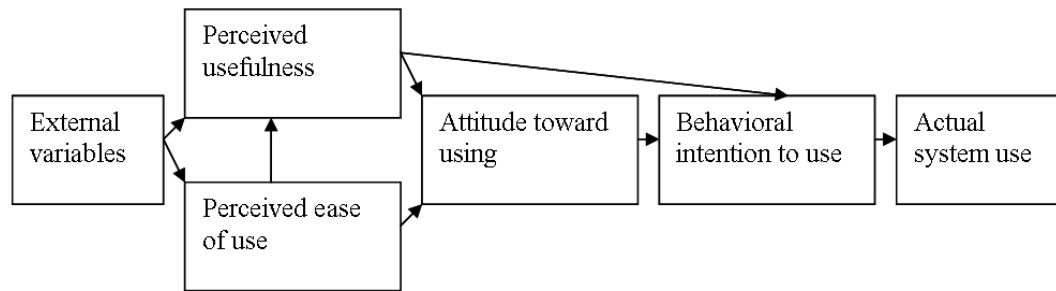
For the actual use of the CAT Fatigue RA, it is important that patients will not face any difficulties during its completion. The CAT is an Internet application that is intended to be used for PRO-monitoring in daily clinical practice and for research purposes. Patients gain access via their personal accounts of the Web-based Rheumatology Online Monitor Application (ROMA) that is used by many Dutch rheumatology units. Usually patients complete questionnaires on the Internet at home before their consultation at the rheumatology outpatient department. If a patient perceives filling in the CAT as difficult, not useful, or not enjoyable, the risk of drop out will be high.

Although many patients are already used to computer-based questionnaires, the completion of a CAT differs from filling in traditional fixed-length questionnaires. In a traditional questionnaire, patients see all questions immediately, and they have the opportunity to reread and to change answers. In contrast in a CAT, only one item at a time is provided on the screen, and often patients cannot skip forward or back [21]. This also means that patients cannot see how many or which items they already filled in and how many and which items are still left to complete.

In this study, patients filled in the CAT Fatigue RA in individual sessions while thinking aloud, and were subsequently interviewed on their experiences with the new instrument. Think aloud is a highly recommended method used to identify possible problems in measurement tools [22]. By combining the methods of think aloud and targeted interview questions, we aimed to identify all difficulties that patients could face while filling in

the CAT. The TAM model served as guideline to report the results.

Figure 1. Technology acceptance model.



Methods

Participants and Procedures

Participants were selected from a sample of patients that had participated in a previous study [11]. All participants who had indicated interest in the results of the study received a thank-you letter with information on the study outcomes. At the end of this letter, patients were informed on future studies, and that they could register per email for participation. In case of registration, the patients received an email with detailed information on the new study, and were asked for agreement to receive a telephone call to make an appointment for an individual session with the first author. The ethical review board of the University of Twente approved the study.

Except for one appointment at a participant's home, all sessions took place at the university. After receiving information on the study (eg, not the person, but the application will be tested), participants signed an informed consent and filled in some background questions. Then participants filled in the CAT while thinking aloud. In case a person forgot to articulate his or her thoughts, the researcher reminded him or her to do so. Finally, a brief interview on the CAT took place. The think aloud sessions and the interviews were recorded on audiotape. The travel costs for the participants were refunded.

Measures

Background Information

Participants answered background questions (gender, age, education, and work status), and gave disease-specific

information (disease duration, comorbidity, numerical rating scale; NRS, global health, pain, and fatigue). The NRSs had eleven points (ranging from 0 to 10) and the following anchors, very good/very poor, no pain/unbearable pain, no fatigue/totally exhausted.

