Grant Final Report

Grant ID: R36HS018239

The Effects of Age, Cognition, and Health Literacy on Use of a Patient EMR

Inclusive project dates: 09/01/09 - 11/30/11

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Abstract

Purpose: This project aims to: 1) examine the ability of middle-aged and older adults to use a patient portal of an electronic medical record (EMR) to perform common health management tasks; 2) examine the relationship between individual characteristics such as age, cognitive abilities, health literacy, and the performance of tasks using a portal; and 3) identify usability problems and initial design solutions.

Scope: It is critically important to understand the extent to which adults can effectively use patient portals of EMRs, and also to understand the factors that influence their successful use of these systems. This study involved 107 adults aged 40-85 years.

Methods: Participants were evaluated with a cognitive battery and health literacy and numeracy tests. Using a simulation of a portal containing a fictitious medical record, participants were evaluated on their ability to perform 15 tasks encompassing medication management, interpretation of lab results, and health maintenance activities.

Results: Older adult participants had lower mean scores on complex tasks and overall performance than middle-aged adults. Age, cognitive variables, health numeracy (a component of health literacy), and Internet experience had an impact on performance. Individuals with lower verbal ability, executive functioning, reasoning skills and health numeracy had lower performance.

Key Words: health literacy; objective numeracy; subjective numeracy; cognitive abilities; patient portals; PHRs

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Purpose

The goal of this study was to systematically assess the ability of a diverse sample of middle-aged and older adults (aged 40-85 years) to use a simulated patient portal of an electronic medical record (EMR), often referred to as a "tethered" personal health record (PHR), to perform health management tasks and to examine how individual characteristics, such as health literacy and cognitive abilities, impact the use of such systems. Particular attention was given to the health numeracy aspect of health literacy, as many of the tasks performed with a portal depend on numeracy skill. Health numeracy has been defined as "the degree to which individuals have the capacity to access, process, interpret, communicate, and act on numerical, quantitative, graphical, biostatistical, and probabilistic health information needed to make effective health decisions (Golbeck, Ahlers-Schmidt, Paschal, & Dismuke, 2005, p. 375)." Portal tasks relying on numeracy include managing appointment dates and times, understanding medication dosage instructions, reviewing lab results, and interpreting health information from charts, tables, and graphs. However, there is no data available regarding the numeracy ability of patients and how this ability affects their use of a patient portal.

The specific aims of this study were to: 1) examine the ability of middle-aged and older adults to use a patient portal of an EMR to perform common health management tasks; 2) examine the relationships between individual characteristics such as age, cognitive abilities, health literacy, health numeracy, and task performance; and 3) identify usability problems inherent in the use of patient portals and identify design solutions.

We focused specifically on three common health management tasks associated with patient portals: 1) medication management; 2) review/interpretation of lab/test results; and 3) health maintenance activities. By systematically assessing the relationship between individual characteristics and the ability to use a patient portal of an EMR system, we can gain insight into "the root" of usability problems, which, in turn, can guide the development of empirically-based interventions to help those in the most need. The outcomes from this research will help identify design changes and interventions that can enable older patients to overcome barriers to use and to enhance their ability to use these portals to manage their health. Changes made to help older adults use portals may make adoption of these systems easier for all age groups as, generally, the human factors literature indicates that design interventions that benefit older adults also benefit most user groups (e.g., Fisk, Rogers, Charness, Czaja, & Sharit, 2009).

This research is unique and important in terms of addressing barriers to older adults' use of patient portals of EMRs. We must know more about these users and their preferences and usability problems if we expect them to adopt and successfully use these systems. Currently, the literature available on this topic is very limited. Results will also contribute to the existing literature on the health numeracy aspect of health literacy. Although there is a vast amount of literature on health literacy, there is only limited information about older adults and health numeracy. This project is very timely and of great public health significance, as the number of older patients using patient portals tethered to an EMR is likely to increase as electronic records become more widely used.

Scope

Electronic personal health records (PHRs) are increasingly being used by diverse patient populations, and technology is becoming a critical aspect of health communication and healthcare. PHRs are transforming healthcare by providing patients with increased access to personal health information. The types of PHRs available include “standalone” models, in which information is entered by the patient, “integrated” models that extract information from insurance claims and pharmacy data, and “tethered” PHRs that are linked to the patient’s electronic medical record (EMR) and offer the patient access to parts of their medical record via web portals (Detmer, Bloomrosen, Raymond, & Tang, 2008). Patients using portals have the ability to view their medical history, review laboratory results and medication lists, communicate with their provider, and follow links to credible health information online (Yamin et al., 2011).

The Institute of Medicine (IOM) has concluded that EMRs are needed to increase the quality and decrease the costs of medical care and that patients should have unfettered access to their own medical information (IOM, 2001). Thus, EMRs can be expected to become more widespread in the coming years. However, the existing literature does not provide much data on the use of patient portals of EMRs by older adults to manage their health. By evaluating how older adults are able to utilize the health management tools of patient portals of EMRs and examining the individual characteristics that impact use—such as age, health numeracy, and cognitive abilities—we will be able to propose design interventions that will aid this population in using these important health management tools. Furthermore, this study gives attention to the numeracy aspect of health literacy as it has been noted that “[t]he reporting of health literacy without disaggregating prose from numeracy obscures health numeracy skill” (Donelle, Hoffman-Goetz, & Arocha, 2007, p. 652). Although health numeracy skill can have a significant impact on an individual’s ability to manage their health, few existing studies have focused on how health numeracy relates to health outcomes (Golbeck et al., 2005).

