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Designing and Testing a Web-based Interface for Self-Monitoring of Exercise and Symptoms for Older Adults with COPD

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Introduction

The use of information and communication technologies (ICT) to support collaborative self-management of chronic obstructive pulmonary disease (COPD) and associated symptoms such as dyspnea (shortness of breath) is particularly appealing since most people with COPD continue to experience dyspnea with their activities of daily living despite optimal medical therapy. Patients, therefore, must engage in the long-term tasks of self-management.¹ Self-management has been defined as an “individual’s ability to manage the symptoms, treatment, physical and social consequences and lifestyle changes inherent in living with a chronic condition”.^{2(p. 178)} Exercise is one such self-management strategy that has been shown to improve symptoms and functioning in patients with COPD.³

Similar to other clinical and healthy populations, long-term engagement and persistence with an exercise regimen for these patients can be challenging.⁴⁻⁶ Strategies that support self-management and maintenance of lifestyle changes such as exercise have, for the most part, been guided by the core principles of social cognitive theory.⁷ These interventions generally focus on increasing patients’ confidence in their ability to manage their condition by providing: 1) relevant education so patients understand how their perception and behaviors affect how much an illness interferes with their lives, 2) training on specific skills, strategies, and problem solving techniques, 3) tools for goal setting and self-monitoring of cognitive, affective, and behavioral factors, and 4) regular follow-up, assistance, and reinforcement of lifestyle changes by a health professional.

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There are encouraging reports on the use of ICT, guided by the principles of social-cognitive theory, to support self-management tasks and activities in both healthy and clinical populations in recent years.⁸⁻¹⁵ However, there are few published reports about the software development process. The use of ICT as partial solutions to improve health outcomes rests in the ability of these tools to engage and motivate users over time without being cumbersome. The purpose of this paper is to describe our process of developing a set of integrated tools to support collaborative symptom and exercise monitoring for patients with COPD. These tools will be described with respect to two delivery modalities provided to patients, a mobile device and a secure desktop web site. It is important to note that the tools discussed herein are embedded within a larger comprehensive cognitive-behavioral dyspnea self-management program that is currently being tested in a clinical trial; a discussion of the entire suite of tools is beyond the scope of this paper.

Methods and Results

We followed user-centered design principles throughout the software development process.^{17,18, 19} As both philosophy and method, user-centered design places the user, in this case patients with COPD, at the center of an iterative process to ensure that the application meets their needs. This is particularly important when working with a clinical population; patient end-users are most privy to their own physical, cognitive, and emotional states and how these factors could potentially interact with various tools and applications to enhance or interfere with their self-management.

We conducted a four-phase study to develop a set of integrated tools for self-management. In Phase I, individual semi-structured interviews were conducted with participants who completed a study on Internet-based dyspnea self-management. In Phase II, we conducted a targeted review of publicly available self-monitoring tools, developed paper prototypes, and conducted alpha usability testing using the prototypes. Approximately two months were dedicated to full-time software development (Phase III), followed by field usability testing (Phase IV). The University of Washington institutional review board approved all activities related to the software development and field usability testing.

Phase I. Understanding Patient-End User Needs

Methods—The goal of Phase I was to identify specific patient self-management education and support needs and to elicit patients' perceptions of how the tools may have helped or not help to increase their confidence in self-care. As is the case with software development, content expertise and experiential knowledge from iterative studies are critical.

We meticulously documented process measures from an ongoing study on dyspnea self-management and conducted individual semi-structured interviews with the first cohort of patients as they completed the 6-month study (n=8). In that study, the intervention had four major components (education and training on strategies to manage and cope with dyspnea, exercise, support and reinforcement from the study nurses, and peer interaction), thus the overall goal of the interview was to elicit patient feedback on specific components of the program that were perceived as most or least helpful to managing their dyspnea. Two broad questions were posed to patients: (1) "In what ways has this program been most (or least)

helpful to you with managing your shortness of breath?” and (2) “Are there certain things you think we should do differently that would have been more helpful to you?” Probing questions were used to obtain feedback about the technologies used to facilitate/deliver the four program components.