Computer Adaptive Test Fatigue Rheumatoid Arthritis

The CAT item bank consists of 196 items and three dimensions; severity (13 items, example, *Did you feel tired during the last 7 days?*), impact (169 items, examples, *Have you felt down or dejected because of fatigue? During the past 7 days, I was too tired to do my most important tasks.*), and variability (14 items, example, *How did your fatigue change during the last 7 days?*). Each participant answered 20 questions, after which the CAT stopped automatically. It started with two random start-items per dimension, and always administered at least five items per dimension. These characteristics of the CAT were based on previous simulations in approximately 1000 virtual patients. This combination of numbers of items was found to be the most optimal solution in terms of test-length and measurement error on each dimension. Figure 2 shows an example screenshot of the CAT. The item with its response options is presented in the center of the screen. After answering the item, the patient can get to the next item by clicking on the yellow button. The blue bar shows the progress of the CAT administration by informing the patient which percentage of items is already filled in. The progress bar is part of the ROMA system and could be implemented because the CAT Fatigue RA has a fixed length of 20 items.

Figure 2. Screenshot of the CAT Fatigue RA.

Mijnroma.nl Vragen & uitleg Ingelogd als: [user] Uitloggen

ROMA
Testcentrum

NAVIGATIE: Home Polikliniek POEET PROs

Voelde u zich vermoeid gedurende de laatste 7 dagen?

nooit
 zelden
 soms
 meestal
 altijd

Verder >

Voortgang van deze vragenlijst: 5% Geschatte eindtijd bezoek: onbekend

Thinking Aloud

The method of think aloud is the most prominent user-based usability method [22]. Participants are asked to state directly what they think, while completing a certain task using an application. This gives immediate insight into cognitive processes; whereas retrospective reports on thought processes imply the danger of losing information due to censoring and distortion. The usability tester should intervene with the participants thought process as little as possible. However, it is accepted to remind a participant to keep talking. Furthermore, it is important to conduct a think aloud study with a

representative subject sample, meaning those people who will finally use the application. The think aloud approach is a good method to identify usability problems. It can detect deficiencies of the system, and also provides insight into the reasons why users experience certain deficiencies as a problem [22].

Interviews

After completing the CAT Fatigue RA, participants were asked about their experience with, and opinions on, the new measurement instrument, according to the interview scheme shown in [Textbox 1](#).

Textbox 1. Interview scheme. CAT: computerized adaptive test.

1. How did you experience completing the instrument?
2. What do you think about the successive administration of only one item per screen?
3. Did you notice that the response formats changed? What do you think about that?
4. How well could you read the questions? What do you think about letter size, colors, etc?
5. Did you notice the progress bar? What do you think about it?
6. What do you think about the length of the test/the number of questions?
7. Do you have any further comments about the CAT, did you notice anything else?

Analyses

The audio material (think aloud sessions and interviews) was transcribed verbatim. The interview material was sorted per interview question. The comments from the think aloud part were sorted per participant. To thoroughly analyze the data, a code scheme was developed in a combination of bottom-up (search for meaningful units in the transcripts) and top down (guided by TAM) methods by reading the transcripts in detail [22]. For each interview question, and for the think aloud material, topics with subcodes were identified and assigned to the transcripts. Topics that were mentioned in the interview material, as well as in the think aloud material, were not coded in the interview material, but reported together with the think

aloud material to prevent double codes. The coding process was conducted in consensus between the first two authors.

Results

The Participants

There were six men and nine women diagnosed with RA that participated. Mean age was 56.13 years (SD 10.82) and mean disease duration was 12.40 years (SD 7.18). An overview about the participants and further patient characteristics are shown in Table 1.

The results of the think aloud sessions and the interviews will be reported in terms of the TAM and illustrated by quotes.

Table 1. Overview of participants.

