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# Considerations for the design of safe and effective consumer health IT applications in the home

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## ABSTRACT

**Introduction** Consumer health IT applications have the potential to improve quality, safety and efficiency of consumers' interactions with the healthcare system. Yet little attention has been paid to human factors and ergonomics in the design of consumer health IT, potentially limiting the ability of health IT to achieve these goals. This paper presents the results of an analysis of human factors and ergonomics issues encountered by five projects during the design and implementation of home-based consumer health IT applications.

**Methods** Agency for Healthcare Research and Quality-funded consumer health IT research projects, where patients used the IT applications in their homes, were reviewed. Project documents and discussions with project teams were analysed to identify human factors and ergonomic issues considered or addressed by project teams. The analysis focused on system design and design processes used as well as training, implementation and use of the IT intervention.

**Results** A broad range of consumer health IT applications and diverse set of human factors and ergonomics issues were identified. The design and implementation processes used resulted in poor fit with some patients' healthcare tasks and the home environment and, in some cases, resulted in lack of use. Clinician interaction with patients and the information provided through health IT applications appeared to positively influence adoption and use.

**Conclusions** Consumer health IT application design would benefit from the use of human factors and ergonomics design and evaluation methods. Considering the context in which home-based consumer health IT applications are used will likely affect the ability of these applications to positively impact the quality, safety and efficiency of patient care.

## INTRODUCTION

Over the last decade, the healthcare industry has recognised patients' changing role as consumers of health information and their increased use of health IT to support patient-provider communication and patient-centred care.<sup>1</sup> Consumer health IT applications have the potential to improve care delivery, empower patients to be active participants in their care and support health management activities—key components of patient-centred care, which the Institute of Medicine has identified as important to ensuring quality and patient safety.<sup>2</sup> While health IT has been demonstrated to improve patient safety and quality of healthcare provided in clinical settings, realising the potential quality and safety benefits of consumer health IT interventions

rests on several factors: (a) the interventions are designed to 'fit' consumers and the environment in which they will use them, (b) consumers adopt and effectively use the interventions, and (c) structured evaluation measures exist to assess the impact of the interventions on quality and safety.<sup>3–4</sup>

Consumer health IT applications are electronic information and communication technology applications that individuals use to improve their health outcomes and/or participate in healthcare decision-making processes.<sup>5</sup> Examples include in-home monitoring, disease management, self-management and web-based portals that give patients access to information from their provider's medical record system.<sup>6</sup>

Similar to clinical health IT applications, consumer health IT applications have been developed using a technology-push approach, which does not allow developers to design applications appropriate for the home environment or understand their impact following implementation.<sup>7–10</sup> Lack of fit between clinical health IT systems and their users, as well as their users' work environment, can create inefficiencies and facilitate error risks that could lead to decreased patient safety.<sup>11–12</sup>

In addition, poor design processes affect adoption and appropriate use of consumer health IT applications, and create barriers that may hinder user acceptance and limit overall use.<sup>13</sup> Jimison *et al*, for example, found several barriers to consumer use of interactive health IT, including lack of a perceived benefit; lack of fit with users' normal daily routines; overly cumbersome data entry; low clinician participation; lack of fit between the application's recommendation and the patient's mental model; technical issues; and limited access to the technology needed to use the application.<sup>6</sup> Barriers to the adoption and appropriate use of clinical health IT systems that have led to negative impact on clinician workflow, quality and patient safety have been well documented.<sup>11–14–17</sup>

The field of human factors and ergonomics provides a structured evaluation framework to guide the design and implementation of consumer health IT applications, which can then influence the adoption and appropriate use of these systems and ensure that they can be used to improve healthcare quality.<sup>18</sup> Specifically, human factors and ergonomics methods and approaches can assist with understanding the tasks required for individuals to take care of themselves and use the IT solution; understanding user needs and preferences; assessing users' physical and cognitive abilities; and ensuring the context and environment in which the technology is being used are taken into account.<sup>19</sup> For example, human factors and ergonomics methods and techniques are increasingly applied to

## Original research

the study of the impact of clinical health IT systems to better understand healthcare patterns of communication and workflow that contribute to system inefficiencies, poor quality and safety risks.<sup>14–20</sup>

This article focuses on the grants funded by the Agency for Healthcare Research and Quality (AHRQ) through its Health IT Portfolio that developed a consumer health IT intervention for use by patients and/or care givers in the home.<sup>21–22</sup> The authors used multiple methods to capture human factors and ergonomics issues considered or faced by AHRQ grantees during the design and implementation stages of home-based consumer health IT applications.