This study involved 107 participants: 56 middle-aged adults, aged 40-59, and 51 older adults, aged 60-85. Study participants included males and females recruited from the Miami area. There were no exclusion criteria with respect to gender or ethnicity. All participants were required to be English-speaking and non-cognitively impaired as measured by a score greater than 26 on the Mini Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975), adjusted for age and education using the correction established by Mungas and colleagues (1996). The potential for cognitive impairment was assessed to ensure that the participants were able to participate in usability testing.

An age range of 40 to 85 was used to ensure that input came from a representative sample of users, as it is anticipated that both middle-aged and older adults will interact with patient portals. It was also of interest to examine age-related differences on task performance and the relationships among age, cognitive abilities, health literacy, numeracy, and performance outcomes. This study excluded adults over 85 years of age to minimize issues of visual and hearing deficits, or cognitive impairment.

Participants were recruited from the community through placement of flyers in community organizations and senior centers and by word of mouth. Interested individuals contacted the study investigator by telephone. The study investigator provided an overview of the study and administered a telephone prescreening, which included screening questions (e.g., age, highest educational attainment, primary language) and the Wechsler Memory Scale III (WMS-III;

Wechsler, 1997). Participants who were eligible and interested are scheduled for participation. Table 1 displays the demographic profile of the participants who participated in the study.

Table 1. Sample characteristics

	Total Sample	Middle-aged	Older
Number	107	56	51
Age in years, M(SD)	58.87 (11.89)	49.36 (5.36)	69.33 (7.45)
Gender (%): Male	45.8	51.8	39.2
Gender (%): Female	54.2	48.2	60.8
Ethnicity (%): Hispanic	23.4	16.1	31.4
Ethnicity (%): Non-Hispanic White	25.2	12.5	39.2
Ethnicity (%): Non-Hispanic Black	49.5	67.9	29.4
Ethnicity (%): Non-Hispanic Other	1.9	3.6	0.0
Education (%): High School or less	36.4	50.0	21.6
Education (%): Some College	40.2	33.9	47.1
Education (%): College Graduate/Post-graduate	23.4	16.1	31.4
Yearly Household Income (%): Less than $20,000	68.2	80.4	54.9
Yearly Household Income (%): $20,000 to $49,999	16.8	12.5	21.6
Yearly Household Income (%): $50,000 or more	15.0	7.1	23.5
General Health (%): Poor	1.9	3.6	0.0
General Health (%): Fair	19.6	26.8	11.8
General Health (%): Good	46.7	44.6	49.0
General Health (%): Very Good	24.3	19.6	29.4
General Health (%): Excellent	7.5	5.4	9.8

Methods

Prior to formal initiation of the study, the study protocol was pilot-tested to ensure that the simulation of the patient portal was operating effectively and that the instructions associated with the task problems and general use of the patient portal of the EMR were clear. Three participants aged 40+ who had participated in previous studies at the Center for Research and Education on Aging and Technology Enhancement (CREATE) were included in the pilot testing.

Measures

Background Questionnaire. This questionnaire gathered demographic data such as gender, age, ethnicity, education, and income (Czaja et al., 2006a). It also gathered information on participants' perceptions of their health, their medical conditions, and medications taken. This questionnaire also assessed participants' attitudes toward computers (Czaja et al., 2006a; Jay & Willis, 1992).

Technology Experience Questionnaire. This questionnaire assessed use of common technologies such as ATMs, cell phones, and computers (Czaja et al., 2006b). Those who reported having experience with computers responded to questions concerning their frequency and duration of computer use. Those who reported having Internet experience responded to questions concerning their frequency and duration of Internet use, as well as where they use the Internet and what types of activities they perform on the Internet.

Heart Disease Fact Questionnaire. The Heart Disease Fact Questionnaire (HDFQ; Wagner, Lacey, Chyun, Abbott, 2005) is a 25-item true/false questionnaire designed to assess respondents' knowledge of major risk factors for the development of coronary heart disease (CHD). Approximately half of the questions address diabetes-related CHD risk factors (e.g., "A person who has diabetes can reduce their risk of developing heart disease if they keep their blood pressure under control"). The HDFQ is readable to an average 13-year-old. This test was used in this study as a measure of participants' background health knowledge, as some of the portal tasks involved topics such as heart disease and diabetes.

Health Literacy and Numeracy Measures. The Test of Functional Health Literacy in Adults (TOFHLA; Parker, Baker, Williams, & Nurss, 1995) consists of a 50-item reading comprehension test and a 17-item numeracy component that consists of hospital forms and prescription bottles. TOFHLA scores range from 0 to 100 and are categorized as follows: Inadequate (0-59), Marginal (60-74), and Adequate (75-100). Individuals who have "adequate" functional health literacy should be able to read, understand, and interpret most health texts. However, those who have "marginal" or "inadequate" functional health literacy will likely have difficulty reading, understanding, and interpreting most health materials.

The objective numeracy measure developed by Lipkus, Samsa, and Rimer (2001) is a frequently used measure that consists of 11 questions: three general numeracy questions developed by Schwartz, Woloshin, Black, and Welch (1997) and eight additional questions that focus on numeracy in a health context. The general questions assess one's ability to convert a percentage to a proportion, convert a proportion to a percentage, and determine how many times out of 1000 rolls a fair die would come up an even number. The eight additional questions use similar mathematical operations as the general questions, but are phrased in the context of health risks. Correct answers are given 1 point, resulting in scores that range from 0 to 11.