Participant	Gender	Age, years	Education	Work	Disease duration, years	Comorbidity	NRS health ^f	NRS pain ^g	NRS fatigue ^h
1	F ^b	45	High ^c	Full-time	24	Yes	3	2	7
2	F ^b	49	High ^c	Full-time	15	Yes	7	5	6
3	F ^b	46	High ^c	Part-time	20	No	7	7	7
4	F ^b	66	Moderate ^d	Retired	6	No	4	6	7
5	F ^b	69	Moderate ^d	Retired	23	No	2	1	3
6	M ^a	59	High ^c	Part-time	10	No	6	4	3
7	M ^a	54	Moderate ^d	Disabled	10	No	5	5	8
8	F ^b	63	Low ^e	Household	5	Yes	4	4	5
9	F ^b	62	Moderate ^d	Retired	13	No	5	6	9
10	M ^a	71	Low ^e	Retired	3	No	0	0	1
11	F ^b	60	High ^c	Full-time	23	Yes	2	1	6
12	F ^b	63	Low ^e	Household	7	No	7	8	8
13	M ^a	60	Low ^e	Full-time	11	No	3	2	5
14	M ^a	40	Moderate ^d	Disabled	12	No	6	6	7
15	M ^a	35	Moderate ^d	Disabled	4	No	3	6	5
Mean		56.13			12.40		4.27	4.20	5.80
SD		10.82			7.18		2.12	2.46	2.18

^aM=male

^bF=female

^cHigh, more than 14 years of education

^dModerate, 13-14 years of education

^eLow, 12 or less years of education

^fNRS health, 0 = very good and 10 = very poor

^gNRS pain, 0 = no pain and 10 = unbearable pain

^hNRS fatigue, 0 = no fatigue and 10 = totally exhausted

Perceived Ease of Use

There were 80% of the participants (12 out of 15) that said that they experienced the CAT as clear and/or easy to complete. There were 87% of the participants (13 out of 15) that regarded

it as advantageous to fill in only one question per screen, as it improved clarity. They found this presentation of items clear and well organized, making it easier to concentrate on the question and being really engaged in answering it. It was argued that too many questions at the same time can be overwhelming

or cluttered, and with more simultaneous questions, people have the tendency to look ahead at the next question.

Quite clear, good. Yes, because of course you shouldn't let yourself be tempted to read all the questions as quickly as possible because that is a mistake people often make, that they just immediately do everything, and then they maybe do not give a truly orientated answer. [Participant 7]

Only two of the 15 participants reported that the presentation of only one item per screen did not really matter to them.

However, concerns also emerged related to this way of item presentation. In two thirds of the sessions, the CAT selected three or four of the following items of the dimension severity, Item 2, *During the last 7 days I felt tired.*; Item 3, *During the last 7 days I felt fatigued.*; Item 5, *Did you feel tired during the last 7 days?*; and Item 8, *Did you feel fatigued during the last 7 days?*. Most of the concerned participants (7 out of 10) were wondering whether the CAT provided the same question more than once, because to them the items looked very much alike. Due to the fact that it is not possible to scroll forward or backwards in the CAT, they became confused whether they had previously answered the item or not, and two of the seven participants indicated that they felt not able to answer in a consistent way.

All but one participant recognized that not all items had the same response options. There were 40% of the participants (6 out of 15) that said that they did not mind, it was no problem, and it did not distract them. There were two thirds of the participants that mentioned that it was advantageous that not all items had the same response options. In this way, items and response options match well with each other, which improves clarity. It was also argued that changing response options prevents people from always giving the same answer. Only one participant mentioned that it can be difficult to switch from one response format to another, however, this participant also reported having learned to fill in this kind of questions without thinking about them too long. All participants described the readability of the questions as clear, good, or comfortable to look at.

Regarding test-length, all participants were positive. They reported that the CAT was quick to complete, and they experienced the CAT as a clear and brief instrument, also in comparison to other measurement instruments. Moreover, for 40% of the participants (6 out of 15), the number of questions turned out smaller than they had expected. In general, participants described the test-length of the CAT as great, clearly better than expected, brief, or to the point.

Perceived Usefulness

There were 40% of the participants (6 out of 15) that declared that they regarded the CAT as useful, for example, one participant considered the CAT to be a nice questionnaire with relevant questions.