## METHODS

The authors examined AHRQ grants funded under the Transforming Health Care Quality through the Health IT (THQIT) initiative.<sup>21–22</sup> Project abstracts and applications were reviewed to determine which projects included an IT intervention intended for use by patients and/or their families and care givers. Grants were further screened to identify projects where patient use of the IT intervention occurred primarily in the home. The authors defined the home environment as private residences, such as apartment-type dwellings and freestanding units, but not more structured facilities such as nursing homes and assisted living communities.<sup>23</sup>

For selected projects, the authors conducted an in-depth review of the original grant application, subsequent interim status and final reports, and available publications. The grant documents were reviewed for background information on the project; system design and design processes used; and reported information on training, implementation and use of the IT intervention. Background review focused on the type of health IT intervention, its purpose and platform, the target population for the project, whether the system was currently live and the setting in which the system was expected to be or was used. System design and process review focused on IT application development (in house or vendor), customisability, requirements criteria, IT application piloting or prototype testing, and the extent of contextual influence on the design or purchase of the application. Finally, the authors reviewed whether training or educational materials were provided to users, application implementation and system use.

Following the document review, open-ended discussions were scheduled with project investigators and/or study coordinators

to clarify items abstracted from the grant documents. During the telephone discussions with grantees, the researchers took detailed notes, which were enhanced and annotated following the conversations.

Documents and discussion notes were analysed to understand which human factors issues were considered or faced by grantees during design, implementation and use of the health IT applications. In particular, the authors looked for commonalities and differences across projects and the extent to which they might be affected by the type of application and target population.

## RESULTS

### Projects, health IT interventions and user populations

Five AHRQ-funded projects implemented consumer health IT applications that targeted patients' home use. Of these, two were developed specifically for home use as part of the patients' usual health monitoring and management. One was developed for patients to share medical information with physicians after leaving the hospital. The remaining two were web-based and could potentially be used from the home as well as from other remote locations with internet access. Four of the applications were commercial solutions, while a fifth application started as a manual, homegrown process for information gathering and was later integrated with a commercial electronic health record (EHR) system. Table 1 summarises the health IT applications used in the selected projects.

Projects 1 and 2 in table 1 included clinician feedback. Information entered into the IT system was sent to the clinician for either immediate response or review with the patient during the next visit. In particular, the interactive voice response (IVR) system would generate reports at the clinician's office every time the patient submitted personal data (ie, blood pressure, weight). Projects 1, 2 and 4 included care management components as part of the intervention.

As also shown in table 1, all but one of the projects targeted patients with chronic diseases. Project 5 focused on premature infants with complex medical needs and at risk for neurodevelopmental disorders. Projects 2 and 5—IVR and PDHR—focused specifically on patients in rural settings.

### Human factors and ergonomics considerations

#### Design considerations

Because all five grants were research projects, the investigators had specific functionality in mind when selecting vendor products or