The Subjective Numeracy Scale (SNS) developed by Fagerlin et al. (2007) is a self-report measure of perceived ability to perform various mathematical tasks and preference for the use of numerical versus prose information. It is significantly correlated ($r = 0.68$) with the Lipkus et al. scale (Fagerlin et al., 2007). The SNS consists of eight items: four questions that assess respondents' beliefs about their skill in performing various mathematical operations and four questions that assess respondents' preferences for presentation of numerical information. There are no right or wrong answers; participants answer each question on a 6-point Likert-type scale. Possible scores on the SNS range from 8 (for those participants rating themselves lowest on ability to perform mathematical tasks and preference for the use of numerical information) to 48 (for those participants rating themselves the highest on numeric abilities and preference for numerical information).

Cognitive Battery. This battery is given in two parts: one part is in a group-testing format and the other part is administered individually (Czaja et al., 2006a). The group portion contained the following measures: Paper Folding Test (Ekstrom, French, Harman, & Dermen, 1976); Cube Comparison Test (Ekstrom et al., 1976); Letter Sets Test (Ekstrom et al., 1976); Shipley Institute of Living Scale (Shipley, 1986); and the Number Comparison Test (Ekstrom et al., 1976). The individual portion included: Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975); Trails A test (Reitan, 1958); Trails B test (Reitan, 1958); Digit-Symbol Substitution (WAIS-III; Wechsler, 1981); a computerized version of the Stroop Color & Word Test (Stroop, 1935); and Animal Fluency (Rosen, 1980).

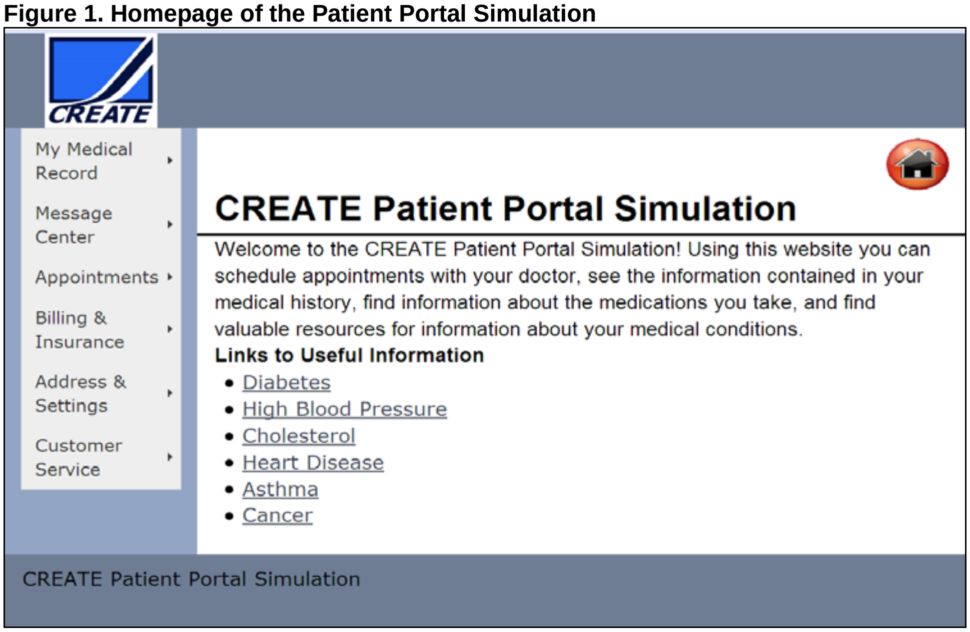
Usability Questionnaire. A usability questionnaire was developed for the study to assess how participants felt about using the patient portal simulation. There were two sections to the questionnaire. The first section contained seven questions concerning how they felt in general about using a patient portal like the simulation they had just used (e.g., would it help them to perform health management tasks more quickly, would it be useful). The second section contained 10 questions that concerned the experience they had just had using the simulated patient portal (e.g., was it difficult to locate information, were the numerical tables confusing). Each question was answered on a 5-point Likert scale (1 = agree; 5 = disagree). In addition, there was a yes/no question to assess whether they would use a patient portal like the simulated one if it were available from their doctor.

Patient Portal Simulation

The simulated patient portal was based on EPIC's MyChart, which allows patients to schedule appointments, view test results and x-rays, renew prescriptions, send and receive emails from their health care providers, and link to health information from trustworthy sources. MyChart was chosen because of its widespread use; an estimated 50 million patients see healthcare providers who use the EPIC software system (Kaelber, Jha, Johnston, Middleton, & Bates, 2008). A thorough analysis EPIC's MyChart was completed to ensure that the simulation captured the relevant features of the existing system.

Figure 1 shows the homepage of our simulated patient portal, referred to as the CREATE (Center for Research and Education on Aging and Technology Enhancement) Patient Portal Simulation, which captured all of the relevant features of the existing MyChart system. The portal was populated with data for a fictitious patient referred to as "Pat." Pat had conditions such as diabetes, high blood pressure, and high cholesterol. This enabled the simulated portal to be populated with a variety of information on which to base the tasks.