(...) they are relevant questions, they are also much more focussed and clear questions, so I think it is a nice questionnaire (...) it really goes into fatigue and in a good way. So yes, I found it surprising, a surprising thing to do. Then it gives me more the notion that it is worthwhile to complete. You can enter, I was tired lately, the last 7 days, yes, the last month, but that says so little about fatigue. [Participant 11]

There was one person that reflected on the adaptive testing mechanism.

What I really noticed was that if I had completed a question, that the computer sometimes took longer to get to the next question, and then I think, yes, that is logical, because then it is choosing the next question after all. (...) they are going to select which question fits with the answer to your previous question. I found it quite pleasant this way. [Participant 5]

This person was of the opinion that the questions were useful, having good response options. There were 20% of the participants (3 out of 15) that criticized that not all questions were applicable to each patient (eg, being too fatigued to do voluntary work).

Perceived Enjoyment

Completing the CAT, and the successive administration of only one item per screen, was experienced as pleasant, nice, great, excellent, or positive by two thirds of the participants. Furthermore, 40% (6 out of 15) described the progress bar as pleasant, great, useful, or comforting. There were 53% of the participants (8 out of 15) that liked the possibility of estimating their progress in completing the CAT; mostly the progress bar was recognized immediately.

A participant described it as pleasant that it did not take a lot of time to fill in the CAT. There were one third of the participants (5 out of 15) that were said to be glad with research into fatigue, and liked to support it through their participation. There were two participants that noted that it had been pleasant to fill in the CAT.

Please continue this because it is very nice. (...) I found it very nice after many years' experience with ROMA and especially with the paper questionnaires. In the past I occasionally completed one of those things every two months. And then you think, aaaach, you really get to take such a pile of homework with you. So, no, it was very nice. [Participant 11]

There were two other participants that also reported enjoying the idea that the CAT is testing adaptively.

To provide an overview about the different topics that are inherent to the use of a CAT in relation to those that are also inherent to Internet questionnaires in general, we summarized the main results in [Table 2](#).

Table 2. Usability topics and their specificity to CAT.

Topic	Participants, N=15, n (%)	CAT specific/Internet fatigue measurement
Clear and/or easy to complete	12 (80)	Concerns CAT and Internet measurement
One question per screen		CAT specific
Advantageous	13 (87)	
Did not matter	2 (13)	
Similar formulated items in two thirds (N=10) of the administrations		CAT specific
Confusion	7 (70)	
No comment	3 (30)	
Different response options, N=15		CAT specific
Positive opinion	15 (100)	
Good readability	15 (100)	Specific to Internet measurement
Good test-length	15 (100)	Concerns CAT and Internet measurement
Usefulness	6 (40)	Concerns CAT and Internet measurement
Criticism about not applicable items	3 (20)	CAT specific
Enjoyment	14 (93)	Concerns CAT and Internet measurement

Discussion

Usability of the Computer Adaptive Test

This study investigated the usability of the first version of the CAT Fatigue RA in a sample of its end users. Overall, the CAT was positively evaluated. It was described as easy to use, clear, and brief. Also some participants reported to perceive the CAT as a useful instrument, and appreciated the idea of the adaptive test mechanism. Participants reported pleasure while filling in the CAT. However, usability problems were also identified regarding similarity between items and the general applicability of some items.

Several elements are important for acceptance of new technology and actual use of a system. The perceived ease of use of the CAT was supported by this study. All participants described reading the questions as clear and good, and were positive about test-length. They said that the CAT was quick and easy to complete. Moreover, it was argued that changing response options prevents people from always giving the same answer. Nearly all participants appreciated the successive presentation of one item on the screen at a time, as it improves clarity and makes it easier to concentrate on the question.

The item presentation in the CAT gave participants less control during completion than they would have had while filling in a traditional questionnaire. Since there is no opportunity to skip forward or backwards, it is impossible to see all questions at the same time, answer them in a flexible order, or review and change already given answers [21]. Our results, however, give a first indication that end-users might experience filling in one item at a time as an advantage of a CAT.