**Table 1** Consumer health IT interventions, target population, users and healthcare settings

Project	IT application	Medical devices used	Target population	Home users	Other users	Healthcare settings involved
1	Videophone and Camcorder or Digital Camera	<ul style="list-style-type: none"> <li>▶ Glucometer</li> <li>▶ Blood pressure monitor</li> <li>▶ Scale</li> </ul>	Elderly, Medicare beneficiaries with chronic wounds	<ul style="list-style-type: none"> <li>▶ Patients</li> <li>▶ Care givers (spouse or son/daughter)</li> <li>▶ Home health staff</li> </ul>	<ul style="list-style-type: none"> <li>▶ Wound-care specialists</li> <li>▶ Diabetes educators</li> <li>▶ Clinicians</li> </ul>	<ul style="list-style-type: none"> <li>▶ Home health agencies</li> <li>▶ Long-term care facilities</li> </ul>
2	Interactive Voice Response System and Modem	<ul style="list-style-type: none"> <li>▶ Glucometer</li> <li>▶ Blood pressure monitor</li> <li>▶ Scale</li> </ul>	Older, medium- and high-risk congestive heart-failure patients	<ul style="list-style-type: none"> <li>▶ Patients</li> <li>▶ Care givers</li> </ul>		<ul style="list-style-type: none"> <li>▶ Primary care clinics (across four states)</li> </ul>
3	Tethered Personal Health Record (focus on secure messaging)		General adult patient population and subsamples for: (1) depression, (2) diabetes and (3) congestive heart failure	<ul style="list-style-type: none"> <li>▶ Patients</li> <li>▶ Care givers or proxies</li> </ul>	<ul style="list-style-type: none"> <li>▶ Clinicians</li> </ul>	<ul style="list-style-type: none"> <li>▶ Primary care practices (affiliated with integrated delivery service networks)</li> </ul>
4	Tethered Personal Health Record with care management component	<ul style="list-style-type: none"> <li>▶ Glucometer</li> </ul>	Adult patients with diabetes	<ul style="list-style-type: none"> <li>▶ Patients</li> </ul>	<ul style="list-style-type: none"> <li>▶ Nurse managers</li> <li>▶ Primary care providers</li> </ul>	<ul style="list-style-type: none"> <li>▶ Primary care practices (affiliated with integrated delivery service networks)</li> </ul>
5	Portable Personal Developmental Health Record CD or DVD		Infants born prematurely at risk for neurodevelopmental problems	<ul style="list-style-type: none"> <li>▶ Patient representatives (parents or guardians)</li> </ul>	<ul style="list-style-type: none"> <li>▶ Physicians</li> <li>▶ Nurse practitioners</li> </ul>	<ul style="list-style-type: none"> <li>▶ Neonatal intensive care unit (public hospital)</li> <li>▶ Family medicine clinics</li> </ul>

developing the intervention. If working with a vendor, design considerations focused primarily on the functions offered by the vendor's product, the level of support offered and the ability to modify functions or features if needed. For example, one of the personal health record projects sought the capability for proxies to access information on the behalf of children under 13 years of age as well as geriatric patients. All of the projects focused on the content that could be stored or transmitted by the technology. For example, one project team asked for the health IT system to include information such as birth records, primary care records, hospital records and medications.

While all projects targeted patient populations or care givers with unique healthcare needs, two of them targeted older populations. These teams considered the unique needs of their users when interacting with devices and computers. For example, both project teams wanted their devices to automatically transmit patient information with the push of a single button. They understood from prior research that older populations may not be computer-savvy and would be unwilling to use a computer-like device. To incorporate users' needs, both teams worked closely with vendors to modify initial system designs. One team knew from prior research that their patients found early videophones frightening, so the team and the vendor developed a videophone that operated 'like a regular phone' and included a flip-down lid for privacy. Finding usable devices, however, was not always easy. One project team had not found a spirometer, used to measure pulmonary function, that was easy for patients with arthritis to operate. Another team was unable to locate extra large or extra small (eg, paediatric) blood pressure cuffs.

Project teams looked for flexibility from vendors. Patients used different models of glucometers, so teams needed to ensure the information from different models could easily be sent to the information system. One team also needed the commercial system to adjust for variance in care plans, ensuring that patients could transmit data no matter what combination of devices were installed in the home.

### Design approach, testing and prototyping

Study designs were examined to understand the design approach and to assess whether patients and/or care givers were involved in the selection or design of the system. Patient involvement varied from project to project, but most projects tried to gather feedback before deploying the technology. For example, when difficulties arose during initial use of the system, the IVR project stopped the study and used volunteers to test both the devices (eg, scale and blood pressure monitor) and the IVR system itself. Volunteers pilot-tested the equipment at home, revealing several issues with the system and the reports it generated. The project team subsequently asked the vendor to make revisions to minimise user error and provide better feedback.