Results—Most patients who participated in the dyspnea study expressed that it was important for them to report their daily exercise and symptoms to the study nurses since they had made a “commitment to do so”, whether or not they felt it was useful for them track or maintain these records. We also found that aside from submitting the daily data for the study, a few patients reported that they also maintained their own extensive paper records, an example of which is shown in Figure 1. This particular patient used a calendar to archive and summarize her overall efforts at managing dyspnea which included detailed records of her exercise, symptoms, weather, and other activities that shaped her symptom experience. Another patient reflected a similar sentiment when asked about his plans to keep up with his exercise, “I’m plan driven, I like to plan. I think I will use a day planner from this point to track my exercise, even though I have a PDA. I like to see things. I’m a visual person.” These examples illustrate the value of tools that can be configured according to individual needs, as well, concise displays of information for patients who perceive a benefit from and respond to self-monitoring.

We also learned from a previous pilot study that patients wanted greater convenience with recording their daily exercise and symptoms.¹⁵ Several patients reported that they did not log onto their computers due to the “hassle factor” when they were feeling ill or when their symptoms were worsening. Use of a hand-held device, e.g. internet-ready personal digital assistant (PDA) was suggested as a way to streamline daily recordings. PDA’s could be used to “push” reminders to patients to submit their data on a daily basis instead of relying on patients to “pull” the web page from their desktops.¹⁶ Theoretically, this could facilitate more complete real-time data collection and allow nurses to intervene more promptly when symptoms worsen.

Phase II. Survey of Existing Tools and Alpha Usability Testing

Methods—We conducted a targeted survey and analysis of free and publicly accessible Internet tools for exercise, diet, and symptom monitoring. Activity-monitoring tools from the following web sites were included in the final analysis: The President’s Challenge²⁰, United States Department of Agriculture, Center for Nutrition Policy and Promotion²¹, and the Department of Health and Human Services [DHHHS].²²

Results—Of the three web sites that we surveyed, two included exercise tracking tools that allowed users to tailor the exercise fields for quick entries. ^{20,22} All three tools captured at least two of the three dimensions of exercise, mode, duration, or intensity. While the President’s Challenge site presumed that all users would have a generalized goal of exercising at least five days per week which is consistent with national recommendations,²¹ the DHHS tool allowed users to set their own goals. However, these goals were non-specific. The President’s Challenge tool provided both ipsative (compared to self) and normative (compared to similar others) feedback with relatively clear representation using a 5-point

star image. Points of the star were shaded in for each logged exercise session. The DHHS site offered a simple line graph and calendar summary of the exercises; however, it required a user to click on an exercise link to view the details in a small pop-up window and did not interface with a users' exercise goals. The Center for Nutrition Policy and Promotion site also used a line graph to plot physical activity scores based on a 0-100 scale and provided a qualitative assessment of performance.

Methods—Based on findings from the survey of existing web-based tools, we developed paper prototypes of desktop and PDA web-interfaces for (1) exercise goal setting and (2) exercise and symptom monitoring. The paper prototypes were computer and hand-generated to replicate the size and appearance of a desktop web page and PDA screen (Figures 2 and 3) and were used in alpha-usability testing.

Two researchers facilitated the alpha-usability testing sessions with three participants who had COPD. One researcher guided participants through the representative tasks while the other researcher recorded participant responses and behaviors. Participants were encouraged to verbalize their actions and thoughts as they interacted with the paper prototypes. The tasks simulated typical user-scenarios and included: setting an exercise goal, recording information on exercise and respiratory symptoms, and interpreting graphical summaries of these data. After the tasks were completed, we elicited additional feedback and clarifications from the participants on their preferences regarding the interface (layout, navigation), content (types of information they believed would be useful to monitor to manage their symptoms), and graphical summaries.

Results—During the alpha usability testing activity, participants commented about the small font size on the PDA prototypes; however, they did not express any difficulty using the prototypes and their feedback was generally positive. All participants believed that it was important for them to see their exercise goals and a graphical summary of their exercises on one web screen. There was an overwhelming preference for the calendar graphical summary over the star or line graph displays. Participants commented that they preferred the calendar format over the star display since it was difficult to distinguish whether the colored arms of the star represented completed exercise or not; also, there were no specific dates associated with the stars. Participants reported that they would be more motivated to exercise if they received immediate feedback regarding their exercise goal attainment but did not specify a particular feedback format.