Figure 1. Homepage of the Patient Portal Simulation



Tasks

Fifteen tasks were developed to test participants' performance on health-management tasks commonly carried out using a portal in three categories: health maintenance, lab/test results, and medication management. The tasks were developed with input from a physician to ensure that they were realistic and accurate. Furthermore, tasks were designed to span the spectrum of numeracy ability proposed by Golbeck et al. (2005): (1) basic numeracy, which involves identifying numbers and making sense of quantitative data that does not involve manipulation of numbers; (2) computational numeracy, which involves counting, quantifying, computing, and performing simple manipulation of numbers, quantities, items, or visual elements in a health context; (3) analytical numeracy, which involves inference, estimation, and understanding proportions, percentages, frequencies, and often requires information to be integrated from multiple sources and formats; and (4) statistical numeracy, which involves understanding probability statements, having the skills to compare information presented on different scales (probability, proportion, percent), having the ability to critically analyze quantitative health information such as life expectancy and risk, and understanding statistical concepts such as randomization.

To determine the task's difficulty, four independent raters were asked to evaluate each of the 15 tasks. The raters were asked to review all of the tasks and assign the value of "5" to the task/tasks that they determined to be the most complex and assign the value of "1" to the easiest task/tasks. The rest of the tasks were ranked in relation to these endpoints. The computation of Cronbach's alpha revealed a high inter-rater reliability ($\alpha = .842$) among the four raters. The four ratings given to each task were then averaged to get an overall rating of the difficulty of that task. After averaging the four ratings for each task, the resulting weights given to the tasks ranged from 1.25 to 4.50. These weights were used in two different analyses.

First, based upon these weights, tasks were divided into two categories: 7 "simple" tasks (weights from 1.25 to 2.25) and 8 "complex" tasks (weights from 2.50 to 4.50). The total possible scores for simple and complex tasks were determined by summing the number of possible points in each category. Answers by participants that were left blank or incorrect were given a score of 0 points, partially correct answers (on tasks that had multiple parts) were given 1 point, and completely correct answers were given 2 points. Thus, the maximum scores for the simple and complex task sets were 14 and 16, respectively.

Second, in a separate analysis, the weight given for the task was multiplied by the points received on the task and then summed over all the tasks to determine an overall performance score for each participant. As in the first analysis, answers by participants that were left blank or incorrect were given a score of 0 points, partially correct answers (on tasks that had multiple parts) were given 1 point, and completely correct answers were given 2 points. The overall performance scores had a possible range of 0-80.5.

Table 2 displays examples of tasks, the corresponding category of portal function of the task, the steps necessary to perform the task, the corresponding type of numeracy skill involved in performing the task, and the assigned difficulty rating.

Table 2. Examples of tasks and the corresponding portal function, type of numeracy skill required, cognitive skills, and difficulty rating

Task	**Portal Core Function**	**Type of Numeracy**	**Cognitive Skills**	**Difficulty Rating/ Category**
Pat has an appointment with a new doctor scheduled soon, but cannot remember the date of the appointment. Fourtunately, this information is available to you in the patient portal. What is the date and time of Pat's next doctor's appointment?	Health Maintenance	Basic Numeracy – identify numbers & make sense of quantitative data requiring no manipulation of numbers	*Verbal ability* needed to comprehend the question, *Executive function* need for planning a solution, *Selective attention* needed to find link, *working memory* needed to hold onto the information while searching for the appropriate links, *processing speed* needed to support working memory	1.25/ Simple
Pat's doctor has included in the health record a table of Pat's target glucose levels for before and after meals. Use the information in this table and the information in the glucose monitoring weekly summary to determine if Pat's average glucose levels are on target. Is Pat's average glucose level after lunch in the range it should be?	Lab/Test Results	Computational Numeracy – count, quantify, compute, and otherwise use simple manipulation of numbers, quantities, items, or visual elements	*Verbal ability* needed to comprehend the question, *Executive function* need for planning a solution, *Focused attention* and *reasoning* needed to compare the numbers, *working memory* needed to hold onto information while making the comparison, *processing speed* needed to support working memory	1.50/ Simple
Pat checks his/her blood sugar just before eating. Pat takes 1 unit of insulin (Apidra injection) for every 10 grams of carbohydrates eaten. Along with basic dosage instructions, Pat's doctor has also included a schedule in the patient portal that indicates the amount of insulin that should be added to the usual dose based upon blood sugar levels. Use the link to the insulin dose schedule to answer the following question. Pat's blood sugar is 284 and Pat ate 40 grams of carbohydrate at breakfast. How much total insulin does Pat need to take?	Medication Management	Analytical Numeracy – involves higher level concepts such as inference, estimation, proportions, percentages, frequencies, and equivalent situations; often requires information to be pulled from multiple sources and in multiple formats	*Verbal ability* needed to comprehend the question, *Executive function* need for planning a solution, *Selective attention* needed to find correct link, *working memory* needed to hold onto information while looking for the test results, *processing speed* needed to support working memory, *quantitative reasoning* needed to determine which mathematical operations to use	4.50/ Complex

Table 2. Examples of tasks and the corresponding portal function, type of numeracy skill required, cognitive skills, and difficulty rating (continued)

Task	Portal Core Function	Type of Numeracy	Cognitive Skills	Difficulty Rating/ Category
During Pat's last visit the doctor explained that high blood pressure can lead to health problems such as heart attack, stroke, heart failure and kidney disease. Based upon Pat's personal profile (age, gender, height, weight, and current blood pressure), the doctor created a graph of Pat's estimated risks for these conditions and put the graph in the patient portal of Pat's health record. Use the link to "High Blood Pressure Health Risk Calculator" to view the graph and answer the following questions. What does the first graph show about Pat's risk of heart failure compared with the normal risk?	Health Maintenance	<u>Statistical Numeracy</u>– involves an understanding of basic biostatistics involving probability statements, skills to compare information presented on different scales (probability, proportion, and percent), the ability to critically analyze health information such as life expectancy and risk, and an understanding of statistical concepts such as randomization and a "blind" study	*Verbal ability* needed to comprehend the question, *Executive function* need for planning a solution, Visual scanning and *focused attention* needed to stay in the same link and look for further information, *working memory* needed to hold onto information while interpreting the information presented in the second graph, *processing speed* necessary to support working memory, *focused attention* to find relevant information in the graph, *reasoning* needed to interpret information presented in the graph	3.00/ Complex