Item Formulation

Regarding item formulation, participants reported that four items in the severity dimension were formulated in a very similar way. As they could not skip back within the CAT, they were

wondering whether the CAT presented items twice. To prevent a person feeling confused by these items while filling in the CAT, the first version of the CAT was adapted. Before the start of the instrument, a brief introduction has now been included. Therewith, patients are informed that some items may seem similar. In this way, it should be prevented that people will become distracted from filling in the CAT attentively, or that they might feel uncomfortable because they feel unable to answer in a consistent way. Another solution of this usability problem might be a more sophisticated algorithm that is able to recognize similar items, and consequently would avoid presenting them within one administration. However, then, usability issues might conflict with the selection of the best item in psychometric terms.

Useful Instrument

Nearly half of the participants reported to perceive the CAT as a useful instrument. They emphasized that the CAT contained relevant and clear questions that cover patients' fatigue experience. Furthermore, participants liked the idea of the adaptive test mechanism, and to receive items matched to their individual level of fatigue. Since participants were not explicitly asked about the usefulness of the CAT, this result is of special interest. Probably a higher percentage of participants had supported the usefulness of the CAT if a precise question about this topic had been included in the interview scheme.

However, some participants mentioned that not all questions were applicable to every patient. As a consequence, the response option "not applicable" was added to six items in the next version (eg, items about the impact of fatigue on work, cooking, or driving the car). When the "not applicable" option is chosen, the CAT receives no information for the fatigue estimation through this item, and will select the next optimal item for that particular patient as a substitute. In general, a comparable method might also be used to enable a skip forward function in a CAT. This could be useful in situations where it is adequate

to give patients the possibility to skip questions they do not want to answer, for example, regarding private information. However, then an adequate way would be needed to communicate the option to skip items to patients without stimulating them to actually do this. Otherwise, too much loss of information might be the consequence. In the CAT Fatigue RA, a skip forward option does not seem necessary since the item pool has carefully been developed with a Delphi approach [23], and none of the participants of this usability study indicated the wish to leave an item unanswered.

Technology acceptance is also related to perceived enjoyment. Participants perceived completing the CAT as a pleasant experience. They enjoyed answering successively one item on the screen at a time, and liked the progress bar, as it informed them on their completion progress. Other positive remarks explicitly referred to the idea that the CAT is testing adaptively.

Conclusions

The TAM turned out to be an adequate guideline to study the usability of the CAT Fatigue RA. Most participants reported to perceive the CAT as easy to use, and nearly half of the participants expressed that they perceived the CAT as useful. Perceived usefulness is of special importance for acceptance and use of new technology, and might be partly explained by the perceived ease of use [17]. We also found evidence for the role of perceived enjoyment [19] in this study. The combination of perceived ease of use, usefulness, and enjoyment, point to good acceptance and use of the CAT Fatigue RA when administered via the ROMA system in daily clinical practice in the future. Previous studies also reported a satisfactory acceptance of CAT in health care [14-16]. Furthermore, our results give a first indication that CAT methodology may outperform traditional questionnaires not merely on measurement precision, but also on usability and acceptance valuation.

This usability test provided important insights for further research with CATs. Similar formulated items and items that might not be applicable to each participant are typical issues that may be faced when implementing a CAT technology into practice. From a theoretical viewpoint, it is beneficial to include as many items as possible in the CAT item bank. Items that are similar to each other may also be useful, as they can be selected to measure very precisely at a certain level of fatigue. However, for the user, this rationale is not always clear, and may lead to usability problems. The same applies to an item bank with items that have no “not applicable” options. CAT was originally developed for educational and assessment purposes, where “not applicable” options are not appropriate. Adopting this technology into the health care context poses new usability questions.