Phase III. Software Development

Methods—Information gleaned from Phase I and II informed the design of the web-based desktop and PDA exercise and symptom monitoring interfaces and graphical summaries . The desktop web interface was developed following universal design principals using web standards designed to be cross-browser compatible and accessible to a broad audience. 23,24,25 Minimal use of graphics was employed with most presentational aspects controlled through linked style sheets. A 'liquid' page layout was chosen, allowing content to expand and contract as browser windows were resized and desktop resolutions change. This layout ensured maximal use of screen space and display on older, low resolution, monitors which is

common of systems used by older adults. A horizontally arranged tabbed navigation interface was chosen as previous experience and other research has demonstrated this to be an intuitive navigation mechanism.²⁶ The only specific browser requirement was the presence of the Macromedia Flash plugin. This plugin is generally pre-installed in all new releases of major browsers and is easily downloaded and installed at no cost for the end user. To reduce software development time and leverage publicly available code, we integrated and modified an external graphic tool to display the symptoms data.

Client side logic, notably form validation, was coded using standard-based JavaScript while server side logic was coded with PHP. Our infrastructure was developed entirely on an open source platform. This particular set of software, often referred to as the “LAMP” platform, consists of the Linux operating system, the Apache Web server, the MySQL database management system, and the PHP or PERL or Python programming languages.²⁷ All communication with the server was encrypted with 128bit Secure Sockets Layer protocols.

We chose the Palm Treo 650® for mobile data entry since it had the largest screen size of the moderately priced PDAs on the market and users have the option of using either a stylus or buttons for navigation. Web pages designed for data entry through the PDA followed many of the coding standards as the desktop pages. Some exceptions were a constraint on the number of text and form elements on each entry page and ensuring that the full page would render on the 320 by 320 pixel screen resolution without scrolling.

Results—The Palm Treo 650® was our primary data collection device. Users initiated a data entry session by pressing a dedicated button on the PDA which automatically loaded their unique web page on the browser. All data elements were in the form of drop-downs, radio buttons, or checkmarks for easy navigation. Coding was added to prevent users from logging symptom and exercise data in the future but users were able to record data for a previous date. A typical session queried users about their respiratory symptoms followed by their exercise. Symptom ratings that exceed pre-determined thresholds triggered an email alert to the research nurse along with a message on the PDA stating, “It looks like you might be having a flare-up of your COPD. A study nurse will be in touch with you within 24 hours. Also, feel free to call the study office. You may want to contact your health provider as well.” Depending on what users selected to record their exercises, subsequent screens asked for additional information conditional on their selections (Figure 4). Users also had the option of recording their symptom and exercise data on a desktop interface.

The desktop interface also included the following tools: exercise goals, calendar and numerical summary display of completed exercises and line graphs of respiratory symptoms (Figures 5 and 6). Consistent with the principles of mastery learning, the exercise goal setting tool was designed to be detailed and specific and included the type of planned exercise, frequency, duration, where the exercise will be completed, and the user’s confidence in his or her ability to achieve the exercise goal. The calendar displayed completed exercise sessions with exercise-type specific color coded checkmarks that users can easily benchmark against their current exercise goals. Users could also mouse over any of the checkmarks to see a more detailed summary of the exercise data. A secondary numerical summary of the endurance and strengthening exercises were also displayed on the

far side of the calendar. These raw tallies of exercise sessions and duration replaced the “percent of completed exercise” summaries (Figure 5). Respiratory symptoms were rated on Likert-like scales and plotted in two separate line graphs. Changes in dyspnea, cough, and sputum are the hallmark signs and symptoms of COPD exacerbations (Figure 6).

Phase IV. Field Usability Testing

Methods—The purpose of field testing was to evaluate the usability of the desktop and PDA tools by representative end-users on computers in their homes to uncover challenges with access and use. Field usability testing was conducted in the home of 3 participants with COPD (2 females) whose age ranged from 69 to 81. All participants used a desktop computer and Internet access via a digital subscriber line.

We used the resources of the Laboratory for Usability Testing and Evaluation of the Department of Technical Communication, University of Washington including the portable Usability Equipment (Usability Systems, Atlanta, GA) to conduct simultaneous audio and visual recording of the usability testing sessions. The equipment was attached to the participant’s computer monitor to allow for screen capture of all computer activities. A camera set on a tripod video recorded participants as they completed tasks with the desktop and PDA tools. A microphone was inconspicuously placed on the desktop near the participant’s computer.