Procedure

Participation in the study took place over two days. The first day was conducted on an individual basis or in small groups (4-9 people). Participants were asked to read and sign an IRB-approved informed consent. Participants were given the Background Questionnaire, Technology Experience Questionnaire, and Heart Disease Fact Questionnaire to complete. Next, they were administered the subjective numeracy and objective numeracy tests, followed by the group testing components of the cognitive battery. They were provided with breaks as needed. Participants were paid $25 for their participation and provided with free parking.

On the second day, participants participated on an individual basis. The second day was divided into two parts. The first part consisted of a vision test, the individual testing components of the cognitive battery, and the TOFHLA. Participants who scored greater than 26 on the MMSE qualified to continue on to the second part. Irrespective of their Internet experience, all participants worked through a tutorial on basic computer skills (such as using a mouse and scrolling) to ensure that they had adequate knowledge of basic operations required for interacting with the simulated patient portal. They were then given a brief training session on how to use the portal.

Participants were told to pretend they were a relative of Pat and were to use the portal to help Pat manage his/her health. Participants were given a packet that contained the 15 tasks, with space provided below each question for them to record their answers. They were allowed up to two hours to complete all of the tasks. Each participant's onscreen activities were recorded using a screen-capture utility (Morae 3.2) that outputs his or her task performance to a digital movie.

These videos were saved so that they could later be reviewed to assess any usability difficulties encountered by the participants while completing the tasks. Following the completion of the tasks, participants were asked to complete a usability questionnaire. At the completion of data collection, brief interviews were conducted with each participant. The emphasis in these interviews was on determining the perceived benefits of using the portal and which aspects of the portal were difficult to use. Participants were paid $40 for their participation and provided with free parking.

Results

All analyses were conducted with IBM SPSS Statistics Version 19. Participants' self-reported Internet experience, participants' scores on measures of health literacy, subjective numeracy and objective numeracy, and participants' responses to the usability questionnaire were summarized using descriptive statistics. The correlation between subjective and objective numeracy scores was determined by using Pearson's *r* correlation. Three hierarchical regression models were constructed for predicting the effects of education, Internet experience, cognitive abilities, objective numeracy scores and age on task performance. In the first model, the dependent measure was performance on simple tasks; in the second model, the dependent measure was performance on complex tasks; and in the last model, the dependent measure was overall performance on all fifteen tasks. In all the models, the predictor variables were entered in the following order: education, Internet experience, cognitive abilities, objective numeracy, and age. Education was entered first as a control variable due to the variability in the level of education among participants.

Selection of the cognitive ability measures was based upon the results of correlation analysis. Due to the large number of cognitive measures, the correlation between each measure and the performance outcomes was examined. The analysis revealed that the following measures were most correlated with performance outcomes: Trails B (executive function), Shipley Institute of Living Scale (verbal ability), and Letter Sets Test (reasoning). These cognitive measures were thus selected for inclusion in the hierarchical models. A natural log transformation of Trails B (time score) was performed to normalize the results before inclusion in the models.

Internet Experience

Twenty-two participants (11 middle-aged and 11 older adults) reported having no experience with the Internet. The remaining participants had varying levels of experience. Table 3 indicates how long the participants had been using the Internet, as well as how often per week, on average, they used the Internet. To create a variable that captured the participants' overall Internet experience, the responses to the duration question (coded 1 to 4) were multiplied by the responses to the intensity question (coded 1 to 4), resulting in scores ranging from 1 to 16 for those participants who had Internet experience (participants with no prior Internet experience received a score of zero). This variable was used in the hierarchical regression models.

Table 3. Participants' internet experience

	Total Sample (%)	Middle-Aged (%)	Older (%)
Length of time using the Internet: Less than 6 months	11.2	10.7	11.8
Length of time using the Internet: Between 6 months and 1 year	6.5	7.1	5.9
Length of time using the Internet: More than 1 year, but less than 5 years	17.8	25.0	9.8
Length of time using the Internet: 5 years or more	43.9	37.5	51.0
Hours/week using the Internet: Less than 1 hours	20.6	23.2	17.6
Hours/week using the Internet: Between 1 hour and 5 hours	25.2	26.8	23.5
Hours/week using the Internet: More than 5 hours, but less than 10 hours	12.1	10.7	13.7
Hours/week using the Internet: 10 hours or more	21.5	19.6	23.5

Heart Disease Fact Questionnaire

Scores on this measure ranged from 9 to 25 (M = 19.19, SD = 3.78). Scores were similar in both middle aged (M = 18.20, SD = 3.92) and older group (M = 20.27, SD = 3.34). A correlation analysis indicated that participants' performance on this measure was not correlated to performance on either simple or complex tasks, or overall performance.

Functional Health Literacy

TOHFLA scores in the sample ranged from 59-100 (M = 88.28, SD = 9.823); for the middle-aged group the scores ranged from 60-100 (M = 90.29, SD = 8.542) and for the older group the scores ranged from 59-99 (M = 86.08, SD = 10.716). There was not much variation in the scores, and most participants performed very well. Ninety-five participants (52 middle-aged and 43 older adults) had scores in the "Adequate" range (75-100). Of the remaining participants, one participant in the older group had a score in the "Inadequate" range (0-59), and eleven (4 middle-aged and 7 older adults) had scores in the "Marginal" range.