This study has shown that the technology of CAT was well accepted by those who are intended to use it. The method of thinking aloud in combination with a consecutive interview on

the participants' experiences with the CAT has proven to be effective in uncovering usability problems, and thereby provided the opportunity to further improve the CAT. However, it cannot be ruled out that only those patients registered for the study who were already relatively familiar with using the computer. A small group of patients without computer experience [24,25] might possibly perceive using the CAT as less easy, less useful, and less enjoyable than the current sample that was between 35 and 71 years of age. Furthermore, in the think aloud part of the study, some participants had difficulties in distinguishing between issues regarding the CAT, issues on item level, and their personal situation. Some participants wanted to tell their personal stories, while others experienced the CAT as so easy to fill in that they could hardly find anything to comment on. This might be explained by the fact that many of the participants were already used to computer-based questionnaires. That no comments emerged on layout issues might also be related to the participants' familiarity with ROMA, and the fact that it is a well established Web application that has already been in use for many years. The CAT runs in the same Web environment as ROMA, using the same colors and letter types. This points to the importance of layout familiarity in broad use of computer-based testing.

A possible field for future research on the CAT Fatigue RA is the development of a CAT version with a flexible stopping rule that ends the item administration in cases when a certain measurement precision is reached before 20 items have been administered. This could lead to even more efficient measurement. However, the realization is challenging because the standard error on the separate dimensions does not always decrease monotonously as in a unidimensional CAT. Such nonmonotone progress of the standard error is inherent to the multidimensional CAT algorithm that takes information into account of all three dimensions at the same time. Future research should make clear which possibilities are available for our CAT regarding a flexible stopping rule.

To conclude, the CAT Fatigue RA turned out to be perceived as an easy and useful measurement instrument that was also enjoyed by participants. This study provided insight into usability problems, leading to adaptations to the CAT. Moreover, participants described usability aspects that exceed traditional questionnaires. Next questions concerning the usability of CAT methodology are related to attractiveness of adaptive measurement in the long run. It is possible that the initial enthusiasm for this innovative measurement instrument will decrease when patients use the CAT on a regular basis and also for different purposes. However, there is a good chance that CATs will remain attractive since patients receive different items each time, which prevents boredom and predictability. However, it might also be imaginable that those different items provoke scepticism about the comparability of CAT scores of repeated measures and/or between persons. These topics have to be examined in detail in future research.

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Conflicts of Interest

None declared.