We provided scripted training instructions on how to navigate through the desktop and PDA exercise and symptom monitoring tools to simulate the training that would be provided to all patient end-users. We also instructed participants on how to “think aloud”²⁸ during the testing. The think aloud method of usability testing encourages participants to verbalize their thoughts and feelings while completing the assigned tasks in order to fully capture users’ cognitive and affective response to the tools.²⁸

We asked participants to complete six sequential tasks, beginning with the easiest task in order to build their confidence levels. Each task was typed and placed on a separate sheet of paper using large font for ease of reading. We instructed participants to say ‘done’ when they completed a task and were ready to move to the next task. The tasks were written as typical use scenarios. For example, the first task was, “You want to record your symptoms for today. Your shortness of breath was mild but you had a bit more coughing than usual but no sputum”. Other tasks included: (1) view and interpret a graphical summary of dyspnea ratings for the past two weeks, (2) enter exercise goals, (3) record endurance exercise, (4) record strengthening exercise, and (5) review and interpret a summary of completed exercises over a two week period. Participants also completed a 13-item questionnaire and a semi-structured interview at the end of the testing session. The questionnaire asked participants to rate the initial training on the tools, general ease of use, visual layout of the interface, ease in recording exercise and symptom data, ease in understanding the graphs, ease in setting goals, and the time required to record the symptom and exercise data using a 4-point Likert scale (works well to needs to improve). The semi-structured interviews allowed participants to elaborate on self-identified and researcher-observed usability challenges and to offer suggestions for improvements.

Results—Usability analyses were based on data from the audio-video tapes, questionnaires, and semi-structured interviews. Results are presented within the framework of Nielsen's²⁸ five quality components, learnability, efficiency, memorability, errors, and satisfaction.

The first quality attribute is *learnability*, how easy it is for users to accomplish basic tasks the first time through and to be able to work quickly without spending much time searching for instructions and screen interface commands.²⁸ Overall participants remarked how easy and quickly they were able to learn to use the tools. The problems experienced were minimal, e.g. participants had some difficulties using a stylus to scroll the PDA web pages and using the pull-down menu to rate their symptoms; they also tended to forget that the exercise and symptom monitoring tools were located on separate desktop web screens.

Efficiency refers to how quickly a user takes to perform a task.²⁸ As expected, each of the six tasks took participants one to two minutes to complete. For instance, participants took an average of 2:07 minutes (range, 1:05-2:40) to complete the first task of recording their symptoms on the PDA. Interestingly, the participant who took half the time to complete this particular task actually used the desktop tool instead of the PDA. It is important to note that during the training, participants were not shown how to use the desktop tool to enter exercise or symptom data. Thus, for this one participant, the desktop tool was an intuitive interface and logical place to record the symptom data.

The final task asked participants to review and interpret a graphical summary of their exercise over a two week period. The data were displayed in a calendar format along with three summary columns depicting the percentage of completed exercise goals. Participants were engaged in this task for an average of 1:25 minutes (range, 0:47-1:49). Although participants from the alpha usability testing suggested that presenting the percentage of exercise completion would be informative and easy to understand, our implementation was not successful. None of the participants were able to provide an accurate interpretation of the summary. This task was considered the most cognitively complex since participants were asked to simultaneously process and synthesize multiple data elements.

It is important for tools to have a high degree of *memorability*, ease at reestablishing proficiency after a period of non-use.²⁸ Users need to be able to use an application without having to relearn the details with each use. Following the training session, participants were able to complete the six tasks with little to no prompting indicating that the system and tools had good memorability attributes. Participants commented that having a paper help manual would assist them initially to become more familiar with how to use the tools.

Errors should occur at a low frequency with use of any tool.²⁸ It is equally important that users can recover quickly from any errors. Overall, we found that user errors were infrequent. However, as mentioned above, we observed and participants expressed difficulty in understanding the summary of completed exercise. One participant actually requested a calculator so she could compute the numbers herself. Two participants who did not respond to all the symptom queries before submitting data received an error message that was easily self-corrected without guidance from the researcher.

Last, the quality attribute, *satisfaction* refers to how pleasant it is for users to use a tool.²⁸ In general, participants gave favorable reviews of the exercise and symptom tracking tools. Participants reported that the tools seemed reasonably easy to learn and ranked the training and ease of use for both the desktop and PDA web tools as either “works well” or “good” except for one report that the ease of use of the PDA was fair. Although participants had some difficulty distinguishing between the blue and purple check marks that represented specific exercise types on the calendar, they expressed high satisfaction with the calendar summary display of their exercise. The layout of the fields within the exercise goal-setting tool was not clear to one participant. Another had a strong negative reaction to the graphical display of the symptom data. She commented, “I don’t think of my symptoms until they become a problem. Fundamentally, I’m not defined by this illness”.