Two of the projects used focus groups that influenced some of the technology's features (eg, ability to enter glucose readings or refine alerts provided to patients). Another project used patient focus groups in the early development of the system, focussing on the information being provided and usability testing of the interface. One of the project teams tested the telemonitoring technology during prior work and found video cameras were less expensive and worked better than medical device cameras. Two of the projects used continuous evaluation and iteration based on feedback from both patients and clinicians, which, for one of the personal health record (PHR) projects, resulted in the addition of a new feature to satisfy requests from patients, employers and purchasers.

### Implementation

Approaches for enrolling patients and/or offering patients the technology varied across projects. One of the PHR projects employed many strategies to boost enrolment, including making brochures and CDs available from clinic staff, purchasing advertisements on buses and prime-time television, instituting an incentive programme to enrol patients and asking clinicians to encourage patients to use secure messaging. The other PHR project enrolled patients through kiosks. Parents of premature infants at risk for neurodevelopmental disorders were asked at the time of discharge from the neonatal intensive care unit (NICU) if they wanted a personalised CD created for them.

Patients participating in the wound care project were enrolled through a home health service, but the wound care centre installed the equipment, including needed devices (ie, glucometer, blood pressure monitor, or scale), and provided training on use. The IVR system project enrolled patients discharged following an episode of care related to chronic heart failure (CHF). Equipment was sent to patients' homes after enrolment for self-installation. However, some participants encountered significant barriers, such as a lack of compatibility between the IVR and voice-over internet protocol (VOIP) or cellular phones. The project team found that some patients did not have the device installed 30–60 days after receiving it. Because patients were dispersed over a large geographic area, home visits to install the devices were delayed, and researchers eventually contracted for that service.

### Training and support

All projects provided patients with training or user manuals. The approaches varied from project to project. One of the projects using a PHR allowed patients to view a demonstration from the provider's website to learn how the portal worked. Another project developed training guides for patients, providers and patient service representatives, and distributed training materials to the patients directly. The vendor for a third project sent the device to the home and provided installation instructions. A fourth project provided training to family members on how to use, update and access the technology. The last project provided training at the point of installation; furthermore, patients were given training on how to use a glucometer and were referred to a diabetes educator.

All projects provided IT support for their patients to address questions or problems while using the technology. IT support methods included providing a 24 h help desk, secure messaging to clinic staff, technical assistance by project (study team) staff and phone support through a vendor.

### Use

Four of the five projects reported information on adoption and use. The two PHR projects examined which patients used secure messaging or portal features, respectively. Both found that use varied with patient characteristics and was influenced by clinicians' engagement.<sup>24</sup> Applications were used more commonly by female patients who were chronically ill. While elderly patients did use secure messaging, in some instances their proxies or care givers were the main users of the PHR. The second PHR study found that race, education and prior internet use influenced adoption and use. Access to broadband internet also influenced use. Information often did not download fast enough for dial-up users, which resulted in fewer dial-up adopters than broadband.

In the two telemonitoring projects, the context of home use influenced people's ability to operate the technology and determined how it was used or whether any changes were needed.

For the IVR project, researchers found some participants had no phone outlets in the bedroom or bathroom, or had rotary phones that could not be used to transmit weight and other data. Outlets and phone lines were installed where needed or touch-tone phones provided to accommodate those participants. Other patients were homeless or transient, so phones were set up where they worked or at other locations. Finally, Native American participants shared common homes; therefore, the phone system was set up at a clinic where participants would go daily to use the devices.

The way in which some daily health-management tasks were conducted affected how the technology was set up and used. For example, depending on the location of the phone and the room in which patients kept their medical device, (eg, scale), some patients had to tape the modem's cable along the wall from the kitchen to the bedroom. One patient in the wound care study wrote down weights and called them into the provider later because of the distance between the scale and the phone outlet. In addition, when using scales, several patients failed to recognise that scales perform differently when placed on carpet than on flat surface flooring. Elderly patients who needed assistance to walk often had trouble standing still long enough to record an accurate weight measurement.