References

1. van der Vaart R, Drossaert CH, de Heus M, Taal E, van de Laar MA. Measuring actual eHealth literacy among patients with rheumatic diseases: A qualitative analysis of problems encountered using Health 1.0 and Health 2.0 applications. *J Med Internet Res* 2013;15(2):e27 [FREE Full text] [doi: [10.2196/jmir.2428](https://doi.org/10.2196/jmir.2428)] [Medline: [23399720](https://pubmed.ncbi.nlm.nih.gov/23399720/)]
2. Aletaha D, Neogi T, Silman AJ, Funovits J, Felson DT, Bingham CO, et al. 2010 Rheumatoid arthritis classification criteria: An American College of Rheumatology/European League Against Rheumatism collaborative initiative. *Arthritis Rheum* 2010 Sep;62(9):2569-2581 [FREE Full text] [doi: [10.1002/art.27584](https://doi.org/10.1002/art.27584)] [Medline: [20872595](https://pubmed.ncbi.nlm.nih.gov/20872595/)]
3. Tack B. Fatigue in rheumatoid arthritis. Conditions, strategies, and consequences. *Arthritis Care Res* 1990 Jun;3(2):65-70. [Medline: [2285744](https://pubmed.ncbi.nlm.nih.gov/2285744/)]
4. Hewlett S, Cockshott Z, Byron M, Kitchen K, Tipler S, Pope D, et al. Patients' perceptions of fatigue in rheumatoid arthritis: Overwhelming, uncontrollable, ignored. *Arthritis Rheum* 2005 Oct 15;53(5):697-702 [FREE Full text] [doi: [10.1002/art.21450](https://doi.org/10.1002/art.21450)] [Medline: [16208668](https://pubmed.ncbi.nlm.nih.gov/16208668/)]
5. Repping-Wuts H, Uitterhoeve R, van Riel P, van Achterberg T. Fatigue as experienced by patients with rheumatoid arthritis (RA): A qualitative study. *Int J Nurs Stud* 2008;45(7):995-1002. [doi: [10.1016/j.ijnurstu.2007.06.007](https://doi.org/10.1016/j.ijnurstu.2007.06.007)]
6. Nikolaus S, Bode C, Taal E, van de Laar MA. New insights into the experience of fatigue among patients with rheumatoid arthritis: A qualitative study. *Ann Rheum Dis* 2010 May;69(5):895-897. [doi: [10.1136/ard.2009.118067](https://doi.org/10.1136/ard.2009.118067)] [Medline: [19854716](https://pubmed.ncbi.nlm.nih.gov/19854716/)]
7. Hewlett S, Chalder T, Choy E, Cramp F, Davis B, Dures E, et al. Fatigue in rheumatoid arthritis: Time for a conceptual model. *Rheumatology (Oxford)* 2011 Jun;50(6):1004-1006 [FREE Full text] [doi: [10.1093/rheumatology/keq282](https://doi.org/10.1093/rheumatology/keq282)] [Medline: [20819797](https://pubmed.ncbi.nlm.nih.gov/20819797/)]
8. Nikolaus S, Bode C, Taal E, van de Laar MA. Fatigue and factors related to fatigue in rheumatoid arthritis: A systematic review. *Arthritis Care Res (Hoboken)* 2013 Jul;65(7):1128-1146. [doi: [10.1002/acr.21949](https://doi.org/10.1002/acr.21949)] [Medline: [23335492](https://pubmed.ncbi.nlm.nih.gov/23335492/)]
9. Chauffier K, Salliot C, Berenbaum F, Sellam J. Effect of biotherapies on fatigue in rheumatoid arthritis: A systematic review of the literature and meta-analysis. *Rheumatology (Oxford)* 2012 Jan;51(1):60-68 [FREE Full text] [doi: [10.1093/rheumatology/ker162](https://doi.org/10.1093/rheumatology/ker162)] [Medline: [21515629](https://pubmed.ncbi.nlm.nih.gov/21515629/)]
10. Hewlett S, Ambler N, Almeida C, Cliss A, Hammond A, Kitchen K, et al. Self-management of fatigue in rheumatoid arthritis: A randomised controlled trial of group cognitive-behavioural therapy. *Ann Rheum Dis* 2011 Jun;70(6):1060-1067 [FREE Full text] [doi: [10.1136/ard.2010.144691](https://doi.org/10.1136/ard.2010.144691)] [Medline: [21540202](https://pubmed.ncbi.nlm.nih.gov/21540202/)]
11. Nikolaus S, Bode C, Taal E, Oostveen JC, Glas CA, van de Laar MA. Items and dimensions for the construction of a multidimensional computerized adaptive test to measure fatigue in patients with rheumatoid arthritis. *J Clin Epidemiol* 2013 Oct;66(10):1175-1183. [doi: [10.1016/j.jclinepi.2013.05.010](https://doi.org/10.1016/j.jclinepi.2013.05.010)] [Medline: [23958376](https://pubmed.ncbi.nlm.nih.gov/23958376/)]
12. Swaminathan H, Hambleton R. Fundamentals of item response theory. Newbury Park [CA]: Sage Publications; 1991.
13. Segall DO. Principles of multidimensional adaptive testing. In: Linden WJVD, Glas C, editors. Elements of adaptive testing. New York: Springer; 2010:57-75.
14. Fliege H, Becker J, Walter OB, Rose M, Bjorner JB, Klapp BF. Evaluation of a computer-adaptive test for the assessment of depression (D-CAT) in clinical application. *Int J Methods Psychiatr Res* 2009;18(1):23-36. [doi: [10.1002/mpr.274](https://doi.org/10.1002/mpr.274)] [Medline: [19194856](https://pubmed.ncbi.nlm.nih.gov/19194856/)]
15. Turner-Bowker DM, Saris-Baglama RN, Smith KJ, DeRosa MA, Paulsen CA, Hogue SJ. Heuristic evaluation and usability testing of a computerized patient-reported outcomes survey for headache sufferers. *Telemed J E Health* 2011;17(1):40-45 [FREE Full text] [doi: [10.1089/tmj.2010.0114](https://doi.org/10.1089/tmj.2010.0114)] [Medline: [21214341](https://pubmed.ncbi.nlm.nih.gov/21214341/)]
16. Anatchkova M, Rose M, Ware J, Bjorner JB. Evaluation of a role functioning computer adaptive test (RF-CAT). *Qual Life Res* 2013 Jun;22(5):1085-1092. [doi: [10.1007/s11136-012-0215-6](https://doi.org/10.1007/s11136-012-0215-6)] [Medline: [22695829](https://pubmed.ncbi.nlm.nih.gov/22695829/)]
17. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly* 1989 Sep;13(3):319-340. [doi: [10.2307/249008](https://doi.org/10.2307/249008)]
18. Chen SC, Li SH, Li CY. Australian Journal of Business and Management Research. 2001. Recent related research in technology acceptance model: A literature review URL: http://www.ajbmr.com/articlepdf/AJBMR_19_04i1n9a14.pdf [accessed 2014-11-28] [WebCite Cache ID 6UQG9pWWM]
19. van der Heijden H. MIS Quart. 2004. User acceptance of hedonic information systems URL: <http://misq.org/user-acceptance-of-hedonic-information-systems.html?SID=7681gmr0quc4ch9iofud8kqnv1> [accessed 2014-11-28] [WebCite Cache ID 6UQGJ0TCB]