Subjective and Objective Numeracy

Overall, subjective numeracy scores ranged from 14 to 48 (M = 31.36, SD = 8.54) and objective numeracy scores ranged from 0 to 11 (M = 5.24, SD = 2.740). There was a small but significant correlation between the two scores (r = .430, $p < 0.001$). Scores on both subjective and objective numeracy measures were fairly equal between the two age groups. In the middle-aged group, scores on the SNS ranged from 16 to 48 (M = 30.09, SD = 7.75), while in the older group scores on the SNS ranged from 14 to 48 (M = 32.76, SD = 9.20). For objective numeracy, middle-aged participant had a range of scores from 1 to 11 (M = 5.20, SD = 2.81) while the older participants' scores ranged from 0 to 11 (M = 5.29, SD = 2.69). There was a higher correlation between subjective and objective numeracy in the middle-aged group (r = .476, $p < 0.001$) than in the older group (r = .395, $p < 0.01$). However, in both age groups, the majority of participants (54.2%) correctly answered 5 or fewer objective numeracy questions, while subjectively rating their skills as quite high. Thus, most participants, regardless of age, tended to overestimate their numeracy ability.

Patient Portal Task Performance

Scores for the simple tasks ranged from 0 to 14 (*M* = 9.07, *SD* = 4.04) and scores for the complex tasks ranged from 0 to 16 (*M* = 6.79, *SD* = 4.00). On simple tasks, the two age groups had similar performance. In the middle-aged group the mean score for simple tasks was 9.45 (*SD* = 3.68), while in the older group the mean score was 8.67 (*SD* = 4.41). On complex tasks, there was a significant difference in performance between the age groups ($t = 2.243$, $df = 105$, $p = 0.027$). The middle-aged group had a higher mean score (*M* = 7.61, *SD* = 3.85) than the older group (*M* = 5.90, *SD* = 4.01).

In the entire sample, overall performance scores ranged from 0 to 80.5 (*M* = 38.78, *SD* = 20.12). There was a very wide range of performance, however there was a significant difference between the two age groups ($t = 1.99$, $df = 105$, $p = 0.05$). The middle-aged group had a higher mean score (*M* = 42.41, *SD* = 19.32) than the older group (*M* = 34.78, *SD* = 20.41).

As indicated in Table 4, numeracy and age were not significant in the model for predicting performance on the simple tasks; therefore we chose Model 3 as our final model. In the model for simple tasks (*adj.* $R^2 = .465$) education accounted for 8.6% of the variance in performance on simple tasks, and Internet experience resulted in a significant increment in R^2, accounting for an additional 16% of the variance. Finally, the addition of the cognitive ability measures accounted for an additional 25% of the variance. Examination of the cognitive variables indicated that Trails B was the most influential cognitive ability ($\beta = -.297$) followed closely by the Shipley Scale ($\beta = .276$). Letter Sets was not found to be significant in the model predicting performance on simple tasks.

The final model for predicting performance on complex tasks (Table 4, Model 5) was quite different. In this model, Internet experience, Trails B, Shipley Scale, Letter Sets, objective numeracy, and age were all significant predictors of performance on complex tasks, while education was not found to be significant in the model. In the final model for the complex tasks (*adj.* $R^2 = .597$), Internet experience accounted for 23.3% of the variance and cognitive abilities accounted for an additional 26.9% of the variance. After accounting for both Internet experience and cognitive abilities, the addition of objective numeracy accounted for an additional 4.7% of variance, and age accounted for an additional 3.7% of the variance beyond objective numeracy. Interestingly, in this model, Letter Sets was found to be the most influential cognitive ability ($\beta = .188$), followed closely by the Shipley Scale ($\beta = .158$) and then Trails B ($\beta = -.086$).

The final model (Table 4, Model 5) predicting overall performance (*adj.* $R^2 = .623$), education accounted for 5.8% of the variance, Internet experience accounted for an additional 23.3%, and cognitive abilities accounted for an additional 29.5%. After accounting for education, Internet experience, and cognitive variables, the addition of objective numeracy accounted for an additional 3.6%, and age accounted for an additional 3.0% of the variance beyond objective numeracy. In this model and examination of the cognitive abilities found that Shipley Scale was the most influential ($\beta = .204$) followed by Letter Sets ($\beta = .185$) and then Trails B ($\beta = -.123$).

Table 4. Hierarchical regression models

	R^2	Adj. R^2	ΔR^2	ΔF	DF	p-value
Simple Tasks: Model 1*	0.086	0.068	0.086	4.867	2, 104	0.010
Simple Tasks: Model 2†	0.246	0.224	0.160	21.869	1, 103	0.000
Simple Tasks: Model 3‡	0.495	0.465	0.249	16.447	3, 100	0.000
Simple Tasks: Model 4§	0.508	0.473	0.013	2.606	1, 99	0.110
Simple Tasks: Model 5**	0.515	0.475	0.007	1.415	1, 98	0.237
Complex Tasks: Model 1*	0.041	0.023	0.041	2.243	2, 104	0.111
Complex Tasks: Model 2†	0.274	0.253	0.233	33.045	1, 103	0.000
Complex Tasks: Model 3‡	0.544	0.516	0.269	19.668	3, 100	0.000
Complex Tasks: Model 4§	0.590	0.561	0.047	11.312	1, 99	0.001
Complex Tasks: Model 5**	0.627	0.597	0.037	9.644	1, 98	0.002
Overall Performance: Model 1*	0.058	0.040	0.058	3.184	2, 104	0.046
Overall Performance: Model 2†	0.290	0.270	0.233	33.761	1, 103	0.000
Overall Performance: Model 3‡	0.585	0.561	0.295	23.734	3, 100	0.000
Overall Performance: Model 4§	0.621	0.594	0.036	9.323	1, 99	0.003
Overall Performance: Model 5**	0.651	0.623	0.030	8.495	1, 98	0.004