Patient responses to problems while using the technology varied. Some refused the home devices as soon as they received them. For some participants, if the technology failed once or twice, they no longer wanted the device. Others vented their frustration regarding the need to frequently replace batteries (and pay for them) or interact with unresponsive vendors. Finally, in some cases, equipment was replaced multiple times, and disillusioned patients did not give the technology a fifth or sixth chance.

### Other design, implementation and use factors

#### Provider interaction

Provider interaction affected application design and use. All projects depended on clinicians interacting with the application in some way; therefore, their needs were incorporated as part of the design of the intervention, and in some cases, their level of use influenced the patients' use. The institution affiliated with one of the PHR projects implemented a philosophy that secure messaging had become a daily part of patient care and provided clinicians with training on its use. The second PHR project created institutional policies about the use of the clinician interface with the application; physicians were given an hour-long training session on the portal's functionality. The PDHR project also incorporated clinicians' feedback once a mock CD had been developed. The team conducted focus groups with clinicians, NICU nurses and primary care practitioners to obtain feedback on the CD's content. All pilot testing involved families as well as primary care practitioners, whose feedback influenced revisions to the PDHR's format.

Clinicians' use of or interaction with the application had an effect on patient use. For the wound care project, the study team found increased compliance with patients who were aware that someone was 'watching' the information flow. They also found the perceived engagement of the clinician providing care instructions influenced how closely patients followed instructions. For example, wound healing time increased when patients or their care givers used remedies recommended by friends or others. However, having a clinician reassert during tele-consultations that patients follow instructions provided by home health workers increased patient adherence. Finally, a practice effect occurred during the course of the IVR study.

Reports were sent to clinicians after each data entry. The practice found the increased volume of information overwhelming. Patients were subsequently educated on how to send readings once a day.

#### Vendor support

All five projects worked with vendors, and in some instances, the vendor's level of support affected the participants' ability to use the system. For one project, the vendor's unreliable response was frustrating to patients and researchers alike. Furthermore, vendor support was only available weekdays from 9:00 until 17:00 EST. This affected patients' and clinicians' ability to get help outside those time limits.

Compatibility of devices with the information system in use was another issue. One project received a new model of glucometers for patient participants, but the vendor system did not have the appropriate protocols to recognise the newer device. Project researchers obtained the needed protocol from the manufacturer of the new device; in the interim, older glucometers were used, or data were input by patients manually.

Finally, the PDHR project team began developing the CD by uploading data directly on site at the hospital. As they began to work with a vendor to automate the creation of PDHRs, they encountered several delays because the PDHR was not an original component of their system. Getting vendor agreement on the categories of information for the CD presented one barrier. The vendor solution also took longer than expected, so the project team developed an intermediate solution and hired a consultant.

### DISCUSSION

The projects included diverse interventions and environments that raise several human factors and ergonomic issues. First, the projects involved a range of end users (patients, care givers and providers) with distinct physical and cognitive capabilities and limitations. In addition, the applications were intended for use in homes with different physical characteristics. The studies carefully examined and tailored system design to meet the needs of care providers. A similar approach is also needed in system design to recognise patients' different capabilities, limitations and varying constraints of the home environment.

For example, gradually introducing technology to an older population has been shown to promote health IT use.<sup>6</sup> Accordingly, the two projects that targeted older patients considered needs such as patient comfort with devices and technology. These teams tried to find technologies that were easy to install and use, although they were constrained by what was available in the market. Another project explicitly considered the care giver's role by allowing them proxy access to the patient's information.

If users' needs and capabilities are not carefully considered, less than optimal installation or use of the application may result. For example, two studies found differential use of the consumer health IT application due to prior internet use and age, which suggests, consistent with literature reviews, that some patients' needs may not have been met by this application.<sup>6</sup> In these two studies, patients who did not use the system likely had a higher disease burden.