Discussion and Implications

Similar to the methodical development of any health care intervention or program, our systematic approach to building the suite of web-based tools to support patients with COPD in managing their symptoms involved four distinct phases. We used both qualitative and quantitative methods to identify, characterize, and integrate end-user needs and preferences into the planning, design, and development of these core tools.

The usability challenges uncovered during the field testing were mostly minor and were easily corrected. More importantly, the feedback we received from participants during the development and field testing helped us develop a detailed “help manual” for patients using screen shots and call outs with step-by-step instructions. The findings from the intervention study that tests this suite of tools will not be available for another three years. While this report chronicles our methods and does not necessarily present novel findings related to software development for patient end-users per se, we explore a design issue below that could have important implications for future development efforts.

A general rule of thumb in usability testing is that five end-users should be able to identify approximately 85% of the potential use problems.²⁹ Nielsen also suggested that if one’s budget allows, to test more users in batches, that is, following identification of initial problems, the system is immediately redesigned and subject to repeat usability testing with a new group of potential end-users. We had a total of 14 participants who informed the development and testing of these web-based self-monitoring tools (8 in Phase I and 3 each in Phases II and IV). We believe that under the time constraints of having to quickly develop and launch the application for the intervention study, we were successful in developing a set of tools that met the core criteria for usability and were received positively by end-users.

It is important to note that we developed the set of self-monitoring tools for an “average” user even though our target end-users of patients with COPD are rather heterogeneous in their disease severity, level of engagement in self-management, and degree of comfort with various technologies. While challenges to effective use of any application reflect a combination of individual competencies and system design limitations and since it is harder to modify user characteristics, systems could be designed with a generalized set of tools that can be configurable to meet the wide spectrum of patient needs. Patients with fewer

functional limitations from their disease may be able to engage in complex self-care regimens and desire to use tools that allow them to track their activities and other clinical indicators in greater detail. In contrast, patients with significant functional and cognitive limitations may appreciate simpler or fewer tools. Other individual characteristics also shape preferences for self-monitoring, including gender, personality types, or personal level of motivation and engagement. While there are general design principles that guide the development of tools for an aging population such as accommodating declines in psychomotor skills and processing capacity (working memory) through simple designs with intuitive interfaces, the question here is whether we should strive to meet the needs of both “super” users and “typical” users within one application?

The existing research literature primarily address the use of information and communication technologies to customize or tailor health communications and behavior change messages.^{30,31} However, there has been little research on the impact that more robust applications which allow end-users to customize or personalize the actual tools themselves to suit their needs and preferences would have on user satisfaction. A recent qualitative study which explored patient and caregiver perceptions of existing interactive health applications found that these end-users desired easy access to multiple interactive tools. They particularly wanted to have greater control over the application by either suppressing or activating a particular tool and/or customizing sub-elements of the tool depending on their needs.³² In another study, investigators found that participants quickly formed an idiosyncratic preference for a few components of a system and then repeatedly used only those tools onward.¹⁴ We hypothesize that the design of more flexible patient-centered tools that allows users greater control may result in greater patient satisfaction, sustained engagement, and more positive outcomes. We plan to enhance the existing set of self-monitoring tools in the near future. The new framework will use modular code blocks so that future applications are both flexible and extensible. We will repeat the iterative software development cycle with a much sharper focus on obtaining a more comprehensive understanding of what patients with COPD deem as important data elements, graphical displays, and interactions that will engage and motivate self-management.

In conclusion, it is our hope that the tools we have developed will provide a common framework for delivering patient-centered interventions. Information and communication technologies, such as mobile devices and secure desktop websites, can be used to support collaborative symptom-management and are appealing to patients. The processes and principles described herein could be easily extrapolated to the development of symptom monitoring tools for other patient populations.

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Figure 1.
Sample of a Participant's Symptom Management and Exercise Log

Figure 2.
Hand-drawn paper prototype of exercise progress for a desktop web display.

Figure 3.
Computer-generated paper prototype of exercise progress for a desktop web display (left) and a mock PDA (right) for entering exercise data.

Figure 4.
Symptom and exercise entries on a PDA

Figure 5. Desktop interface displaying goals and completed exercise. depicts completed weekly goals by percent.

Figure 6.
Desktop interface displaying symptoms.