* Education
† Education, Internet Experience
‡ Education, Internet Experience, Trails B, Shipley, Letter Sets
§ Education, Internet Experience, Trails B, Shipley, Letter Sets, Objective Numeracy
** Education, Internet Experience, Trails B, Shipley, Letter Sets, Objective Numeracy, Age

Usability Ratings

Approximately 89% of all participants (91.1% middle-aged and 86.3% older adults) indicated that they would use a patient portal like the simulation if it were available from their doctor. Of those who indicated that they would not be interested in using a portal, five were middle-aged and seven were older. Many had limited or no experience using the Internet and, thus, thought that the portal was “confusing” or “difficult” to use. However, among those who said that they would not use a patient portal like the simulation, only one participant thought there was no benefit in using a portal. The other participants who indicated that they would not use a portal acknowledged certain benefits that included having the ability to get test results or medication information without having to leave the house or call a doctor, to schedule and keep track of appointments, and find to information pertinent to health conditions from links in the portal.

Participants, both middle-aged and older, tended to have a positive opinion of patient portals in general. Ninety-four percent of participants either agreed or somewhat agreed that a patient portal would improve their ability to perform health management tasks (i.e., review test and lab results, schedule a doctor’s appointment, or look for information about a medical condition), and 95% either agreed or somewhat agreed that a patient portal would allow them to get information that would help them understand issues related to their health. However, participants did have some difficulty in using the portal simulation: 40.2% either agreed or somewhat agreed that it was difficult to navigate within the portal and 51.4% either agreed or somewhat agreed that it was difficult to locate the information that they needed within the portal. Table 5 summarizes participants’ responses to questions regarding their difficulty in comprehending information contained in the simulation.

Table 5. Participants' feelings about information contained in the portal

	% Agree Total Sample	% Agree Middle-Aged	% Agree Older
I thought that the numerical tables (e.g., the glucose tables) used in the portal were confusing.	31.8	25.0	39.2
I thought the graphs about health risks used in the patient portal were confusing.	25.2	21.4	29.4
I thought the graphs about blood test results used in the patient portal were confusing.	19.6	12.5	27.5
In general, I thought that the information I needed to answer the questions regarding health management tasks was difficult to understand.	22.4	19.6	31.4

Four of the Morae videos were selected and analyzed to determine the types of usability problems participants encountered while interacting with the simulated portal. One participant was randomly selected for analysis from each of the following groups: High Internet Experience/High Numeracy Skill, High Internet Experience/Low Numeracy Skill, Low Internet Experience/High Numeracy Skill, Low Internet Experience/Low Numeracy Skill. The amount of time taken to complete the tasks was much higher for the two participants with low Internet experience (1 hour 43 minutes and 1 hour 24 minutes) than the two participants with high Internet experience (both spent just under 45 minutes).

A common usability problem seen in the videos of the participants with low Internet experience was that the participants did not click on the correct link although it was visible on the page. Also, both participants clicked through many unnecessary pages while looking for the answers to the tasks. In contrast, both participants with high Internet experience were able to take much more direct paths to the pages for which they were looking. However, of the two participants in the high Internet experience category, the participant with high numeracy was able to find the information more directly than the participant with low numeracy. Furthermore, with regard to the participants with high Internet experience, the participant with low numeracy was not able to complete the tasks with the same level of accuracy as the participant with high numeracy, even though they both looked at the pages containing the correct information. While these results are based on a small sample, they point to the relatively independent effects of Internet experience and numeracy ability on performance. While being adept with browsers or Internet technologies is clearly an advantage, this benefit may be negated if users with low numeracy ability must perform tasks based on numerical information.

Discussion

PHRs have the ability to deliver useful and trustworthy health information and data to patients to help them better manage their health and chronic conditions. This benefit of patient portals, however, is contingent on the ability of patients to be able to use the information provided in these systems in a meaningful way. Results from this study strongly suggest that older adults may encounter problems performing common tasks using patient portals and that individual characteristics such as age, cognitive abilities, and health numeracy are important to performance.

An interesting result from this study is the discrepancy that was found between health literacy and health numeracy skills in this sample. Approximately 89% of the participants in this study were determined to have "adequate" health literacy based upon their TOFHLA scores, implying that they should be able to read, understand, and interpret most health texts. However, the sample had health numeracy scores that were quite low; 54.2% of participants could not correctly answer the majority of objective numeracy questions. This result indicates that if the health texts used by middle-aged and older adults in patient portals involve numeric concepts, they may encounter problems even if they are considered to have “adequate” health literacy. As mentioned previously, it has been noted that “[t]he reporting of health literacy without disaggregating prose from numeracy obscures health numeracy skill” (Donelle, Hoffman-Goetz, & Arocha, 2007, p. 652) and the results from this study clearly underscore the importance of separately evaluating the health literacy and health numeracy of an individual. The results of the TOFHLA in this study are even more interesting when considering the extensive literature indicating that older populations and minorities are often found to have poor health literacy, yet in this sample containing both older individuals and minorities, the overwhelming majority were considered to have “adequate” health literacy. This result points to the need for more sensitive measures of health literacy.