To maximise the benefit of consumer health IT applications, system designers need to understand how to support the needs, abilities and limitations of patient populations and how to complement health IT applications with other interventions. A successful intervention must accommodate providers and patients to enhance the patient interface and to promote

patients' ability to use the system. Designers will need to consider how to design for these distinct sets of users and to strike a balance so the system is easy to use and useful for all end users. Furthermore, as future health IT applications for home use develop, it is unclear how much input purchasers will have over the design. Therefore, project teams should conduct robust needs assessments and have very specific design requirements when selecting a commercial product.

User testing with the target population in the five projects was limited. A few projects used focus groups or developed a mock product. One project conducted a large pilot test, although the diversity and number of users involved in the product design were limited. After uncovering problems with using the technology, the project team performed extensive user testing, which led to improvements in the application's design. However, additional issues were uncovered when implementation resumed. Engaging the target user population in the testing may have yielded further improvements to design and increased overall adoption and use.

In some cases, the technology was designed to be used in a manner incompatible with health management tasks or household arrangements. For example, one project found that many people did not have phones in bedrooms. Rather, phones were located in other areas of the house, such as the kitchen, while most scales were kept in bathrooms. Device arrangements may be unsafe, in particular for older or disabled populations, by having cables crossing rooms. Alternatively, requiring people to write down information and relay it to clinicians or electronic systems may increase errors. In addition, people living in diverse household arrangements (eg, transient or shared homes) influenced how the consumer health IT application was implemented and used.

The problems encountered by users suggest a need to assess the functional tasks patients and/or their care givers needed to perform as well as to test and observe the applications in the context in which they will be used. However, each project approached IT system development from a clinical study perspective, focusing on an established healthcare need. Based on guidelines of care or clinician recommendations, they found a technology that could provide a solution. The needs identified by the investigators centred primarily on content and IT functionality. While it may be difficult to account for all possible

variations of households, assessments conducted prior to design can better ensure compatibility of the health IT system with a majority of the patient population and promote system use.<sup>6</sup>

The level of provider interaction with system information and with patients appears to be critical to the success of most of these projects, which is also consistent with findings from the literature on consumer health IT.<sup>6</sup> This suggests that careful attention must be paid to ensure that providers see the value of, and will be able to use, the IT application when needed. Additional research may be needed, however, to determine the optimal level of provider involvement and what may be feasible within the context of a clinician's workload.

Two projects found differential use of the technology based on access to the internet, especially broadband. Differential access to internet services due to cost may prevent different user populations from benefiting from consumer health IT applications. Testing the final application might have indicated download ease by internet speed. Similarly, while project teams were limited by the technology available in the market, in some instances, they did not recognise these limitations until the application's implementation and use. The declining use of land lines will be an important consideration in design of consumer health IT applications, as well as the lack of newer technology among some older patients. Furthermore, the compatibility between devices and information systems also needs to be tested. Persistent technical issues led to patients refusing to use the system in some instances or abandoning it altogether, thus affecting its impact on quality.<sup>6</sup>

Engaging patients through clinical settings was the primary method used to enrol patients. However, installation experiences varied among projects. For more complex IT applications, project teams were required to visit patients' homes to install the devices, as patients were unable to do so themselves. While all of the projects provided support or customer service, feedback on its effectiveness, from the patients' or care givers' perspective, was unavailable for all but one project. Some of these applications were designed to be used as part of a home care visit, in which the visiting nurses or home care workers could provide additional training or support to the patients, but many did not anticipate further help for the patient. Even though the potential risk of harm from misuse of consumer health IT applications might be less than with complex medical devices, appropriate