20. Davis FD, Bagozzi RP, Warshaw PR. Extrinsic and intrinsic motivation to use computers in the Workplace. *J Appl Social Psychol* 1992 Jul;22(14):1111-1132. [doi: [10.1111/j.1559-1816.1992.tb00945.x](https://doi.org/10.1111/j.1559-1816.1992.tb00945.x)]
21. Wise SL, Kingsbury GG. *Psicologica*. 2000. Practical issues in developing and maintaining a computerized adaptive testing program URL: <http://www.uv.es/revispsi/articulos/ly2.00/wise.pdf> [accessed 2014-11-28] [[WebCite Cache ID 6UQGSWgHO](#)]
22. Jaspers MW. A comparison of usability methods for testing interactive health technologies: Methodological aspects and empirical evidence. *Int J Med Inform* 2009 May;78(5):340-353. [doi: [10.1016/j.ijmedinf.2008.10.002](https://doi.org/10.1016/j.ijmedinf.2008.10.002)] [Medline: [19046928](#)]
23. Nikolaus S, Bode C, Taal E, vd Laar MA. Selection of items for a computer-adaptive test to measure fatigue in patients with rheumatoid arthritis: A Delphi approach. *Qual Life Res* 2012 Jun;21(5):863-872. [doi: [10.1007/s11136-011-9982-8](https://doi.org/10.1007/s11136-011-9982-8)] [Medline: [21805365](#)]
24. Or CK, Karsh BT. A systematic review of patient acceptance of consumer health information technology. *J Am Med Inform Assoc* 2009;16(4):550-560 [[FREE Full text](#)] [doi: [10.1197/jamia.M2888](https://doi.org/10.1197/jamia.M2888)] [Medline: [19390112](#)]
25. Barbosa Neves B, Amaro F. *The Journal of Community Informatics*. 2012. Too old for technology? How the elderly of Lisbon use and perceive ICT URL: <http://ci-journal.net/index.php/ciej/article/view/800/904> [accessed 2014-11-28] [[WebCite Cache ID 6UQGXrdtG](#)]

Abbreviations

CAT: computer adaptive testing/computerized adaptive test
IRT: item response theory
NRS: numerical rating scale
PEOU: perceived ease of use
PRO: patient reported outcomes
PU: perceived usefulness
RA: rheumatoid arthritis
ROMA: Rheumatology Online Monitor Application
TAM: technology acceptance model

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