Another interesting result of this study was the relatively weak correlation (r = .430) found between subjective and objective numeracy in this sample, with most of the participants tending to overestimate their skills. This correlation is much smaller than the correlation (r = .68) reported in the literature (Fagerlin et al., 2007). Perhaps this difference is due to the sample; the higher correlation reported by Fagerlin et al. (2007) was found in a convenience sample taken from a hospital waiting area and cafeteria, while the results found here were from a diverse sample of community-dwelling adults. Because our sample was not taken from a hospital setting, it is possible that our participants had less experience with numeracy in the healthcare setting. The weak correlation found here implies that both middle-aged and older adults, who perhaps have not had much experience with numeracy in their healthcare, may believe that they can comprehend and use the numeric information provided in the portal correctly when, in fact, they cannot. This could result in false assumptions that could easily lead to serious problems such as taking medications incorrectly or believing that abnormal test results are in the proper range. Furthermore, the older group was found to have a weaker correlation between subjective and objective numeracy (r = .395) than the middle-aged adults (r = .476) indicating that they may be at higher risk for such problems.

The hierarchical regression models provide some important insights into factors that impact performance of common health management tasks using a patient portal. Across all three models, Internet experience was determined to account for a large percentage of the variance in performance: 16% for simple tasks, and 23% for both complex tasks and overall performance. Interestingly, the cognitive abilities predicting performance were determined to vary according to task type. On simple tasks, it was determined that executive function was most influential, followed by verbal ability; on complex tasks reasoning was most influential, followed by verbal ability and then executive function. For predicting overall performance across tasks, verbal ability was most influential, followed by reasoning and then executive function. Another remarkable finding from the regression models is that after accounting for education, Internet experience and cognitive ability, when numeracy was added to the model it resulted in an additional 4.7% of the variance in complex tasks being explained and 3.6% of the variance in overall performance. This result shows the importance of numeracy, above and beyond Internet experience and cognitive abilities, in using a portal to perform common health tasks.

Results from this study can help identify interventions that may enhance the usability of patient portals for older adults. For example, results indicated that Internet experience had a significant impact on task performance. This could be expected, as many of the functions of the portal require skills that are consistent with those necessary for Internet use (i.e., scrolling, clicking on links, and closing windows). One implication is that healthcare providers and designers of these portals should be able to identify patients, especially older adults, with little or no prior Internet experience and provide instructional resources that could facilitate their proper use of the functions in their patient portals.

Another implication for design of these portals comes from the findings that, depending on the task, verbal ability, reasoning, and executive function have varying degrees of impact on performance. Developers of patient portals need to be aware that deficits in these cognitive abilities may make it difficult for users to locate and understand the information in the portal. The addition of info-buttons to help explain technical terms and providing search aids within the patient's health record may make use of portals easier for those with lower cognitive abilities.

The results from this study also strongly suggest that careful consideration needs to be given to the presentation of numerical information in patient portals. For instance, 25% of middle-aged participants and 39.2% of older participants found the numerical tables to be confusing. It should be noted that these tables were not unusual in their numeracy demands, but rather were representative of the types of tables patients encounter in a portal. This result indicates that tables displaying numeric information in the portal need to be formatted to provide information in a way that is more readily understood by those with low numeracy. Numbers given in a table or in a list of lab results that are out of the proper range for the patient could be highlighted to call attention to the fact that they are too high or too low, and audio and/or video explanations could be added to help patients understand and interpret this and other types of numeric information.

Analysis of the performance videos indicates that the information needs to be organized in a more logical way than it is currently. For instance, many of the links to health information were only located on the homepage, causing problems for even the participants with high Internet experience. This type of information might be more readily accessible if links were located in the "Current Health Issues" section under "My Medical Record." That way, a user could look up this information without having to go back to the homepage after looking at a list of their current conditions. Furthermore, links that take the user from a table of test results to a related graph or from a medication listing to more information about that medication need to be highlighted to call attention to the fact that they are there. In all of the videos analyzed, regardless of Internet experience or numeracy, participants missed links to information (necessary to correctly complete the tasks) that were visible on the page at which they were looking.

The great potential of patient portals to deliver important health information to patients lies in the ability for information to be tailored to meet the needs of the individual using the PHR. Krist et al. (2011) note that preventive care recommendations given to patients through their PHRs are already personalized according to the established guidelines, but point out that content and presentation of the PHR could be further personalized based upon other factors including race/ethnicity, socio-economic status, literacy and numeracy. Results from this study strongly suggest that the numeracy aspect of health literacy is a critical factor to consider when tailoring PHRs to meet the needs of older adults.

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List of Publications and Products

A manuscript focused on the data from the group of older adults has been submitted to the Journal of Applied Gerontology. Further dissemination will take place through publication of additional findings in a journal such as the *American Journal of Public Health, Psychology and Aging*, or *The Gerontologist*. These are journals from a variety of disciplines where the outcomes of this study would be relevant. We also hope to present the findings from this study at a professional meeting such as the Annual Meeting of the Gerontological Society of American or the Annual Meeting of the American Medical Informatics Association. Further, research findings can be disseminated widely through CREATE's distinguished partners at Palo Alto Research Center, IBM, and INTEL. The dissertation resulting from this work will be completed by May 2012.