**Table 2** Recommendations to improve design of consumer health IT and sample relevant human factors methods

Recommendations	Human factors methods
The design process should consider the physical and cognitive needs and abilities of all types of end users (eg, patients, care givers or clinicians)	<ul style="list-style-type: none"> <li>▶ Cognitive task analysis</li> <li>▶ Function analysis</li> <li>▶ Usability evaluations (eg, usability tests; heuristic evaluations; cognitive walkthroughs; think-aloud protocols)</li> <li>▶ Visual and hearing impairment simulators</li> </ul>
The design process should be user-centred with the goal of understanding the 'health work' of the users and the context in which the work occurs	<ul style="list-style-type: none"> <li>▶ Cognitive work analysis</li> <li>▶ Task analysis</li> <li>▶ Function analysis</li> <li>▶ Work system analysis</li> <li>▶ Interviews</li> <li>▶ Direct observations</li> <li>▶ Focus groups</li> <li>▶ Analysis of artefacts</li> </ul>
The design process should be iterative, and evaluations should be conducted in environments in which the intervention will be used. Subjects involved in testing should represent all possible users.	<ul style="list-style-type: none"> <li>▶ Usability evaluations</li> <li>▶ Field testing</li> <li>▶ Interviews</li> <li>▶ Direct observations</li> </ul>
Appropriate training and IT support should be available to users	<ul style="list-style-type: none"> <li>▶ Usability evaluations</li> <li>▶ Field testing and evaluation</li> </ul>
Technology, platforms and devices used should consider compatibility and user access (eg, by considering using different platforms or testing using varying internet speeds)	<ul style="list-style-type: none"> <li>▶ Pilot tests</li> <li>▶ Surveys</li> <li>▶ Review of services and infrastructure available in the community</li> </ul>

training and support are still needed.<sup>25</sup> In addition, system purchasers may need to negotiate appropriate levels and availability of support for patients and training modules ahead of time.

Table 2 includes a list of design recommendations based on the human factors and ergonomics issues encountered by the five projects along with sample methods to implement each recommendation. The recommendations are congruent with suggestions to improve clinical IT systems and proposed methods, such as usability and pilot testing, which have been shown to improve the ease of use and usefulness and improve overall technology acceptance.<sup>26–30</sup>

## CONCLUSIONS

The innovative work in these five projects has helped begin a discussion around human factors and ergonomic considerations for in-home use of consumer health IT. The projects illustrate the diversity of applications that can be implemented for in-home use and the breadth of human factors and ergonomic issues that can arise during implementation and adoption.

Overall, the different projects and applications illustrate important lessons regarding the complexities of supporting home healthcare activities through health IT. First, the interaction between technology, patients, care givers, the home environment and the clinician must be considered in the design and implementation of the technology to produce a dynamic that will improve care. Devices and applications that are difficult to use or abandoned will likely fail to achieve the quality, safety and efficiency goals of consumer health IT advocates and designers. Second, a lack of attention to human factors and ergonomic issues could lead to inadvertent threats to safety by creating hazards in the home environment or facilitating user error.

Moving forward, consumer health IT application developers should design in-home applications to function in the absence of significant IT support. Human factors and ergonomics should be incorporated early and iteratively into the design of consumer health IT. If human factors and ergonomics considerations are incorporated at the end of the development process, any redesign work may be resource-intensive and significantly impair technology acceptance.<sup>29</sup> Therefore, developers should include human factors professionals in the multidisciplinary design team to adequately inform the concept, needs assessment and development process. Consumer health IT developers can also look to other industries that develop consumer products or software to see how human factors and ergonomics are embedded in their development processes. Appropriate inclusion of these considerations in the design of consumer health IT applications will enhance adoption and enable long-term achievement of quality, safety and efficiency goals.

## LIMITATIONS

The application of lessons described in this study to other in-home consumer health IT projects is limited by the small number of research projects examined. While the lessons here are important, they may not be applicable in all settings and contexts. Furthermore, none of the studies employed structured methods to collect data on human factors and ergonomic issues encountered when designing, implementing or using the consumer health IT applications. Thus, other important issues may exist that were not documented in project reports but are nonetheless important to consider in the adoption, use, quality or safety of in-home consumer health IT products. Future research should explore these and other human factors and ergonomic issues in more depth and in relation to primary

research studies that examine in-home consumer health IT application use.

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